HOTSPOT ANALYSIS OF PHOTOVOLTAIC MODULE USING EL & IR TECHNIQUES

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ABSTRACT

Solar cells allow the energy from the sun to be converted into electrical energy; this makes solar energy much more environmentally friendly than fossil fuel energy sources. These solar cells are connected together in a photovoltaic (PV) module to provide the higher current, voltage and power outputs necessary for electrical applications. However, the performance of the PV module is limited by the performance of the individual cells. Hot Spots are generated when there is mismatch in Short circuit Current of the cells connected in series due to various reasons ie. some cells are damaged or shaded and produce lower current output than the other cells in the series connected string. The localized heat generation results in a hot spot which can cause damage to the cell material, melting the interconnection solder, discolouration in the EVA and cracks in the glass .The cell mismatch lowers the module performance and can result in further damage as the weak cells are reverse biased and dissipate heat(Hot Spots). PV modules can be characterized using various techniques, each providing important information about the performance of the module. .Some of these techniques are Electroluminescence & Infra Red imaging.

INTRODUCTION

In this study Hot Spots in a photovoltaic module will be investigated by using several characterization techniques and comparing the results in order to fully understand the effects of shaded and damaged cells on the module performance. The effect of cell mismatch will be investigated in the measured current-voltage (I-V) characteristic curve by comparing it with the simulated curves and extracting the device parameters. Further aims involve comparing the results from electroluminescence (EL) imaging & thermal Image of Module.

EXPERIMENTAL ELECTROLUMINESCENCE (EL) SET-UP

EL was used to non-destructively evaluate the extent of the degradation in PV modules[1]. The modules under investigation were forward biased to a current greater than the short circuit current of the module. The emitted luminescence of a silicon sample has a peak at about 1150 nm and a portion of this peak is detected by the coolSamBa HR-830 Si CCD camera which has a range of 300-1000 nm [1]. The CCD camera is cooled to 50 °C below ambient and has a resolution of 3300 x 2500 pixels. The data acquisition time is in the range of 1.5 to 2.5 seconds. The experimental set-up is illustrated in figure 1

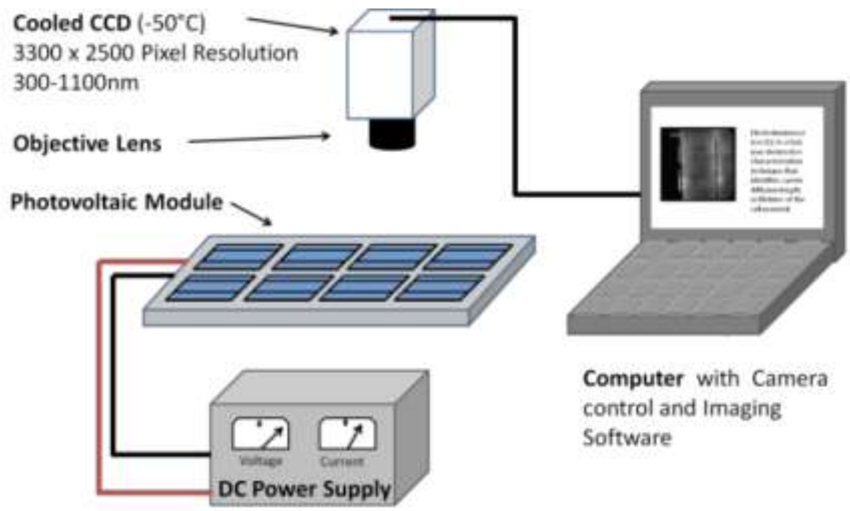

Fig.1: EL Experimental Set up.

Infrared Imaging

Infrared energy is emitted by an object proportional to its temperature. Thermal imaging cameras are able to detect the infrared electromagnetic radiation and focus the image using appropriate optics onto an infrared detector. The infrared image uses a color scale to differentiate between temperatures. Thermal imaging is used in conjunction with EL images to differentiate between intrinsic material defects such as grain boundaries and extrinsic defects such as manufacturing faults, broken contact fingers or cracks. Variations in the module temperature, hot-spots, indicate poorly performing cells. A hot-spot occurs when that cell is performing worse than the other cells in the series string. It becomes reverse biased and starts to dissipate power and heat up.

PV Module:

We have taken a has 72CellsModule(Mono) crystalline cells connected in 3 series strings. there is visible delamination affecting about 4 cells . The module has been damaged and areas of delamination are present in two of the three strings. The effect of this damage on the performance of the module was determined by the current voltage characteristic and infrared imaging.

RESULTS

Infrared Imaging

The cell mismatch present in the module results in hot spots which can be seen using infrared imaging techniques. An infrared image of the damaged area of the module is shown in figure 2. along with the optical image. The module has bypass diodes connected across the strings so while the damaged string is not reverse biased by more than +/-0.5 V, the activation voltage of the bypass diodes, the damaged cells will still be reverse biased and dissipating heat. The damaged area in string C is highlighted in region i) in both images. The initial cause of damage to these cells is not known but could be attributed to a micro crack in the cell that degraded further with thermal cycling resulting in a severely cracked cell. The heat generated by this cell caused the delamination, the encapsulant has separated from the cell and the cell is visibly cracked. The cracked cell area is visible as a cold area in the infrared image. The rest of the cell heats up to over 40°C as the cell is reverse biased. This heating causes the further damage to the cell and the delamination spreads across the surrounding cells. The infrared image of the module shows a hot spot in string B, labelled ii), which is not visible on the front of the module. This hot spot could with time spread and result in delamination and possibly cracked cells like what is seen in string C. Evidence of the hot spot is visible on the back of the module where a bubble has occurred in the encapsulant.

a)
b)

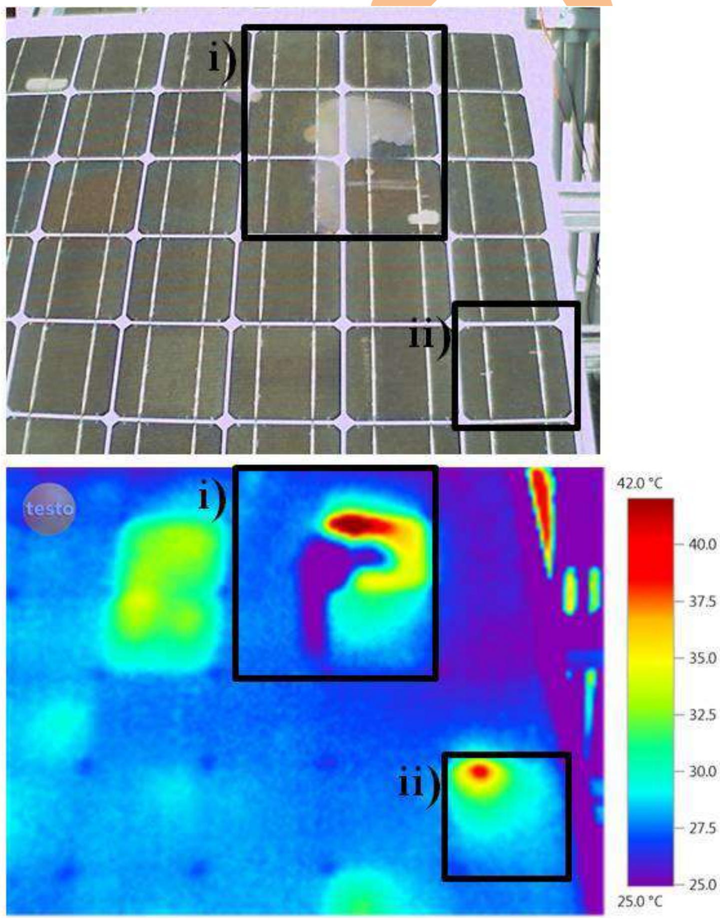

Figure 2 a) Optical image and b) Infrared image of the same portion of the module with damaged portion of string C labelled i) and a hot spot in string B labelled ii).

EL Image

The El image of the delaminated cell is shown in figure 3.

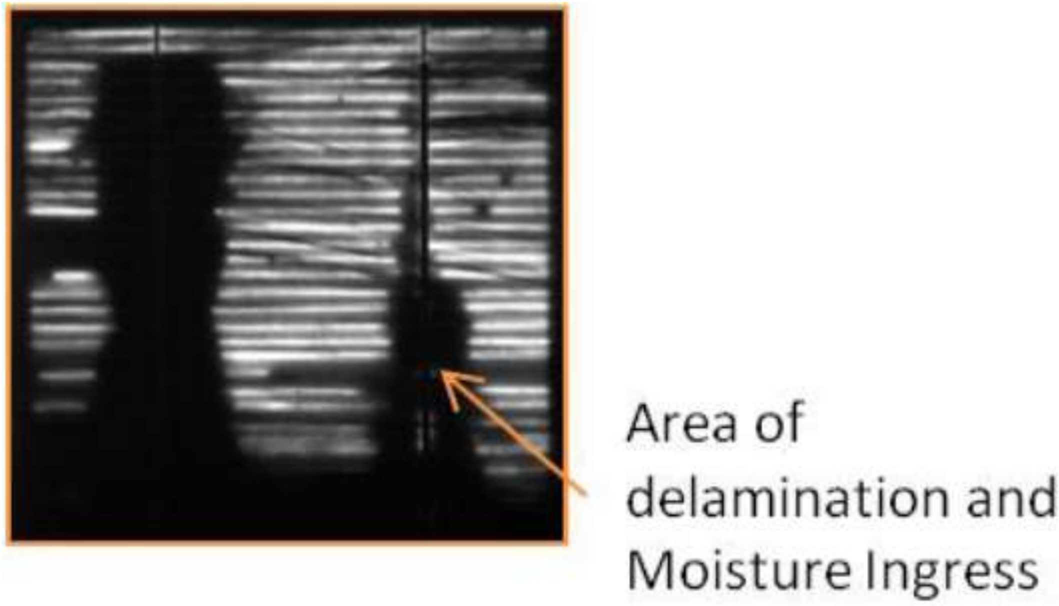

Figure3: EL image of delaminated cell

CONCLUSION

The visible damage to this module has caused the power output to drop from a potential 72W to 38W. Since the damage occurs on two of the three strings it is too severe to be offset by the use of bypass diodes. The bypass diodes increase the Isc value but don't substantially increase the power output. The damage to the module results in hot spots which are visible in the infrared images of the module. The thermal image indicates the hot spot over the damaged cells which has caused the delamination and cracks to spread. These hot spots can result in further damage to the module as they cause further delamination and cell degradation. The bypass diodes are helpful in preventing hot spot formation and further degradation.

REFERENCES

[1]W. Herrmann, W. Wiesner, W. Vaaben, " Hot Spot investigations on PV modules-New concepts for a test standard and consequences for module design with respect to bypass diodes," in the proceedings of the 26th IEEE Photovoltaic Specialists Conference, Anaheim, California (1997) pp. 1129–1132.

[2] C.A Honsenberg and S. Bowden, "Photovoltaic CDRom," http://pveducation.org/pvcdrom/modules/mismatch-for-cells-connected-in-series