The Impact of Plane-of-Array-Based TMYs on Solar Resource for PV Applications

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THE IMPACT OF PLANE-OF-ARRAY-BASED TMY DATA SETS ON SOLAR RESOURCE FOR PV APPLICATIONS

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ABSTRACT:

This study attempts to apprise stakeholders of the accurate use of a typical meteorological year (TMY) data set for decision-making that could potentially speed up the acceptance and deployment of projects and reduce risks to financiers and developers. A TMY data set represents hourly concatenation of 12 typical meteorological months constructed using multiyear data sets. Typically, TMY data sets are constructed under horizonal irradiance conditions that are then used in photovoltaic (PV) performance models for available energy calculations in a location after transposing the data to represent a desired plane-of-array (POA) orientation. In this study, we attempt to show that a POA TMY generated with corresponding POA irradiance time-series information produces significantly different results than a POA TMY generated by transposing a TMY data set. In some months, the differences can be more than 3% for irradiance and energy yield. These results point to the need for generating TMY data sets using POA irradiance time series representing the orientation at which PV panels will be deployed.

Keywords: TMY, TGY, TPY, TGPY, NSRDB, POA

1 INTRODUCTION

TMY data sets are constructed using multiyear hourly time-series global horizontal irradiance (GHI), direct normal irradiance (DNI), temperature, dew point, and wind speed data. A typical month is selected by comparing a cumulative distribution frequency (CDF) of a month from a certain year to the long-term monthly average CDF of the same month from many years, in this case -1998-2017 [1] (Figure 1). TMY data sets were primarily developed for building simulations, and the variables are weighted to represent their influence on energy use in buildings. Multiyear monthly weighted data are used to identify a median month, which is then used to construct the TMY. For solar energy applications, however, custom TMYs can be developed. As examples, a typical GHI year (TGY) or a typical DNI year (TDY) can be constructed by assigning a 100% weight to the GHI or DNI, respectively. TMYs or TGYs are widely used in the System Advisor Model (SAM) [2], PVWatts [3], PVSyst [4], and PlantPredict [5] to simulate generation from photovoltaic (PV) plants. PV arrays are generally operating in some planes of array (POAs) that optimize the energy generation for a location. Therefore, such energy simulations require conversion of the GHI and DNI which are traditionally available from databases such as the National Solar Radiation Database (NSRDB) [6], to the appropriate POA using transposition models [7]–[8]. Although TMY or TGY data sets represent monthly mean and median and the persistence of weather patterns [1] for solar radiation in the horizontal plane, that assumption will no longer hold when used in a nonhorizontal POA, which is mainly because of the inhomogeneities in the timing of cloudy and clear periods during a day. This paper seeks to demonstrate the differences between a POA TMY constructed using a POA irradiance time series and a POA TMY constructed by transposing a TMY data set. Section II contains a short description of the methodology, Section III the results, and Section IV the conclusions from this study.

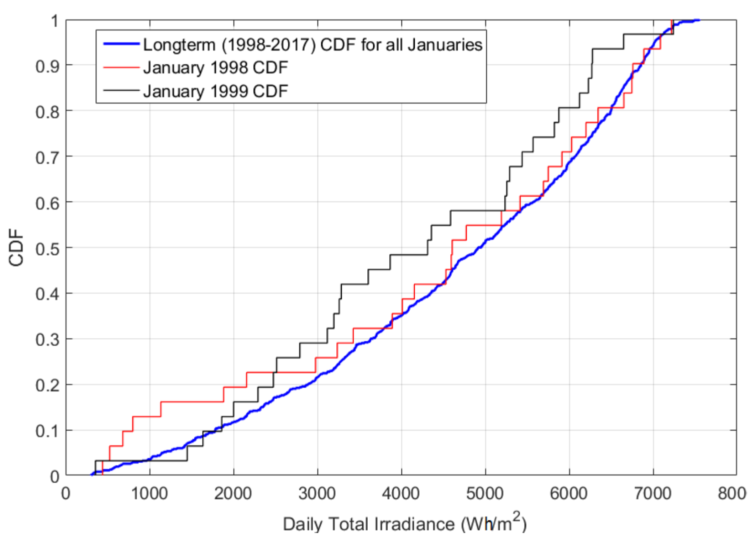

Figure 1: Example of selection process of a typical month of a certain year (e.g., 1998 or 1999) by comparing it to the long-term monthly CDF (1998-2017). For demonstration, only January 1998 and January 1999 are included.

2 METHOD

Typical year data are created using the 20 years (from 1998 to 2017) of hourly NSRDB gridded satellite-derived data. The NSRDB is available at a 4-km by 4-km resolution covering longitudes 25° W on the east and 175° W on the west and latitudes -20° S on the south and 60° N on the north. NSRDB time-series data for a few locations are used to generate POA irradiance data for latitude tilt and single-axis tracking (east-to-west tracking) orientation because they are widely used in PV deployments. Hourly data from the POA

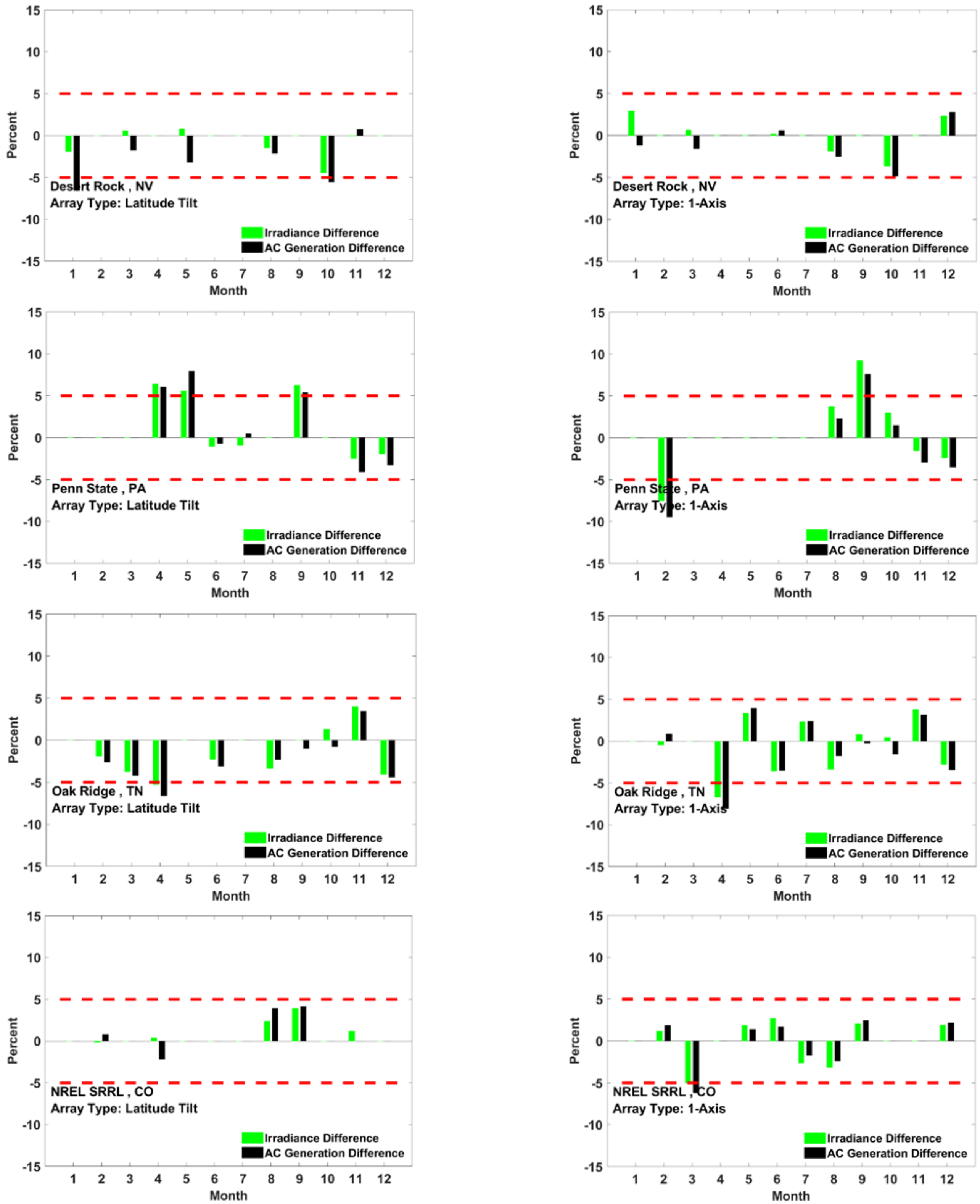

Figure 2: Comparison of TPY to TGPY for four locations and two possible orientations on a monthly basis. The percentage differences are shown.

irradiance time series are then used to generate a typical POA year (TPY) by setting the weight to all other variables except the POA to 0. For comparison we use the Perez transposition model to generate a POA irradiance TGY from the same pixel. For this paper, we call this the typical GHI-based POA year (TGPY). The TPY data generated from fixed latitude-tilt and single-axis tracking orientations are then compared to the corresponding TGPY data.

3 RESULTS AND DISCUSSION

Four locations were selected for this preliminary study. The Desert Rock location represents the west desert region of the United States, the National Renewable Energy Laboratory (NREL) location (Golden, Colorado) represents the southwest region, the Penn State location represents the eastern United States, and the Oak Ridge, Tennessee, location represents the southeastern United States. The four locations were chosen because they lie in regions of interest of PV development in the United States and represent different climatology. For each site, the TPY was calculated for two orientations: fixed latitude tilt and single-axis tracking. The monthly differences between the TPY and TGPY are shown in Figure 2 for each site and orientation. It is easily observed that certain months have larger difference than others. Because Desert Rock and NREL have low cloudiness, the differences are small for most of the year. The Penn State site has significant differences for most months of the year for both orientations, with the single-axis tracking mode showing an increased difference for the month of April. The Oak Ridge location—both the fixed tilt and single axis—show some differences for most months. Overall the differences can be significant and can range to greater than 6% for particular months, as shown for the single-axis tracking mode at Penn State. For all four sites, there can easily be a 3% difference between the TPY and TGPY.

The study also analyzed the effect of these monthly irradiance differences on energy yield predictions using PVWatts [9]. The DC-to-AC ratio was assumed to be 1 for both array types to reduce clipping effects. The energy effects of the differences between the TPY and the TGPY were a similar magnitude to the irradiance differences, with the difference in average energy between the two ranging from -9% to 11% when different months were selected. The energy effects are not exactly the same as the irradiance effects because the calculations to go from irradiance to power are (1) not completely linear—specifically in the inverter model at low light levels—and (2) rely not only on irradiance but also on temperature.

Table 1 shows the differences in annual values when the TPY and TGPY are compared for the four locations and for the two different orientations. For a fixed latitude-tilt system, some monthly errors can cancel out, thereby showing better agreement on an annual basis, but the same is not true for single-axis-tracking comparisons.

Table 1. Annual Solar Resource Averages for the Two Scenarios

Location	Annual Average (kWh/m^2/day)			
	TGPY		TPY	
	Latitude tilt	1-axis	Latitude tilt	1-axis
Desert Rock, Nevada (36.62, -116.02)	6.61	7.61	6.58	7.60
NREL, Colorado (39.74, -105.18)	5.50	6.01	5.53	5.99
Oak Ridge, Tennessee (35.96, -84.29)	5.14	5.74	5.07	5.70
Penn State, Pennsylvania (40.72, -77.93)	4.51	5.01	4.57	5.06

4 CONCLUSIONS

This study demonstrates the difference in the estimation of solar irradiance in the POA when a POA-based time series is used to compute a TMY (represented by TPY) compared to a TMY being directly transposed (represented by TGPY). Monthly errors can range up to 6% in some cases, which implies significant errors in potential generation at a site. Currently, the TGPY data are widely used by the industry to estimate annual production, and the study shows that this will lead to differences up to 3%. Although this study is preliminary, it indicates that there might be a need to build "custom" TMY data sets for individual case to account for the impact of orientation.

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