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Detection and Study of Failure Modes for Photovoltaic System

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***Abstract*— The solar power generation systems uses the photovoltaic (PV) effect to transform solar energy into electrical energy. Thus, the PV system may subject, like any other industrial process during its operation, to various faults and abnormalities leading to a drop of its efficiency up to its unavailability. In order to optimize the performance of a PV system, it must at first, aim the recognition and the classification of faults that may affect the efficiency of the PV system. This work focuses on the collection of the different symptoms and causes of some faults in the DC part of a PV module. Furthermore, it proposes a global analysis of the I-V characteristic of the PV module by conducting the least measurements to meet the economic constraints. A MATLAB-based modelling and simulation scheme have been elaborated to study and validate the I–V and P–V characteristics of a PV module under a non uniform change and due to external parameters.**

***Keywords*— PV system, Mismatch Faults, shading, Matlab-based simulation.**

I. INTRODUCTION

Due to the rise of the environmental consciousness, the traditional energies are being replaced by the renewable ones especially the solar power systems since they have greater power generation capacities than other renewable energies. Hence, photovoltaic installations are being increasingly employed in several applications. The PV market was a great success, thanks to several factors. Where, the reduction of production costs and support policies are the most important stimulating factors. However, the PV system may be exposed to diverse trouble or failing causing a decreased performance. Definitely, it involves the drop of the productivity of the plant.

The literature review shows that many studies have focused on evaluating the impact of various defects by analyzing the ensuing static characteristic (I-V) so as to establish, with an appropriate way, a causal relationship between the main considered defects and the static characteristic. The researchers have studied, throughout the years, the characteristics of PV modules and the factors affecting them. Walker [1] has proposed a MATLAB-based model of a PV module to simulate its characteristics to study the effect of temperature, irradiation, and load variation on the available power. However, the model does not consider the effect of shading on the PV characteristics. Alonso-Gracia and al. [2] have experimentally obtained the I–V characteristics of the PV module and the constituent cells to study the effect of partial shading. Kawamura and al. [3] have also investigated the effect of shading on the output of the PV modules and the associated change in their I–V characteristics. A numerical algorithm, which considers the mismatch in individual PV cells and their shading levels, has also been proposed [4] to simulate the complex characteristics of a PV array. It requires each element to be represented by a mathematical expression. This can render accurate results, though at the expense of complex modeling, involving large and complex matrix computations, more computation time and efforts, and higher memory requirement. It is not only the total number of modules of the PV array but also the number of modules in series and parallel that significantly affects its power output, and therefore, the performance of the system under abnormal conditions.

Firstly, all issues related to the productivity of a photovoltaic system are discussed to show the need for such a study of different types of faults. Then the various components of a photovoltaic system are described and their associated defects are also identified. The preliminary selection of the main defects is conducted on the basis of the analysis of their criticality and their occurrence. The second section is devoted to the modeling of a PV module with defects to get the I-V characteristic for any default and any configuration of the PV system (module, string or field). The modeling is done in both healthy and faulty operation of the PV field. Potential symptoms are then identified from this knowledge base.

Finally, we bring to the end of the paper a conclusion on this work and present some perspectives tracks updates.

II. PHOTOVOLTAIC MODULE

In this section, we firstly point out the context and purpose of our study. We discuss all issues related to the productivity of a photovoltaic system and how these issues require a detection and fault location study.

Secondly, the various components of a photovoltaic system are described as well as the identification of the defects associated with these components. Among the identified defects, only the major faults are selected, based on their criticality and their consequences.

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Solar cell is an important invention, which uses to transform solar energy into electrical energy with a P/N junction semiconductor device. A PV cell can be represented by an equivalent circuit, as shown in Fig. 1.

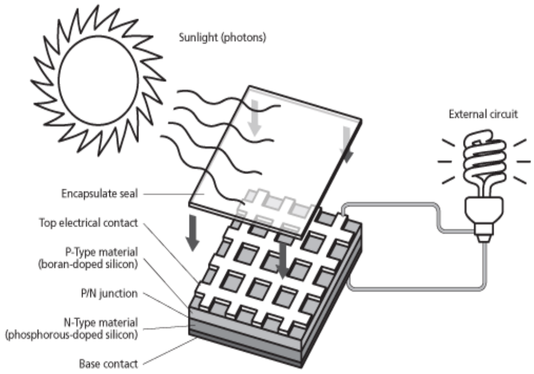

Fig. 1 Working of a solar cell

The factory standard rating of a solar cell is 0.5 volts, 1.75 watts. The characteristics of this PV cell can be obtained using the standard equations. Several cells are connected in parallel for current buildup to form an array and several cells are connected in series for voltage buildup.

Without loss of generality, the solar power generation system considered in this paper consists of a Photovoltaic module of 36 cells, string of 2 modules and a field of 2 strings. Fig. 2 shows the different I-V characteristics of different configuration.

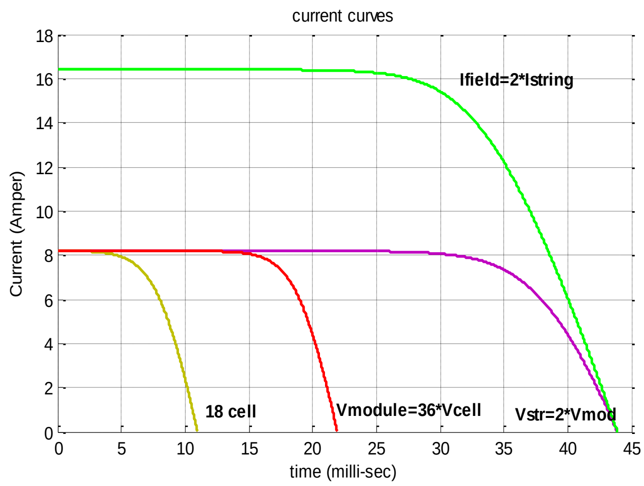

Fig. 2 Establishment of the field characteristics from that of the cell

In the presence of both parasitic series resistances and shunt resistances in a solar cell circuit, the model of the solar cell is described by the following equation:

$$I = I_L - I_0 \exp[\frac{q(V + IR_s)}{nkT}] - \frac{V + IR_s}{R_{sh}} \quad (1)$$

All cells of the module are illuminated. The I-V characteristic of all cells is measured in the module. The insolation is an external condition that can affect obviously the working of a PV system.

These features are shown in the Fig. 3.

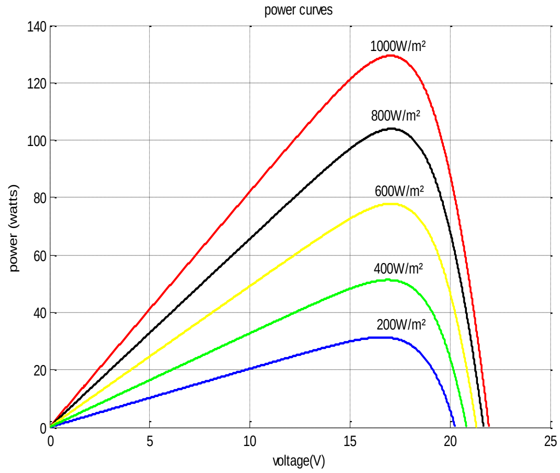

Fig. 3 Dependence of PV power output on solar radiation

We focus now on two key points:

- Identification of potential symptoms in the faulty behavior of the PV field.
- The evolution of this behavior, so the identified symptoms.

In a healthy operation, the behavior of all cells is identical which results in the blocking of the bypass diode. We will see in the next section that this is not the case for a failed operation.

III. Productivity of PV System

The productivity of a PV system can be improved by reducing the rate of availability and by operating the system to an optimal performance. As for the non-optimal performance of the PV system that is caused by the partial failures of the installation components, the detection of this failure mode is not evident. The productivity of a PV system is affected by the performance and the plant availability [5]. The performance of a PV system refers to the overall efficiency of the power conversion chain. The performance of a PV system is influenced by losses that can be divided into two types; System losses: which are the losses that occur in the converter. They relate to the performance of conversion devices.

We have also the capture losses of the PV generator, which occur mainly on the DC side of the PV conversion chain and they are attributed mostly to the following factors:

- High Operating Temperatures.
- Non-optimal capture of the sunlight.
- Dispersion between the panels forming the field.
- Non-optimal extraction of the power produced.
- Aging of the modules.

There are several ways to assess the performance of a PV system. The simplest approach is based on "performance index" proposed by the European directive, [6]. The effective availability is defined as the actual power produced divided by the total power that could have been produced. The typical annual average value for an installation, in normal operation, varies between 0.6 and 0.8 [7]. An indicator with a value below this range means that there is an additional loss caused by a specific defect. An inspection on the performance index of less than 0.6 yielded to specific reasons inducing a decreased productivity.

IV. THE MOST FREQUENT DEFECTS AND THEIR ORIGINS

A list of the most frequent origins of defects in a PV system is shown in Table 1. It was established by considering the fault's type and its degree of impact on production system.

TABLE I
MAJOR FAULTS IN THE PV GENERATOR

Faults	**Consequences**
Soiling (pollution, sand, snow)	Power loss
Misdirection or tilt	Shading, reduction in yield
Under or un-ventilated Module	Overheating
Fissure	Cell damage
Moisture penetration	Hot spot, leakage current Increased
Partial shading, tree leaves	Cell damage
Degradation due to the light	Over voltage and destruction of diodes
Degradation due to the heat	Overheating, Deterioration of gasket

The establishment of the knowledge base of a faulty behaviour is about the causal relationship between faults and symptoms obtained from the I-V characteristic of the module itself. To start, a series of simulation must be made for a list of scenarios considered defects. A single fault is considered and the characteristic outcome of this simulation is examined in order to identify potential symptoms that can be traced back to the nature of the defect.

The scenario for the defects' simulation can be established by taking into account, for each fault, the various factors that can help change the characteristic symptoms of this defect. It should be noticed that we have many categories of defects for modeling, such the shading defects and mismatch.

- Symptoms S1: Loss of the maximum power.
- Symptoms S2: Loss of the open circuit voltage.
- Symptoms S3: Loss of the Short circuit current.
- Symptoms S4: Presence of inflection points.
- Symptoms S5: Deviation of the slope.

The symptom S1 is the first one to be extracted from this comparison because it's clear that once a defect appears, it provokes a loss of productivity. Hence, that's not always true because some defects, when appearing alone, don't cause any losses; for instance, disconnection of the bypass diode. S2 represent the gap between the open circuit voltage of the PV system in normal operation and in the failed operation. By the same, S3 is the gap of the short circuit current. S4 refers to the deviation in the faulty I-V characteristic defect that leads to one or more inflection points. S5 refers to the deviation of the slope of the I-V characteristic in default compared to that in healthy operation.

The severity of the defects can be defined by two parameters: the amplitude and the number of faulty components. However, the severity of certain defects can be quantified only with the number of faulty components. Table 2 shows how we define the severity of defects considered.

TABLE III
DEFINITION OF THE SEVERITY DEFECTS

Fault class	**Fault**	**Severity**	**Symptoms**
Mismatch Defect and Shading	Series resistance	Rs increase	S1, S2, S5
	shunt resistance	Rp decrease	S1
	Shading	Icc decrease	S4, S3
	Temperature	T increase	S3
Bypass diode defect	Defected Diode	Rdp decrease	S1, S3

V. SIMULATION RESULTS

In severe cases of mismatch in irradiance or cell characteristics hot spots and related failures can occur. Different types of shading are performed on a module. The shape of the curves is very similar to that obtained for the shading of a cell except that the symptom is less visible.

As the partial shading happen (the blue curve) in Fig. 4, it's noticeable that there is an inflexion point, where the short circuit current and the photocurrent are decreasing, therefore we obtain a loss of the maximum power.

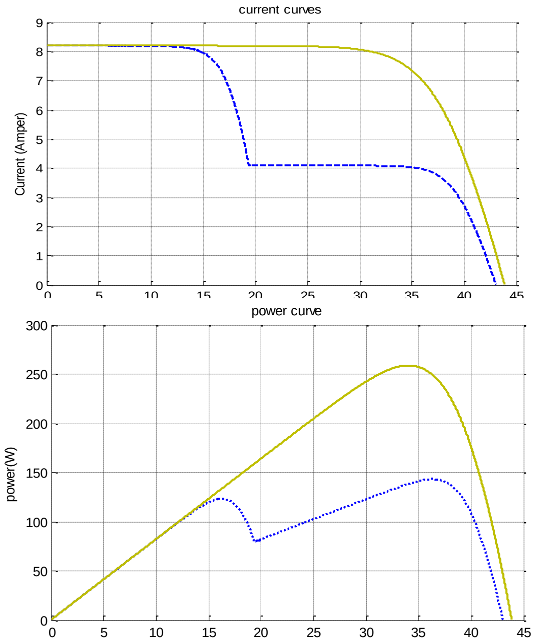

Fig. 4 Partial shading

The series resistance (RS) represents the sheet resistance of the semiconductor body or surface. Fig. 5 indicates that we lose the short circuit current when the series resistance became bigger but with a different slope of the curve.

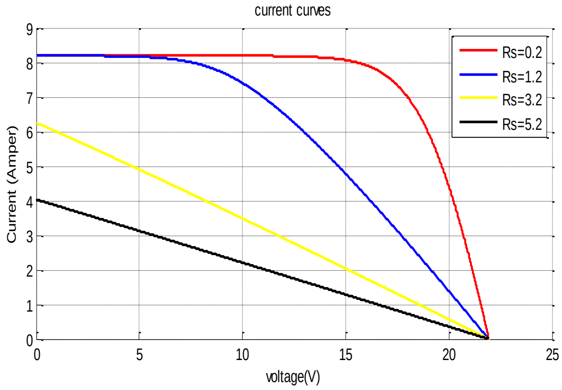

Fig. 5 Series resistance

Parallel resistance (RP) is considered to block the leakage current from the PV cell and so the overheating. The case of the family of defects caused by reduced resistance parallel elements Fig. 6 for explanation. Considering the beginning voltage drop profile in the figure, the deviation of the slope is the major observation.

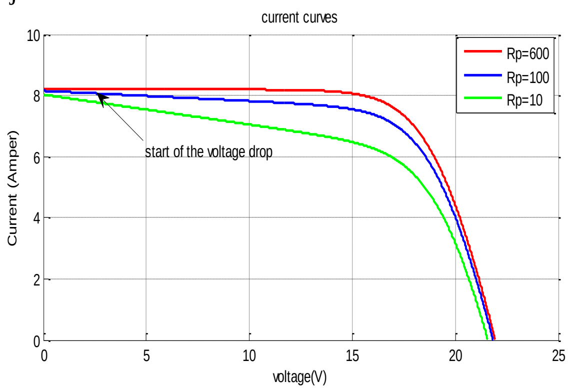

Fig. 6 Shunt resistance

Different temperatures are given by the Fig. 7 the slope of the curve is degrading due to the heat. Hence a deterioration of gasket and overheating can be a result. When the temperature is little (blue curve), the short circuit voltage increases.

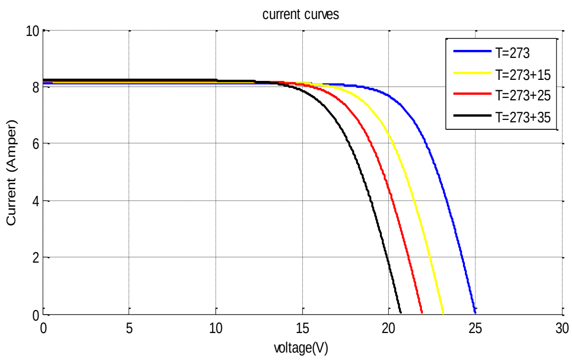

Fig. 7 Temperature's change

The bypass diode is connected in anti-parallel with a group of cells to protect the weaker cells, especially in the case of inhomogeneous irradiation, against the reverse bias. Thus, the bypass diode protects the PV cell from overheating during partial shading. The red curve of the Fig. 8 is the healthy behavior such the two bypass diodes are conducting, but it loses about 20 V when one diode is shunted or inversed (blue curve).

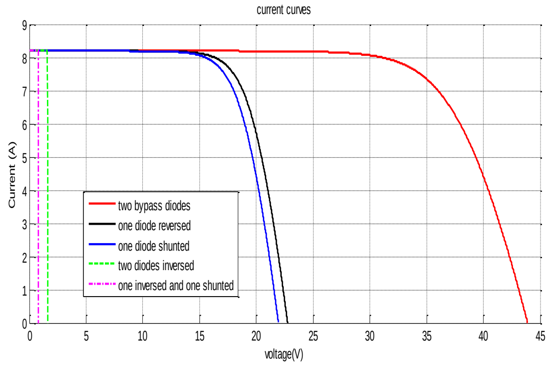

Fig. 8 bypass diode fault

VI. Conclusions

After filling of the knowledge basis of the failed behavior of a PV module, potential symptoms have been identified. Comparing the characteristic of a PV field during the normal functioning and failing one due to various defects considered in the knowledge base, some symptoms were retained. The results obtained with MATLAB simulation allow the investigating and discussing of the PV system behavior working under nonuniform change and abnormalities. This work opens many prospects. We can mention the essential tasks that could be carried out; First, continue the diagnosis of the PV installation considering the converter, next, consider other types of modules, other PV system configurations and therefore other faults manifestations in the I-V characteristic.

Acknowledgment

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References

[1] G.Walker, "Evaluating MPPT converter topologies using a MATLAB PV model," J. lectr. Electron. Eng. Aust., vol. 21, no. 1, pp. 49–56, 2001.

[2] M. C. Alonso-Gracia, J. M. Ruiz, and F. Chenlo, "Experimental study of mismatch and shading effects in the," Solar Energy Mater, Solar Cells, vol. 90, no. 3, pp. 329–340, Feb. 2006.

[3] H. Kawamura, K. Naka, N. Yonekura, S. Yamanaka, H. Kawamura, H. Ohno, and K. Naito, "Simulation of I–V characteristics of a PV module with shaded PV cells," Solar Energy Mater. Solar Cells, vol. 75, no. 3/4, pp. 613–621, Feb. 2003.

[4] V. Quaschning and R.Hanitsch, "Numerical simulation of current–voltage characteristics of photovoltaic systems with shaded solar cells," Solar Energy, vol. 56, no. 6, pp. 513–520, Feb. 1996.

[5] L.BUN, " Détection et localisation de défaut pour un système PV, " thesis, University of Grenoble, 2011.

[6] G. Blaesser, and D. Munro, "Guidelines for the Assessment of Photovoltaic Plants, Document B, Analysis and Presentation of Monitoring Data", Commission of the European Communities (CEC), Issue 4.1, 1995.