Bifacial Outdoor Rotor Tester

BIFROT

Franz Baumgartner*, Giordano Petrzilek, Steve Schartinger, Markus Klenk, Nico Keller, Thomas Baumann, Fabian Carigiet and Hartmut Nussbaumer
ZHAW SoE, IEFE, Technikumstrasse 9, 8401 Winterthur, Schweiz
*Email: bauf@zhaw.ch; www.zhaw.ch/~bauf

Zürcher Hochschule für Angewandte Wissenschaften
School of Engineering
IEFE Institut für Energiesysteme und Fluid-Engineering
www.iefe.zhaw.ch

Motivation & Approach

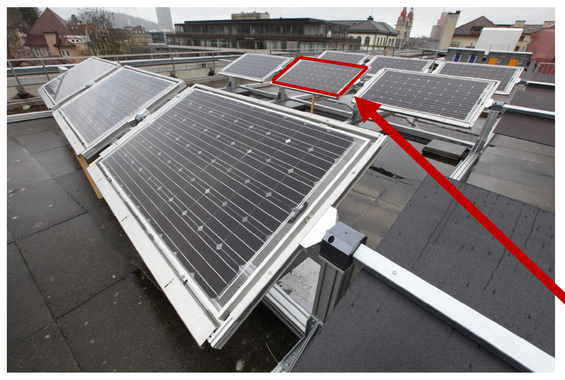
Bifacial technology

- Bifacial technology - presently in the focus to increase PV yield
- Still considerable uncertainty about actual benefit due to bifaciallity (+5%?, +20?)
- Available measurement data – mostly from stand-alone modules without row shading
- Simulation of energy harvest for bifacial module installation limited [1]
- What are optimized mounting conditions (height, tilt angle, also function of albedo)?
- Planning considerably less straightforward for bifacial than for standard systems

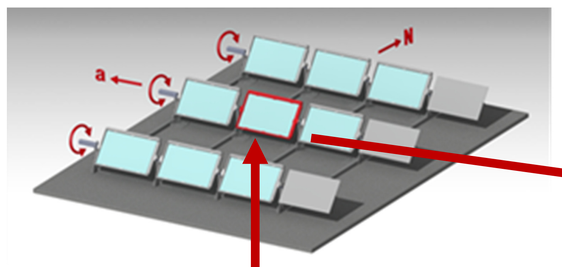
Approach

- Bifacial Module installed in standard rows
- Measurement with permanently revolving modules
- Measured energy yield as a function of tilt angle
- Shading effects considered
- Uniformity of incoming module irradiance measured to improve modelling as a function of albedo

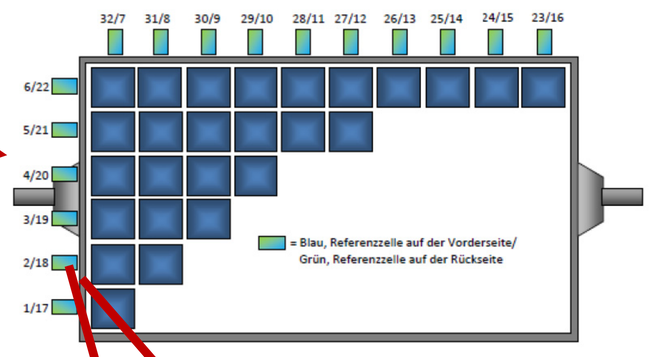
Measurement concepts

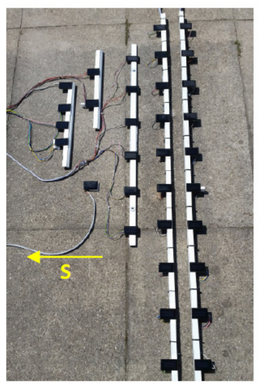


Test array with commercial available 60 cell bifacial modules 270W front STC power is rotated in the range of 0° to 90° tilt angle while the iv characteristics and thus the MPP is measured at selected tilt angles.

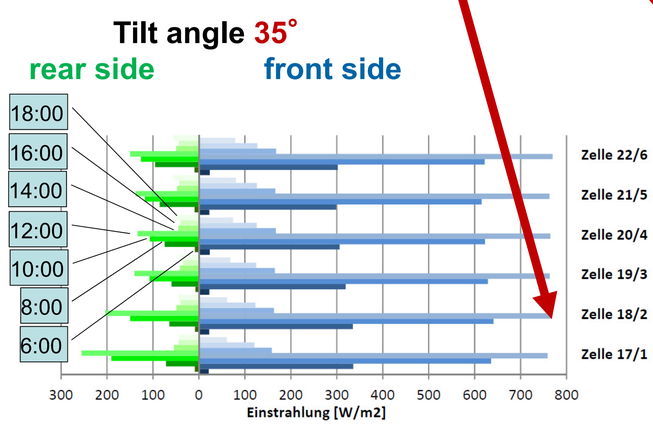


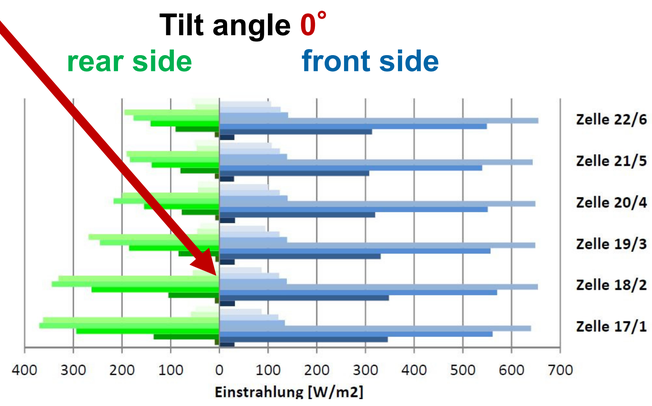
Measurement setup BIFROT with permanently revolving modules. Height, distance between the rows and reflecting ground can be changed manually. Also the global orientation of the array can be varied. The most relevant module in the center, which is best suited to represent the actual conditions in real installations, is marked red.





⇒ **The uniformity of the irradiance of the "center" module is measured by small test cells mounted on the frame on the front and on the rear side. (2016/07/05)**





Results & Conclusions

Mapping of energy yield versus tilt angle and horizontal global irradiance

- The same matrix method developed for PV inverter performance described in Ref. [3] is applied to fit the PR performance ratio as MPP output of bifacial modules P_{DC} relative to the horizontal global irradiance P_{in}.

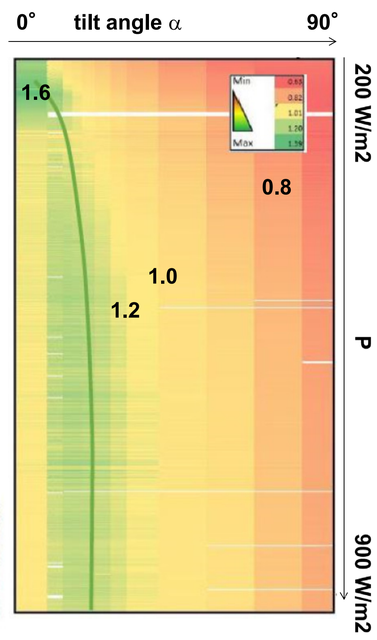
$$PR = \frac{P_{DC}\,[W/m^2]}{P_{STC}\,[W/m^2]} \Big/ \frac{P_{in}\,[W/m^2]}{1000\,[W/m^2]}$$

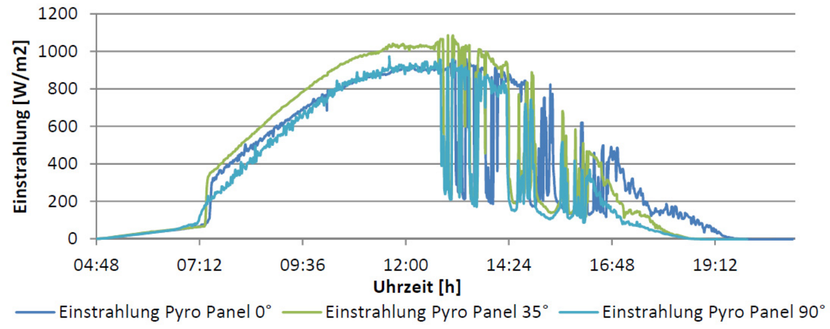
- This PR is described by the following polynomial formula as a function of tilt angle α and horizontal irradiance P

$$\begin{aligned} PRh(\alpha,P) = {} & (c_{00} + c_{01}\times P + c_{02}\times P^2 + c_{03}\times P^3 + c_{04}\times P^4) \\ & + (c_{10} + c_{11}\times P + c_{12}\times P^2 + c_{13}\times P^3 + c_{14}\times P^4)\times \alpha \\ & + (c_{20} + c_{21}\times P + c_{22}\times P^2 + c_{23}\times P^3 + c_{24}\times P^4)\times \alpha^2 \\ & + (c_{30} + c_{31}\times P + c_{32}\times P^2 + c_{33}\times P^3 + c_{34}\times P^4)\times \alpha^3 \\ & + (c_{40} + c_{41}\times P + c_{42}\times P^2 + c_{43}\times P^3 + c_{44}\times P^4)\times \alpha^4 \end{aligned}$$

- The result of the fitting to measured PR values leads to the following coefficients

c4	c3	c2	c1	c0	
8.33E-19	-1.82E-15	1.35E-12	-3.88E-10	1.62E-08	a4
-1.40E-16	3.03E-13	-2.17E-10	5.44E-08	1.33E-06	a3
7.72E-15	-1.79E-11	1.44E-08	-4.50E-06	8.65E-05	a2
2.14E-14	1.85E-11	-1.12E-07	1.02E-04	-2.20E-02	a1
-7.32E-12	1.59E-08	-1.19E-05	3.45E-03	1.04E+00	a0





Measured solar irradiance by pyrometers at BIFROT Test setup in Winterthur at 2016/0705.

Conclusions

- Starting with the given time series of the global horizontal irradiance at a given location the above collected matrix coefficients method could result in an prediction of the energy yield at different tilt angles including the optimum one by the use of the bifacial BIFROT test setup.
- Longer term typically annual measurement results needed in order to conclude in optimized tilt angle at given mounting height and albedo
- Comparative results of the energy yield to a miniaturized test array showed a deviation in a range of ±1% [2] There changes of several parameter are under investigation
- Analysis of the measurement data of May 2016 result in 20° as an optimum bifacial tilt angle

References

[1] U. A. Yusufoglu et. al., "Analysis of the Annual Performance of Bifacial Modules and Optimization Methods," *IEEE J. Photovoltaics*, vol. 5, no. 1, pp. 320–328, 2015
[2] H. Nussbaumer et. al. «Influence of Low Concentration on the Energy Harvest of PV Systems Using Bifacial"; this conference , 5BV.4.
[3] F. Baumgartner et. al. 22nd European Photovoltaic Solar Energy Conference and Exhibition, 3-7 September 2007, Fiera Milano, Session 4DO.4.6
[4] S. Schartinger, G. Petrzilek, Bachelor Thesis 2016 at ZHAW SoE IEFE, www.zhaw.ch

Visual Presentation , EU PVSC , PV Cells and Modules, %BV.4.6, 21st June 2016