

Photovoltaic Panel Faults Diagnosis: The use of the bishop model for confirmation of the diagnosis method based on the fill factor analysis and use of Artificial Intelligence techniques

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Article Info

Article history:

Received , 30/04/2025
Revised , 20/05/2025
Accepted , 10/06/2025

Keywords:

Photovoltaic Panel
Faults Diagnosis
Bishop Model
Artificial Intelligence
Fill Factor

ABSTRACT

Solar Energy Has Become a Demanded Renewable Source of Electricity, Pushed by Significant Improvements in Solar Panel Efficiency Due To Advancements in Semiconductor Materials Science Worldwide. The Performance of a Solar Panel Is Not Limited by Design and Materials; It Is Greatly Affected by Faults That Can Disturb or Reduce Its Efficiency. To Face These Malfunctions and Identify Them Promptly, Various Techniques and Methods Have Been Proposed Such as The Use Artificial Intelligence Techniques. On A Previous Work [1] Through the Model with a Single Diode of The Photovoltaic Cell, We Proposed a Diagnostic Method Based on The Artificial Intelligence Techniques and The Use of The Fill Factor (FF) And the Maximum Value of The Short Circuit Current (I_{sc}) As Input Parameters. This Method, in Addition to Its Simplicity, Has Proven to Be Reliable and Efficient. The Choice of These Two Input Criteria Is Justified by Their Importance: The Variation in Short Circuit Current Is a Significant and Variable Value Depending on The State of The Photovoltaic Cell, While the Fill Factor Provides a Better Visualization of Efficiency and The Resultant Current-Voltage Characteristic. The Diagnostic Process, Simulated in The MATLAB Environment as Like: The First Step Involves Threshold Detection, Where Defect Identification Is Based on The Threshold of Each Symptom, While the Second Step Use the Artificial Intelligence Techniques in Defect Identification, Particularly for Cases with Identical Fault Symptoms. In This Work, We Propose the Use of The Bishop Model of the Photovoltaic Cell to Redo the Diagnosis and Confirm the Reliability of The Proposed Method. This Method Enables the Diagnosis of Faults in Photovoltaic Panels.

I. Introduction

To maximize the performance of photovoltaic power plants, it is crucial to protect them from various faults or, at the least, intervene quickly to correct them. This objective can only be achieved through accurate diagnosis of PV system faults. Various lists of the most probable faults in a PV system have been compiled [3, 10], each reflecting the significance and severity of the proposed faults. The most well-known faults have been studied individually in numerous works. Total or partial shading is the most frequently discussed fault in the literature, while hotspots are

detailed extensively in several studies [4, 5, 13]. Dust-related faults have also been addressed in some works [14]; however, a long list of defaults are detailed in the literature.

It is easy to diagnose faults with unique symptoms or signatures; however, the difficulty arises in diagnosing faults that have the same symptoms. The fuzzy logic techniques have shown their ability to distinguish defects that have the same signature and can classify the majority of possible defects.

In a previous work we proposed a simplified diagnostic method using the simple one diode model of a PV cell; in order to confirm the reliability of this proposed diagnostic method, we will restart the diagnosis using the bishop model.

We have started with the modeling and simulation of a photovoltaic cell (PV) and the simulation of a solar panel as a result, and then a little reminder on the fill factor of a PV system is given. A list of selected faults has been simulated, and their signatures based on the admissible thresholds of our system are illustrated.

The probable deviations of the fault simulation compared to the safe functioning mode of our system require analysis based on artificial intelligence techniques to discriminate faults with same signatures.

At the end of this work, we confirmed the proposed technique of a photovoltaic panel Faults Diagnosis based on the fill factor analysis and the use of Artificial Intelligence techniques. Most of simulations with MATLAB environment of this technique have given us a very good diagnosis of faults.

II. Bishop Model of Photovoltaic (PV) Cell

Modeling a photovoltaic module is above all trying to understand what is happening, and describing it mathematically, through equations in order to study its operation, optimize its design, and predict its behavior in the face of various malfunctions.

When a PV module is partially shaded, the PV cells under the shade may not generate power; on the contrary, they could consume the energy produced by the other cells of the module. In this phenomenon, called reverse polarization, the cell presents a negative voltage at its terminals; and operates in the second quadrant (negative voltage and positive current). The models already proposed for modeling the PV cell; and cannot accurately represent this phenomenon at the cellular level. The inverse characteristics were implemented by the model proposed by Bishop as mounted in FIG.1. in which the solar cell with forward and reverse characteristics. However, it includes an additional multiplication term $M(V_j)$ for the reverse current which is inserted into the shunt branch so that it is connected in series with the parallel resistor R_{sh} .

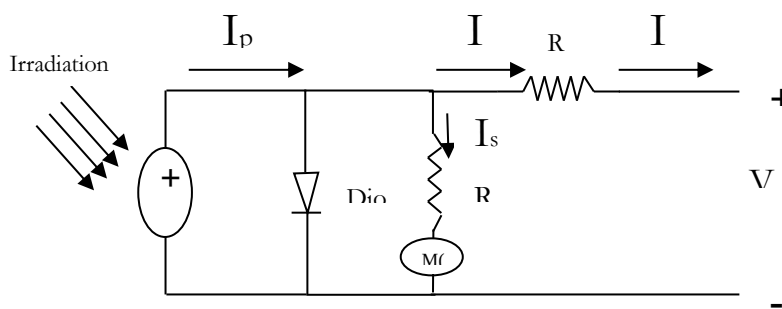


Figure 1. BISHOP Electric model of a photovoltaic cell.

This model is governed by the following equation:

$$I = I_{pv} - I_d - I_{sh}$$

Although

$$I_{sh} = \frac{V_j}{R_{sh}} \left[1 + a \left(1 - \frac{V_j}{V_t} \right)^{-n} \right]$$

The current equation will be:

$$I = I_{ph} - I_o \left[\exp((V + R_s I)/V_t) - 1 \right] - V_j / R_{sh} \left[1 + a \left(1 - V_j / V_t \right)^{-n} \right]$$

Where:

I_{ph} : photonic current generated by the source of the current as a function of solar radiation.

R_s : is the internal resistance of the cell; it depends mainly on the resistance of the semiconductor used, on the contact resistance of the collector gates and on the resistivity of these gates. In an ideal model R_s is zero.

R_{sh} : this resistance corresponds to a leakage current at the junction; it depends on how it was done. In an ideal model R_{sh} is infinite.

I : line current supplied by the PV cell.

V : Voltage at the terminals of the PV cell.

V_t : Breakdown voltage specific to the semiconductor.

V_j : is the voltage across the shunt term.

a : is the fraction of ohmic current involved in the breakdown voltage.

n : is the avalanche rupture exponent.

III. Electrical Modeling of Photovoltaic (PV) Panel

A photovoltaic panel is formed of a number of photovoltaic cells connected in series; to simulate our PV system, the following characteristics TAB.1 of an existing photovoltaic panel are chosen:

Table 1. Characteristic Values of the simulated panel

Maximum Power, in STC (P_{max})	100 W
Optimal Voltage (V_{opt})	17.8 V
Optimal current (I_{opt})	5.62 A
Open circuit voltage (V_{co})	22.4 V
Short-circuit current (I_{sc})	5.95 A
Number of cells	36
Serial resistance R_s	0.01 ohm
Shunt resistance R_{sh}	54.15 ohm

A protection bypass diode should be inserted for each group of cells (string), in this case each 18 cells.

IV. Chosen Faults of Photovoltaic (PV) Panel

In this work we will deal with the most frequent faults in the domain TAB.2. These faults can be categorized into two main types: shading faults (caused by any reason) and material faults. Various degrees of

severity are selected for fault simulations to cover all sensitivity zones of our photovoltaic installation.

Table 2. Table of simulated faults

faults	Severity level of fault
Partial shading caused by dust	Shading level at 1%
	Shading level at 3%
	Shading level at 10%
Partial shading	1cell/ Shading level at G=700
	3 cells on the same string/ Shading level at G=700
	18 cells on the same string/ Shading level at G=700
	3cells on different strings/ Shading level at G=700
	General partial shad / Shading level at G=700
Total shading	1cell/ Shading level at G=0
	3 cells on the same string/ Shading level at G=0
	3cells on different strings/ Shading level at G=0
Hot spot	1 Hot spot
	2 hot spots and more on different strings
Bypass Diode	bypass Diode shunted
	Open bypass Diode/safe panel
	Open bypass Diode/ panel in fault
Serial resistance increased from 0,01 au 1 Ohm	1 cell
	3 cells

V. Simulation and Panel Faults Diagnosis

- Simulation: The simulation under MATLAB SIMULINK in accordance with the characteristic values of our panel given the following results TAB.3.
- Sensitization thresholds: The results of simulation under MATLAB SIMULINK of these faults showed an offset from the values of a safe panel. To make of these values detectable by our equipment, they should be sufficiently sensitive to the detection thresholds.

The sensitivity thresholds of the measurement equipments of this work are those of our laboratory and are given as follows:

Current sensitivity: 3% Voltage sensitivity: 2% Power sensitivity: 6%

- Illustration of the simulated faults signatures: The deviations of the simulation results under MATLAB SIMULINK for these faults, compared to the values of a safe panel, can be represented in binary form as follows: if the deviation exceeds the sensitization threshold, it is assigned a (1), otherwise it is assigned a (0). The results are shown in TAB.3.

Table 3. Table of simulation results.

simulation Conditions	ISC	VOC	PMAX	DI/I	DV/V	DP/P	S1	S2	S3	FIL FACTOR
Safe PV panel	5,95	22,40	98,87	0,00	0,000	0,000	0	0	0	74%
Dust Shading level at 1%	5,70	22,36	97,93	0,04	0,002	0,010	1	0	0	73%
Dust Shading level at 3%	5,50	22,29	96,00	0,08	0,005	0,029	1	0	0	72%
Dust Shading level at 10%	5,35	22,02	89,27	0,10	0,017	0,097	1	0	1	67%
Partial shading on 1cell/ Shading level at G=700	5,95	22,36	84,73	0,00	0,002	0,143	0	0	1	64%
Partial shading on 3 cells on the same string/ Shading level at G=700	5,95	21,29	83,33	0,00	0,050	0,157	0	1	1	63%
Partial shading on 18 cells on the same string/ Shading level at G=700	5,95	20,76	76,05	0,00	0,073	0,231	0	1	1	57%
Partial shading on 3cells on different strings/ Shading level at G=700	4,33	22,25	82,70	0,27	0,007	0,164	1	0	1	62%
General partial shading / Shading level at G=700	4,17	21,13	69,69	0,30	0,057	0,295	1	1	1	52%
Total shading on 1cell/ Shading level at G=0	5,64	10,93	37,90	0,05	0,512	0,617	1	1	1	28%
Total shading on 3 cells on the same string/ Shading level at G=0	5,64	10,88	37,63	0,05	0,514	0,619	1	1	1	28%
Total shading on 3cells on different strings/ Shading level at G=0	0,19	1,63	0,28	0,97	0,927	0,997	1	1	1	0%
1 Hot spot	5,65	11,76	49,44	0,05	0,475	0,500	1	1	1	37%
2 hot spots and more on different strings	0,00	0,00	0,00	1,00	1,000	1,000	1	1	1	0%
bypass Diode shunted	5,65	11,76	49,44	0,05	0,475	0,500	1	1	1	37%
Open bypass Diode/safe panel	5,95	22,40	98,87	0,00	0,000	0,000	0	0	0	74%
Open bypass Diode/ panel in fault	0,41	3,52	1,33	0,93	0,843	0,987	1	1	1	1%
Serial resistance increased 1 cell	5,95	20,46	71,07	0,00	0,087	0,281	0	1	1	53%
Serial resistance increased 3 cells	5,95	17,45	43,61	0,00	0,221	0,559	0	1	1	33%

A first observation on the table allows us to distinguish the non existence of signatures with only one corresponding fault diagnosis, and all of faults must be treated with artificial intelligence skills.

On the other side Signatures with several corresponding fault diagnosis are resumed as shown in TAB.4. To solve this problem the use artificial intelligence tools is imposed.

Table 4. Signatures corresponding faults.

0.0.0	Safe PV panel
	Open bypass Diode/safe panel
1.0.0	Dust Shading level at 1%
	Dust Shading level at 3%
1.0.1	Dust Shading level at 10%
	Partial shading on 3cells on different strings/ Shading level at G=700
0.1.1	Partial shading on 3 cells on the same string/ Shading level at G=700
	Partial shading on 18 cells on the same string/ Shading level at G=700
	Serial resistance increased 1 cell
	Serial resistance increased 3 cells

1.1.1	General partial shading / Shading level at G=700
	Total shading on 1cell/ Shading level at G=0
	Total shading on 3 cells on the same string/ Shading level at G=0
	Total shading on 3cells on different strings/ Shading level at G=0
	1 Hot spot
	2 hot spots and more on different strings
	bypass Diode shunted
	Open bypass Diode/ panel in fault

The diagnosis method proposed in [1] is based on the use of one of the most significant data of a photovoltaic panel: the short circuit current I_{sc} . The combination of this data with the fill factor value can solve the problem and differentiate the fault diagnosis under the same signature.

VI. Results and Discussions

It should be noted that the main objective of this work is the diagnosis of faults without too much detail about the level of severity of the fault in order to simplify as much as possible the exploitation of the results, therefore we see useful to collect the faults according to their nature.

Signatures are categorized according to their current values registered during simulations in ranges or intervals. Also for each one of the I_{sc} current intervals we can distinguish different values of the fill factor FF; these values can also be categorized in sub-intervals as shown in TAB.5.

Satisfying the condition of appurtenance to the two intervals of the current and that of the fill factor FF can be translated in fault diagnosis using fuzzy logic tools.

Table 5. Table categorization of simulated faults.

Faults Diagnosis	Isc Interval		FILL FACTOR
Safe PV panel	Isc=5,95		74%
Serial resistance increased			33-52%
Total shading on 1string/ G=0	5,64	5,94	28%
Bypass diode shunted _ Check the existence of a Hot spot			37%
Dust Shading	5,36	5,63	72-73%
Serious Dust Shading	4,33	5,35	62-67%
Partial Shading			55-62%
General partial shading / Shading level at G=700	4	4,33	52%
serious failure: several hot spot / total shading ...	0	0	0%

The operating conditions are 1000W / m² for solar irradiance and 25 ° C for ambient temperature. In these operating conditions and with a safe panel; the maximum panel power found is equal to 98.87 W; the open circuit voltage is 22.4 V; the short circuit current is 5.95A and the limit fill factor is 74%.

The amplitudes of the symptoms resulting from the different faults are shown in the table above TAB.3. Using our equipments sensitivity threshold, the table of fault's signatures of our PV system can be illustrated.

The arrangement of these signatures (18 Signatures) showed the existence of Signatures having several corresponding fault diagnoses. In order to differentiate between these signatures, we continued to class our data in

a deeper way based on the recorded values of I_{sc} and the fill factor FF value. we can observe that even for signatures having the same current category I_{sc} we can differentiate them using the form factor values FF.

Satisfying the condition of appartenance to the two intervals of the current and that of the fill factor FF can be translated in fault diagnosis using fuzzy logic tools

VII. Conclusion

In this work, we have been interested to confirm the diagnosis faults method based on the fill factor analysis and use of Artificial Intelligence techniques proposed in [1] using bishop model instead of the simple diode.

Using Fuzzy logic tools to treat the new combined input data: the short circuit current and the fill factor, allowed as to confirm that the algorithm can discriminate all the faults considered. The simple faults diagnosis algorithm quoted above was established and confirmed through the various simulations carried out under MATLAB SIMULINK

This work based on the use of the Bishop PV cell model have shown the algorithm capability to distinguish the majority of possible defects, and may be the subject of practical confirmation in a future work.

VIII. References

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