# Comparison of a coupled PV Module Simulation with experimental Measurements

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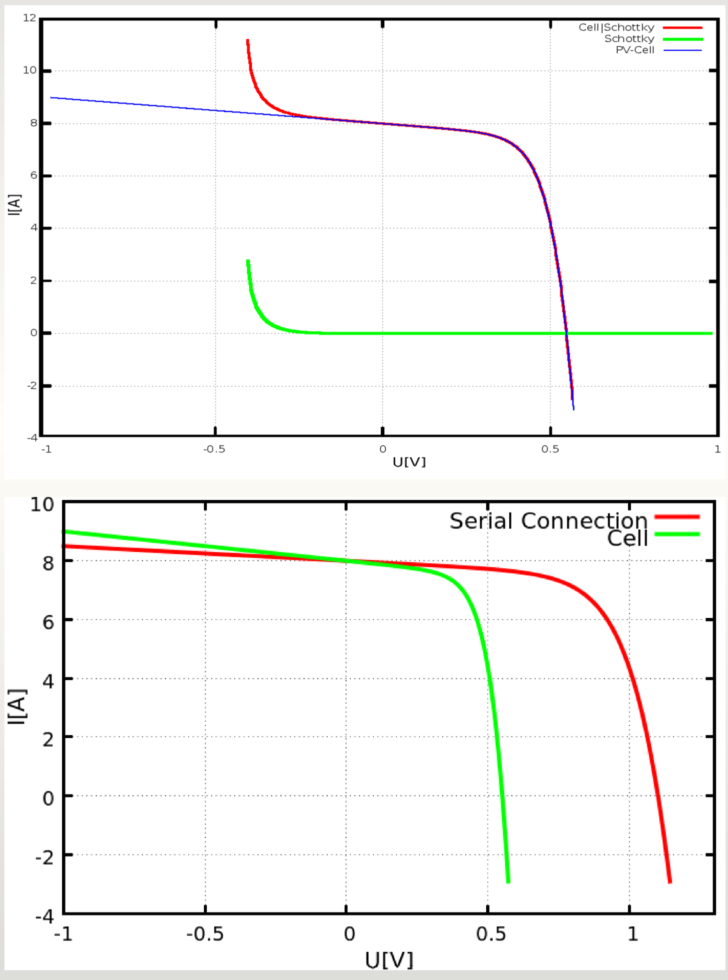
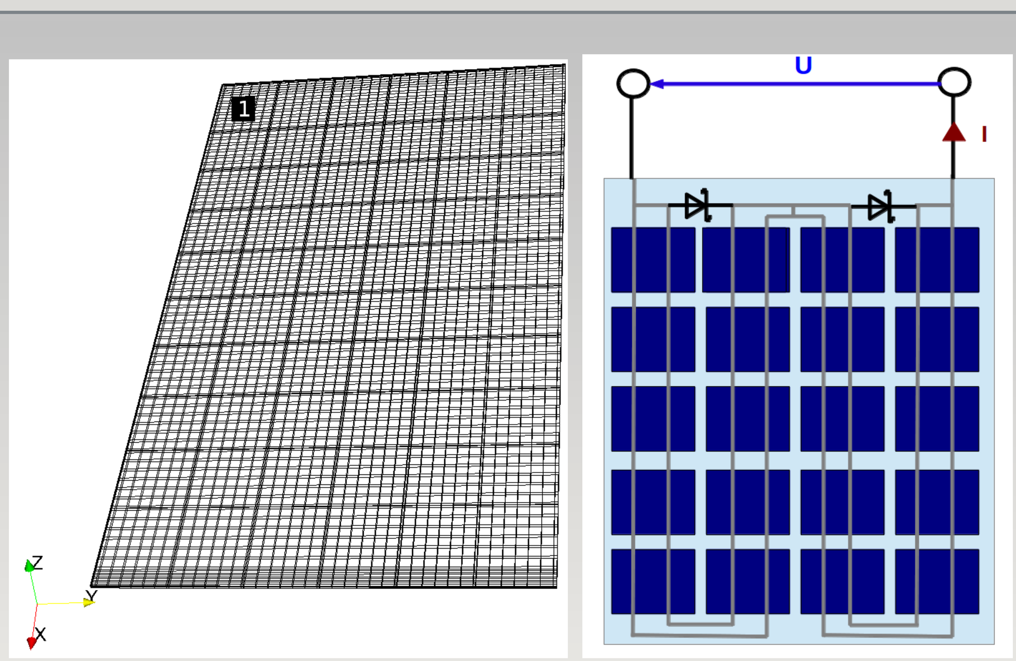
## Abstract:

A previously existing 1d model [1] of the cooling of PV modules was expanded to a 3d model. It calculates the heat flux within the layered module while simultaneously calculating the coupled temperature dependent electrical network model. Various effects of external parameters can be tested conveniently.

Additionally to the thermal cooling model [1] a C++ tool based on the sparse matrix toolkit PETSC was developed, to calculate the thermal conduction under nonlinear boundary conditions [1]. The discretization is performed using the **Finite Volume** approach on an structured grid [2].
Through additional volumetric heat sources, e.g. the front glass in which absorption occurs, it is useful to apply more than one discretization within homogenous materials.




*Above: a parallel setup of cell and bypass diode, below a series connection between two cells that doubles the voltages.*



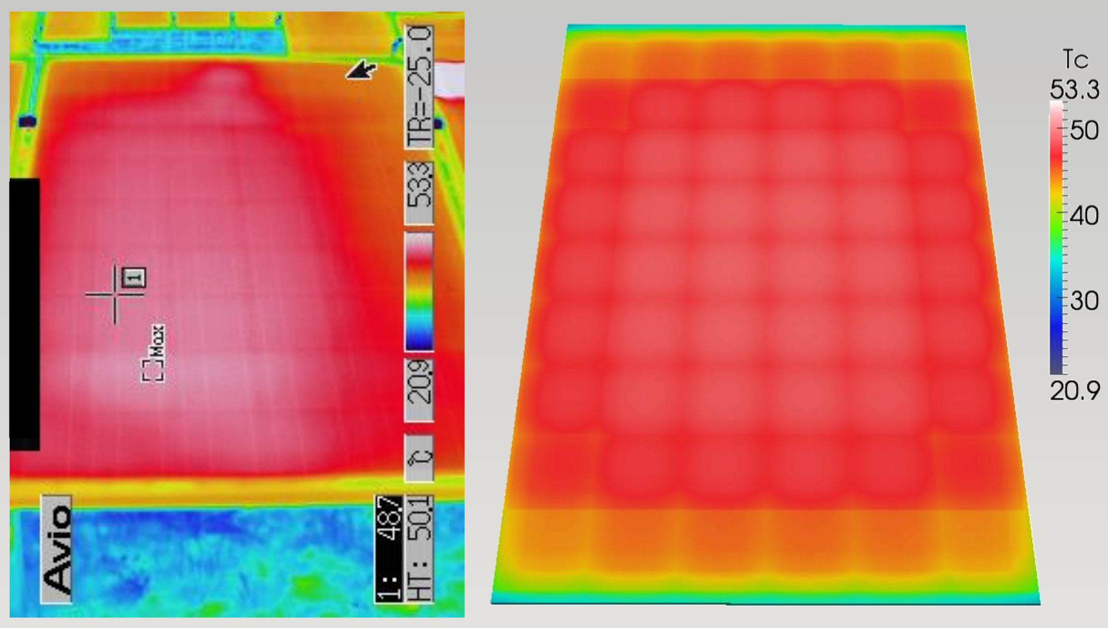
*Left: An illustration of the automatized meshing result. Right: an exemplary electric network model that is co-simulated in the same C++ code.*

The **electrical network model** is based on a temperature-corrected two-diode model.
Each individual cell and bypass-diode parameter is defined in an XML configuration file.
The initial assumed cell-temperatures are adopted through an iterative 3d solution of the heat-conduction equations. The heating power depends of the external electric current, the cell temperature, and the illumination. A continuous coupling of the simulation parts is necessary apart for the optical simulation.
The result is a 3d temperature distribution, as well as a total UI-characteristic.

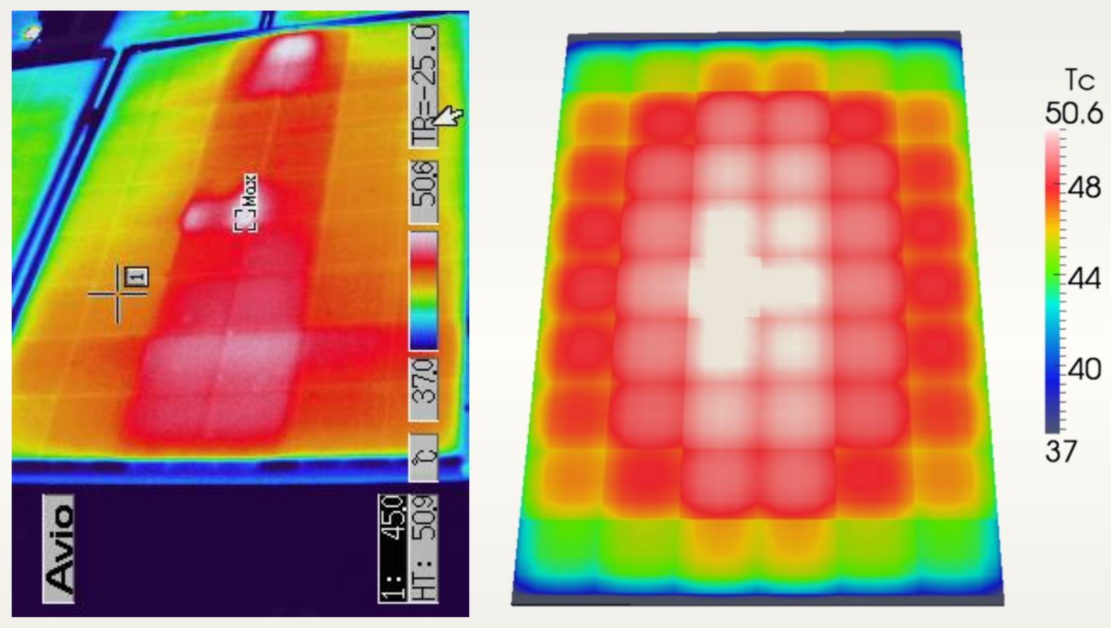
## References:

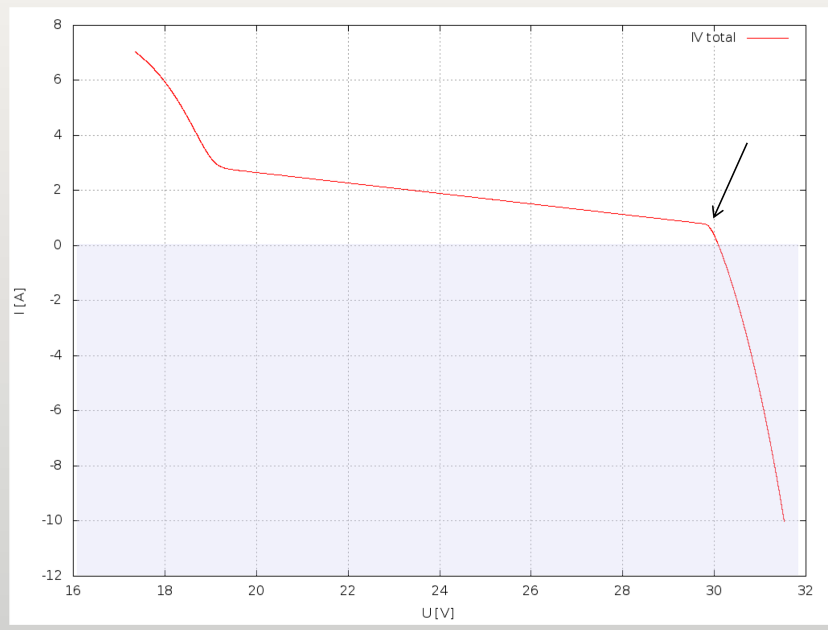
[1] B. Kubicek, M. Wagner, M. Rennhofer, „Thermische Auswirkungen von alternativen Einkapselungs-materialien auf den PV-Modulwirkungsgrad", PV-Symposium Bad Saffelstein, 2014.
[2] M. Wagner, "3-Dimensional Simulated Infrared Thermography of PV Modules", TU Wien, diploma thesis, 2014.

## Comparison with field measurements:



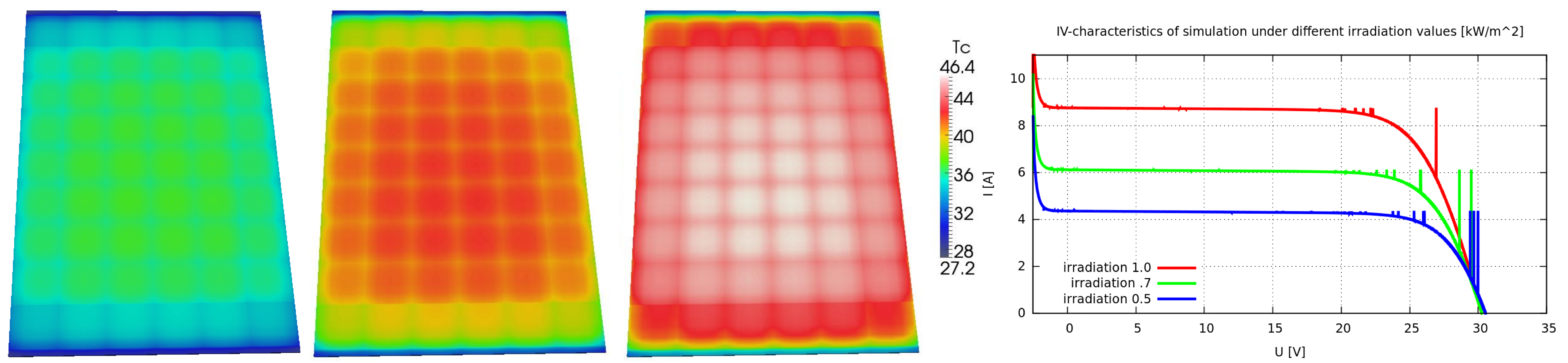

Outdoor thermography und simulation result of a module. The specific layering as well as the environmental conditions were regarded.



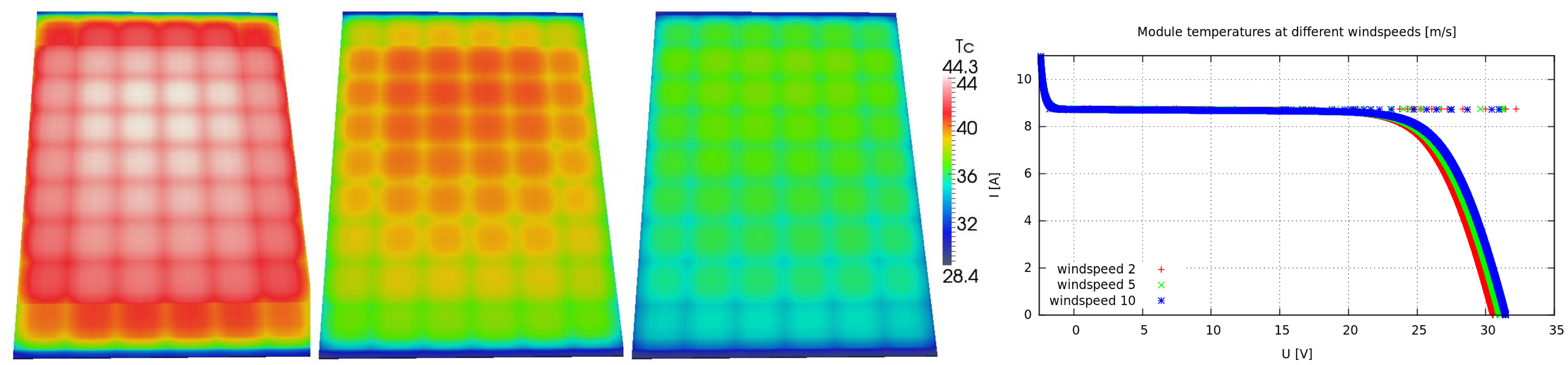
Simulation of a fully shaded cell for the case that the module is driven in the secondary MPP, thus no bypass diode is triggered
Both simulations show a too strong heat conduction in the module plane.

## Irradiation




500 W/m² 700 W/m² 1000 W/m²

## Wind




2 m/s 5 m/s 10 m/s