ILLUMINATION HOMOGENEITY OF BIFACIAL SYSTEMS – OUTDOOR MEASUREMENTS WITH SYSTEMATICALLY VARIED INSTALLATION CONDITIONS

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Motivation and Approach

Bifacial technology

- Bifacial technology is currently in the focus to increase PV yield
- More complex conditions for bifacial installations compared to standard, monofacial ones, due to additional effects from backside illumination (albedo, shading, ...)
- Limited predictability of the output by simulation or by comparison with similar systems
- Optimized mounting conditions (height, tilt angle, ...) are vague
- Actual benefit due to bifaciality unclear → possible investors are deterred

Approach

- Nine bifacial modules installed on BIFOROT (Bifacial Outdoor Rotor Tester) test array
- Measurement at twelve different tilt angles per minute with permanently revolving modules
- Shading effects considered
- Uniformity of incoming module irradiance measured on front and backside
- Provide systematic data to test and improve simulation algorithms
- Find optimised tilt angle for the specific installation conditions

Specifications

- Azimuth angle: 0° (north-south orientation)
- Axis height: 0.75 m (from ground to axis centre)
- Axial spacing: 2.86 m (from the centre of the axis to the centre of the axis)
- Tilt angles: 0°, 10°, 15°, 18°, 21° 25°, 30°, 35°, 40°, 45°, 60°, 90°
- Ground albedo: 0.51 (measured at axis height)
- Module height: lower edge depending on tilt angle (Figure 6), module centre always at axis height (0.75 m)
- Module 1 (M1): frontside covered for $I_{SC,back}$ measurement
- Module 2 (M2): IV curve measurement ($I_{SC,bifacial}$)
- Module 3 (M3): backside covered for $I_{SC,front}$ measurement

Long time measurements

- Data acquisition from 5th of October 2016 until 27th of March 2017

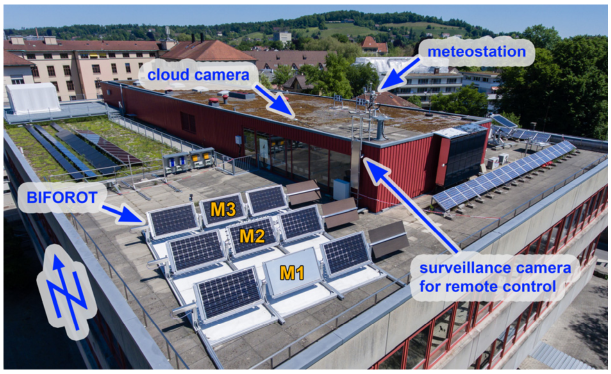

Figure 1: South orientated installation of the BIFOROT test array on the roof of the ZHAW in Winterthur. Aerial view on the roof and test array from southwest direction. The module tilt angle is changing permanently in a synchronized manner within an interval of one minute. Module 1 to module 3 (M1 –M3) are the devices under test (DUT).

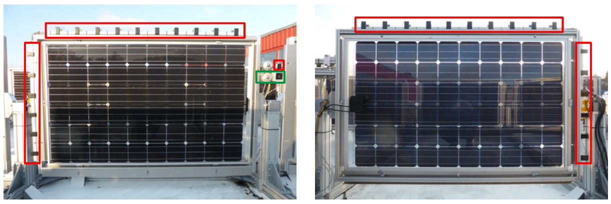

Figure 2: Small irradiance sensors - crystalline silicon cells - (red marked) enable a detailed analysis of the mapping of illumination intensity and homogeneity on the module front (left picture) and backside (right picture) of module 2 (M2). The rotating pyranometer and silicon reference sensor ISE cell (green marked) are mounted on the east side of the module mounting frame, moving synchronised with the modules. The bifaciality B is 0.694. This value is low compared to other bifacial modules because of the shading on the module back side, which is caused by the junction box. B is calculated as follows: $B = P_{mpp,rear} / P_{mmp,front} = 0.694$.

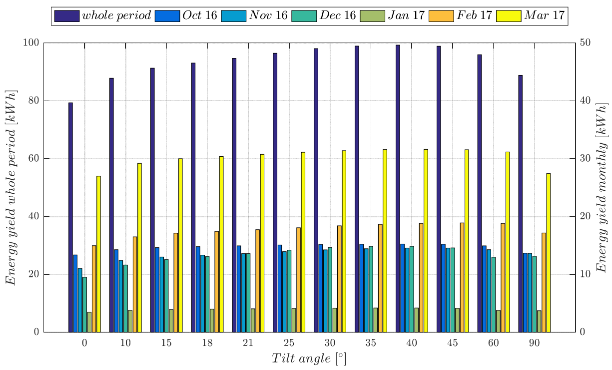

Figure 3: Energy yield (dark blue, left y-Axis) over the whole measurement period (05.10.2016 until 27.03.2017) and energy yield per month (coloured, right y-Axis) per tilt angle of module 2 (M2). Due to heavy snowfall and icing of the rotating axis, the yield of January is low.

Results, Conclusions and Outlook

Results and Conclusions

- Maximal energy yield for measurement period (winter season) and given setup achieved at 40° tilt angle (Figure 3)
- Backside illumination sum (Σ $I_{SC,back}$ (M1)) over the measurement period nearly constant for all tilt angles (Figure 4)
- The relative contribution of the backside to the total illumination was measured between 0.15 (45°) and 0.35 (0°) dependent on the tilt angle (Figure 4)
- The minimal irradiation on the backside of the module limits the bifacial gain, compare red line in Figure 4 (Bc) and Figure 5 (minimal value)

Outlook

- Extend and optimize the measuring device and carry out further measurements
- Further work on an energy yield simulation model in cooperation with ISC Konstanz

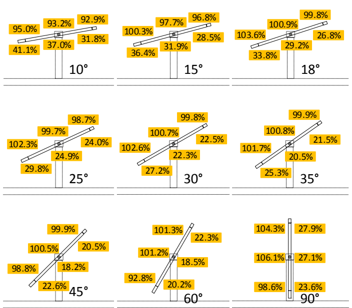

Figure 6: Vertical irradiation sum on module front and backside of module 2 (M2) over the whole measurement period relative to ISE irradiation on module frontside

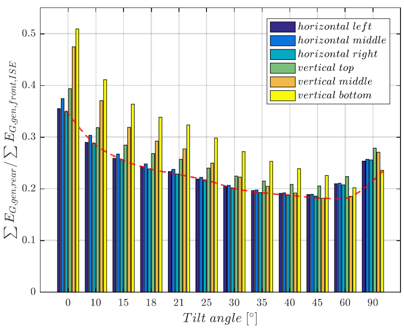

Figure 5: Irradiation over the whole measurement period on the module backside of module 2 (M2) at six different positions in relation to irradiation on the module front side (ISE cell)

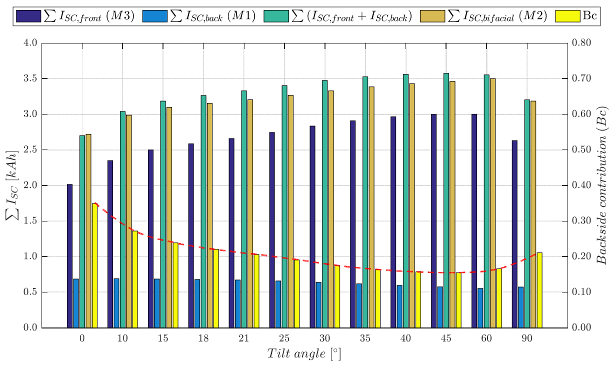

Figure 4: Short circuit current sum over the whole measurement period of front (module 3, M3), back (module 1, M1), sum of front and back and bifacial (module 2, M2) per tilt angle. The contribution of the backside (yellow, right y-Axis) was calculated as follows: $Bc = \Sigma I_{SC,bifacial} / \Sigma I_{SC,front} - 1$.

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