Hogeschool van Arnhem en Nijmegen
HAN University of Applied Sciences

Sustainable Electrical Energy Centre of Expertise

New Energy Systems

Autonomous Solar Tracking on a PLC for CPV in the Built Environment

Jurgen Reintjes, Paul van Kan, Marc van der Sluys, Piet Sonneveld
HAN University of Applied Sciences, Arnhem, The Netherlands

Introduction

Energy consumption for climate control in buildings and greenhouses can be very high. Still, sufficient entry of light through façades or windows is essential. Admission of light, however, also means that large amounts of heat enter the interior in summer.

A significant reduction of energy consumption may be achieved by collecting the available solar energy for the production of electric as well as thermal energy. With Fresnel lenses, visible and near-infrared radiation is focussed on triple-junction solar cells. These cells must be actively cooled: the cooling circuit extracts the thermal energy from the building or greenhouse interior. This concept, however, only works when the solar panels are kept perpendicular to the sun. We have implemented a robust method for solar tracking of such CPV systems, as part of the HCPV-GO project (Highly Concentrated Photovoltaics for the Built Environment) currently carried out at HAN University.

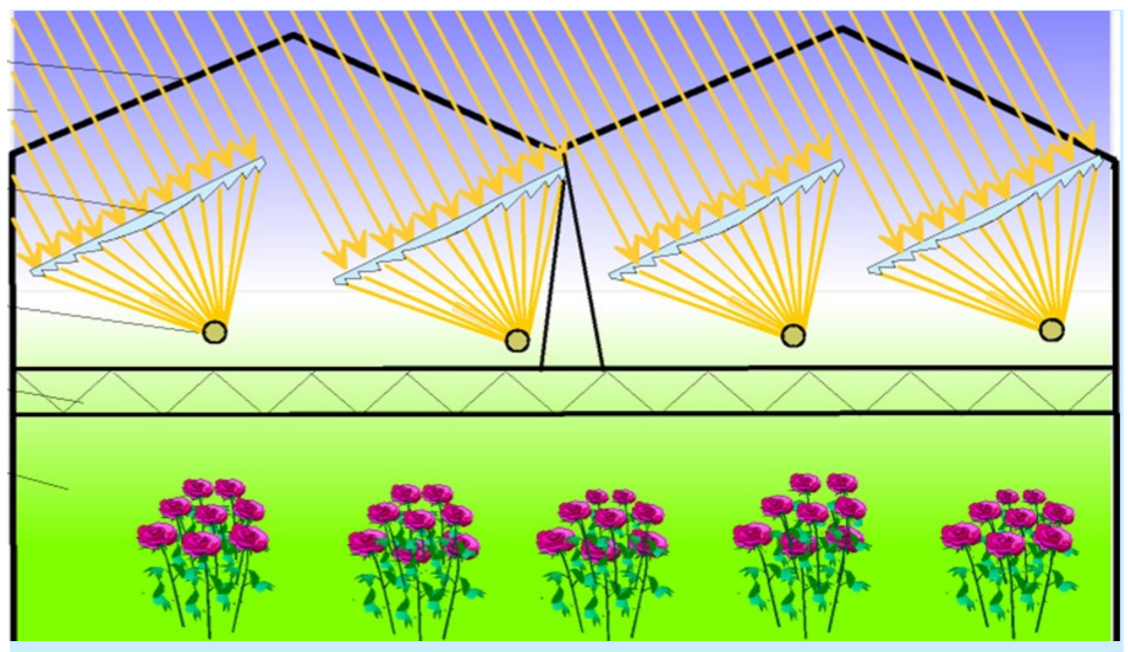
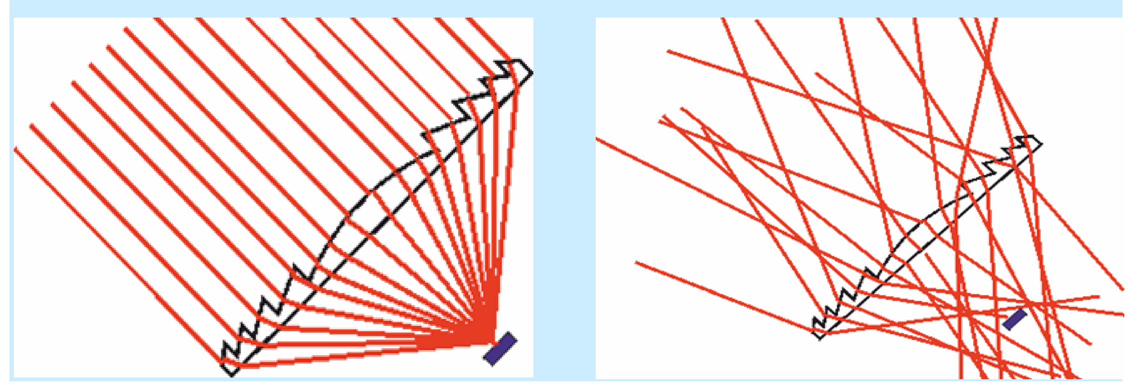


Fig. 1 The CPV-units consists of a number of Fresnel lenses that direct solar radiation to central receivers where electric energy is generated and heat is captured in a liquid heat transfer system. The diffusely transmitted light is sufficient for illumination and even for plant growth.



Major goals

- **Supply of electrical energy**
- **Delivery of thermal energy in cooling circuit**
- **Reduced energy consumption for climate control**

Main requirements

- **Follow the sun's position with 0.1° accuracy.**
- **Follow the sun's position in the built environment**
- **Follow the sun's position in all weather conditions**

- **Implemented on a PLC**
- **Autonomous under normal operation conditions**
- **No unnecessary motion**

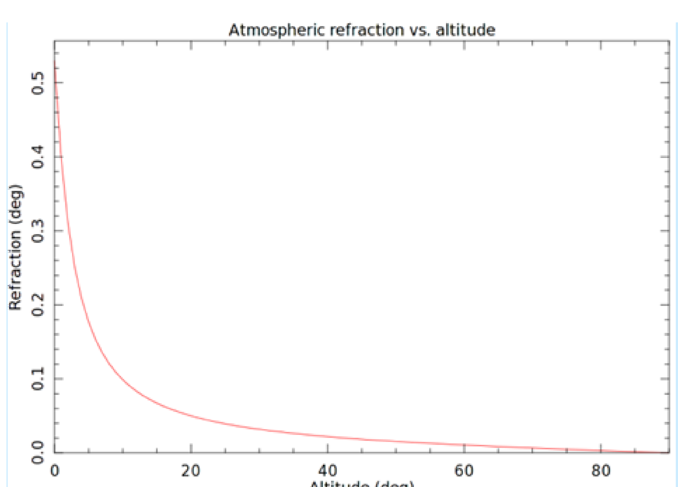


Fig. 2 Influence of atmospheric refraction. Difference between apparent and real zenith angle of the sun as a function of the sun's altitude above the horizon.

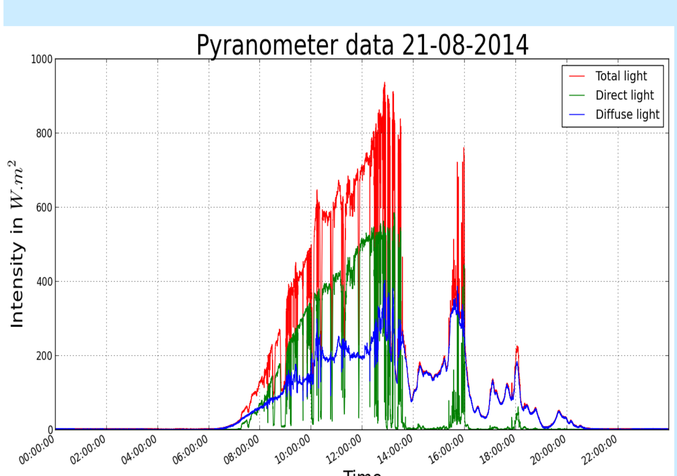
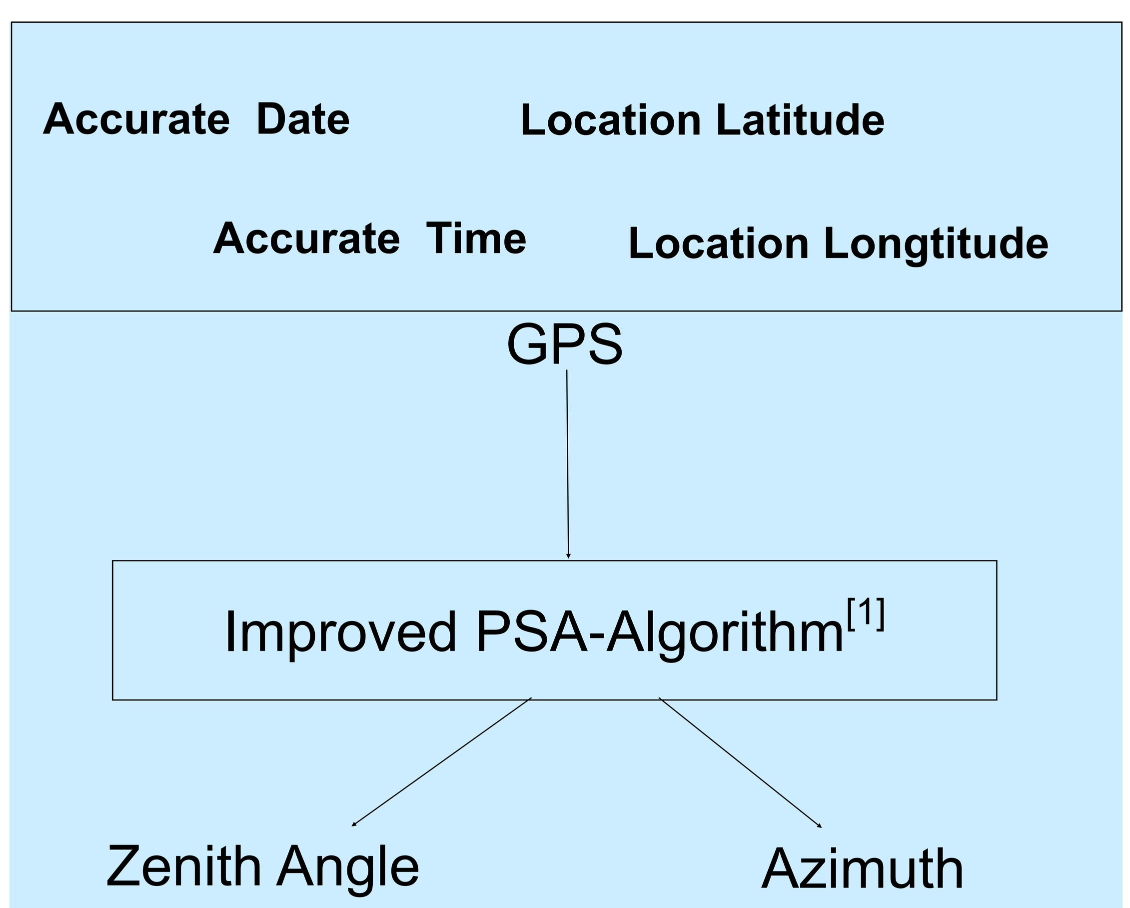


Fig. 3 Example pyranometer data: direct and diffuse light on a day with a sunny morning and a mostly clouded afternoon. Our system shows controlled response on changing weather conditions.



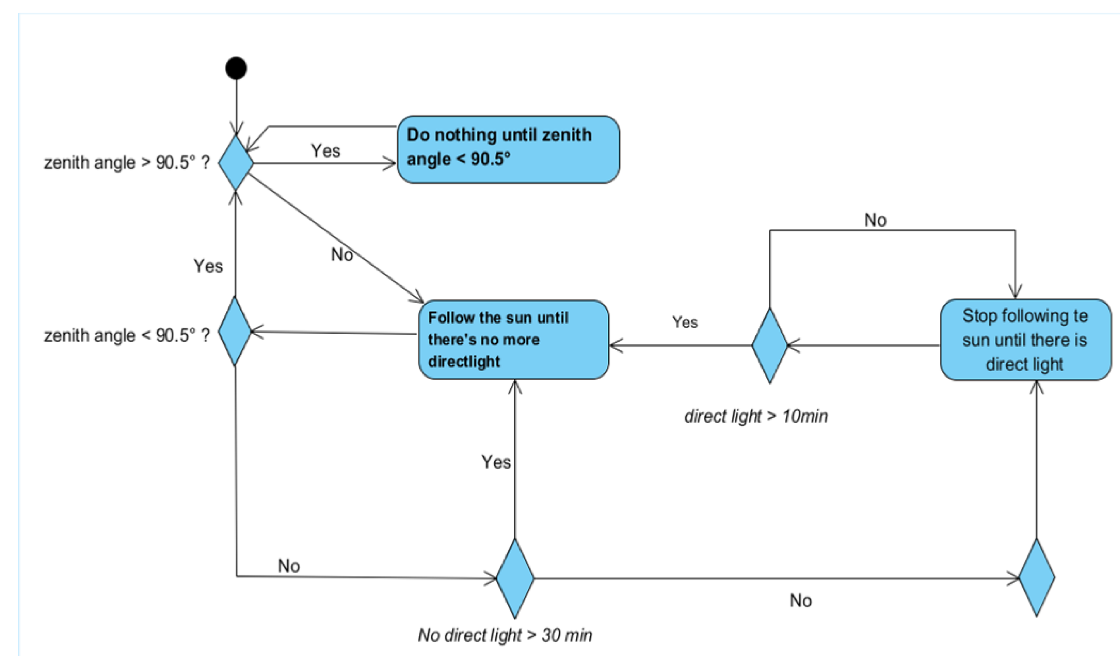


Fig. 4 Flow chart showing the behaviour of the improved tracking algorithm using a GPS receiver and a pyranometer. Thus, correct and robust tracking is possible under changing weather conditions and in locations at high latitudes, even in the winter season.

Results and Discussion

Solar tracking with 0.1° accuracy under all weather conditions during all seasons poses a challenge for CPV systems in the built environment. Our investigations in a model greenhouse indicate that reflection of windows or outdoor white surfaces make optical sun tracking devices unreliable. These devices also react unpredictably on sudden changes in weather conditions.

Our solution for this tracking challenge is using an algorithm which predicts the position of the sun with high accuracy, without using excessive computation time. It is an improvement of the PSA algorithm which allows accurate tracking even when the sun is at low altitude. Validation with VSOP87 [3] shows an average zenith angle error of less than 0.004°, an improvement factor of about 19.

Acknowledgement

This research is funded by Sustainable Electrical Energy Centre of Expertise (SEECE) of the HAN University and the Ministry of Education, Culture and Science of The Netherlands.

Input variables for the improved PSA-algorithm are collected by a GPS device. These variables are: Longitude, latitude and GPS time, which is corrected to Universal Time (UT1).

Changing weather conditions are detected by a Class 1 pyranometer, which measures direct and diffuse sunlight. If direct sunlight exceeds 120 W/m^2, the sun's position is tracked. In the absence of direct sun light, the CPV system automatically assumes a favorable position for overcast skies [2] is automatically realized (see flow chart in fig. 4).

In the flow chart, the criterion for sunrise and sunset is set at a zenith angle of 90.5°, assuming an angular extent of the solar disk of about 0.5°.

Finally, we have been able to implement all functionality into a modern PLC system, equipped with stepper motor drivers for variable (low) speed motion. Which runs autonomously, once the software has been deployed.

Further investigations include testing our method in practice with a system of Fresnel lenses and triple-junction CPV cells in the model greenhouse at HAN University.

Conclusions

We have achieved an improved performance of the PSA solar tracking algorithm by adding a lightweight calculation for atmospheric refraction.

Accuracy has improved sufficiently to rely completely on predictive tracking. This opens opportunities to perform solar tracking in the built environment.

A PLC system is able to do the necessary calculations while observing the incoming data of a GPS receiver and a pyranometer.

In clouded circumstances, controlled motion is guaranteed.

References

[1] http://www.sciencedirect.com/science/article/pii/S0038092X00001560
[2] http://www.sciencedirect.com/science/article/pii/S0038092X09001923
[3] http://adsabs.harvard.edu/abs/1988A&A...202..309B
[4] http://www.wmo.int/pages/prog/gcos/documents/gruanmanuals/CIMO/CIMO_Guide-7th_Edition-2008.pdf

HAN MASTERS PROGRAMMES AND RESEARCH

For more information please contact: e-mail: piet.sonneveld@han.nl, tel. + 31 26 365 8379.
www.han.nl/lectoraatDE