BIGEYE: ENERGY YIELD OF BIFACIAL SYSTEMS

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› Yield calculation for bifacial systems
  › Issues & design options
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› ECN.TNO’s BIGEYE:
  › description
  › validation
  › Bifacial energy gain in different configurations
INNOVATION THROUGHOUT THE PV VALUE CHAIN

Materials

- Cell design & manuf.
- Module design & production
  - x-Si and thin film based

Module design & production

- Cell and module characterisation

System design & production

- Outdoor testing
- Field testing

Integration & application

- Module reliability testing and diagnostics
- Power electronics testing and diagnostics
- Yield modelling and simulation
RECENT MATERIAL

› Bifacial workshop 2019:

› History of bifacial PV
› Bifacial (silicon crystalline) PV technologies
› Impact of the system design on the achievable yield
› Yield prediction software
ISSUES IN BIFACIAL SIMULATION

- Technical issues:
  - Inhomogeneous irradiance on rear side
  - Edge effects
  - Support structures: shading and scattering
  - Obtain ground irradiance

- Design options
  - Dual ground use
  - DC/AC ratio
  - Single axis tracking
MODELLING APPROACHES

› Ray-tracing
› Statistical method
› Track (many) rays through system until error is below certain threshold
› Contingent on parallel processing
› bifacial_radiance (NREL)

› View factors
› Linear algebra based:
› meshing (adaptive) of surfaces
› matrices represent radiative exchange between surfaces.
› MoBiDIG (ISC Konstanz) quasi-3D view factors
› PVsyst
› assumes infinitely long sheds or SAT trackers, at same pitch
› inhomogeneous illumination effects to be captured by user in “mismatch loss factor”
ECN.TNO BIGEYE FEATURES

- Designed from onset with bifacial systems in mind
  - 3D irradiance model
    - View factor based
    - Used for both front- and rear side, no approximations for rear side
    - Sub-cell spatial resolution (beam shade)
  - Flexible in geometry, provides SAT
  - Optical and thermal models adapted for bifacial.
  - Development hand-in-hand with applications → validation

- From inhomogeneous irradiance to IV of string of modules
  - Series connection
    - Cell IV curves (accounting for shading)
    - Module IV (bypass diodes) → string of modules
    - Mismatch accounted for implicitly

- Design-of-Experiments
  - scan multiple configurations, parameter ranges

Two sheds before a diffusely reflecting wall
VALIDATION: USING FULL IV CURVES

› Test rig at ECN.TNO
  › Intentional shading
  › measure full IV curves

› Allows to validate BIGEYE IV curve modelling.
Set-up at Zurich University of Applied Science
Simulation programs
- Pvsyst, MoBiDig (ISC), BIGEYE

Conclusions from the comparison [1]
- The three simulation tools give similar results
- are in agreement with the experiment
- bifacial yield modeling is reaching a stage of maturity.

BIGEYE VALIDATION: HOPEWELL (NC)

- 1 MW commercial bifacial SAT site
  - More details talk Jenya Meydbray, bifacial workshop 2019 (available for download)
  - Realized by Cypress Creek Renewables (CCRE) for Randolph Electric Membership Corporation
  - US DoE grant: additional instrumentation for validation
    - GHI, $T_{\text{module}}$, albedo, $G_{\text{POA,fr}}$, $G_{\text{POA,re}}$
    - 5 minute time resolution
    - PV Evolution Labs, CCRE

- Monitoring started in January 2019
- Early results, pending full report.
VALIDATION: ALBEDO AND TRACKING

- System provided with an albedo meter (up+down looking pyranometer)
- Verification of logged tracking angles and measured tracking angles.
  - Follow sun, but avoid casting shade on neighbouring tracker (back-tracking)
**ALBEDO OVER TIME**

- High correlation up/down facing
- Small spread over period observed

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VALIDATION: POA IRRADIANCE

- Pyranometer mounted on both front- and rear side, with tracking
- POA irradiance calculated from:
  - GHI, measured albedo, time.
- Note: scale difference front/rear irradiance, spread.

![Graph showing POA irradiance comparison](image-url)
Module temperature measured for 2 modules

- Comparison with calculated (day time)

Energy production
IEA PVPS Task 13: Subtask 1.2: Bifacial PV - Bifacial PV Modeling Comparison

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Site layout
- Design e.g. for kWh/m², kWh/kWp, ground irradiance
- With edge effects
- As function of e.g. ground albedo, geometry, module transparency

GCR: m² PV/m² area
bifacial HSAT, 4900 Wp system

Bifacial gain is evidenced by shift in current distribution, but 98% <10 A

Typical inverter limitations will not frequently be breached by this I_MPP distribution

hardly any difference in voltage distribution, slightly narrower for bifacial both at low and high end of distribution!

![Graph showing distribution of V_MPP and I_MPP for bifacial and monofacial systems.](image-url)
If the AC power limitation is surpassed, the output power is clipped.

For HSAT low power situations rare as sun is tracked (hardly ever poor angles) in sunny climate!

Circled cost points are optimal DC:AC ratio for this system and our cost assumptions.
SUMMARY

- Bifacial energy yield modelling is maturing
  - Multiple programs
  - Multiple validation efforts

- System design:
  - Energy yield an important input
  - But for LCOE: subsidies/tariffs, m² prices, climate, building constraints, …

- BIGEYE:
  - Developed for bifacial systems and general geometries
    - Inhomogeneous illumination mismatch implicitly calculated
  - Significant effort put in validation, leading to confidence in results.