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Vertical reflector for bifacial PV-panels

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Motivation

Bifacial solar cell modules can provide a price advantage in production relative to normal solar cell modules if the effective light collecting area can become twice the area of a normal single-sided solar cell module of the same size. This can only be achieved by designing an adequate reflector. Particularly, a design which is optimized for local winter conditions has our highest interest.

We intend to use ray tracing simulations to model and optimize the interaction between the vertical bifacial solar cell module and vertical reflector designs.

In this work, we demonstrate preliminary results on simulations of power gain, using the bifacial solar cell module relative to a single-sided solar-cell module of same size. In case we could unfold the bifacial PV cell the optimum power gain would be 2.
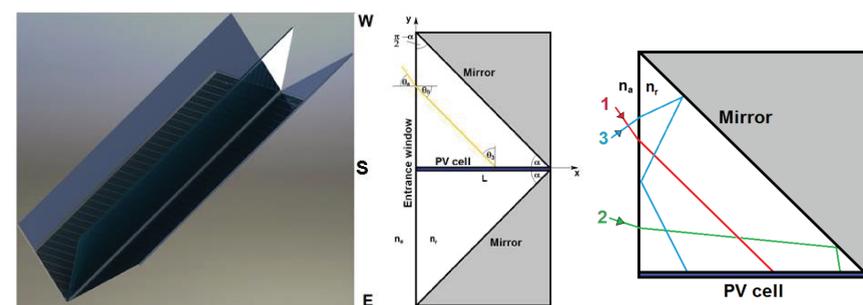

Fig.1 (a). The bifacial solar cell and its two reflectors are illustrated in a 3D plot. The corresponding horizontal profile is illustrated in (b). In (c) the three ray models, which are included in the model, are illustrated. The three colors mark the same contributions in Fig.3.
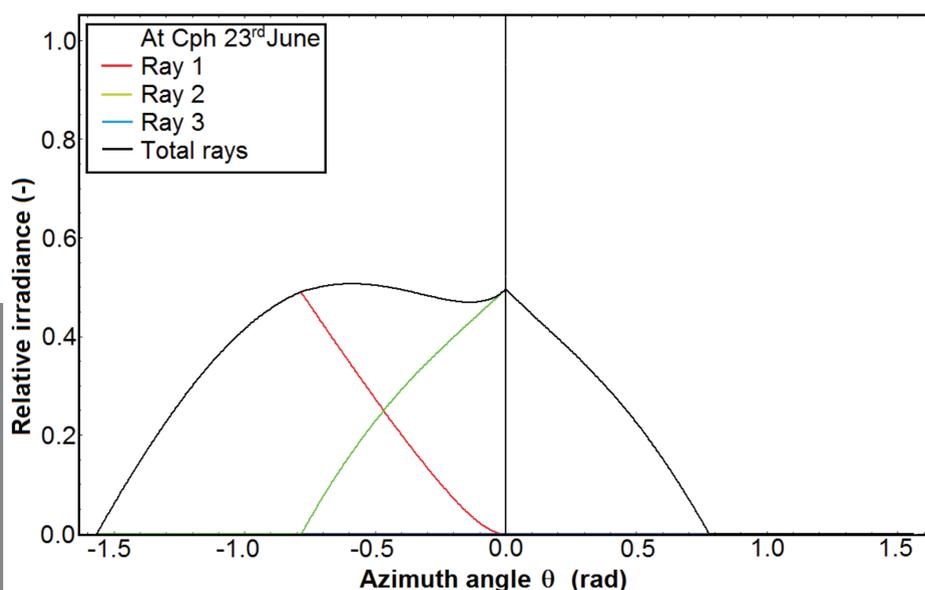

Fig. 2. The simulated relative irradiance for one half of the bifacial PV-cell and reflector. (nr = na)

The model

The vertical reflector consists of two mirrors mounted at 45 deg. relative to the x-axis. The bifacial PV cell coincides with the x-axis, and all three components meet at x = L. As illustrated in Fig. 1a and Fig. 1b, the PV-cell and the reflectors are surrounded by air with a refractive index of (na). The cavity between the mirrors contains air, but could also contain a transparent medium with a refractive index of nr. The path of the incoming light is modelled by three ray paths, as it can be seen in Fig. 1c. Direct incidence of light onto the PV cell is modelled by the red line. Light reflected once at the mirror and then incident onto the PV cell is modelled by the green line. Light reflected once at the mirror, and again at the entrance window/interface – if a medium is present - is modelled by the blue line.

The preliminary results does not include optical loss at reflection at the mirrors or absorption in the cavity of the mirrors in case nr > 1. The sun model does not include diffuse light and we assume that the sun intensity is constant as long it is above the horizon.

The results

In Fig. 2 the individual ray contributions are plotted as a function of azimuth angle of the incoming light. The red curve is direct light incidence onto the PV-cell, which peaks at 45˚ (0.79 rad). The green curve is light reflected once, while the blue line contributes with zero power when no medium is present in the cavity, nr = na.

In fig. 3 the model plots the relative power obtained by the bifacial solar module when located at a latitude of 55.7˚ (Copenhagen), for a day in the summer (23/6) and a day in the winter (21/12).

The table below lists the power gain modelled at four locations of different latitudes, and modelled for a day in the summer (23/6) and a day in the winter (21/12).

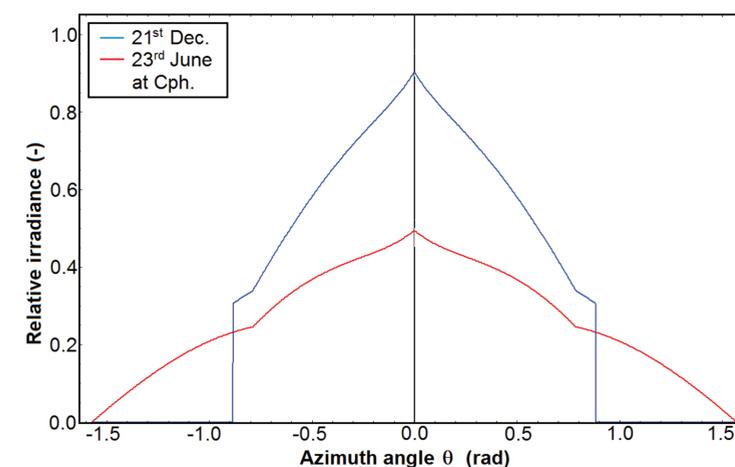| Latitude	Power Gain December	Power Gain June
Trondheim (64°)	1.68	1.36
Copenhagen (56°)	1.45	1.35
Münich (48°)	1.39	1.33
Rome (42°)	1.38	1.35

Fig. 3. The simulated relative irradiance for the entire bifacial PV-cell and both reflectors. (nr = na). The location is a latitude of 56˚ (Copenhagen) and a summer day and a winter day are considered.

Conclusion

An optical raytracing model has been introduced to the bifacial PV-cell, given the presented configuration of reflectors. We demonstrate that relative to a single-sided PV-cell of the same size we can obtain 30-70% more light with the bifacial PV cell. The efficiency increases with latitude.

Outlook

The model will be developed further in the near future, to include diffuse light, realistic sun data and different reflector configurations.