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Wind and solar energy resources in India

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Abstract

This study assesses the potential for combined grid-connected wind and solar resources for the regional power grids of India and explores if spatio-temporal complementarity in these resources can minimize the effect of grid-scale intermittency. Wind and solar resources estimated from the MERRA Reanalyses show that the southern grid has the most potential for renewable energy followed by the western, eastern and northeastern grids. Using the spatio-temporal complementarity in these resources to reduce renewable energy intermittency problem is realistically possible only in the northern grid.

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Keywords: Wind energy; Solar energy; Intermittency; Spatio-temporal complementarity; Renewable energy in India.

1. Introduction

Wind and solar power are likely to be a part of the solution to the climate change problem. That is why they feature prominently in the energy policies of all industrial economies including India. One of the major hindrances that is preventing large-scale deployment of wind and solar energy is the issue of intermittency [1, 2]. It is well known that wind and solar resource availability varies due to meteorological/climatological processes operating at a wide range of scales starting from small-scale turbulence, diurnal cycle, synoptic-scale weather patterns, seasonal cycles and even longer term processes. This is a major problem because in a rapidly moving economy, energy production must match the patterns of energy demand. Moreover, sudden increase and decrease in energy supply may destabilize the power grids leading to disruptions in power supply. Attempts to address the intermittency

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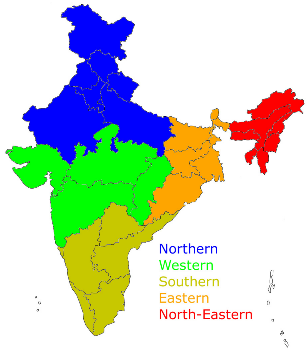

Fig. 1 Regional power grids of India

problem involve 2 different approaches: (i) geographical aggregation, where variability in one resource at a site can be offset by the variability in the same resource at a different site within a large power grid and (ii) cogeneration, where intermittency in one resource can offset that in another resource at the same site [2].

In this study we combine both approaches to explore if the patterns of variability in wind and solar energy availability can offset each other to reduce grid-scale intermittency. As a first step, this work focuses only on the seasonal-scale variability for each of the 5 regional power transmission grids (south, north, west, east and north-east, Fig. 1) in India. Earlier studies on India have looked at wind and solar resources separately. Combined renewable potential has been explored only in the case of distributed generation [3]. This is one of the first studies on grid-connected combined wind-solar resources and quantitative exploration of the spatio-temporal complementarity of these resources. This study may help accelerate renewable energy penetration in India by identifying regional grid(s) where the renewable energy resources are high and the intermittency problem is minimal.

2. Materials and methods

2.1 Solar resource assessment

Solar resource is estimated using the downward shortwave flux from the MERRA Reanalysis data (http://gmao.gsfc.nasa.gov/merra/) for the 1979-2013 period assuming a 20% conversion efficiency of the solar PV panels. This efficiency is typical for many currently available commercial solar PV panels. The estimates are applicable only for idealized solar-tracking panels. Studies show that fixed-tilt PV panels typically have 25%-45% lower efficiency [4].

2.2 Wind resource assessment

Wind resource is estimated from eastward and westward velocity components at 50 meters from the MERRA Reanalysis data for the 1979-2013 period. Wind speeds are extrapolated to 100 m, the hub-heights of typical modern-day commercial wind turbines, using the Hellman exponential law given by:

$$\frac{v}{v_0} = \left(\frac{h}{h_0}\right)^{\alpha} \tag{1}$$

where v is the velocity at height h, v_0 is the reference velocity at the reference height h_0 and the exponent α=1/7 that is appropriate for neutral stability over flat terrain. The exponent can vary depending on the characteristics of the underlying space as well as atmospheric stability [5] leading to differences in wind speed estimates. Sensitivity studies are performed with different values of the exponent to quantify the uncertainty due to different stability