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FACTORS THAT REDUCE THE RELIABILITY OF SOLAR PANELS

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INTRODUCTION

Environmental problems and real climate change make it increasingly necessary to work on the design and innovation of new forms of clean and renewable energy. This is the case with solar panels. In recent years, their study, design and implementation have evolved in order to make the most of the benefits of solar energy and minimize the use of non-renewable energy. However, something that has been partially done is to evaluate the reliability of these panels. Determine its duration of life, what aspects would cause its degradation and at what speed, what would be the points to take care of in order to avoid premature old age. These are some questions, among others, that are worth exploring and answering. This article presents the main factors that cause the reduction, and even the loss, of the reliability of solar panels.

DESCRIPTION OF THE REDUCTION OF THE RELIABILITY OF SOLAR PANELS

The technology used in renewable energies, particularly in solar, has evolved over the years. From the traditional solar panels, or better known as photovoltaic modules (MFV), based on semiconductor materials and with a rectangular geometric shape placed at an angle of inclination, to the modules designed to be placed in asphalt folders and windows which take advantage of the different positions of the star king. However, as expressed (Ndiaye, 2016) *"today, the lack of information on the different modes of degradation of MFVs in terms of frequency, speed of evolution and the degree of impact on the duration of life and the reliability of the aforementioned modules"*. In other words, it focuses more on technological development and little on the evaluation and measurement of the reliability of these modules. Despite the time this was said, the information has not grown significantly. Studies have been carried out that estimate an average lifespan of photovoltaic modules of 25 years (Remi *et al.*, 2011). On the other hand, it is important to note that despite the degradation that an MFV may experience, its main function, which is to provide electricity thanks to its solar exposure, can continue, however, with low efficiency and with little electrical capacity.

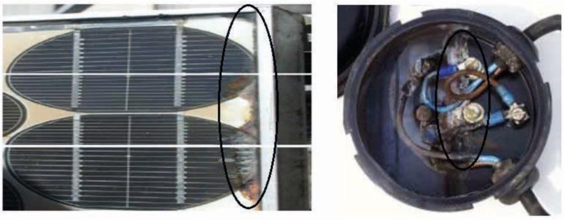
Several authors have carried out studies in which they state that physical variables such as: temperature, humidity, irradiation, dust, mechanical impacts, can reduce the functionality or degrade solar panels (Munoz, 2011), (Ndiaye, 2013)., (Osterwald, 2009), (Quintana, 2012) and (Wohlgemuth, 2005). Each of these factors can introduce different types of degradation such as: discoloration, delamination, corrosion, fractures and fissures of the cells (Mun, 2011), (Vaz, 08).

Also the NREL (National Renewable Energy Laboratory, USA) provides, in a table, a list of major degradations on MFV in crystalline silicon (Bosco, 2010), (Wohlgemuth, 2010). It presents both mechanical, electrical, electronic and structural failures. Table 1 shows this information.

It is therefore important to mention that the reliability of solar panels can be estimated through the degradation that they experience. The more descriptive factors of degradation that MFVs present, their efficiency will decrease and, therefore, they are less reliable. Furthermore, within the science of failures, operational safety, degradation it is important to see it through its different modes. That is, not only can it be said that a solar panel degrades, but there are different ways, so-called modes, in which MFVs experience depreciation, deterioration or degradation.

	Degradation
MFV on crystalline silicon	broken interconnects broken cells Corrosion encapsulation delamination Discoloration of the encapsulation broken glass layer overheated points Bypass diode failure Breakage of the interconnecting glues

Table 1. Main degradation modes of crystalline silicon solar panels (Woh_10)



a) edge corrosion b) interconnection corrosion

Figure 1. Photovoltaic module affected by corrosion (Ndiaye, 2016)

MFV RELIABILITY REDUCTION FACTORS

Below is a brief description of the different degradation modes that affect the reliability of a solar panel, as well as the effects they cause. (Ndiaye, 2016) in his doctoral thesis he makes an excellent and complete description of these cases. Based on this and on works carried out by other authors, this article presents a brief summary or description of them in order to arouse interest, study and understanding about what can happen with MFV and that sometimes is not Find an explanation for unexpected behaviors.

CORROSION

Moisture penetrating solar panels through narrow edges causes corrosion (Quintana, 2002). Moisture retention in the module casing increases the electrical conductivity of the material. Corrosion attacks the metal connections of the solar panel cells causing an increase in leakage currents and thus a loss of efficiency. Corrosion also affects the adherence between the module cells and the metallic frame. Figure 1 shows a section of a module affected by corrosion at the edge of an interconnection box.

(Wolghemuth and Kurtz, 2011) have studied the impact of humidity and temperature on the degradation of solar panels from tests called “accelerated” finding 85º C and a relative humidity of 85%. They found that corrosion appears at the end of about 1000 hours of exposure of the module under a temperature of 85º C and a relative humidity of 85%.

DELAMINATION

Delamination reflects the loss of adhesion between the encapsulated polymer and the cells or between the cells and the glass inside. This mode of degradation causes two effects: the increase in light reflection and the penetration of water into the interior of the module structure (Munoz, 2011). Delamination is more common in hot and humid climates. It favors moisture penetration in the MFV and consequently causes different chemical reactions inside the module, inducing degradation such as corrosion of the metals of the module structure most frequently. Figure 2 shows two modules (poly and monocrystalline) presenting severe delamination.

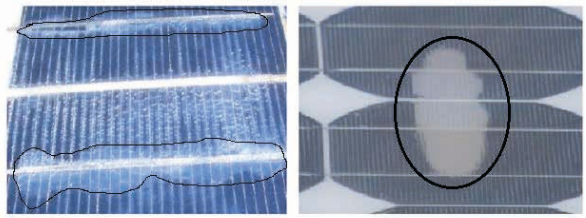


Figure 2. Photovoltaic module presenting a delamination (Ndiaye, 2016)

DISCOLORATION

The discoloration of the MFV results in a change in color of the material used for its encapsulation, which is generally ethyl vinyl acetate (EVA) or an adhesive material between the glass and the cells. This color change can be seen by heating the encapsulated material (Figure 3). The discoloration causes a change in the transmittance of the encapsulation of the cells and consequently the power generated by the module is decreased.

Figure 3. Photovoltaic module with discolored cells (Ndiaye, 2016)

The discoloration of the module degrades the short-circuit current (Icc). This degradation of the short-circuit current can vary from 6 to 8% below the nominal value due to a partial discoloration of the module surface and from 10 to 13% due to a total discoloration of the module. The maximum power (Pmax) that represents the performance parameter, the most important of the module, is also degraded by the discoloration of the MFV encapsulation (Rea, 2013).

CRACKS AND GLASS BREAKAGE

Module glass breakage and cracking are a major factor in solar panel degradation. These occur in most cases during installation, maintenance and, above all, transport operations of the modules on the installation sites (Wohlgemuth, 2011). The module that presents cracks or ruptures can, however, continue to produce energy. Figure 4 shows a cracked polycrystalline silicon photovoltaic module during its first commissioning and which has operated for five years in association with other modules. However, the risk of electric shock and moisture penetration may be higher. Breaks, glass breakage and cracks are generally followed by other types of degradation such as corrosion, discoloration, delamination (Quintana, 2002).

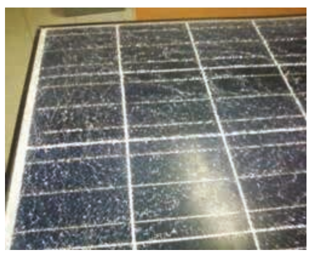


Figure 4. Photovoltaic module presenting glass breaks (Ndiaye, 2016)

HOT SPOTS OR HOT-SPOTS

A solar panel is an association of cells in series and parallel. Its global characteristic can vary depending on the brightness, the temperature, the aging of the cells and the effects of the shadow and the non-homogeneity of the lightening. Furthermore, shadowing or degradation of a cell placed in series is sufficient to cause a sharp decrease in the current produced by the module. When the current generated or demanded is higher than the current produced by the faulty or weakly illuminated cell, its voltage becomes negative and it behaves like a receiver. Thus, the cell is in relatively high thermal dissipation and this can lead to its total destruction: it is the phenomenon of the hot spot (in English) (Her, 1997), (Alonso-Garcia, 2006) which the module shown in figure 5 is reached.

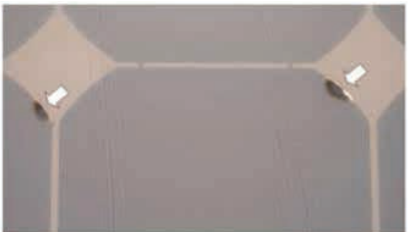


Figure 5. Module that presents hot spots on the edges of the upper corners (Ndiaye, 2016)

THE BUBBLES

The bubbles are generally due to chemical reactions that dissipate gas in the module and become trapped inside the module. This type of degradation is similar to delamination, but, in this case, the loss of EVA adhesion affects only a small surface of the module and is combined with inflammation of the surface where the adhesion has been degraded. When this happens at the rear of the module, a jam appears on the encapsulated polymer thus forming the bubbles. This makes it more difficult for heat dissipation in the module cells, increasing overheating and accelerating their aging (Ste, 2004). Figure 6 shows a module that has a significant number of bubbles on the rear surface. They generally appear in the center of the cell and can occur due to poor cell adhesion caused by high temperature (Munoz, 2011).

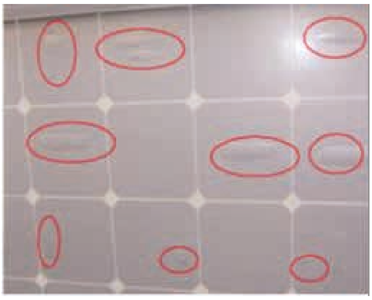


Figure 6. Bubbles present on the back of a photovoltaic module (Ndiaye, 2016)

THE PID

The PID or Potential Induced Degradation (in English) or Potential Induced Degradation (in Spanish) is a "new disease" of the solar panel, made evident in 2010, it begins to touch more and more modules. The first symptom of this phenomenon is a rapid and unexplained degradation of power. This decrease in the performance of the modules, which can reach more than 20% in a few months, is not due to the classic aging of the modules or to a poor installation of the module.

Individual modules in photovoltaic systems are connected in series in order to increase the system voltage. The potential difference of the chain thus formed can sometimes reach several hundred voltages (Sch, 2011a). Consequently, in order to protect people against electric shocks, all metallic structures of the modules are normally grounded.

DEGRADATION MODE DETECTION METHODS

The different works carried out on the subject show that the main factors that favor the PID are the voltage of the system used, the humidity and the operating temperature.

(Ndiaye, 2016) presents (Changwoon, 2012) a summary of the main degradation modes that occur in silicon MFVs. Figure 7 shows us that the most common mode is delamination, followed by glass breakage and corrosion. The modes that occur the least are discoloration and fissures, among others. This information will allow paying attention to its different causes and how it affects the module. Specialists will have to observe the implications and handle the modules appropriately.

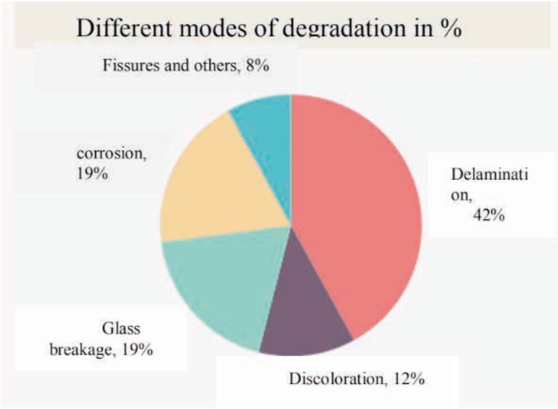


Figure 7. Representativeness of the different modes of degradation (Ndiaye, 2016)

Given the reality of the existence of these modes of degradation, there are techniques that allow detecting the degradation suffered or experienced by the solar panel. (Ndiaye, 2016) presents a table in which the main techniques for detecting the degradation of a solar panel can be observed. Table 2 indicates the detection method, the type of degradation that is detected and the means of control.

Methods	Detectable degradations	Controlled means
Visual inspection	- discoloration - Delamination - Bubbles - Fissures - Hot spots	Module overview
power measurement	- Power - Current - Voltage - Form Factor	Power Current Voltage form factor
infrared image	- Red point	Images
thermography	- short circuit - Open circuit	Images
Electroluminescence and Photoluminescence Imaging	- Fissures	Images
Ultrasonic Vibration Resonance	- Microcracks	Response frequency variation

Table 2. Methods of detection of degradation modes of solar panels

FINAL COMMENTS

Talking about the degradation modes of solar panels is useful and necessary. This will allow understanding and attending to technical and material situations. From the studies carried out by various authors, the installation and handling of solar panels can be done in a careful and professional manner. Below are some important points.

SUMMARY OF RESULTS

The knowledge of the degradation modes of solar panels will allow to be careful in the transport, installation and handling of the panels. Know how electrical aspects can be taken care of from this perspective. Also, having detection techniques or methods is crucial to increase the reliability of solar panels.

CONCLUSIONS

After observing the different modes of degradation for a solar panel, it is observed that it is essential to consider the detection methods in order to increase the reliability of the panel. Visual inspection will continue to be the basis and foundation of this detection. Having specialized instrumentation will be very helpful.

RECOMMENDATIONS

The reading, study and analysis of the models that also exist on the modes of degradation and that allow analytically visualizing the behavior of a solar panel under certain conditions or situations is recommended.

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