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BifacialSimu: Holistic Simulation of large-scale Bifacial Photovoltaic Systems

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Summary

Due to the ongoing anthropogenic climate change and a global effort to switch energy production from fossil sources to renewable energies, bifacial photovoltaic (PV) markets are recently growing (Fischer et al., April 2021). In this context, the consideration of bifacial PV in simulation programs is gaining importance in research and engineering sectors. Bifacial PV can absorb solar radiation arriving on the front side as well as on the rear side of a PV module and use it to generate electricity, which increases the overall efficiency and energy yield of a PV module of the same area compared to monofacial PV. Because of the significant impact of the rear side irradiance on energy yield in bifacial PV, the inclusion of exact albedo simulation, which indicates the light reflectivity of a surface (usually the ground) is indispensable. The bifacial simulation program BifacialSimu, a Python package developed at the University of Applied Sciences Cologne (Germany), calculates the energy yield of a bifacial PV system based on a variety of simulation models, which the user is able to select. Moreover, it offers the option to use a constant, time-variable (Chiodetti et al., June 2016) or geometric spectral albedo (Ziar et al., 2019) to calculate the light reflectivity of the ground surface. The energy yield can be calculated using two different electrical models (Singh et al., 2014).

Statement of need

Current forecasts expect PV to be the third-largest power generation technology by 2050 and will play a significant role in future global electricity generation (International Renewable Energy Agengy, 2019). Since the specific yield of a PV system can be increased with respect to monofacial PV, bifacial PV has become the focus of research in recent decades (Cuavas, june 2005). With the rapidly growing market for bifacial PV, there is also a demand for precise simulation programs for this technology to enable planners and investors to make accurate energy yield forecasts. In recent years, more and more simulation programs and models have been published that allow the simulation of bifacial PV systems (Stein et al., April 2021). In contrast to the simulation of monofacial PV, the simulation of bifacial PV is more complex since several additional factors impact the energy yield due to the rear side radiation. In addition to the bifaciality and the geometry of the photovoltaic field, these factors include the ground albedo, which indicates the light reflectivity of the ground. There is a need for an open-source software tool to simulate bifacial PV, which combines existing radiation models with new albedo and electrical models and also provides a graphical user interface (GUI) to involve every potential user group. BifacialSimu offers various model options for each simulation step and is well documented. Especially advanced albedo models are necessary to simulate in regions where no measurements are possible. BifacialSimu has already been applied in two publications (Grommes, 2020), (Grommes et al., 2020), three publications regarding the validation were presented at the World Conference on Photovoltaics Energy Conversion (WCPEC-8), and one

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publication was submitted to the 17th Conference on Sustainable Development of Energy, Water and Environment Systems (SDEWES) in 2022.

State of the field

In contrast to other bifacial simulation software, BifacialSimu is the only open-source bifacial simulation software that combines the two radiation models leading to the most accurate forecast: viewfactor for the front side and raytracing for the rear side (Berrian et al., October 2017). Only one paid option MoBiDiG hybrid from International Solar Energy Research Center Konstanz also offers this combination (Berrian et al., October 2017). SAM by National Renewable Energy Laboratory (NREL) does not include the option to choose between different models for electrial and albedo calculation (Freeman et al., n.d.). The radiation models in BifacialSimu are based on existing, open-source software. Bifacial_radiance from NREL is used for raytracing (Deline & Ayala, 2017). This makes full simulation of a bifacial PV system more complex and time-consuming. Neither of the commonly known open-source software packages using the viewfactor model (pvfactors (Anoma et al., 2017) and bifacialVF (Marion et al., 2017)) have energy yield calculations or GUIs, limiting both the target audience and application scope. The commonly used software PVsyst offers an energy yield calculation and a GUI, but the physical models it uses have limited documentation and the software is not free (PVsyst SA, n.d.). To the authors' knowledge, BifacialSimu is the only available software offering all these choices for albedo, radiation, and electrical models.

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References

Anoma, M., Jacob, D., Bourne, B. C., Scholl, J. A., Rily, D. M., & Hansen, C. W. (2017). View Factor Model and Validation for Bifacial PV and Diffuse Shade on Single-Axis Trackers. *44th IEEE Photovoltaic Specialist Conference*. https://doi.org/10.1109/PVSC.2017.8366704

Berrian, D., Libal, J., & Glunz, S. (October 2017). *MoBiDiG: simulations and LCOE*. International Solar Energy Research Center - ISC Konstanz; Fraunhofer Institute for Solar Energy Systems ISE; Unpublished. https://doi.org/10.13140/RG.2.2.20990.08008

Chiodetti, M., Lindsay, A., Dupeyrat, P., Binesti, D., Lutun, E., Radouane, K., & Mousel, S. (June 2016). *PV BIFACIAL YIELD SIMULATION WITH A VARIABLE ALBEDO MODEL*.

Cuavas, A. (june 2005). *The early history of bifacial solar cells*. The Autralian National University.

Deline, C., & Ayala, S. (2017). *Bifacial_Radiance*. National Renewable Energy Laboratory (NREL). https://doi.org/10.11578/dc.20180530.16

Fischer, M., Woodhouse, M., Herritsch, S., & Trube, J. (April 2021). *International Technology Roadmap for Photovoltaic (ITRPV): Results 2020* (VDMA e.V. Photovoltaic Equipment, Ed.; 12th ed.).

Freeman, J. M., DiOrio, N. A., Blair, N. J., Neises, T. W., Wagner, M. J., Gilman, P., & Janzou, S. (n.d.). *System Advisor Model (SAM) General Description (Version 2017.9.5)*. https://doi.org/10.2172/1440404

Grommes, E.-M. (2020). *Performance estimation of bifacial PV systems using the view factor matrix*.

Grommes, E.-M., Blieske, U., & Mueller-Ost, J. (2020). The impact of albedo measurements on power density calculations of bifacial modules. *EU PVSEC 20*, *September*.

International Renewable Energy Agengy. (2019). *Future of Solar Photovoltaic: Deployment, investment, technology, grid integration and socio-economic aspects: A Global Energy Transformation: paper*.

Marion, B., MacAlpine, S., Deline, C., Asgharzadeh, A., Toor, F., Riley, D., Stein, J., & Hansen, C. (2017). A Practical Irradiance Model for Bifacial PV Modules. *Get energized with solar power*, 1537–1542. https://doi.org/10.1109/PVSC.2017.8366263

PVsyst SA. (n.d.). *PVsyst 7.2*. PVsyst SA.

Singh, J. P., Aberle, A. G., & Walsh, T. M. (2014). Electrical characterization method for bifacial photovoltaic modules. *Solar Energy Materials and Solar Cells*, *127*, 136–142. https://doi.org/10.1016/j.solmat.2014.04.017

Stein, J. S., Reise, C., Castro, J. B., Friesen, G., Maugeri, G., Urrejola, E., Ranta, & Samuli. (April 2021). *Bifacial Photovoltaic Modules and Systems: Experience and Results from International Research and Pilot Applications: Report IEA-PVPS T13-14:2021* (IEA PVPS Task 13, Ed.).

Ziar, H., Sönmez, F. F., Isabella, O., & Zeman, M. (2019). A comprehensive albedo model for solar energy applications: Geometric spectral albedo. *Applied Energy*, *255*, 113867. https://doi.org/10.1016/j.apenergy.2019.113867