Data Mining Photovoltaic Cell Manufacturing data

Rhett Evans[1,3], Jonathon Dore[1,3], Erik Van Voorthuysen[2], Jingbing Zhu[4], Martin Green[3]

[1]Australian Centre for Advanced Photovoltaics, UNSW, Sydney, NSW 2052, Australia, [2] School of Mechanical and Manufacturing Engineering, UNSW, Sydney, NSW 2052, Australia, [3]Suntech R&D Australia, Sydney Olympic Park, NSW 2027, Australia, [4]Wuxi Suntech Power Co Ltd, New District Wuxi, Jiangsu, 214028, China

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Introduction

→ PV manufacturing generates large amounts of data

→ Extensive statistical analyses are preformed on this data

→ Studying this data offers great opportunities to reduce the cost of PV.

A barrier to sharing this expertise may be the commercial sensitivity of data. *This is resolved in other industries through data normalization.*

Methodology

→ ***In this study***, a sample set of data (10,000 mc-Si cells) is taken from a Suntech Manufacturing facility in Wuxi China in 2013.

→ Simple manipulations are done to the Voc, Isc and FF data to show insights into cell material properties, sources of production variance and improved statistical process control (SPC) techniques.

→ Data is normalized (to Voc', Isc', FF')

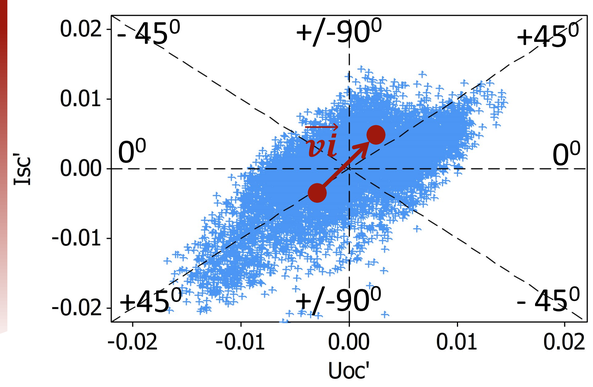
Variance: → *% of mean*. **Mean**: *shifted* → *zero*

→ The "differenced" data is calculated from the difference between consecutive cells, and forms the main subject of this study.

Given this cell, why is the next one different?

Results

Isc vs Voc Relationship



The difference data is expressed by the vector $\overrightarrow{vi}$. This vector will represent how data moves around the Isc' vs Voc' relationship from one point to another.

The vector can be represented by its length, $|vi|$ and its direction $\theta_{vi} = \arg(vi)$

Figure 1. Isc' vs Voc' with the difference vector $\overrightarrow{vi}$ also represented. Direction is -90 to 90, calculated from a $\tan^{-1}$ function. 0^0 is the +ive Voc' axis. Vectors of exactly opposite direction have the same value.

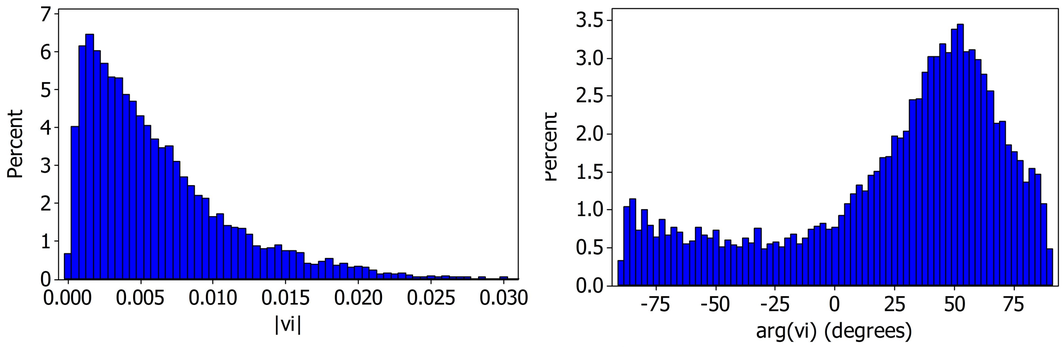


Figure 2. Length and direction of the difference vector $\overrightarrow{vi}$. 52^0 is the modal response for $\theta_{vi} = \arg(vi)$

FF vs Voc Relationship

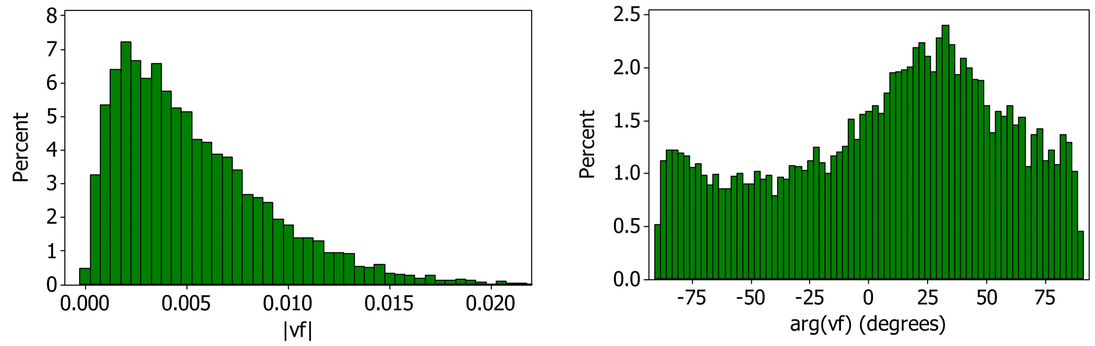


Figure 3. The same approach can be taken with the Voc vs FF relationship. These graphs show the length and direction of the difference vector $\overrightarrow{vf}$. 32.5^0 is the modal response for $\theta_{vf} = \arg(vf)$

Common Causality – Material Lifetime.

Plotting θ_{vf} vs θ_{vi} as a 2D contour histogram shows their respective modal responses coincide, indicating a common causality. PC1D modelling shows lifetime variation in the wafer to be the likely cause. The modal response in θ_{vi} and θ_{vf} provides further information of the dominant recombination mechanisms.

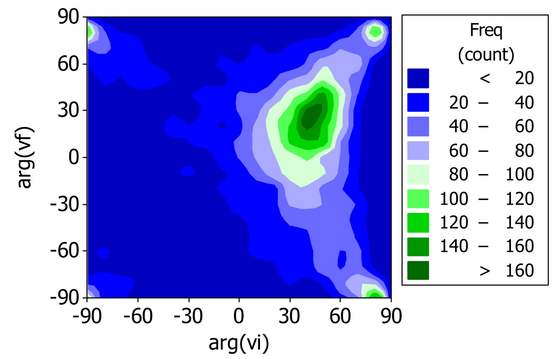


Figure 4: θ_{vf} vs θ_{vi} . Modal responses coincides.

Rotated Axes

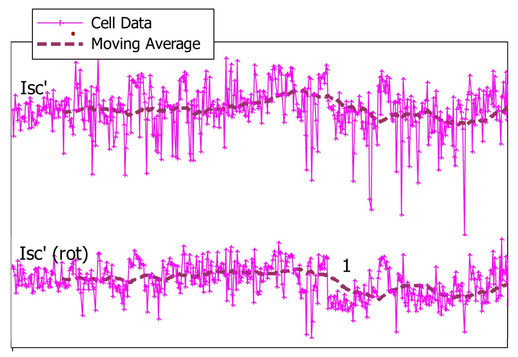


Figure 5: SPC with rotated axes isolates material variance, reducing variance in general and highlighting other performance drops (1)

A principal axis rotation can be done using the angles from the modal response to isolate material related variation. SPC undertaken on the rotated axis (figure 5) will highlight other changes

Voc' (rot) → Material Variation Axis

Isc' (rot)

FF' (rot)

Variation on rotated axis is independent of material changes

Conclusions

Simple data manipulations can give some surprising insight into cell recombination properties and variance in production. Axis rotation can be used to remove the effect of material variance and improve interpretation of SPC graphs. Many opportunities for further study arise out of this work, such as extending the technique to other relationships and exploring the link to recombination properties in more detail.

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