Future Solar Resource Variability and Intermittency across Australia

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Introduction

Australia is undergoing a fast transformation towards high penetration of renewable power generation in its energy system to meet the large-scale Renewable Energy Target [1]. The installed capacity of grid-connected solar power systems is rapidly increasing in Australia [1]. However, Integration of large-scale PV into the electricity grid poses a significant technical challenge due to sensitivity of PV to weather-induced variability. Variability in solar resource increases uncertainty and its intermittent nature imposes limitations on its reliability. On a daily scale, short-term weather events over a region can induce periods of no-to-minimum output during the day. Irregular cloud movements during the day cause abrupt fluctuations in PV power [2] that lead to inaccuracies in the solar power forecast and introduce grid stability issues at higher penetration levels. With the increase in demand for solar electricity generation and integration in Australia, it is essential to understand the nature and magnitude of solar resource variability and intermittency at different timescales. Estimating the long-term PV system performance and resource variability at any given location is necessary for pre-feasibility site assessments, optimal system design and financial viability.

Methods

In this study, we try to understand Australia's solar resource variability and intermittency for the historical (1976-2005) and two future periods (near future:2030-2059 and far future: 2070-2099) under a high emission scenario (representative concentration pathway (RCP 8.5)). We use high-resolution regional climate model projections from the Coordinated Regional Downscaling Experiment (CORDEX) for Australasia [3]. We analyze several metrics to determine solar resource variability and intermittency for the historical and future periods to understand the feasibility of solar power generation in Australia. In this study, variability in the solar resource is estimated using the RCoV. A lower RCoV indicates lower variability, with the resource being highly feasible at the site. RCoV is the ratio of the median absolute deviation of irradiance and median irradiance [4,5].

$$RCoV = \frac{median\ (absolute\ deviation\ about\ the\ median)}{median}$$

The intermittency of the solar resource is characterized using lulls. Lulls are defined as periods of no power generation and are computed as the number of consecutive hours when the resource power density is lower than the threshold, calculated from the lower quartile of solar radiation for the historical period. The abrupt cloud movements during the day can cause sudden drops in energy production and negatively affect the daily energy production rates. Therefore, it is essential to estimate the cloudiness in the sky using the daily clearness index (DCI) to discriminate between the different weather conditions of the day. The DCI can be estimated according to the following equation [6]:

$$DCI = \frac{\sum_{i=1}^{n} GHI_i}{\sum_{i=1}^{n} GHI_{CS_i}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots. [eq\ 2]$$

DCI is close to one under clear sky conditions and has a significantly lower value on an overcast day. We identify clear, intermittent, and cloudy days as per the classification by Huang et al [34]. Short-term variability in power, called ramps, are identified as the difference between successive data points in PV power generated during the day. The step changes in power series, calculated using python PVLIB package, are considered as significant ramps only if the absolute value exceeded 10% capacity in the time interval [7]. Further, we ignore all the ramps occuring in the clear-sky conditions. We determine the ramp frequency and magnitude to understand the cloud-induced future intermittency across Australia.

Results

Preliminary results indicate an abundance of solar power in Australia, especially in the Northern part of the country. There shall be an increase in solar resource power density in Eastern Australia with a decline in the Western part of the country in the future. It is expected that the future solar resource will be more reliable in the Eastern part of the continent during the near and far future periods. Results also indicate a reduction in intermittency over Eastern Australia. Further, it is predicted that the DCI will increase uniformly throughout the country with reduction near the West. On analyzing the mean ramp magnitude per unit capacity, it is revealed that the ramp magnitude is highest in the East and is predicted to decline throughout the continent in the future. This analysis will be further extended to study probabilistic approaches to determine the future solar variability. This long-term future variability analysis will be extremely helpful in quantifying the accurate storage requirements to meet the supply-demand ratio at all times of the day. Further, this type of analysis can be helpful in optimal site selection and technological advancements in ramp rate control systems to manage voltage flicker and grid stability issues at higher penetration levels.

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