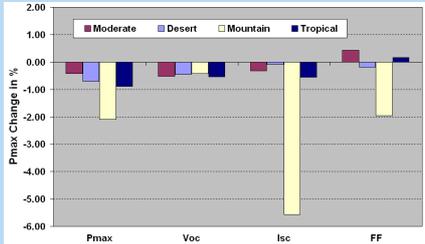


# Outdoor weathering of c-Si PV modules in various climates - measurement and transfer of module data of PV-modules via GPRS -

Nicolas Bogdanski, Werner Herrmann

<sup>1</sup> TÜV Rheinland Energie und Umwelt GmbH, Am Grauen Stein, 51105 Köln, Germany, Phone: + 49 221 806 4741, Mail: nicolas.bogdanski@de.tuv.com

## Previous results

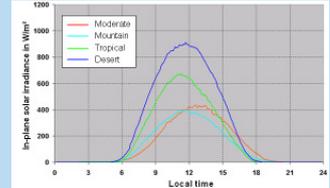
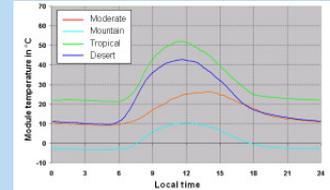


Change of STC Performance after 3 years:  
Averaged parameters of 7 modules from 4 test sites

- Moderate City Climate → Cologne, Germany
- Desert Climate → Sede Boqer, Israel
- Tropical Climate → Serpong, Indonesia
- Mountain Climate → Zugspitze, Germany

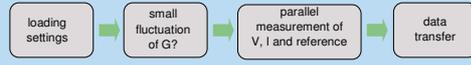
- Average power degradation in the first year for all locations is -0.6%, 3.8% after 3 years (0.7% without Zugspitze)
- Max. power degradation of -6.3% could be explained by cell breakage (location Zugspitze)
- No evidence of deterioration of electrical contacts in the interconnection circuit of the module (indicator = internal series resistance)
- Effect of soiling < 0.5% for Cologne and Zugspitze, but 2.3% – 4% for Indonesia (modules from Israel received in cleaned condition)
- Reliability criteria are fulfilled for all module types
- Impact of transport on module degradation not clear
- None of the modules failed during isolation testing
- Comparability of yearly re-measurement results is limited since the modules constructed equally but are not identical

→ on-site measurement may be beneficial



## Compact on-site Monitoring Programme

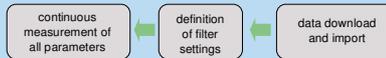
IV-curve measurement 1 per hour (12 modules multiplexed)



weather data measurement



evaluation of data through database



measured data consisting of:

- global irradiation
- UV-A, UV-B irradiation
- calibrated ref. cell
- ambient temperature
- module temperature
- 2D wind
- relative humidity
- module deflection
- rain intensity



Data available via internet platform

### Moderate City Climate

- Cologne, Germany
- Moderate temperatures
- Moderate humidity
- Moderate UV irradiation
- Moderate wind and snow load
- Local partner: TÜV Rheinland Group



### Desert Climate

- Tempe, USA
- high temperatures
- high day/night temperature gradients
- high UV irradiation
- high global irradiation
- Local partner: Ben-Gurion University of the Negev



### Test locations

### Tropical Climate

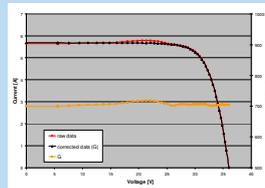
- Serpong, Indonesia
- high temperatures
- high humidity
- high UV irradiation
- high global irradiation
- Local partner: Agency for the Assessment and Application of Technology (BPPT)



## Multiplex IV-measurement

- irradiation is measured by pyranometer and calibrated reference cell
- measurement of IV-characteristic hourly if fluctuation < 2% (configurable)
- data points for irradiation (ref. cell), voltage, current are measured simultaneously → fluctuations of G can be corrected subsequently
- measurement of module temperature enables temperature correction

- 12 channels, extendable through modular design -



- irradiation correction with respect to first value measured
- duration of one IV-measurement 30s
- configurable number of data points
- start of measurement 10/10 in Cologne
- fluctuation and minimum irradiance demands limit number of IV-curves collected to app. 2-3 per day
- degradation not yet detectable

## Results

- change of PV-module parameters can be detected on site, lengthy interruption of exposure period due to yearly shipment for re-measurement can be omitted
- modular design and wireless data transfer enables the measurement in remote areas
- on-site measurement allows to detect soiling effects throughout the year
- to collect all degradation parameters re-measurement at the end of the measurement campaign should still be conducted

## Acknowledgements

Support by the Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit (Federal Ministry for the Environment, Nature Conservation and Nuclear Safety, FKZ 0329978C) and partial funding by the industrial project partners has been greatly appreciated.

2011 NREL Photovoltaic Module Reliability Workshop, Golden Colorado



**TÜVRheinland**<sup>®</sup>  
Precisely Right.