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Sorting Of Solar Cells

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Abstract

A Solar cell utilises the visible spectrum of sunlight to convert solar energy to electrical energy. The power output of cells from same batch of Si wafers may be different. To avoid the Cell to Module losses it requires to use cells of same electrical nature in a particular module. This paper talks of parameters to be considered for sorting so as to reduce cell mismatch in same module and hence reduce the cell to module loss.

The most prevalent bulk material for solar cells is crystalline silicon (c-Si), also known as "solar grade silicon".Bulk silicon is separated into multiple categories according to crystallinity and crystal size in the resulting ingot, ribbon or wafer. These cells are entirely based around the concept of a p-n junction. Solar cells made of c-Si are made from wafers between 160 and 240 micrometers thick. Thickness of silicon wafers as per the current industry standard is 180±20 microns.

1. INTRODUCTION

To manufacture a Solar Module, common industry standard is to connect the solar cells of same bins in series. When cells are connected in series their voltage gets added up and the current in series remains the same. If these cells connected in series mismatches , then cell to module loss will happen as different cells will operate away from their Maximum Power Point. This should be known that the cell and modules are tested at STC i,e Standard Test Conditions – A.M of 1.5, Irradiance of 1000 W/ Sq. meter and 25 deg Celsius temperature. The main electrical parameters of solar cells are the – Short Circuit current (Isc) , Open circuit Voltage (Voc), Maximum current (Imp), Maximum Volatge (Vmp), Fill Factor, Efficiency, and the Maximum power . The Maximum power is the maximum power that can be obtained from a cell (It follows the Maximum power transfer theorem).General practice prevalent in solar industry was to sort/ bin the cell only on maximum power basis and in power band of 0.05 Watts. Here we will discuss the binning method and how it can affect the solar module performance.

The cells are being tested in STC and are sorted with respect to the maximum power obtained in testing.

If the cells are binned only on the basis of power the mismatch possibility is high as same bin may contain cells with different current.
The processes involved in manufacturing of Mono-crystalline solar cells are –

- Texturisation
- Diffusion
- Edge Isolation
- PSG Removal
- PECVD – ARC
- Metallization
- Testing

Texturisation:
To absorb maximum amount of sunlight, surface of sillicon wafer is made rough as flat surfaced wafer reflects one third of light falling on it. Texturisation is a chemical process which uses NaOH as etching agent in addition to a special additive for texturisation.

Diffusion:
It form a p-n junction using phosphorous as adopant.

Edge isolation:
It removes the n-type material from the edges of the cell & hence improves the Rshunt (Shunt Resistance) of the solar cell. It may be Laser based/ RF Plasma based.

PSG Removal:
It uses a HF chemical bath to remove the phosphosilicate glass layer formed on the Si wafer during the diffusion process.

ARC:
It further reduces the reflectivity of the Si wafer to upto 4% .It uses PECVD based deposition technique.

Metallization:
It uses screen printing for forming the front and the rear contact. Which uses the Al back metallization for forming BSF & Silver front paste for front grid.

Testing:
Testing is done under STC, and based on the outputs the cells can be sorted.

Mismatch losses are caused when different electrical output cell are interconnected. Mismatch causes serious problem in PV modules and arrays under some conditions because the output of the entire PV module under worst case conditions is determined by the solar cell with the lowest output.
Here we discuss the testing and sorting when cell are segregated only on basis of

- power O/P
- Current & Power O/P

2. EXPERIMENT S – SORTING CRITERIA

Sorting of solar cells is a vital step to achieve the predetermined power out of the photovoltaic module, also there is a lack of detailed investigations of all relevant parameters defining the global module efficiency. Sorting methods depends on simple electrical parameters such as Pmax, Impp, and Isc. Also there are chances that properties of cell change after it is covered by EVA. We have decided to do cell binning/ sorting based on power output of cell alone first and then by both current and power together. This is done because we expect that it will reduce the cell mismatch and using the same bin of cell we will be able to get more power output.

First we discuss how and what electrical parameters binning is done. It is discussed below:

2.1 BINNING BASED ON POWER OUTPUT ONLY

The cells are tested using Ecoprogetti Cell Tester , Here in our experiment we have programmed cells to be sorted in power band of .05 Watts. Binning is done for every .05 Watts. Now we test 1000 Nos of cells. We get different kinds of bins for 72 cells module and we ckecked the current for particular bin. The current in particular bin varied from 8.9 A to 9.1 A as the open circuit voltage also varies we get these cells in same bin. So we take these cells for making a solar modules in which cells are in power band of .05 Watts & current varies from 8.9 A to 9.1 A.

The modules will be tested using a Ecoprogetti make Sun Simulator.

2.2 BINNING BASED ON POWER OUTPUT & CURRENT TOGETHER

For this type of binning /sorting the criteria is to have the same power band of .05 watts but together with that same bin will have sub bins which will have segregation on the basis of current .

The sub bins are segregated on the current range / bands of 0.1 Amps. So a particular bin has sub bin in range of :

- < 8.9 A
- 8.9 – 9.0 A
- 9.0 - 9.1 A
- >9.1 A

So now a particular bin will have sub bins of A, B , C,D.

2.3 EXPERIMENT RESULTS

The solar cells were tested using a Ecoprogetti Cell tester.
1000 cells were tested using the method one of binning i,e testing with Power only method.
We got 350 cells of same bin of 4.45 Watts Avg peak power.
Out of these 350 cells 75 were given for module manufacturing .
The module is tested using a Ecoprogetti Sun Simulator .The module output is 308 Watts.

Now, remaining 275 cells were tested using method 2 of binning / sorting i,e power output & current . We got the 90 cells in sub bin C i,e in current range of 9.0 to 9.1 A.

We have given these cells for manufacturing of 72 cells modules. The modules are tested using a Ecoprogetti Sun simulator and power output obtained is 311 watts.

3 RESULTS DISCUSSION

In Photo Voltaic modules usually cells are connected in series, when the cells are connected in series the most common kind of mistmatch that can occur is the current mismatch (Imp). Since the minimum current in the series may be forced in whole string, it becomes a very serious issue. It must be kept in mind that though the current mismatch will not allow the cell to operate at maximum power point.

When cell are connected in series, the current in series is same while the voltage gets added up, so if t that the current mismatch occurs the total current in the string is equal to the lowest current (of cells connected in series) .

The open circuit voltage also gets minor effect due to its logarithmic dependence on short circuit current. As the current through the two cells must be the same, the overall current in the string cannot exceed current of the poor cell. So, the current in the string cannot exceed the short-circuit current of the poor cell.

So, when the modules are manufactured with the cells (binned using power only method), the lowest current will be forced in the cells connected in series (in all 72 cell). As a result of which cells will not operate at Maximum power point and the operation point shifts as a result of current mismatch . And the expected optimum power output is not obtained from the module. This is quite apparent in the results of method 1 of sorting of cells.

When the modules are manufactured with cell (binned using current sorting), Since minimum & maximum current are limited to 9.0 A & 9.1 A respectively. The minimum current is 9.0 Amps ,thus all the cells connected in series are operating near to the maximum power point.

4. CONCLUSIONS

Overall, in a module with series connected cell with current mismatch, severe power reductions will be seen if the bad cell produces less maximum power current than the maximum power current of the good cells and also if the combination is operated at short circuit or low voltages, the high power dissipation in the poor cell can cause irreversible damage to the module.
As shown Current mismatch for two cells in series can be quite serious.

5. FUTURE SCOPE

Even the new methods for sorting/ binning of solar cells are still expected to appear, as the solar cell industry develops. This would be very instrumental in reducing the current to module losses (CTM).The current CTM for the mono – crystalline PV technology is less than 3%. There are research going on to sort the cells on the basis of FF also. Integration of new methods to the existing methods and pragmatic analysis can improve the further mismatch issues . now the research for sorting/binning have now moved towards the use of other electrical parameters.

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