Transient Electroluminescence Imaging and current-voltage characteristics of individual cells within PV-Modules

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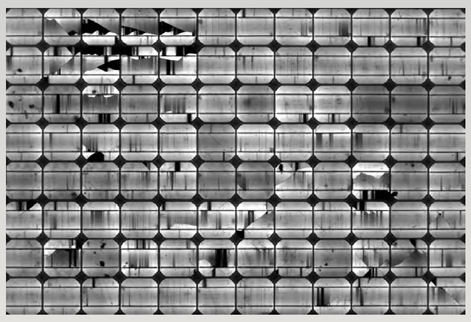
Abstract

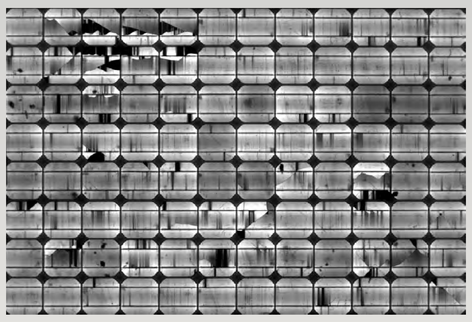
During EL-imaging of PV-Modules a fixed current is applied. This causes transient thermal changes. As the temperature influenced current density distribution changes, also EL images vary with time. This can be exploited for module quality testing.

Transient Electroluminescence Imaging

For EL imaging, the solar panel is supplied with constant current. It thereby is heated.
PV cells are conducting electric current the easier the hotter they are. The current distribution is inhomogeneous, so is the heating power, the cooling and as well the thermal mass.
Since EL images to a big part resemble the current distribution, it can be assumed that EL images change with time, during the current induced heating process. By taking series of short-time exposures this changes can be observed.

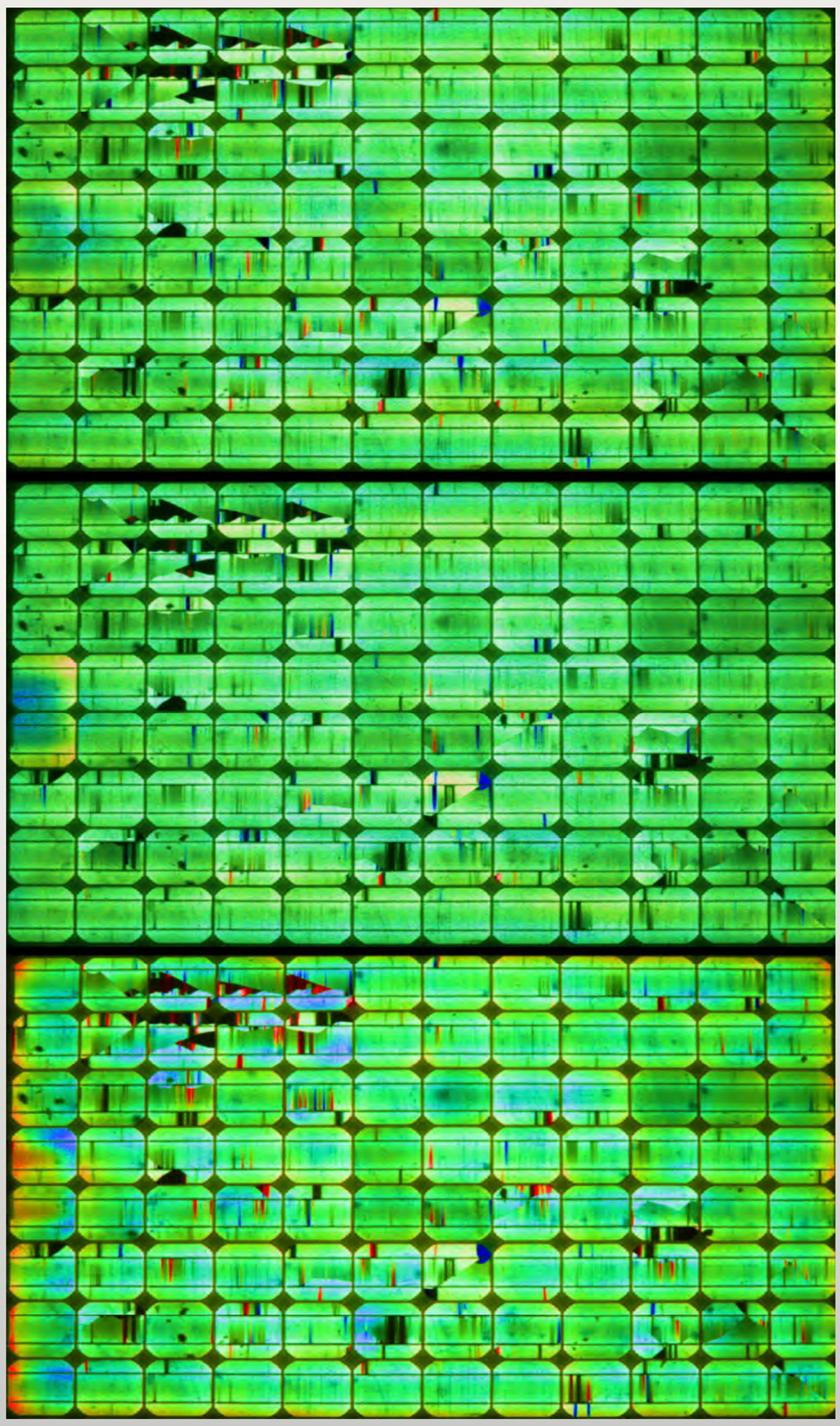


Normalized EL, -8° C



Normalized EL, 35°C

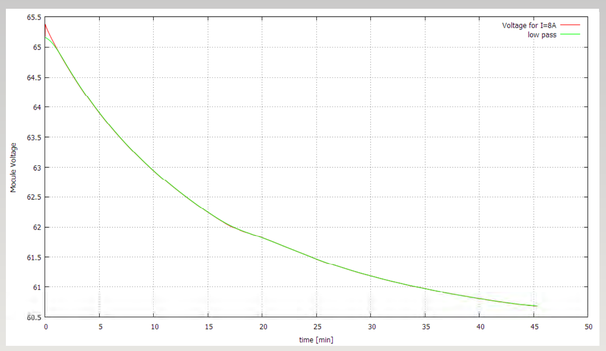
The brightness changes are however small, and can be best visualized by false coloring the rate of change. Red indicates an increase of brightness. The modules started at -8°C and warmed to 35°C in 30 minutes:

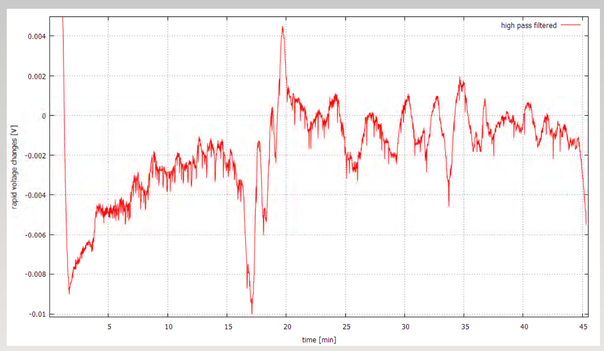


- Defective regions (shards) connect, disconnect or change contact resistance due to thermal expansion.
- Thermal mass of the module connection box and the frame lead to current distribution shifting in the affected cells.

Transient Electric Effects:

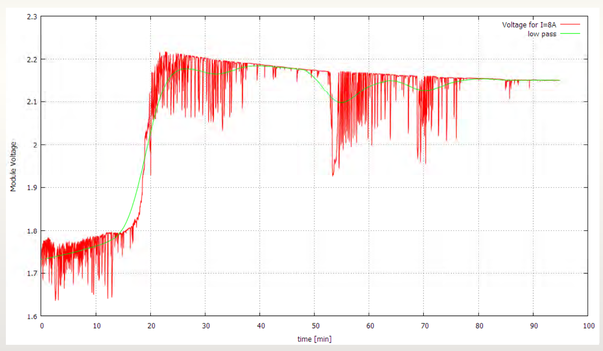
Module voltage vs Time

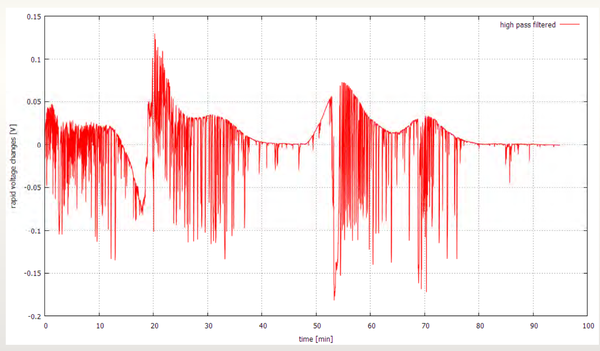




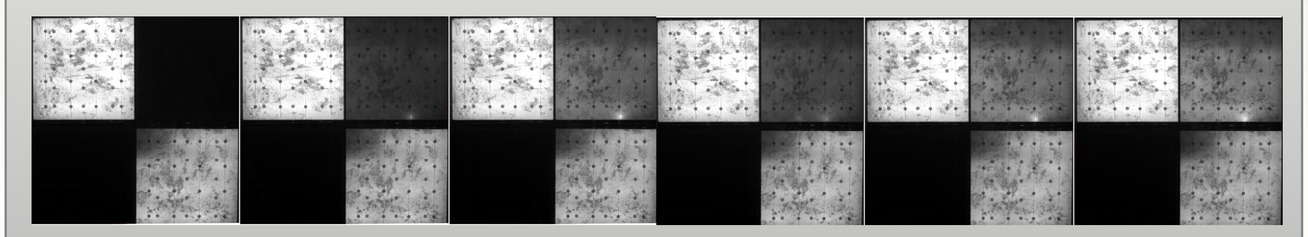
Observing the voltage change of a constant current (8A) heated module, the heatup decreases the needed voltage with time. However, if one only high-pass filtered data is considered, sudden changes ~ 0.1 volt are visible.
To rule out random noise as a possible cause, a 2x2 cell module with known connection problems was tested:

Module voltage vs Time





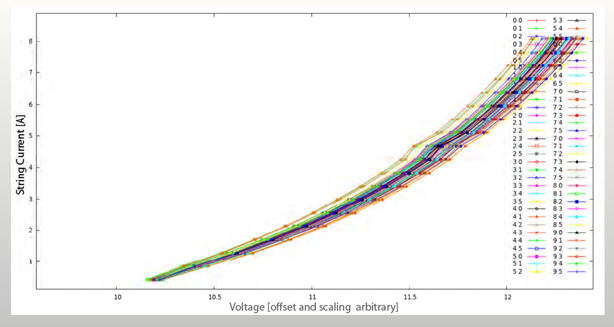
Initially two cells are short-circuited. After 20 minutes of current induced heating, one additional cell with volatile connection is activated. Here, similar voltage changes can be observed, although the voltage logging was more accurate, and changes in individual cells are more visible in the total module voltage change.

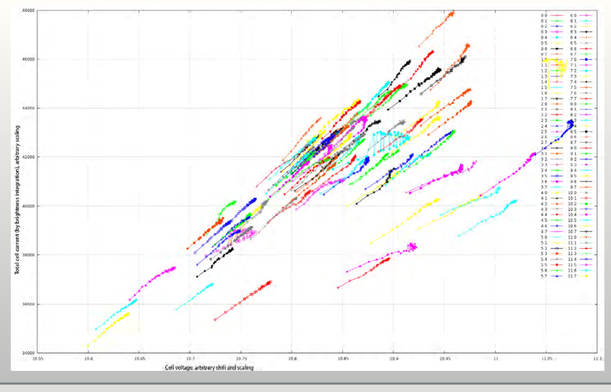


EL Image series of a 2x2 Module, taken at 45 seconds intervals.

Current-Voltage Characteristics:

Based on [2], the individual cell voltages can be estimated as logarithmic brightness of the cells brightest EL pixel, to obtain individual cells dark current-voltage characteristics. In a similar, but less sophisticated approach, the brightness integral over a cell indicates the total current subtracted by the parallel shunt's currents.
Instead of using multiple EL images with different currents, the heating process can be used to gather partial "voltage-current" characteristics. The usage is likely limited to finding volatile cells.





Conclusion:

- EL Images change with time, if the module is not in a thermal stable state. A thermal stable state is seldom reached under typical EL conditions. A "normal" EL image is either a snapshot or an average of such processes, depending on the exposure time.
- These transient changes can be used to observe electric connection problems that are temperature dependent.
- Very likely heat dependent module changes, i.E. volatile connections, can be observed purely electrical as rather quick voltage spikes in the range of ~0.1 Volt.

References:

[1] B.Kubicek, R. Ebner, S. Zamini, „Automatisierte Bildverarbeitung und optische Korrektur von Elektrolumineszenzaufnahmen", 27. Symposium Photovoltaische Solarenergien, 2012.
[2] T. Potthoff, K. Bothe, U. Eitner, D. Hinken, M. Köntges, "Detection of the voltage distribution in photovoltaic modules by electroluminescence imaging", Prog. Photovolt, Res Appl. 2010, 18:100-106.

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