Renewable Energy 111 (2017) 447–454

Contents lists available at ScienceDirect

Renewable Energy

journal homepage: www.elsevier.com/locate/renene

The construction of a modified Typical Meteorological Year for photovoltaic modeling in India

Sean Murphy

Centre for Advanced Research in Building Science and Energy, CEPT University, K.L Campus, University Road, Navrangpura, Ahmedabad, Gujarat, India

A R T I C L E I N F O

Article history:
Received 20 September 2016
Received in revised form
25 February 2017
Accepted 14 April 2017

Keywords:
Solar
Photovoltaics
Climate change
Typical Meteorological Year

A B S T R A C T

Typical Meteorological Years (TMY) provide a basis for modeling solar photovoltaics. Their use, however, assumes continued historical norms inconsistent with climate change. Modifying TMYs with Regional Climate Models (RCMs) responds to this issue and has applications in renewable energy evaluations. This paper provides perspective on using modified TMYs for solar resource assessments, offers methodological improvements, and analyzes the impacts of insolation and irradiation changes on photovoltaic performance. For Ahmedabad, India, a TMY is constructed from Indian Meteorological Department measurements and modified with two Regional Climate Models - REGCM4 and REMO 2009. For each modified TMY and baseline, the performances of three photovoltaic technologies (monocrystalline, polycrystalline, and double-junction amorphous silicon) are considered for 2015–2050. Increases in ambient temperature are found to have small (<1.0%) but increasing negative impacts on monocrystalline and polycrystalline performance through 2050. A less significant positive trend (<0.1%) was observed for double-junction amorphous silicon. Insolation adjustments for REGCM4 were excluded after an error analysis. Insolation changes from REMO 2009 projected a 4% decrease in photovoltaic output by 2050, but should be considered cautiously given concerns over cloud modeling. A sensitivity analysis of monthly insolation modifications on photovoltaic performance revealed the relative impact of insolation changes in different months.

© 2017 Elsevier Ltd. All rights reserved.

1. Introduction

A response to climate change that will limit the increase in global average temperature to 2 C° will require more than a 90% decrease in the carbon intensity of electricity by 2050 [1]. Solar photovoltaics (PV) will play a major in this de-carbonization effort, so it is important to inform resource planning with robust estimates of photovoltaic performance. Since PV performance depends on meteorological conditions, PV system designs necessitate an understanding of the expected climate. While inter-annual variation is expected, a single Typical Meteorological Year (TMY) has prevailed as the default meteorological file for PV system design. A concatenation of individual months that most closely represent their respective long-term averages, a TMY is ideally based on multi-decadal historical datasets [2]. The use of TMYs, however, expects a continuation of historical norms. Given the magnitude of climate change impacts, even in aggressive mitigation scenarios, that assumption becomes increasingly unsound. Designs and decisions predicated on the validity of TMYs, then risk being spurious.

A common methodological response to the need for more informed design and planning has been to use Global Circulation Models (GCM) or downscaled Regional Climate Models (RCM) for either direct use in simulations or for the modification of meteorological datasets and metrics. In an analysis of changes in global solar power potential, GCMs were used to assess the impact of changes in insolation and temperature [3]. The degree of change and the relative contribution of insolation and temperature changes varied geographically. Both in Greece [4] and Croatia [5] the output of RCMs was used for similar purposes. The sign of PV energy output change varied within Greece but was less than 5% in all cases. In the Croatia study, there was no change in PV potential. In all cases, only insolation changes could result in improved PV performance as increasing temperatures reduced PV cell efficiency. The timescale of direct use of GCMs and RCMs limits the temporal granularity of the results and may not be useful for certain applications. The adjustment of TMY values with climate model output, however, provides useful information on sub-monthly climate change [6].

E-mail address: sean.murphy.11@gmail.com.

http://dx.doi.org/10.1016/j.renene.2017.04.033
0960-1481/© 2017 Elsevier Ltd. All rights reserved.

This adjustment method, often referred to as 'morphing' [7], begins with a TMY and, depending on the variable of interest, applies an additive, scaling, or combination additive-scaling factor based on monthly climate model values. TMYs have been modified with this method to explore the impact climate change on building in the UK [8,9], Australia [6], and Hong Kong [10]. As pointed out by Guan [6], the use of the TMY as the baseline maintains diurnal patterns, but it applies possibly unrealistic constant temperature changes throughout the day, and does not account for the relationships between meteorological parameters. Also, implicit in the use of a TMY for simulations is the perpetuation of a seasonal pattern that a future climate may not exhibit [7] and the exclusion of the majority of the time series.

Whereas change in insolation due to climate change can have a commensurate impact on PV energy output [4], the effect of temperature can be significant, but less drastic. The theoretical maximum power of a photovoltaic cell is often expressed as the product of short circuit current and open circuit voltage [11]. While short circuit current increases slightly with temperature, open-circuit voltage decreases more, resulting in a net decrease in efficiency [11]. Consideration of changes temperature and insolation both will inform more accurate solar photovoltaics resource assessments and mitigation strategies. Past studies have mostly considered monocrystalline silicon (mono-Si) modules, but this study will expand the analysis for polycrystalline (poly-Si) and double-junction amorphous (2s-Si).

This paper will review the methodology for TMY construction and modification before offering methodological improvements for the adjustment of insolation data in TMYs with Regional Climate Models. The paper will then provide guidance on the interpretation and appropriate use of monthly RCM data in TMY-modification exercises. Finally, the results will present the impact of changes in insolation and ambient temperature to photovoltaic modules in Ahmedabad, India.

2. Methodology

2.1. TMY construction

The city of interest, Ahmedabad, is the largest city in the western Indian state of Gujarat. Located at 22° 58′ 30″ E and 72° 35′ and 30″ N, its climate is classified as hot and dry by the Indian Bureau of Energy Efficiency's Energy Conservation Building Code [12]. Besides Western Monsoon rains in June, July, and August, the city receives little precipitation.

To construct the TMY, twenty-five years of hourly global horizontal (GHI) and diffuse horizontal irradiation (DfHI) and three-hourly surface (ambient temperature, dew point temperature, sea level pressure, wind speed, and wind direction) data were obtained from the Indian Meteorological Department (IMD) [13,14]. Linear interpolation between the three-hourly data-points was sufficient to create a serial hourly surface dataset. For the insolation records, more cleaning was necessary. GHI values beyond the extraterrestrial radiation expected for Ahmedabad (1400 W/m^2) were excluded. For days that lacked six or more hourly values, insolation values from the two days prior and after for each of those hours were averaged and inserted into the gaps. Months that lacked 5 days or more of readings were excluded from candidacy in the TMY. A final linear interpolation to fill hourly data aps completed the cleaning. The incomplete records and occurrence of some anomalous values did raise concerns about the measurements, but the IMD data represent the most complete and long-term meteorological record for Ahmedabad.

A baseline TMY was constructed following the Sandia method [15,16], which identifies candidate months by comparing short term and long term cumulative distribution functions (CDFs) of monthly parameter values with the Finklesten-Shaefer (FS) statistic. Candidate months (eg. All Januaries in the time series) were ranked according to a sum of their parameters' FS statistics, each weighted according to its importance to the analysis. As was suggested in Ferrari and Lee 2008 [17], weights were selected to be more reflective of insolation. The weights in the Sandia, therefore, were not used. Instead, GHI and DfHI received the highest weights (Table 1). The weights selection was the only methodological divergence from the Sandia method as presented in Wilcox and Marion [15]. The Sandia method completes by evaluating each candidate for the presence of 'runs': days with ambient temperature and GHI above or below fixed percentiles (67th and 33rd respectively) [15]. After removing the candidates with the most runs, longest run, and no runs the candidate with the lowest FS statistic is selected for the TMY.

Through the South Asia portal of the Coordinated Regional Climate Downscaling Experiment, two regional climate models under representative concentration pathway (RCP) 4.5, REGCM4 [18] and REMO 2009 [19], were obtained for the period 1990–2050. The availability of temperature and irradiation data and the focus of this analysis on the impacts of climate change on a technology central to mitigation measures led to the choice of RCP 4.5, which assumes a stabilization of carbon dioxide concentration at 650 ppm by 2100 through moderate emissions reduction [20].

2.2. Morphing method

Table 2 details the algorithms from Belcher [7] that were used for each parameter. The formulae are all simple and only require the calculation of intra-RCM differences or ratios and average baseline values. For each month, parameter, and RCM, average monthly parameter values were calculated for each 5-year increment from 2015 to 2050. The values were then compared to parameter monthly averages from each model's evaluation period. These RCM evaluation periods fell within the baseline TMY period of 1990–2015: 1990–2009 for REGCM4 and 1990–2006 for REMO 2009. Thus, either monthly differences or ratios were calculated for every parameter in each RCM sub-period. Since the RCM baselines did not span the entire baseline TMY period, these intra-model deltas may exhibit a slight positive bias in the direction of the

Table 2
Morphing formulas.

Modification Type	Formula	Variables
Shift	$x = x_0 + \Delta x_m$	Air Pressure
Stretch	$x = a_m x_0$	GHI
Shift and Stretch	$x = x_0 + \Delta x_m + a_m(x_0 - \langle x_0 \rangle_m)$	Ambient Temperature

x_0 = initial TMY value, $\langle x_0 \rangle_m$ = original monthly mean, Δx_m = change in monthly mean for month, a_m = ratio of original monthly mean to new monthly mean.

Table 1
Weighting of climate variables in TMY Construction.

Variable	GHI	DfHI	Air Temperature	Dew point Temperature	Station Level Pressure	Wind Speed	Wind Direction
Weight	0.325	0.325	0.15	0.1	0.025	0.05	0.025

Download English Version:

https://daneshyari.com/en/article/4926320

Download Persian Version:

https://daneshyari.com/article/4926320

Daneshyari.com