Beyond Energy Gains: The Reliability Impacts of Diffuse Stowing in PV Trackers

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Abstract

When overcast sky conditions occur, the lack of directionality of the global irradiance component leads the photovoltaic (PV) module optimal tilt angle for power production to be close to 0°. This led to the development of the so-called diffuse-stow tracking strategy, which orients the module horizontal with overcast conditions. However, its effectiveness depends on the local weather dynamics.

Using an hourly weather dataset – equal to considering hourly movement of the tracker – and state-of-the-art modeling tools, we show that diffuse-stow generally improves energy yield and reduces cumulative tracker movement compared to conventional back-tracking. For Golden, CO, using TMY data, diffuse-stow can increase annual energy yield by 0.26% while decreasing cumulative angular movement by 9.2%. However, when sub-hourly (5-minute) data is considered, the results change. The energy gain increases to 0.36% and the angular movement, instead of decreasing, increases to 100.2%. This shift is attributed to Golden's weather, characterized by short-lived overcast periods.

This study defines the irradiance threshold where diffuse-stow provides meaningful energy gains with minimal impact on tracker movement. Furthermore, it contributes to a broader discussion on single-axis tracker longevity by considering the implications of cumulative angular movement.

Image adapted from https://www.antaisolar.com/tai-universal-multiple-slew-drive-single-axis-2p-tracker_p26.html

Tracking Strategies for Diffuse Conditions

While tracking optimizes PV orientation toward the Sun, diffuse tracking strategies orient the module horizontal during overcast conditions, due to lack of radiation directionality. However, the threshold of overcast conditions at which changing the module orientation becomes beneficial is not well defined. To evaluate this, the optimal tilt angle for a bifacial PV module is analyzed under varying diffuse and direct irradiance conditions, via PVlib's infinite sheds algorithm [1], modeled using C_{dir}:

$$C_{dir} = {}^{DNI}/_{DNI_{clear}}$$

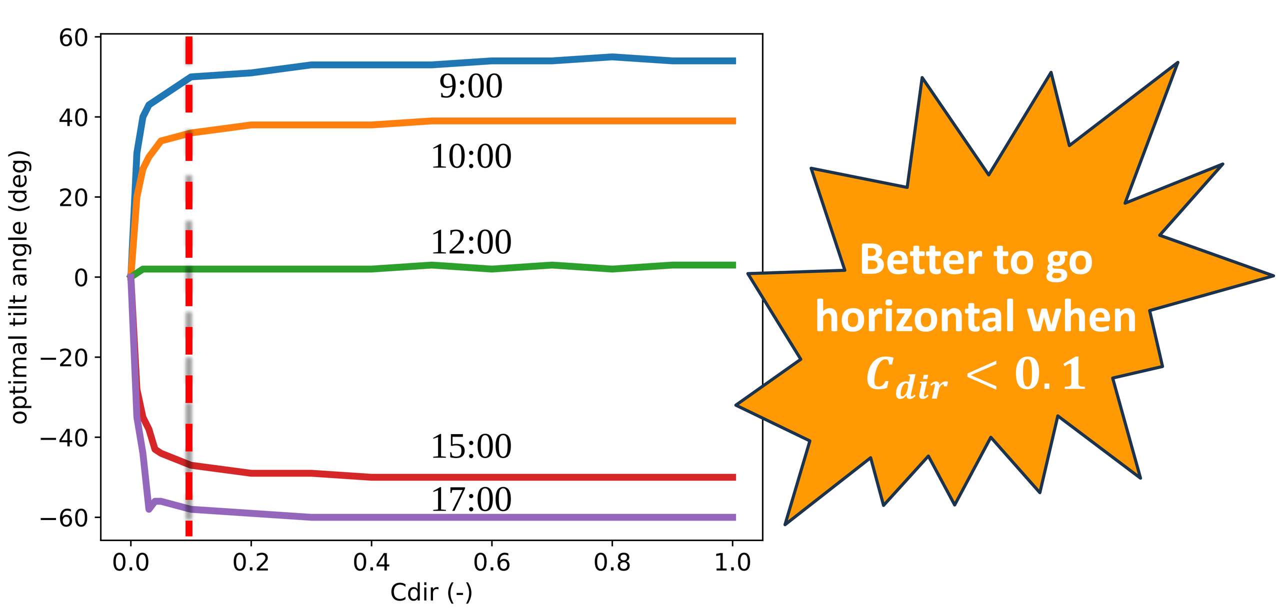


Fig.1 Optimal tilt angle variation for different time of the day and different value of C_{dir}

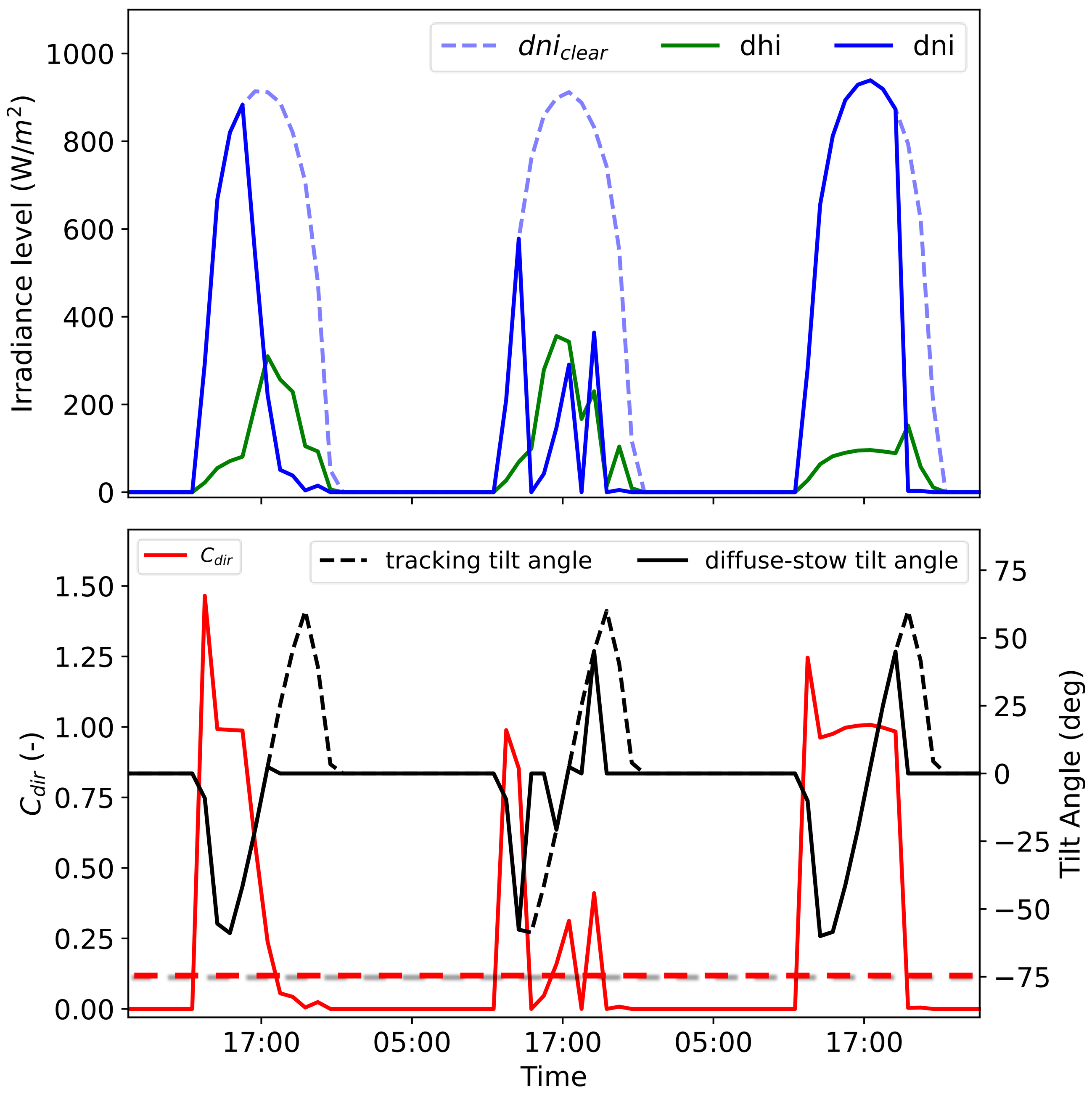


Fig.2 (top) Radiation components for two days, with the (bottom) resulting C_{dir} and tracker angle based on the diffuse tracking strategy

Tracking routine results

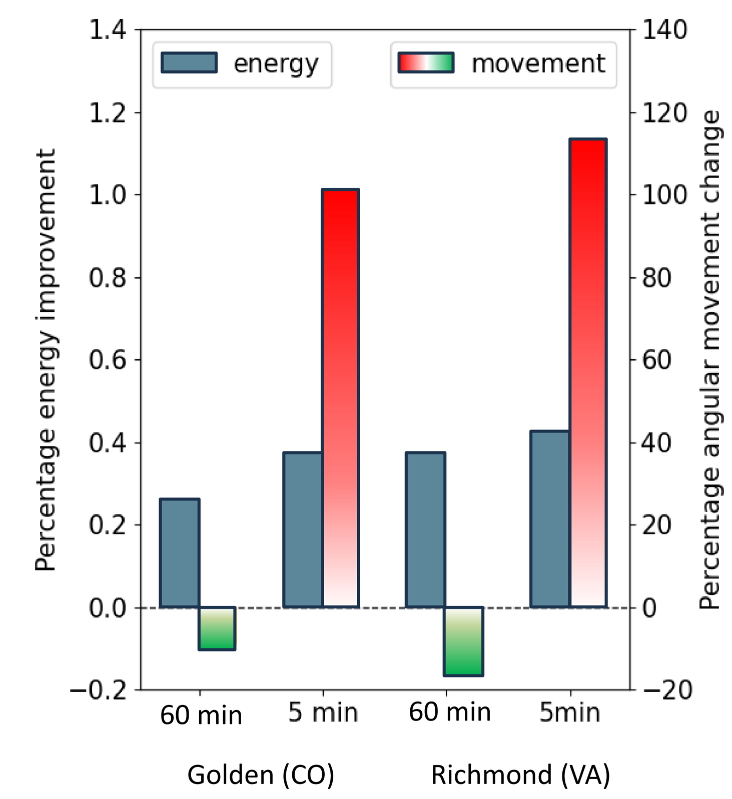


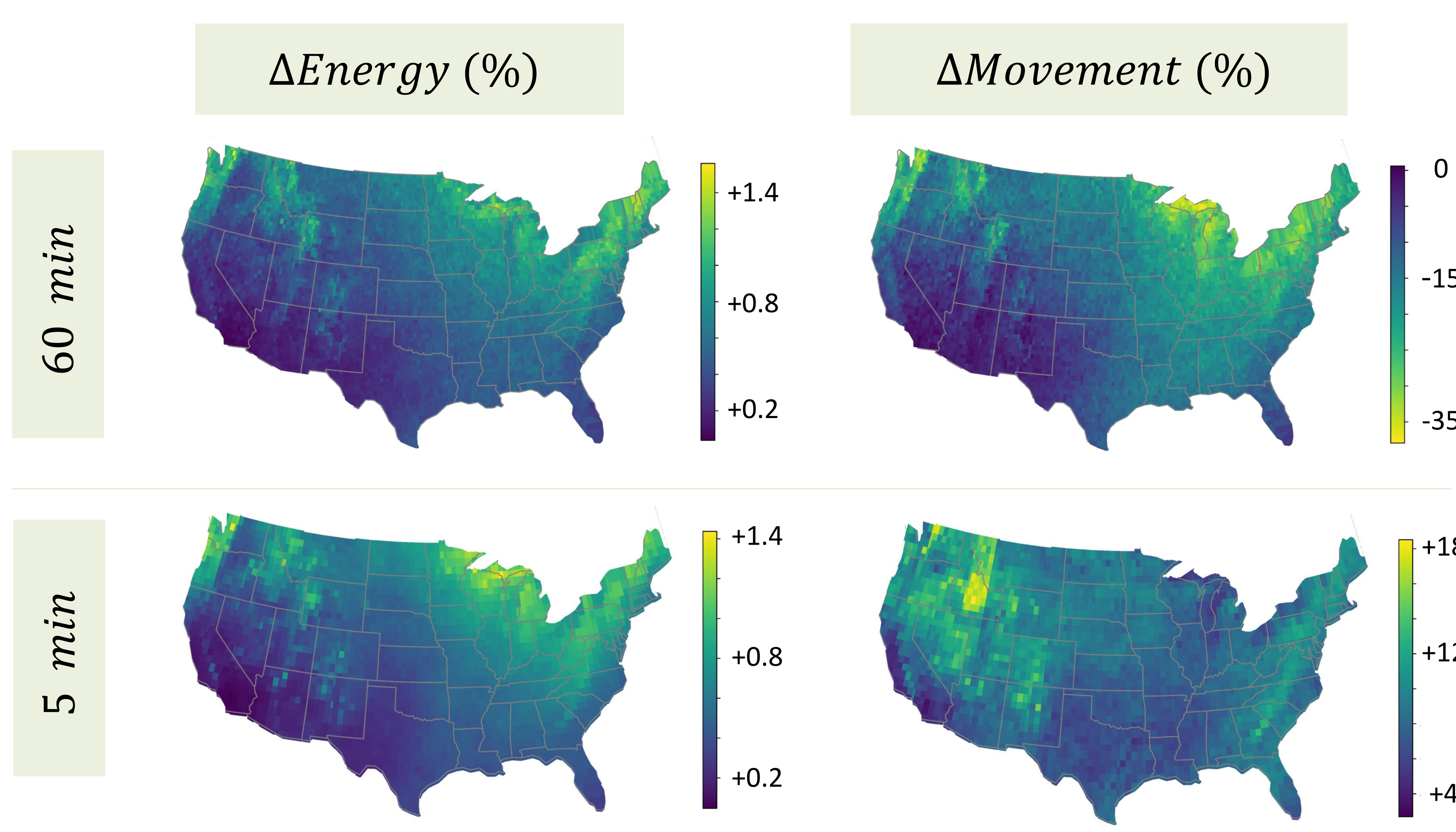
Fig.3 Comparison on yearly energy improvement and cumulative angular movement change for diffuse-stow tracking at hourly (60 min) and sub-hourly (5 min) intervals in Golden, CO, and Richmond, VA.

We first compare the yearly energy improvement and cumulative angular movement change for diffuse-stow tracking at hourly (60 min) and sub-hourly (5 min) intervals in Golden, CO, and Richmond, VA. The blue bars indicate the percentage energy improvement from diffuse-stow tracking. Green-Red bars represent the cumulative angular movement change of the tracker under diffuse stow conditions.

$$\Delta Energy\,[\%] = \left(\frac{\sum Energy_{diffuse-stow}}{\sum Energy_{tracking}} - 1\right)x100$$

$$\Delta Movement\,[\%] = \left(\frac{\sum Movement_{diffuse-stow}}{\sum Movement_{tracking}} - 1\right)x100$$

Diffuse stow provides a net energy gain in all cases, but the magnitude varies between hourly (60 min) and sub-hourly (5 min) datasets. While sub-hourly adjustments yield higher energy gains, they also result in significantly increased tracker movement due to more frequent adjustments. This effect is also seen for our simulation of the whole US below. This increase in tracker movement can potentially impacting reliability. The trade-off between energy optimization and mechanical wear highlights the need for optimized scheduling strategies to balance performance and durability.



Conclusions

Diffuse-stow strategies increase the energy yield of a PV system with single-axis tracker by up to 1.4%. The improvement of energy yield is strongly related with the weather condition of the location, being diffuse-stow meaningful when overcast condition occurs.
However, the cumulative angular movement, that a tracker executes during the year, changes as well. Depending on the weather data resolution considered, indeed, the cumulative angular movement of the tracker changes drastically. While using weather datasets with hourly resolution results in a decrease of the angular movement of 9.2% with diffuse-stow, using 5 minutes resolution results in an increase of 100.2%. Such discrepancy is related with weather condition variability. In particular, the higher is the variability and the higher is the discrepancy. Therefore, using diffuse-stow can cause a higher angular movement of the tracker, which could affect its lifespan and reliability.

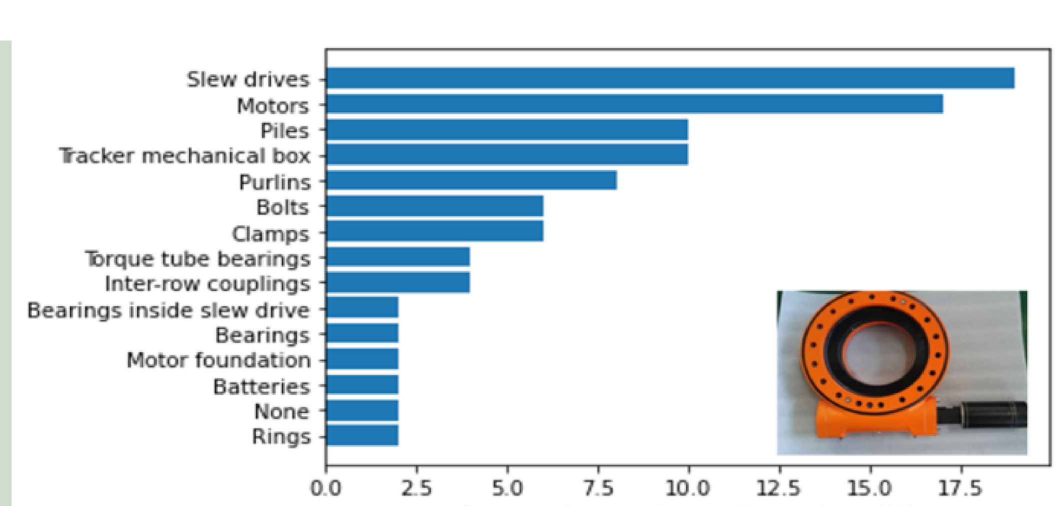


Fig.4 Percentage of surveyed owner/operators reporting tracker component failures. The bottom right corner shows a standard slew drive, which was reported as the most common failed component

Taken from IEA PVPS Task13 report https://doi.org/10.69766/JOIK1919

[1] Mikofski, M., Darawali, R., Hamer, M., Neubert, A., and Newmiller, J. "Bifacial Performance Modeling in Large Arrays". 2019 IEEE 46th Photovoltaic Specialists Conference (PVSC), 2019, DOI: 10.1109/PVSC40753.2019.8980572.

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