IV Measurements of Shingle Solar Cells

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Due to the large variety of contacting probes, the measured *IV*-characteristics of solar cells differ considerably depending on the contacting used. To determine losses due to the cutting process from host to shingle cell, the impact of two different contact units, Pasan´s PCBTOUCH and halm´s universal contact probes (ucp), installed in an inline cell tester was evaluated.

Introduction

- Shingle cell modules are a promising concept for integrated PV applications with strong area limitations and high aesthetic requirements.
- The inline cell tester at Fraunhofer ISE was upgraded so that shingle cells can be automatically unloaded from a box, aligned and contacted in the measuring station.

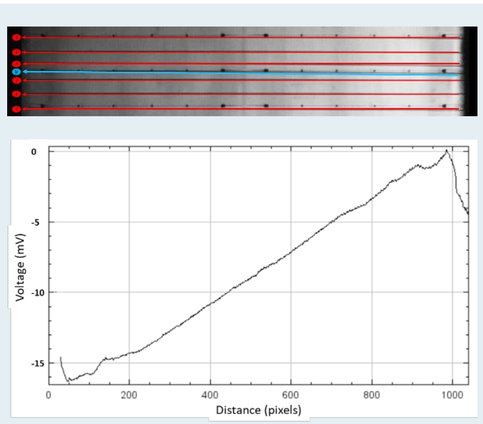
Shingle cells during magazine unloading. The blowing nozzles, which allow the cells to be separated in the magazine, are located to the right and left of the cell stack.

Challenges in Correct Solar Cell Contacting

PCBTOUCH

- With the 4-wire measurement, the wire resistances are compensated from the source-measure unit up to the edge of the cell.
- On the cell, the load and sense wires are electrically connected by the cell's grid fingers.
- ➢ Voltage gradient across the cell
- ➢ The resistance of the wires R_{wire} affects the measurement:

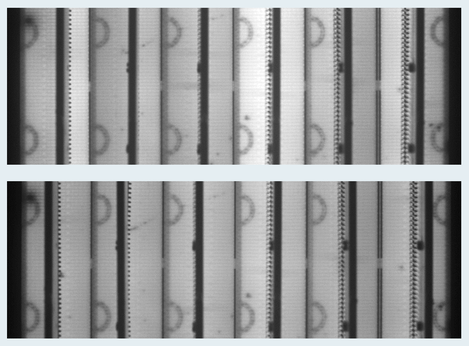
$$R_{wire} = \frac{1}{3 \cdot n_{wire} \cdot n_{connection}} \cdot \rho_{wire} \cdot \frac{l_{wire}}{A_{wire}}$$



Top: EL image section of a solar cell that is contacted with the PCBTOUCH. The wires are only connected on the right side.
Bottom: The voltage gradient was calculated from the color gradient of the EL image.

Universal contact probes (ucp)

- Voltage measurement does not take place on the cell
- Contact resistance between ucp and metallization, line resistance of ucp and shading losses affect the measurement (1.3 mΩ)
- Clear signal fluctuations (top) since the individual shingle cells are not electrically connected to each other (bottom)
- ➢ Limiting resistors in the individual cables improved the homogeneity



Top: Clear signal fluctuations between the individual shingle cells.
Bottom: Limiting resistors in the individual leads have improved the signal homogeneity.

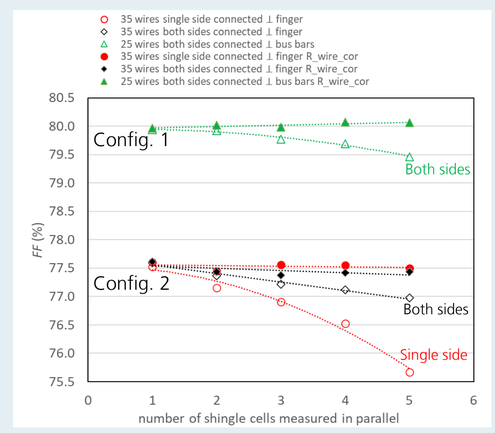
Experiment 1

Variation in the number of shingle cells in the *IV* measurement

- The number of separated shingle cells measured in parallel was increased from one to five.
- Current and voltage terminals were connected on both and in one case at only one side of the wires.

- The measured *FF*s decrease in all test variants of contact configurations (see legend) with an increasing number of shingle cells measured in parallel (open symbols).
- If the series resistance contribution of the PCBTOUCH wires is considered (filled symbols), the *FF* remains almost at the same level with varying number of shingle cells measured in parallel.

EL images of shingle cells (Top) with 35 wires perpendicular to the fingers and (Bottom) with 25 wires perpendicular to the busbars.



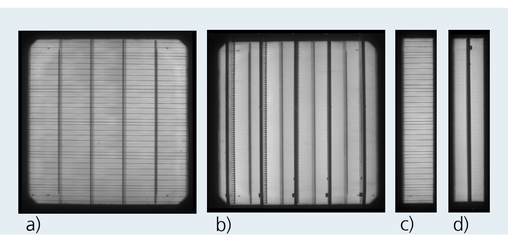
FF depending on the shingle cells measured in parallel.

Experiment 2

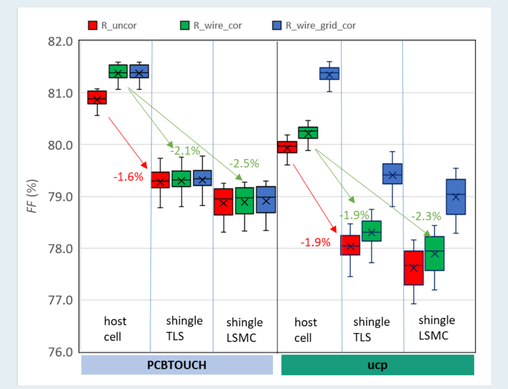
Determination of the losses due to the process for shingle separation

- *IV* measurements of 20 host and 30 shingle cells per group.
- Contacted with ucp in parallel and with PCBTOUCH perpendicular to the busbars.
- *IV* measurements before and after separation with laser scribe and mechanical cleave (LSMC) and thermal laser separation (TLS).

- Without wire resistance correction, the PCBTOUCH measurements underestimate the FF loss 0.5%$_{abs.}$
- *FF* losses determined with the ucp remain the same with and without resistance corrections.
- In grid finger resistance free situation, ucp and PCBTOUCH results are at the same *FF* level.



EL images of (a-b) the M2 host cells and (c-d) the 1/5 shingle cells contacted with PCBTOUCH and ucp.



IV parameters of the host and shingle cells measured with (left) the PCBTOUCH unit and (right) ucp.

Summary and Conclusion

- With PCBTOUCH contacting, the resistance losses of the front wires must be considered, otherwise the *FF* losses caused by cutting will be underestimated by 0.5%$_{abs}$ for the present situation.
- The *FF* losses determined with both contacting units differ by 0.2%$_{abs.}$
- Taking the series resistance of the cell´s contact fingers into account, the contacting-unit-induced differences in the *FF* and η become smaller than the measurement uncertainty.

Link to Fraunhofer ISE contributions of the 40th EU PVSEC
https://ise.link/eupvsec2023

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