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COMPARISON OF PHOTOVOLTAIC PHENOMENON TO ELECTRONIC BEHAVIOURS OF DIODE, RESISTANCE, AND CAPACITY

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ABSTRACT

This paper presents a comparison of the photovoltaic (PV) - photoelectric phenomenon to the following phenomena: diode effect, resistance conceived to respect Ohm's law, and electrical capacity. In order to carry out this analysis, we compared the processes of the electrical behaviour of an amorphous silicon solar cell (a-Si) with those of the conventional electronic components such as: diodes, resistors, and the chemical or ceramic capacitors. This comparison, based on the analysis of the electrical characteristic (Current-Voltage) (I-V) of the PV cell and the electrical or electronic component, is carried out according to field trials. Similarities and differences between the electrical behaviour of the PV cell and that of electrical components were identified. The objective is to better understand the electrical characteristics of a PV cell and subsequently improve, afterwards, the performance modules and solar panels.

Keywords: amorphous cells, capacity, diode, photovoltaic, resistance.

INTRODUCTION

Solar energy is considered as a source of clean, abundant, and renewable energy for the future. PV solar panels are the essential elements in the chain of PV conversion into electrical energy. Knowledge of the characteristics of the PV module and control of behaviour are crucial and necessary in the energy management of PV systems and the design of various applications using these systems [1], [2]. To improve the overall efficiency of the PV string conversion we should first assess the factors limiting the performance effectiveness. Knowledge of the characteristics of the PV cell-photodiode or solar PV cell- allows the understanding and determination of its actual electrical behaviour.

The modelization of PV cells is an essential stage, which allowed in different research to have several models, their differences are generally situated in the number of diodes, shunt resistance, ideality factors, and the various methods used to determinate the unknown parameters [3].

Several methods of extraction parameters have been developed by research. In [4] tree methods of resolution were represented to determine the various parameters of the *I-V* characteristic. By comparing the results of tree method with the data issued by manufacturers, the slope method based in part on its algorithm of geometric calculation was the most accurate. In [5] a new five parameter model was presented to describing the *I-V* characteristic of PV module for each generic condition of operative temperature and solar illumination. The precision of this new model was tested by comparison with models proposed by other research. There is also methods using pattern search algorithm, [6] present a new objective function to the optimal estimated parameter values. In [7] a method for determining the parameters of single-diode cell/panel equivalent circuit combined a solution of algebraic equations system to obtain four unknown parameters.

To improve the overall efficiency of the PV string conversion we should first assess the factors limiting the performance effectiveness. Knowledge of the characteristics of the PV cell-photodiode or solar photovoltaic cell- allows the understanding and determination of its actual electrical behaviour. The model of the PV cell is often presented in two forms: simple diode model and double diode model. Both models have the same purpose and are largely sufficient in characterizing the PV cell [1], [2].

The PV module or cell is considered in this paper as being a new electronic component following the example of the others usual electronic components which it's important to define and to more understand its electric phenomenon to be able to improve afterward its efficiency and performances. We based our experimental comparison on these models. We considered provisionally the PV cell (a-Si) as a new electronic component, compared to other known elements such as diodes, resistors and capacitors. We first proceeded to a comparison of the behaviour of a PV cell with a diode. We compared all the features and properties of the two components on the polarization, the current changes depending on the voltage, and capacity of recovery. In order to determine the capacitive or resistive behaviour of the PV cell, considered here as an electrical component, we compared the behaviour of this cell with that of a chemical/ ceramic capacitor, and with an *Ohmic* resistance.

ANALYTICAL DIODE MODEL

The single model diode for a solar cell is often interpreted by an equivalent circuit including a current

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source represents the conversion of solar radiation into electrical energy, a parallel diode seeking to predict the PN junction, a series resistance R_s corresponds to the various contact resistances and connection carried in a cell, and the shunt resistance R_{sh} represents the state of surface to the periphery of a cell. These both resistances represent the various losses at the level of a cell. The module chosen in this work is made of amorphous silicon up of nine series cells, as represented in Figure-1.

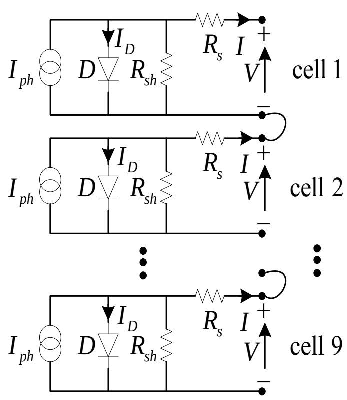

Figure-1. Module (a-Si) consists of 9 series cell.

The analytical formulation of this model, called the five parameter model, is expressed as follows:

$$I = I_{ph} - I_D\left(\exp\left(\frac{q\left(V + R_s I\right)}{nkT}\right) - 1\right) - \frac{\left(V + R_s I\right)}{R_{sh}}. \qquad (1)$$

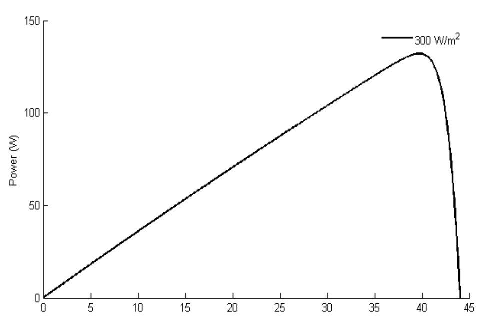

Figure-2. The typical power-voltage characteristics with influence of insolation kW/m².

The typical power-voltage curve of solar cell is illustrated in Figure-2. It is clear that the peak powers are the points, where $\frac{dP}{dV} = 0$.

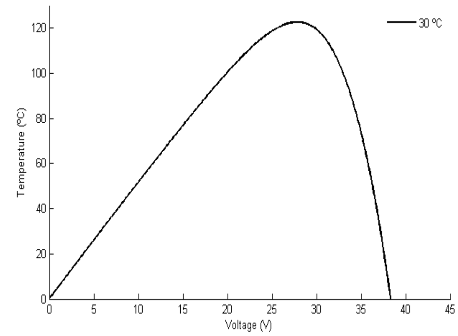

Figure-3. The typical current-voltage characteristics with influence of Temperature °C.

In a PV cell, the parameter most affected by an increase in temperature is the open-circuit voltage; the Figure-3 represents this effect.

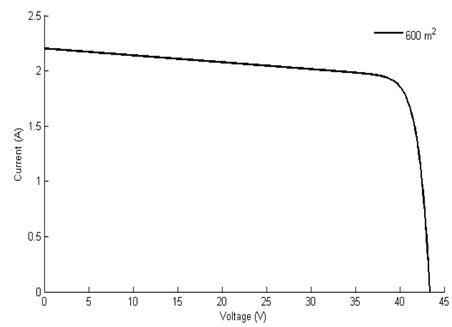

Figure-4. The typical current-voltage characteristics with influence of insolation kW/m².

The current-voltage values issued by the PV cell are dependent on cell properties and also the load at the cell terminals. In the Figure-4 there is an operating point where the electric power maximum.

PHYSICAL COMPARISON OF PV CELL TO REAL DIODE

Comparison of I-V Diode and PV cell characteristics

The diode is used in many common applications, mainly in rectifying circuit. It is considered a non-linear polarized dipole. *Shockley* [8] model expresses its current output according to its bias voltage:

$$I = I_s\left(\exp\left(\frac{qV_D}{nkT}\right) - 1\right). \qquad (2)$$

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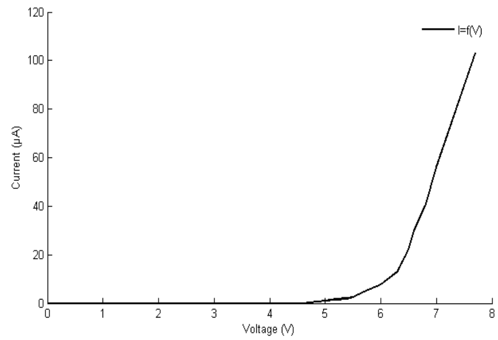


Figure-5. I-V experimental characteristic of PV module in the dark.

This polarization is of paramount importance in initiation of diode and of electric current. The bench test conducted in the laboratory is presented in Figure-5. We note the I-V characteristics in the dark and under illumination. We compare these characteristics to that of a conventional diode.

In dark, when illumination is zero, term of photonic current I_{ph} is negligible. The expression of (1) becomes (2).

We clearly see in Figure-5 that the electrical characteristic *I-V* of PV cell in dark have same shape as that of a single diode.

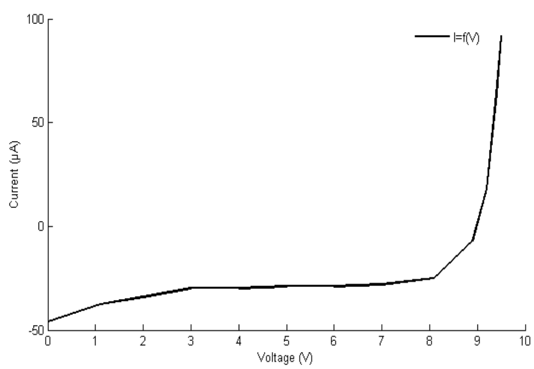


Figure-6. *I-V* Experimental characteristic under illumination.

Under illumination, it is noticed that the characteristic is translated downwardly in response to the irradiance (I_{ph}), as shown in Figure-6.

$$I = I_s\left(\exp\left(\frac{qV_D}{nkT}\right)-1\right)-I_{ph}. \qquad (3)$$

In practical, I_s is much lower than I_{ph}, the current measured is equal proportional to the photocurrent and following the incident irradiation [9].

Polarization

The bench is realized to examine the behaviour of the PV cell in the presence of polarity. The polarization characteristic of the PV cell is different from that of the diode. In fact the PV cell is reversible on current, and can let pass in either direction depending on the sign of the polarization. The PV cell - module which present no sign of polarization, it allows to pass the electric current in both directions. As against can conduct when it’s positively biased. As the diode, the PV cell has a limit of functioning limit beyond which is destroyed (applied DC voltage from one to 36 V, cell is destroyed).

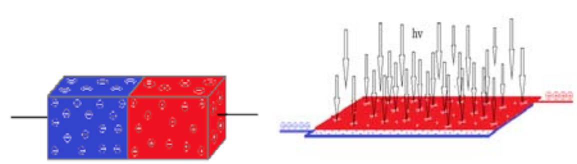
Voltage rectification

The results of the experiment to determine the ownership of the PV cell recovery have shown that it allows no recovery voltage. The effective value of the AC voltage applied to the cell has the same threshold previously limited to 36 V at which the cell is destroyed. We also note that when the solar cell is traversed by a current exceeding double or in some cases three times that it must generate, it is immediately destroyed. However, a conventional diode can withstand, for a short time, the excess current. It will be destroyed suddenly in case of short circuit or malfunction to its electrical system.

Observation

From all the experiments on the diode used and the PV cell (a-Si), to determine the similarities between these two components, the experimental results have shown us that the similarity between a diode and a PV cell exists only in the curve *I-V*. So, there is no physical resemblance between a cell or PV module and a diode. Their electrical or electronic behaviours are very different.

In observation (Figure-7) we can see that the diode is a PN junction volume whereas the PV cell is of the same junction, but surface and superficial. The energy of the first is an “abiding resident” while the energy of the second is purely superficial, it occurs only in quantity.



(a) (b)

Figure-7. PN junction: (a) diode; (b) PV cell. (hʋ: photon energy).

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COMPARISON OF A PV MODULE WITH A CAPACITY

The capacitor is an electrical component considered as an energy accumulator, it is designed to store an electric charge, it is used in several applications, such as storage, filtering. Storage capacity and storage of a PV cell is not similar to that of a capacitor. It has no ability to store an electrical charge or a ripple filter. Consequently, no similarity with chemical or ceramic capacitors may be increased. PV cell- module does not store charges except at the instant of the generation where it is under illumination. In the context of a comparison between the storage capacity and that of a PV cell, we have made manipulations and found the following results: a PV cell or module has no similar behaviour to that of a capacitor; it does not have the capacity to store an electric charge, it has neither the capacity to store an electric charge nor to filter. It also does not have the characteristic of the AC switch and the DC stop or vice versa.

Findings

No similarity between the chemical C_2 or ceramic C_1 capacitors and the PV cell has been found. It stores charge only when load generation is subjected to illumination.

PHYSICAL COMPARISON OF A PV MODULE WITH A REAL RESISTOR

It is known that electric dipole strength is generally used to slow the passage of an electric current and reduce its intensity; it is designed to adequately approach *Ohm's* law over a wide range of electrical or electronic assemblies. Firstly, we have measured the internal resistance in the dark of:

- A PV module (a-Si) its surface is 58.5 cm^2, its resistance R_{pv} = 120 kΩ (see Figure-1).
- A the three PV panels (a-Si) identical to the same series of manufacturing (see Figure-8) and their equal surfaces are 2610 cm^2: each, and their resistances R_{pv}: 750 Ω, 362 Ω, and 20 kΩ.

Which indicated that the *Ohmic* internal resistance value of a PV module (a-Si) is not subjected to any definite physical law, it is determined after the end of production.

Notes

- Under illumination: the measured internal resistance is infinite as if it is just a dry battery.
- Once the light drops, the generation of electric charges also fall, and resistance begins to appear randomly or in a spectacular way,
- This shows that the phenomenon of charge generation hides the resistive phenomenon, and the reverse is not correct.
- And unlike ideas that consider the internal resistance of the PV module is one of the causes limiting performance, the emergence of resistance is almost instantaneous, it is virtually present and tends towards more infinite when the PV cell is under illumination.

The question that arises is: Why - after the above - measuring the internal resistance of solar PV modules found it is never physically fixed and tends to infinite in illumination?

Certainly this virtual existence is responsible because it reduces the number of breakout probabilities of electrons at the same time as the carriers between the valence and the conduction bands. The greater the PV surface is, the smaller the virtual resistance.

The second question: Is the PV output proportional to the PV surface, like the virtual resistance?

We have compared two PV modules, one composed of 29 cells (2610 cm^2 - 96 µA,) forty-five times larger than the other, which is composed of 9 cells (58.5 cm^2 - 7 µA), and found out that the efficiency does not increase in proportion with the expansion of the surface except up to a certain threshold, then it is fixed (almost an increase of 14 times).

Findings

From what is known in an electrical circuit, the components will be destroyed or risk destruction when their resistance values decease. The smaller they are, the greater the risk will be. However, although the value of the internal resistance of the PV cell is infinite, it is destroyed experimentally when traveled by double or triple of its nominal voltage. (24 V voltage threshold (see Figure-1), and 60 V (see Figure-8). But the comparison of the three PV panels internal resistances with three real resistances showed that they are not destroyed when they are traversed by the same tensions.

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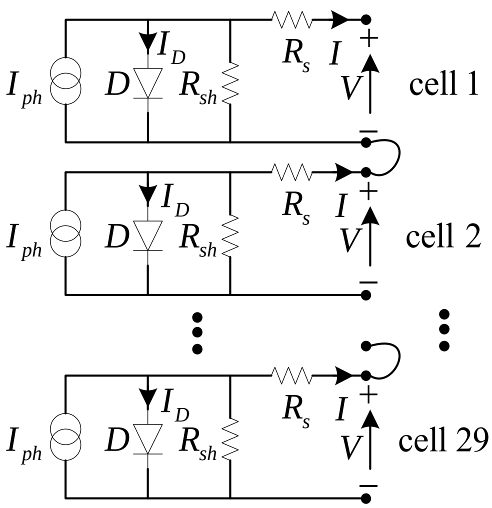

Figure-8. Module (a-Si) consists of 29 series cell.

CONCLUSIONS

In this document we have carried out experiments on the comparison of the electrical behaviour of a PV cell and those of conventional electrical components: diode, resistor and capacity, which showed that the polarization and the rolling loads in the diode has PN junction volume whereas the PV cell is of the same junction, but surface and superficial. The energy generated is surface. The diode allows totally spent loads in the right direction, while when the PV cell is traversed by the charges, they let them go in both directions by imposing a non-fixed resistivity to the most infinite and it does not improve alternating current. So there is no resemblance between a diode and a PV cell except identical shapes of *I-V* curves (see Figure-5).

To further identify the behaviour of the PV cell a second comparison was made with capacitors, which showed that the *PV* cell stores no charge, no filter stops the AC or DC currents as do ceramic capacitors and chemicals: the presence of loads of his *PV* is strictly related to the brightness. And a well detailed comparison with resistance showed that the resistive effect of a PV cell has an almost virtual appearance unlike the physical appearance and actual resistance subject to *Ohm's* law in electrical circuits. Also, it has been proved that the measured value of R_{pv} has never been fixed, and always tends toward more infinite under illumination, as if the generation charges also leads to a large resistivity, and does not protect the PV layers that are destroyed when they are covered by voltage from double or triple voltage they generate. And finally we compared two PV modules, one is nearly forty times larger in area than the other, it was found that the yield does not increase proportionately to the enlargement of the surface. It increases to a certain threshold then it is fixed.

Table-1. Parameters PV specifications at (0.6 kw/m^2, 30 °C).

Parameter	Value
R_{sh}	232.2 Ω
R_s	0.18 Ω
I_{ph}	3.801 A
I_s	1.35.10-4 A
Short-circuit current (I_{sc})	5.75 A
Open-circuit voltage (V_{oc})	44.9 V
K	1.38e-23 JK^{-1}
n	1.8
q	1.6e-19 C
Number of cells in series N_s	9 - 29

Nomenclature

PV	Photovoltaic
AC	Alternative Current
DC	Direct Current
a-Si	Amorphous - Silicon
R_{sh}	Parallel resistance (Ω)
R_s	Series resistance (Ω)
R_{pv}	Internal resistance of photovoltaic module (Ω)
D	Diode
C	capacitor
I_{ph}	Generated photo current (A)
I_D	Inverse current of the diode saturation (A)
I_s	Diode saturation current (A)
I	Current (A)
V	Voltage (V)
P	Power (W)
Q	Electric charge (C)
K	Boltzmann constant (JK^{-1})
N	Ideality factor
T	Temperature (°C)

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