INTRODUCING ELECTROLUMINESCENCE TECHNIQUE IN THE QUALITY CONTROL OF LARGE PV PLANTS

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ABSTRACT: This paper shows that the electroluminescence imaging is very useful on the quality control of the module supply for PV Plant, acting as an ideal complement of tests used nowadays for this purpose. Moreover, information regarding how the EL-test can be implemented in a simple way without affecting the time schedule of the quality control has been provided in this paper. The EL-test has been carried out in modules randomly selected in which a quality control had been previously performed. Results indicate that the additional information provided by electroluminescence imaging has permitted to detect defective modules which have passed previous quality control. Specifically, the EL- test results have correlate visual minor defects, such us visual non-uniformity in cell fingers, with severe damages as cracks in cells.

Keywords: Electroluminescence, Quality Control, Testing and Characterization

1 INTRODUCTION

Because the modules is the most important component of the PV system and its cost represents a high portion of the total investment, all large PV plant construction must incorporate a suitable quality control of PV modules to ensure the profitability of the project. This control begins with the introduction of the technical parameters of the quality control program and acceptance and rejection plan of batches in the supply contract, thus it permits to avoid possible conflicts between manufacturer and client due to test results.

ENERTIS SOLAR is pioneer in the implementation of PV modules quality control on large scale PV plant. It has carried out the quality control of PV modules of more than 90 PV projects with overall power capacity above 700 MW from 2007 until 2011. This quality control was proposed in previous work [1] and it consists in three tests of the IEC 61215: tests 10.1 visual inspection, 10.2 maximum power determination, 10.3 insulation test; and infrared thermography inspection.

The quality control plan must be carried out using sampling procedures to reduce cost keeping high confidence levels. In this aspect, the use of the ISO 2859.1:1999 is recommended to select the appropiated number of samples which will depend on the total amount of modules to control.

The purpose of this paper is to demonstrate how the introduction of the electroluminescence test (EL) in the everyday activity of the quality control procedure of a laboratory leads to a substantial improvement in the defect detection of modules form large PV plants, without affecting the time schedule of the quality control. Moreover, the results of the implementation of the electroluminescence technique in the quality control of the modules in large PV plants will be presented.

2 ELECTROLUMINESCENCE TEST

Electroluminiscence imaging is a non-invasive test which has been established for fast spatially resolved characterization of silicon solar cells. This technique is the result of radiative recombinations of charge carrier excited when forward bias is applied. Forward-biased silicon solar cells emit infrared radiation which is proportional to total excess minority carrier density, so there is reciprocity between electroluminescence emission and quantum efficiency of solar cells [2]. Electroluminescence imaging can be used for characterization of silicon solar cells' properties such us the minority carrier diffusion length [3] and series resistance [4]. But the widest use of electroluminescence is the defects detection in solar cells, mainly cracks, broken fingers in the front metallization, dark dots and inactive cells [5, 6].

3 IMPLEMENTATION OF EL-TEST IN THE QUALITY CONTROL OF PHOTOVOLTAIC MODULES

The introduction of the electroluminescence imaging in the modules' quality control for large PV plants is motivated by:

- Continuous improvement of the quality control.
- Maximization of the risks mitigation, thus avoiding the faulty modules installation in the PV plant.
- Analysis of problems detected in the modules during their operation.
- Prediction of the possible defects emergence in the medium term when the modules were in operation.

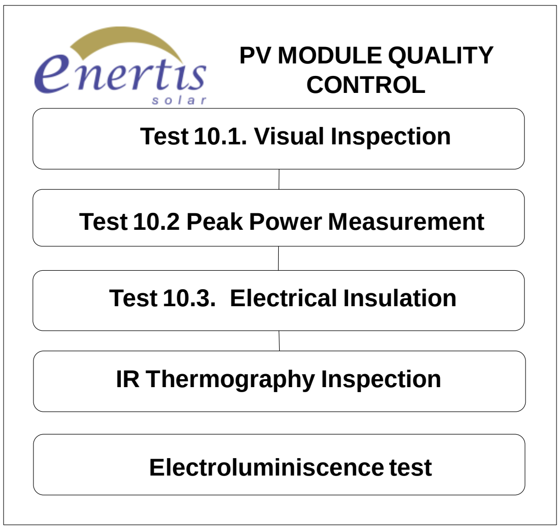


Figure 1: Tests included in the PV module quality control

The new improved quality control can be consulted in the Figure 1. A priori, the main uncertainty in the implementation of the EL-test was in its effect on the quality control duration. This aspect is essential in the construction phase as in the operation phase. During construction, quality control duration is important because each additional day of the installer company in the plant means more cost for the EPC company. In the operation phase, the quality control of PV modules is carried out to verify the warranties terms, so each additional day in the laboratory means energy production losses. In both phases, construction and operation, the duration of the quality control means "lost money".

To avoid increase the duration of PV modules quality control, the EL-test equipment was implemented in the same black room where the IR thermography imaging is performed (see Figure 2).

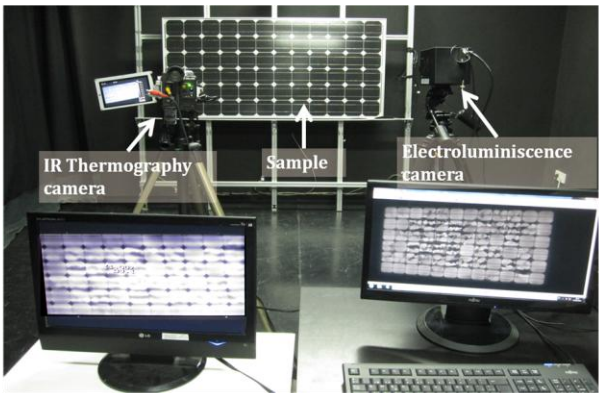


Figure 2: Implementation of the EL imaging equipment

Furthermore, it was necessary to develop new procedures to avoid delays in the return of the modules to the PV plant due to Electroluminiscence test implementation. These procedures include the optimization of the sample handling, test sequence, data registration, etc.

As all new tests in the quality control, it is fundamental to create a valid pass/fail criterion to assure the "quality" of the quality control itself. Nowadays, the electroluminescence test is not regulated by any organization as, for instance, the International Electrotechnical Commission, so the first step in the implementation of the EL-test was to establish a pass/fail criterion based on test results published in the scientific literature. Moreover, as EL-test is a relatively new method for PV modules, an exhaustive training of the laboratory technical staff were performed.

It is important to specify that electroluminescence imaging should not substitute the IR thermography imaging in the quality control of PV modules. With electroluminescence test, as with IR thermography test, cracks, broken fingers and inactive cells can be detected, but EL-test is not appropriate to detect hot spots in soldering and cells, bypass diodes and all electrical connections in the PV module.

4 RESULTS OF THE ELECTROLUMINESCENCE TEST.

Five modules were randomly selected between the samples in which a quality control had been performed. These modules were previously two years in operation. In the quality control, four of them had passed all tests correctly and one was rejected in the IR thermography inspection due to cracks on cells.

In the visual inspection test, marks in the cell fingers were detected and catalogued as minor defects according to acceptance criteria of test 10.1 in IEC 61215:2005. This kind of visual defects was detected in the three of the accepted modules and in the rejected one. Figure 3 shows the IR thermography image one of the three accepted modules where no apparent thermographic defects are observed.

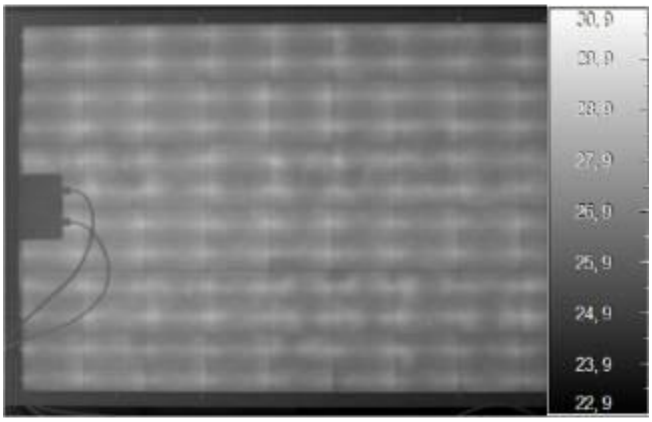
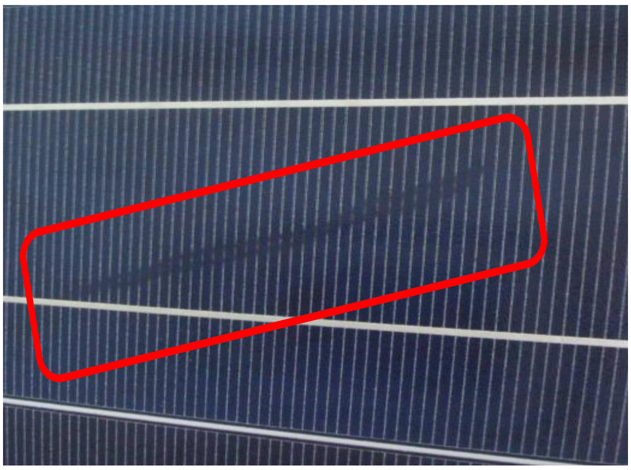
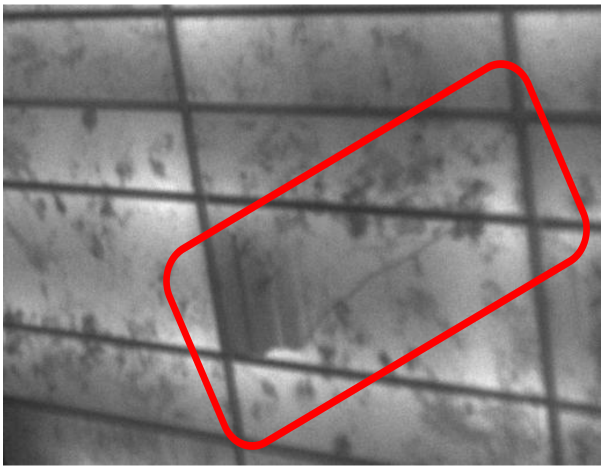


Figure 3: module with no apparent defects in the IR thermography inspection

When the electroluminescence test was performed in the modules with visual marks in the metallization, a correlation between these marks and cell cracks was detected. It is remarkable that this correlation was detected with the IR thermography test only in one of the four modules with visual marks. Figures 4, 5 and 6 show examples of the correlation between visual anomalies in the front metallization of cells and cracks detected with El test.

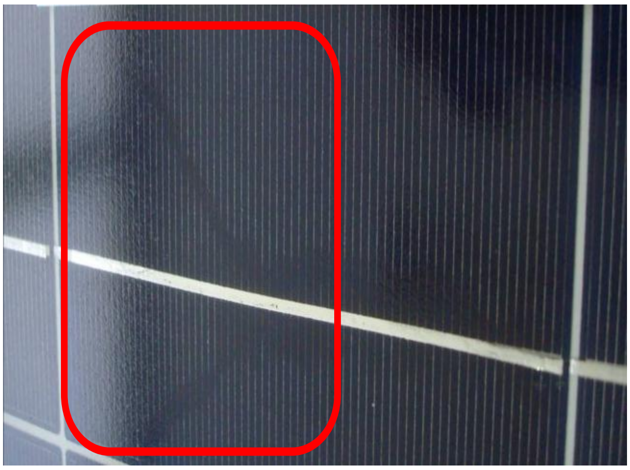


(4a)

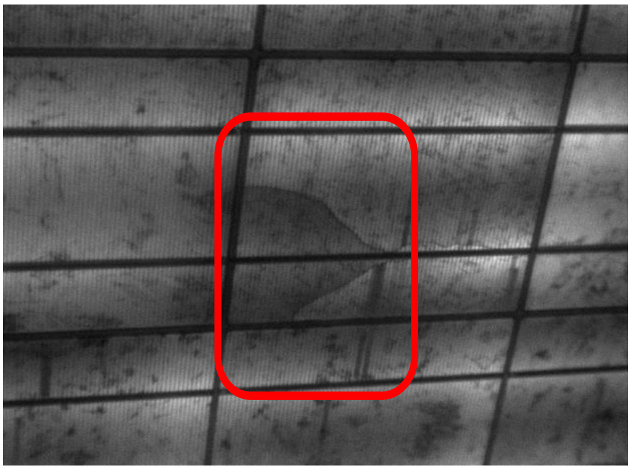


(4b)

Figure 4: example-1 of correlation between visual marks in the cell fingers (4a) and cracks detected by EL test (4b).

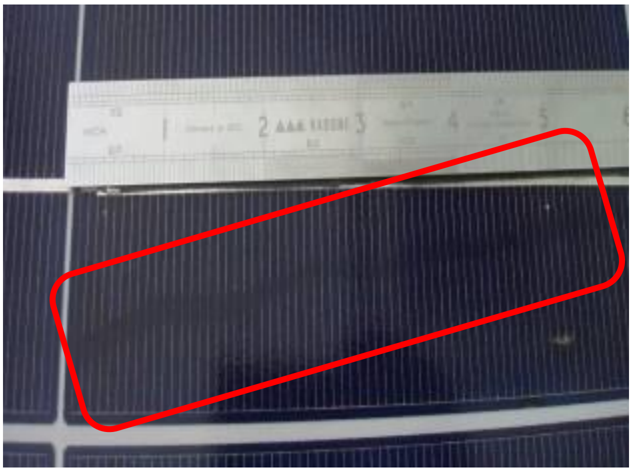


(5a)

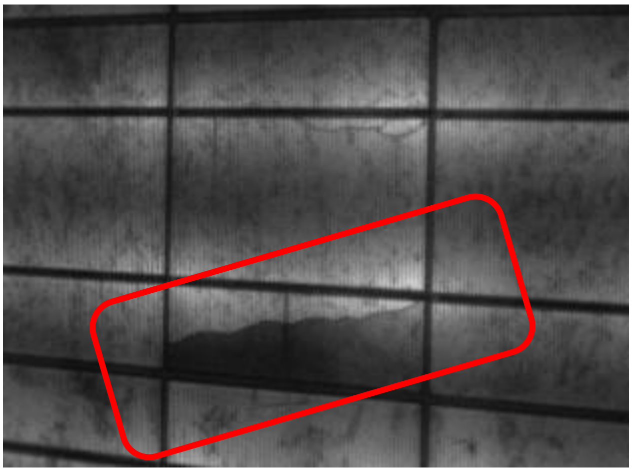


(5b)

Figure 5: example-2 of correlation between visual marks in the cell fingers (5a) and cracks detected by EL test (5b)



(6a)



(6b)

Figure 6: example-3 of correlation between visual marks in the cell fingers (6a) and cracks detected by EL test (6b)

Table I describes the result of the visual inspection, IR thermography imaging and electroluminescence imaging of the five modules selected to analyze the additional information provided by EL-test regarding the visual marks in the cell fingers.

Table I: Comparison the test results

Module	**Visual Inspection**	**IR Thermography Inspection**	**Electroluminescence Inspection**
1	Passed	Passed	Passed
2	Passed (minor defects)	Failed	Failed
3	Passed (minor defects)	Passed	(*) Failed
4	Passed (minor defects)	Passed	(*) Failed
5	Passed (minor defects)	Passed	(*) Failed

EL-test results marked with (*) indicate that the additional information provided by electroluminescence imaging has permitted to detect defective modules which have passed previous quality control. Usually, test included in the previous PV modules quality control can provide enough information and data to guarantee the good quality of the modules supply for a PV plant. However, with the electroluminescence test, the possibility of finding those defects that can lead to module premature degradation or maximum peak power decrease below the expected values is increased. In particular EL-test allow to detect cracked cells (and also micro-cracks) and defects in the contact finger which have been considered, in the typical quality control procedure, as minor defects.

5 CONCLUSIONS

This works suggest that the EL should be introduced as additional non-invasive test in the laboratory procedures to evaluate the PV modules reliability. The EL-inspection is very useful on the quality control of the module supply for PV Plant, acting as an ideal complement of tests used nowadays for this purpose. This is very important, especially in large PV plants where large amount of modules from different manufacturers or different lots of the same manufacturer are installed. Moreover, information regarding how the EL-test can be implemented in a simple way without affecting the time schedule of the quality control has been provided in this paper.

The EL-test has been carried out in modules randomly selected in which a quality control had been performed. Results indicate that the additional information provided by electroluminescence imaging has permitted to detect defective modules which have passed previous quality control. Specifically, the EL- test results have correlate visual minor defects, such us visual non-uniformity in cell fingers, with severe damages as cracks in cells.

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