The effect caused by cell cracking in the efficiency of photovoltaic panels

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Rafael Mateus Figueiredo
Instituto superior técnico
Universidade de Lisboa
Lisboa, Portugal
rafael.figueiredo@tecnico.ulisboa.pt

***Abstract*—Renewable energies are increasingly playing an important role in the world's energy supply. Technologies must be studied and improved in order to maximize their productivity. In photovoltaic modules some problems arise, which lead to a reduction in efficiency affecting energy production. This happens due to several factors, such as the weather conditions to which they are exposed or a bad installation for example. This leads to the appearance of some failures in the panels, such as *cracking*.**

A practical study was made testing the effect of cracking on several solar cells, of different technologies, perovskite, *CIGS*, amorphous silicon and crystalline silicon cells. The aim was to verify the behavior of cells when induced different levels of cracking, writing down the cell parameters along the different processes. With the results obtained, it was possible to verify the negative effect of cracking on the performance of solar cells, with a reduction in parameters.

In parallel, an electrical model was created where it was possible to simulate the behavior of cells through the curves *I-U*, based on the ideal model *1m3p*. The results were somewhat positive, and it was possible to represent a crystalline silicon cell with some precision.

***Index Terms*—*Cracking*, solar cell, efficiency, model**

I. Introduction

Currently, fossil fuels are increasingly a problem for the health of the planet. With climate change becoming more and more visible, renewable energy is gaining an increasingly important role in energy generation. The fact that they are abundant and exist in remote places makes them very attractive. In addition, there can be either a centralized production or a modular production, which are quite adaptable. Currently, it is estimated that 28% of the energy consumed worldwide comes from renewable energies. [1], [2] Thus, in order to improve the performance of different technologies, it is necessary to know their limits and understand how the existing degradation affects them. This article will focus on the study of solar cells and how cracking affects their yields where different levels of cracking were induced, having the cells' comportment before and after degradation.

II. Problems affecting photovoltaic systems

This article focuses only on cracking, but in order to have a better understanding of how a system can be affected by various situations, the most common situations were studied. Knowing how each problem arose and affected the system, it was possible to verify that the appearance of a certain problem led to the creation of cracking, thus getting to know the connections between them.

A. Glass failure

Glass failure occurs when the glass breaks or when dirt accumulates. Poor manufacturing, poor transportation, poor maintenance and poor assembly are the main reasons for glass to break. The biggest risk is the safety for the human being, with the possible exposure of toxic materials or sharp materials. Performance is affected due to blocking of light absorbed by the cracked glass, resulting in less energy generation. In the situation where there is accumulation of dirt, this causes the temperature of the panel to increase, increasing the speed of degradation of all its components. [3]

B. Descoloration

Discoloration is visible when there are areas of the panel to turn yellow or brownish. This will reduce production, due to the decrease in healthy panel area. There is also an increase in temperature that leads to increased degradation of all components. [4]

C. Delamination

Delamination is visible due to the appearance of clear forms of the type of blisters. This can appear on both the front and back of the panel. Frontally, it can arise from the lack of adhesion between the encapsulating layer and the glass, due to a problem in the assembly. It also appears in cells, usually around the busbar. As it is the one that transports the current, some residue may be created, originating a chemical reaction with the release of a gas. Another reason given is the appearance of water, which between heating and cooling the panel evaporates or condenses, thus creating such bubbles. All of this leads to increased component degradation. Clear bubbles will reduce the absorption of sunlight. At the rear of the panel, delamination comes with the release of some gas that cannot be expelled to the outside, which has very little effect on the performance of the panel. [4]

D. Hotspots

Hotspots are zones in the panel where there is a significant increase in temperature. They can arise internally due to a defect in a cell, and the system is constantly affected. Externally it can appear due to partial shading, due to a tree for example, or accumulated dirt. Degradation in components increases and in more severe cases hotspots can even appear as burnt spots along the affected cells. This happens when the cell is in reverse polarization and started to dissipate energy in the form of heat at these points. [6]

E. Cracking

Cracking are cracks that appear in cells, reducing their performance. It can occur during cell production, as well as during transport or installation due to excessive vibration. In some cases, with more adverse climatic situations it can also lead to the same outcome. The crack can be characterized through its direction in relation to the busbar as perpendicular, diagonal or parallel, for example. It can also be defined as inner or outer depending on whether the outer layer is damaged or not. Finally, they are defined in relation to their size, being called just crack when it is visible to the naked eye, or micro crack when it is necessary to use optical methods for its detection. With the appearance of a crack, part of the cell can be deconnected, reducing its production. In the case of micro crack, it is possible that there is always some contact, ending up always leading to losses, which are more difficult to confirm or quantify. [8]–[11]

F. Other problems

Snail trails are small dark lines that appear along the cell, made up of silver particles coming from the fingers of the cell. They are thought to arise due to micro cracks. [11]

The micro arcs appear at the connections between cell lines or between cells. This is due to a poor welding process thus leading to low electrical conductivity. This can lead to a total breakdown of the panel's performance. [3]

The breakage of the frame that supports the panel is a rather common problem in more snowy areas. The extra weight from accumulating snow leads to this breakage, which in extreme cases makes the panel unusable. [3]

The bypass diode protects cells from reverse current, which arises when the panel is affected by shading. It is very sensitive, requiring careful handling. In case of failure, performance will decrease and can lead to the appearance of hotspots. [3]

The electrical box protects the panel connections with the outer terminals. A bad connection can lead, in extreme cases, to the appearance of a fire, damaging the entire panel. There may also be water infiltration in the box leading to increased degradation of the terminals, reducing their production. [3]

III. Experimental procedure

All tests were carried out in the laboratory, with the same conditions for the different cracking inductions. Cell and panel of perovskite, *CIGS*, amorphous silicon and crystalline silicon were used. The objective was to trace the curves *I-V* and *P-V* of the various cells. Both before any crack is applied and between different applications. Some parameters were also removed for analysis, the open circuit voltage *Voc*, the short circuit current *Isc*, the maximum power *Pmax* and the efficiency η. For this, the assembly was made according to the visible circuit in 1, where the cell is in parallel with a voltmeter and with a breadboard with different resistances and an ammeter in series. The multimeters used to perform the voltmeter and ammeter function were of the brand *GWINSTEK GDM-8135*. It was always confirmed that each measurement was made with $300W/m^2$ through an irradiance meter.

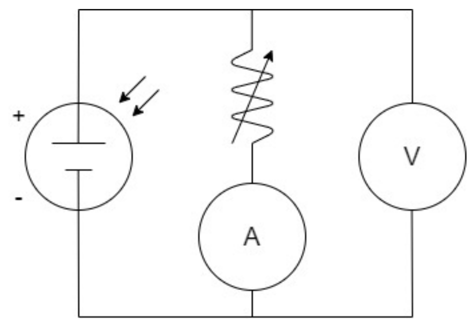

Fig. 1. Equivalent circuit of experimental installation.

A. Tests and results

With the tests performed and the experimental points removed, it was necessary to find an adjustment model that better represents the progress of the curves, both for the initial behavior and for the various cases of cracking. Thus, using MATLAB's Curve Fitting Toolbox tool it was possible to trace all the curves. The double exponential equation was chosen to represent the *I-V* curves. Due to the value of the coefficient of determination, R^2, it was possible to prove the good choice, with this value always being close to 1, with 1 being the value of maximum precision. However, for the cell *CIGS* it was not possible to use this model, where we chose to just join the experimental points.

B. Perovskite cell

The test on this cell consisted of measuring its functioning with the original cell and then comparing it with different levels of cracking. To deteriorate the cell, cuts were created along the cell, with a metallic surface. It started by making two irregular cuts in the cell, followed by two more straight cuts. Finally, the ends of the cells were cross-cracked, figure I.

Looking at the figures 3 and 4 and at the data in the table I, the negative influence that the various *crackings* had on the cell is visible. The curves represented in the figure 3 present the typical appearance of the characteristic curve of this type

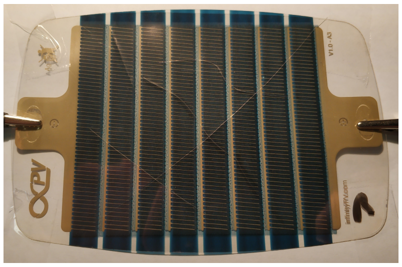

Fig. 2. Perovskite cell after cracking.

of cell. The biggest decrease was felt between the second and third situation with a loss of efficiency around 35%, and among the other situations the losses are somewhat similar, around 25%.

TABLE I
PEROVSKITE CELL PARAMETERS WITH THE INDUCTION OF DIFFERENT LEVELS OF CRACKING.

	Original	**Crack 1**	**Crack 2**	**Crack 3**	**Crack 4**
Isc (mA)	1.384	1.376	1.116	0.972	0.767
Voc (V)	2.39	1.67	1.30	1.25	1.16
Pmax (mW)	1.085	0.7688	0.5019	0.3696	0.2814
η	0.0468	0.0331	0.0216	0.0159	0.012

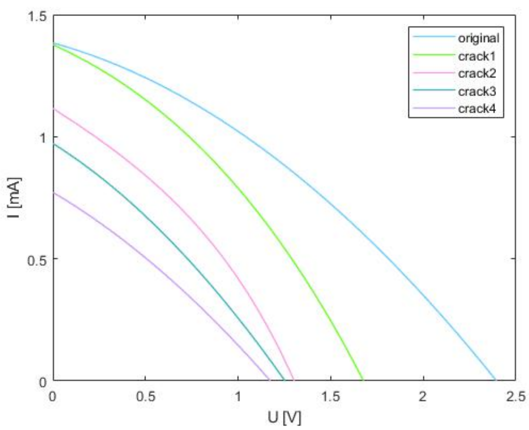

Fig. 3. *I-U* curve of the perovskite cell.

C. Perovskite panel

In the perovskite panel the test was very similar to the cell. As the panel was divided into "columns", they were added somewhat similar cracks in the different columns, always removing data from the panel's operation before the creation of a new crack. In figure II the different levels of cuts made in the panel.

Before analyzing the data on the perovskite panel, it should be noted that this panel is was previously used in another study, and is already quite degraded by the date of the extrial carried out. So the original situation represented is the situation before it was applied any crack in the panel.

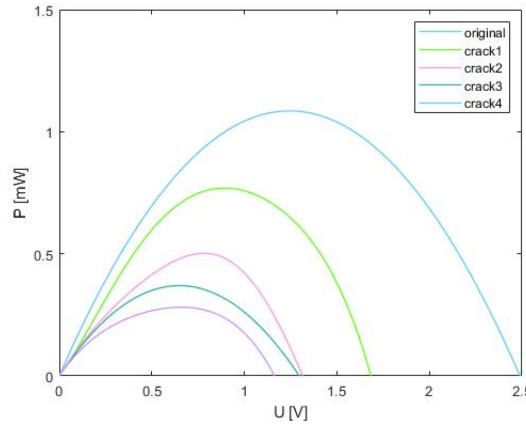

Fig. 4. *P-U* curve of the perovskite cell.

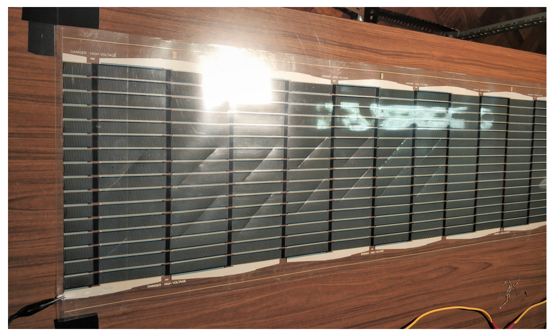

Fig. 5. Perovskite panel after cracking.

With the results calculated and presented in figures 6 and 8 and in table II is possible to conclude that the maximum power variation is very low, as well as the voltage values and current for the different degradation states. As it is visible by the low current that passes on the panel it is possible to see how degraded it was. Such degradation had a lot of influence on its poor performance. However, it is possible to see the low impact that cracking had in a cell already quite damaged, having as a comparison the tests carried out in the other cells, where with the first degradation state its effect on the cell output was visible.

D. CIGS cell

The experimental procedure in the *CIGS* cell differed from those already mentioned. This happend because in its composition there may be cadmium, which is extremely toxic. So it was not possible to apply cuts in the cell with the fear of exposure to this compound. It was then decided to go on bending and creasing part of the cell, always with precaution, in the hope of creating some type of cracking.

Analyzing the data obtained in table III and in figures 9 and 10 it is possible to observe the effect of the different cracks on the behavior of the cell. Despite the decrease in power supplied by the cell over the various degradation states a certain stability in its behavior is visible, with the value

TABLE II
PEROVSKITE PANEL PARAMETERS WITH THE INDUCTION OF DIFFERENT LEVELS OF CRACKING

	Original	**Crack 1**	**Crack 2**	**Crack 3**	**Crack 4**	**Crack 5**	**Crack 6**
Isc (mA)	0.0534	0.05528	0.05697	0.04825	0.04689	0.04183	0.04178
Voc (V)	12.64	11.95	13.01	11.79	12.26	12.53	12.83
Pmax (mW)	0.1837	0.1729	0.1811	0.1503	0.15494	0.1582	0.1399
η	1.8×10^{-4}	1.69×10^{-4}	1.78×10^{-4}	1.47×10^{-4}	1.52×10^{-4}	1.55×10^{-4}	1.37×10^{-4}

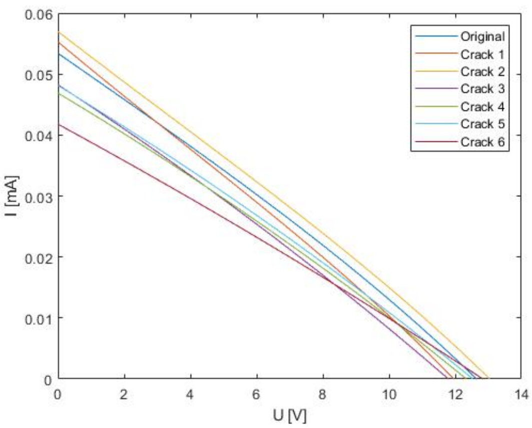

Fig. 6. *I-U* curve of the perovskite panel.

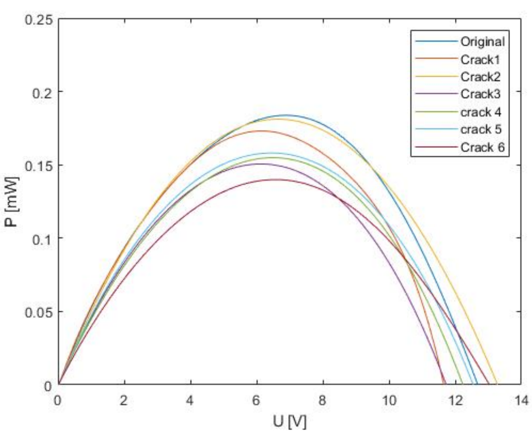

Fig. 7. *P-U* curve of the perovskite panel.

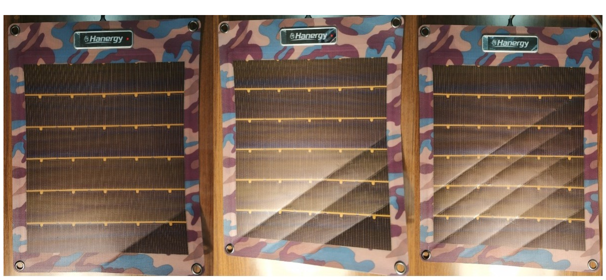

Fig. 8. *CIGS* cell after cracking.

of power being constant for each of the cases presented. In addition, it is possible to verify that between crack 3 and crack 4 was where there was the sharpest decrease in performance. Such can happened due to lack of consistency in the degradation of the cell. By which means that as the cell was not cut, but successively creased, the applied force was certainly not the same, although there was always this concern throughout the process.

TABLE III
CIGS CELL PARAMETERS WITH THE INDUCTION OF DIFFERENT LEVELS OF CRACKING.

	Original	**Crack 1**	**Crack 2**	**Crack 3**	**Crack 4**	**Crack 5**
Isc (A)	0.702	0.633	0.605	0.476	0.242	0.215
Voc (V)	5.14	5.14	5.14	5.13	5.11	5.11
Pmax(W)	0.624	0.576	0.471	0.366	0.106	0.099
η	3.79	3.5	2.86	2.23	0.64	0.60

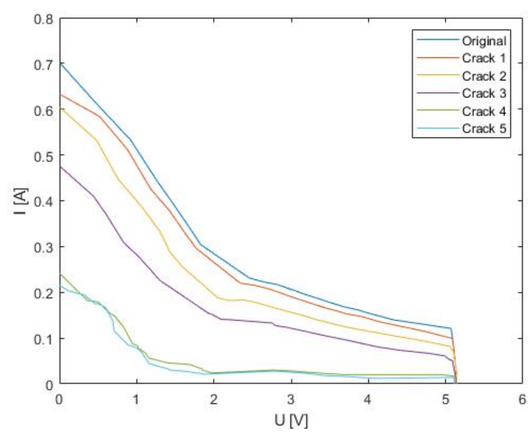

Fig. 9. *I-U* curve of the *CIGS* cell.

E. Amorphous silicon cell

The process of testing the amorphous silicon cell was very similar to the one for the perovskite cell. It was subjected to different crackings, visible in figure 11, with the performance to be measured between defects. It started with three small cuts to catch a small part of the cell, ending in a larger cross-section across it.

In the case of the amorphous silicon cell, the impact of cracking on its performance is again visible, with its decrease being visible along the different degradation states, with the

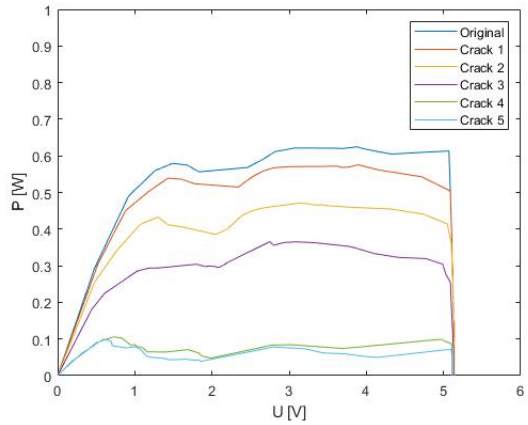

Fig. 10. *P-U* curve of the *CIGS* cell.

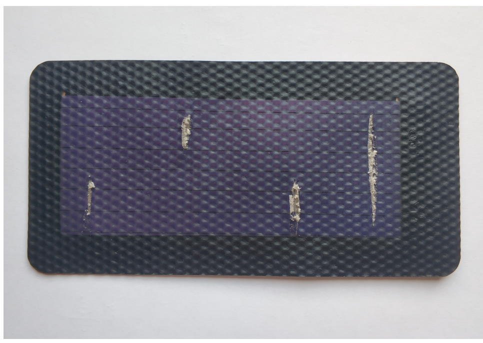

Fig. 11. Amorphous silicon cell after cracking.

first crack made the biggest and most visible impact. There was soon a decrease of almost 93% in efficiency of the cell, table IV. The maximum power point reduces to levels very close to zero, 13. The crack 4 practically left the cell unusable and with residual values. In figure 12 it is possible to see that in the degradation states curve is very similar to a straight line, with Voc values being the most affected factor.

TABLE IV
AMORPHOUS SILICON CELL PARAMETERS WITH THE INDUCTION OF DIFFERENT LEVELS OF CRACKING

	Original	**Crack 1**	**Crack 2**	**Crack 3**	**Crack 4**
Isc (A)	6.627	5.936	4.625	3.990	0.8135
Voc(V)	1.559	0.341	0.147	0.115	0.02
Pmax(mW)	6.978	0.4991	0.1673	0.1137	0.0027
η	0.683	0.0489	0.0164	0.0111	2.64×10^{-4}

F. Crystalline silicon

The silicon cell has a difference from all the aforementioned ones, it is not thin-film. The creation of some kind of crack in the cell becomes more complicated due to its rigidity. An attempt was made to induce some kind of cracking through the continuous friction of a metallic surface in the cell. The results that came out of this test were inconclusive. As there

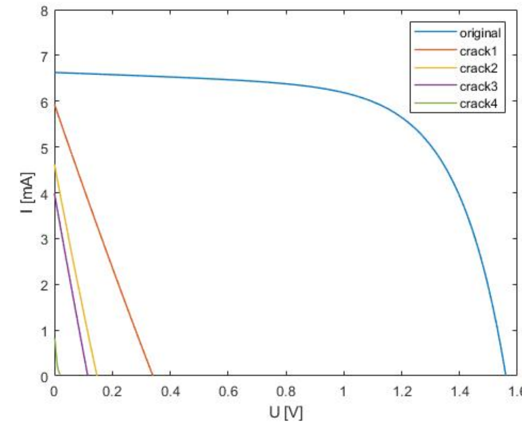

Fig. 12. *I-U* curve of the amorphous silicon cell.

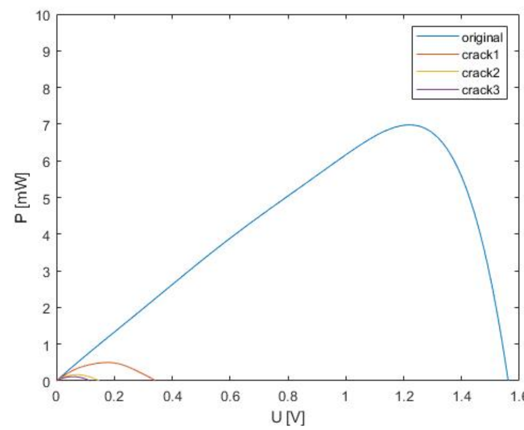

Fig. 13. *P-U* curve of the amorphous silicon cell.

was no certainty that cracks were actually being applied to the cell, it was decided to print force in some points of the cell, in order to cross all the material.

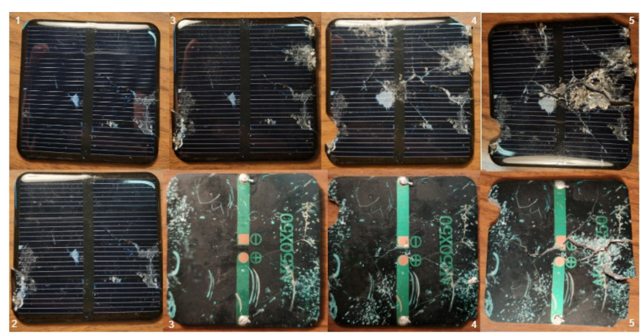

Fig. 14. Crystalline silicon cell after cracking.

Cell performance dropped over different cracks induced in it, figure 15. There was an efficiency loss around 60%, table V, in the first degradation situation. That is visible with the reduction of the maximum power point, figure 16. This reduction is due to the great initial damage caused, a factor that is no longer seen in crack 2, 3 and 4. In the last crack there was also a great loss of efficiency, when compared to the previous crack, since in this case there was part of the cell to became lose and break its connections, thus contributing to the worst performance, because until now, despite the cell being already divided, all its parts still kept in contact.

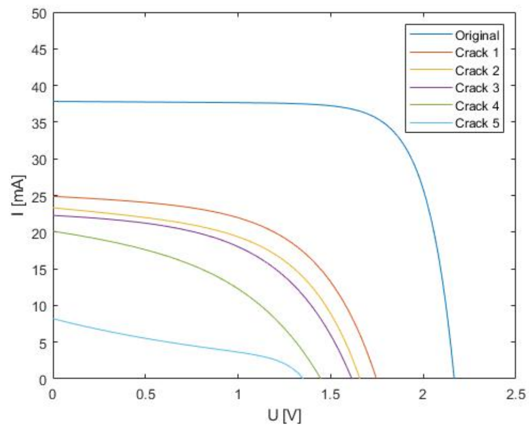

Fig. 15. *I-U* curve of the crystalline silicon cell.

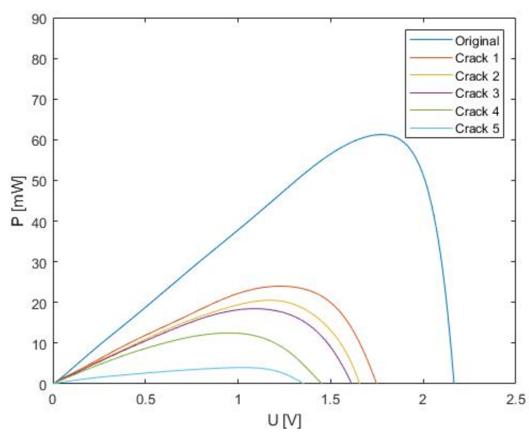

Fig. 16. *P-U* curve of the crystalline silicon cell.

IV. Model

It was needed to find a model where it was possible to simulate the behavior of cells subjected to cracks. The equivalent circuit of the solar cell, the 1m3p, was used as a basis, where there is a current source in parallel with a diode. [12].

Thus, knowing that the voltage on the x-axis and the current on the y-axis come from the axes of the I-U curves, and through Ohm's law it is possible to calculate the slope of a straight line. The equation **??** proves that it is the inverse of the resistance.

$$R = \left| \left(\frac{I}{U} \right)^{-1} \right| \tag{1}$$

Now it would be necessary to be able to represent a curve, as the slope varies. By dividing the curve into several line segments, each line segment with its slope, it would be possible to approximate the curve by putting them all together. Thus, based on the 1m3p model, a circuit was created with the current source, whose value is the short circuit current, and in parallel with the ideal diode, a resistance that is responsible for the slope and a voltage source which shapes from which value the curve is affected by that slope. All this repeated in n branches, image 17

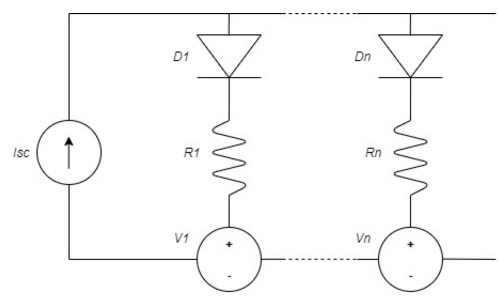

Fig. 17. Circuit for n points.

With the idealized model, it was applied in the cells used in the experimental tests, the perovskite cell and the panel, the *CIGS* cell and the amorphous silicon and crystalline silicon cells. For this purpose, it was decided to take all the experimental points, from the different degradation phases, and calculate the slopes between all these points, leaving the curve *I-U* divided into different straight segments. For a better understanding, imagining the point A and B of a test, the slope of the straight line between these two points was calculated, equation 2, from where it is possible to obtain the value of the first resistance through the equation 1 referred to earlier. The voltage source value would be the voltage value of the initial point of this straight line segment, in this case point A. Then, picking up points B and C, this whole process would be repeated. New branches were added to the circuit as there were experimental points.

$$slope = \frac{I_A - I_B}{V_A - V_B} \tag{2}$$

A. *Results from the model*

To apply this model, *LTspice* was used for the different tests and simulations and *MATLAB* to treat the points and draw the I-U curves presented below.

B. *CIGS*

The curves obtained through the model are quite different from the experimental curves, image 18. Such a result was something to be expected, since this model is based on the similar exponential behavior between the diode and the different solar cells and the *CIGS* cell, since it is the only one in which exponentiality was not present in its characteristic curve. However, its analysis is possible where it is verified that the points of V_{oc} are very far from the values obtained

TABLE V
AMORPHOUS SILICON CELL PARAMETERS WITH THE INDUCTION OF DIFFERENT LEVELS OF CRACKING

	Original	**Crack 1**	**Crack 2**	**Crack 3**	**Crack 4**	**Crack 5**
Isc(mA)	37.82	24.88	23.31	22.28	20.12	8.205
Voc (V)	2.17	1.74	1.65	1.61	1.44	1.35
Pmax(mW)	61.26	24	20.55	18.47	12.51	4.008
η	8.16	3.2	2.74	2.46	1.66	0.53

experimentally. The remaining values are also beyond the expected values. As a positive point, the visible decrease between the various stages of *cracking* should be highlighted.

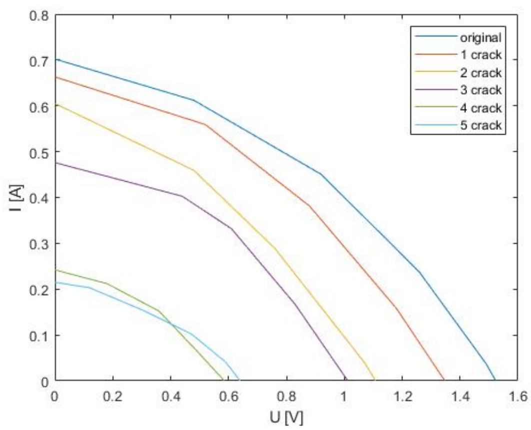

Fig. 18. *I-U* curve of the *CIGS* cell for the model.

C. Perovskite panel

Now the results of the perovskite panel, figure 19, are displayed. The results visible here have some consistency with those presented in the experimental part. The curves show little difference between them but with the points of V_{oc}, again much smaller than those obtained experimentally. The remaining parameters also deviate from the experimental results, as expected. It should be remembered that this panel was already quite deteriorated and that the values obtained during the laboratory experiments were quite low and unstable, with a large dispersion of points. Combining this with the calculation of the different resistances, this drastic decrease existed, reducing the values of the open circuit voltage.

D. Perovskite cell

In the perovskite cell, figure 20, something similar to what happened in the perovskite panel happens. There is a large dispersion of experimental points, leading to a variation of resistance values, sinking the curves, obtaining inaccurate values of all the parameters. However, the curves are somewhat similar to the experimental ones, showing some coherence between the model and the real points.

E. Amorphous silicon cell

The amorphous silicon cell along with the crystalline silicon cell had the best results. When comparing the experimental

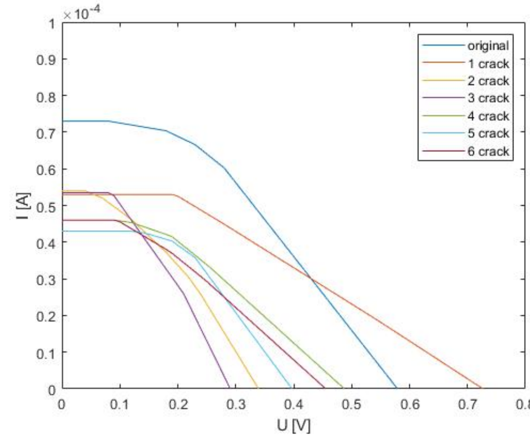

Fig. 19. *I-U* curve of the perovskite panel for the model.

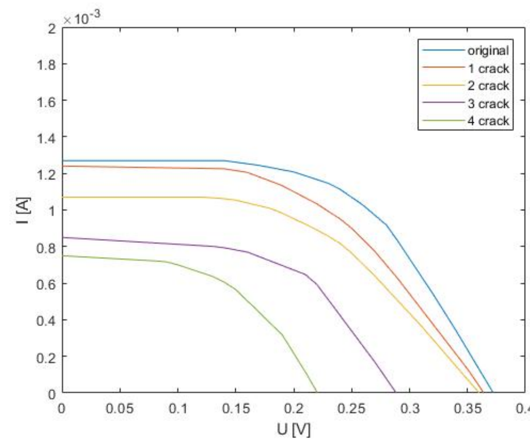

Fig. 20. *I-U* curve of the perovskite cell for the model.

and model curves, figure 22, it is possible to see the existing similarities, despite the decrease in the evaluated parameters, table VI.

F. Crystalline silicon cell

The crystalline silicon results are the ones that most resemble the experimental results visible in the figure 14. The short circuit voltage values had a small drop, except for the last two *cracks*, where the drop is more accentuated. The crystalline silicon cell is more stable than all the others and has less dispersion at the points removed, which ends up being demonstrated in the curves taken from the model.

TABLE VI
COMPARISON BETWEEN EXPERIMENTAL DATA AND MODEL DATA FOR THE PEROVKSITE PANEL.

	Original	**Crack 1**	**Crack 2**	**Crack 3**	**Crack 4**
I_{sc} experimental (mA)	6.627	5.936	4.625	3.990	0.8135
I_{sc} modelo (mA)	6.997	6.001	4.42	3.86	0.86
V_{oc} experimental (V)	1.559	0.341	0.147	0.115	0.02
V_{oc} modelo (V)	0.68	0.064	0.062	0.04	6.2×10^{-3}
P_{max} experimental (mW)	6.978	0.4991	0.1673	0.1137	0.0027
P_{max} modelo (mW)	1.653	0.109	0.114	0.0528	-
I_{mp} experimental (A)	5.715	2.852	2.356	1.833	0.01475
I_{mp} modelo (mA)	4.5	0.989	2.85	2.641	-
V_{mp} experimental (V)	1.221	0.175	0.071	0.062	0.183
V_{mp} modelo (V)	0.36	0.03	0.04	0.02	-

TABLE VII
COMPARISON BETWEEN EXPERIMENTAL DATA AND MODEL DATA FOR THE PEROVKSITE PANEL.

	Original	**Crack 1**	**Crack 2**	**Crack 3**	**Crack 4**	**Crack5**
I_{sc} experimental (mA)	37.82	24.88	23.31	22.28	20.12	8.205
I_{sc} modelo (mA)	37.2	25.1	23.3	22	20.1	8.5
V_{oc} experimental (V)	2.17	1.74	1.65	1.61	1.44	1.35
V_{oc} modelo (V)	2.05	1.33	1.17	1.2	0.66	0.21
P_{max} experimental (mW)	61.26	24	20.55	18.47	12.51	4.008
P_{max} modelo (mW)	59.14	14.58	13.07	10.82	4.62	0.67
I_{mp} experimental (mA)	34.42	19.35	17.56	16.79	13.31	3.89
I_{mp} modelo (mA)	32.67	15.51	15.56	15.68	12.49	4.79
V_{mp} experimental (V)	1.78	1.24	1.17	1.1	0.94	1.03
V_{mp} modelo (V)	1.81	0.94	0.84	0.69	0.37	0.14

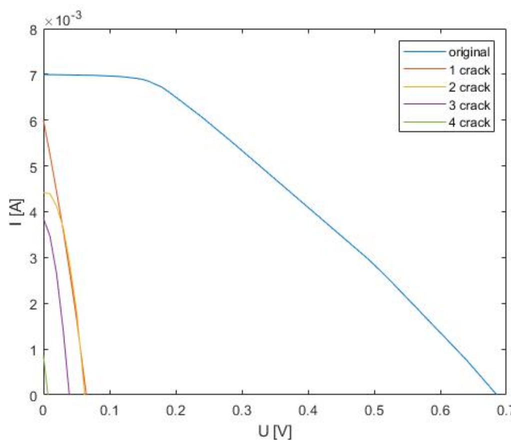

Fig. 21. *I-U* curve of the amorphous silicon cell for the model.

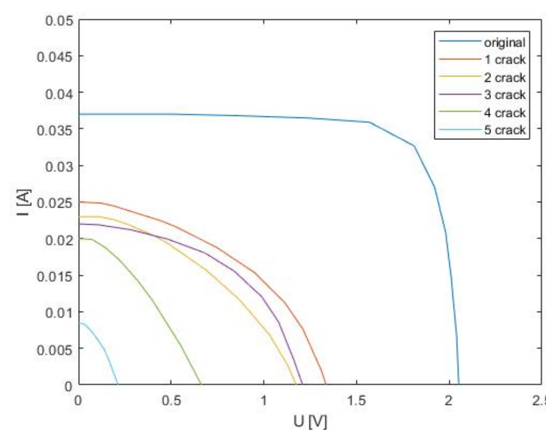

Fig. 22. *I-U* curve of the crystalline silicon cell for the model.

With all these results from the model, it is necessary to analyze some points to be able to draw some conclusions. First situation, the number of points used in each cell. The number of experimental points taken for the different cells varied. In other words, the number of branches will be different for each situation. Another factor is related with points and their disposition. By this it means that there are tests where most of the taken points are at the beginning of the curve, with a greater scarcity of points at its end or vice versa. This causes a higher concentration of branches in a certain range of voltage values, affecting the direction of the curve more.

Still looking at the points used in calculating the different resistance, there were some that were either discarded or could not be used. In the slope calculation there are consecutive points where the voltage value does not change, although the current value varies. This happens because the difference was so minimal that the measuring instruments used were unable to display them. However, it leads to a division by 0 in the 2 equation, which is impossible. So these points were not taken into account. In the discarded points, it is necessary to pay attention to the characteristic curve *I-U* of the ideal solar cell model. This curve has a negative trend, its slope being negative throughout. In the calculation of slopes, there were specific cases in which it was positive. In other words, this would make it necessary to implement a negative resistance, which would also be impossible since there is no such component.

Finally, the last situation also has something to do with the slopes. Returning to the characteristic curve of the ideal model of the solar cell, it is possible to verify that in addition to the slope being always negative, it always decreases along the curve. In other words, it does not include situations in which the slope between point B and C is greater than that of A and B. Thinking now about resistance, its value decreases along the characteristic curve. So whenever the next resistance value is higher than the previous one, the curve should be ”relieved”, delay its decrease. Such situation is not verified, where all the branches are helping in the decrease of the curve. This is perhaps the main reason for a decrease in the values of V_{oc} in all situations presented.

As a result of this analysis, it is possible to point out the points for improvement. Starting with the number of points removed. In order to be the best represented model, this model would need the largest possible number of points, thus having a greater decimal range, in order to arrive at a circuit with *n* branches. It would be necessary to find a way to represent a negative resistance as well as change the circuit to be possible to adjust the curve when a branch with higher resistance appears.

V. Conclusion

The interest in this article arose from the importance that new energy sources have and will eventually have in human life. It is necessary to increase the use of new renewable technologies as well as extend the life of those that already exist. Thus, the main objective of this work was to study the impact that *cracking* had on different solar technologies, namely, amorphous and crystalline silicon cells, *perovksite* cells and *CIGS* cells. To this end, the most common problems affecting photovoltaic panels were studied in order to have a general knowledge of the situations that could affect solar systems and how these or other problems could lead to the emergence of *cracking*.

Tests were carried out in the laboratory to assess the behavior of cells in their healthy state, in order to later be able to make a comparison with the various levels of *cracking*. There was a need to take some special care in how the various *cracks* would be induced. Special care was taken in the *CIGS* cell, as a precaution in case there were toxic substances in its constitution, where there was a successive crease of the cell, in an attempt to simulate some *cracking*. Furthermore, in the crystalline silicon cell, due to its rigidity, it was not possible to cut the cell as it happened in the amorphous silicon and the *perovksite* ones, being necessary force in several points of the cell in order for it to break. There was no possibility of having a direct comparison between cells due to the great difference existing in the experimental method.

In terms of treatment of results, the *fitting* of the exponential double used in *MATLAB* was the one that best represented the data obtained experimentally, both the original curves of the cells, as well as the curves after degraded. This is done using the precision parameter R^2, as well as evaluating the relationship between the curve’s drawing and its points.

By analyzing the results, the impact of cracking on all tested cells is noticeable. All study parameters, the open circuit voltage V_{oc}, the short circuit current I_{sc}, the power P and the efficiency η were affected, with their values to decrease with the increase of the degradation state. It was also observed that there are cases where the first *crack* has a very large impact, as is the case of the amorphous silicon cell, crystalline silicon and perovksite, where the power generated by the cell has dropped considerably, getting the idea that the first *crack* induced in the cell is what has the most effect. This demonstrates the importance of maintaining a healthy photovoltaic system, in order to avoid the occurrence of this degradation, in order to prolong its optimal working point. In relation to the case of the perovksite panel, which, as it was already quite degraded, the successive *cracks* applied had little effect, leading to the idea that a cell already in an advanced state of degradation the cracking will have a low influence on your performance. The *CIGS* cell had a more linear behavior, with a greater loss in the final tests.

The idealized model had the objective of representing the *I-U* curves of the cells using real points measured by the cells. The best result was taken from the crystalline silicon cell, where the curves were similar when compared to the experimental fitting, with the values of V_{oc} being somewhat lower than expected. The stability of this cell, with the good dispersion of points, made the precision in this cell the best. The amorphous silicon cell showed somewhat positive results, due to the visual similarity of its curves. In the cells of perovksita the results were already somewhat average. Despite the decrease in cell performance, depending on the level of cracking, being visible in the curves, they presented values of V_{oc} far from expected. The instability of these cells with the great dispersion of the experimental points had an impact on these results. The *CIGS* cell, as expected, had a bad result, due to its characteristic curve having nothing to do with the *1m3p* model. This model needs some adjustments in order to be able to be more accurately represent the behavior of cells.

With the study carried out in this work, it is possible to conclude that cracking surely influences the performance of a solar cell, where in the extreme it makes the cell unfeasible. In addition to being necessary a good maintenance of solar systems in order to reduce possible losses to the maximum, an evolution of technology is necessary where it is possible to reduce these situations, or even extinguish them, which would optimize their performance.

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