

Estimating non-conventional renewable historical generation with reanalysis data

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ABSTRACT

The Time Series Lab (TSL) is a renewable modeling tool developed by PSR to produce synthetic scenarios of renewable generation that are used as input data by stochastic power system planning tools. Before producing those scenarios, it is essential to obtain reliable historical data that capture important characteristics of the Variable Renewable Energy (VRE) plants, such as hourly (or sub-hourly) variability. In this work, we present a methodology based on Reanalysis databases that produce historical data for any given coordinates and basic physical data such as the wind turbine for wind plants and characteristics of the solar panel for solar plants.

KEYWORDS. Renewables, Reanalysis, Time Series Lab, Wind, Solar, CSP

Renewable modelling tool, Wind speed modelling, Reanalysis database

1. Introduction

Wind and solar energy are generally known as variable renewable energy (VRE) sources due to the variability of the production in time. They depend in great part on the location of the plants. The intermittent characteristic of this source is illustrated in Figure 2, which shows data from the actual operation of the German market in September 2017. There are large fluctuations in the delivered energy from wind power, up to 15 GW, in less than 24 hours. In addition, wind power generation is near zero on some days.

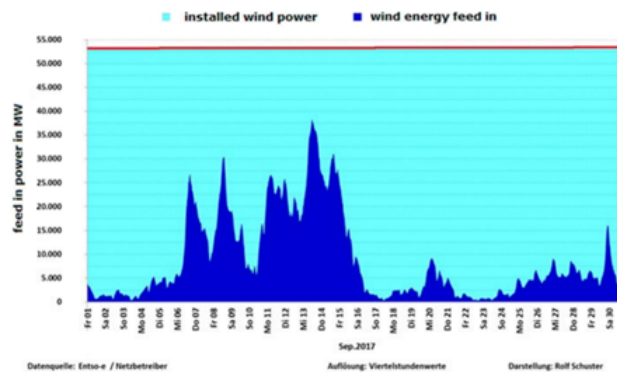


Figure 1: VRE Intermittency

In terms of defining reliable historical data, mesoscale climate models are generally used to produce wind velocity maps and time series with fine spatial resolution, suitable for assessing the insertion of renewable sources and expansion for a country Pfenninger e Staffell [2016]. However, global reanalysis databases can also be used if such data is unavailable. In this work, the ERA5 Store [2021] database is used. It contains chronological data for wind speed, irradiation, and temperature from 1980 to the present with hourly resolution.

The reanalysis combines a system of assimilation of historical meteorological observations with an atmospheric circulation model to infer the state of the global climate system. The model is programmed to replicate historical observations of satellites, field observations, ships, aircraft, etc., simulating the past (hindcast), rather than a future forecast. The reanalysis process assimilates observed data and applies automated quality control to generate a standardized database with uniform spatial and temporal resolution and global coverage. Due to these characteristics, these bases are widely used in the energy sector to understand the availability of renewable wind and solar resources.

2. Wind generation conversion

The reanalysis databases contain primary resource data (wind speed, solar irradiation, temperature, etc.), and since the idea of this work is to produce generation data (in MW) to be used by power system planning tools, the methodology must convert the primary resource data to power. In this work, we calculate wind production through a model based on the Virtual Wind Farm (VWF) Staffell e Pfenninger [2016] model, developed by Renewables Ninja's team and illustrated below.

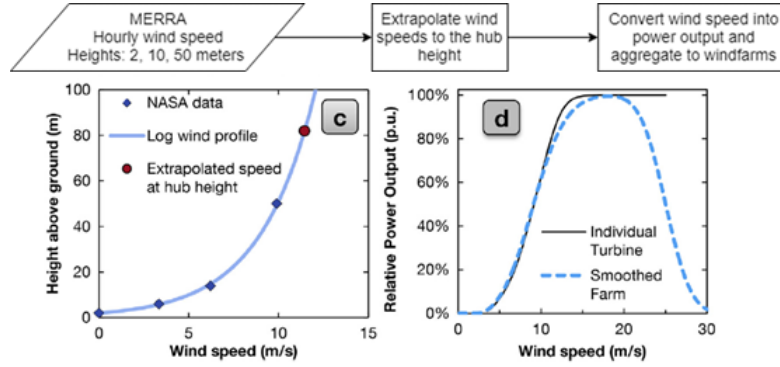


Figure 2: Virtual Wind Farm Model

The proposed methodology has three main parts:

- Correcting the air density for the desired power plant location, considering the height above sea level
- Extrapolating the wind speed velocity to the hub height of the turbine
- Using the wind turbine power curve to convert the wind speed to power generation in MW

The first two parts will be analyzed in the sections below, and last part is straightforward since it is just the application of the wind speed in the power curve function.

2.1. Correction for air density methodology

This methodology will model the fact that the power output of a wind farm depends on the local air density. Since the power turbines are defined for an air density at a standard temperature and pressure, the idea is to "correct" the wind speed to reflect the local air density applying this corrected wind speed at the "standard" power turbine

Let's say z is the height above the sea level, we calculate the air pressure, ρ , as follows:

$$\rho = 101.29 - (0.011837)z + (4.793 \times 10^{-7})z^2 \quad (1)$$

Then, for each hour, we calculate ρ_h^{site} , the local air density at the wind farm:

$$\rho_h^{site} = 3.4837 \frac{\rho}{T_h} \quad (2)$$

Where T_h is the local temperature obtained from the reanalysis database. The "corrected" wind speed, w'_h , is obtained as follows:

$$w'_h = w_h \left(\frac{\rho_h^{site}}{\rho_{std}} \right)^{\alpha_h} \quad (3)$$

Where w_h is the original wind speed, $\rho_{std} = 1.225 \frac{kg}{m^3}$,

$$w'_h = w_h \left(\frac{\rho_h^{site}}{\rho_{std}} \right)^{\alpha_h} \quad (4)$$

$$\alpha_h = \begin{cases} \frac{1}{3} & w_h \leq 7.5 \text{ m/s} \\ \frac{1}{15}w_h - \frac{1}{6} & 7.5 \leq w_h \leq 12.5 \text{ m/s} \\ \frac{2}{3} & w_h \geq 12.5 \text{ m/s} \end{cases} \quad (5)$$

2.2. Vertical wind speed extrapolation

The conversion of the wind speed from the specific height of the reanalysis database to the height of the power turbine is done by the following equation:

$$v_x = v_1 \left(\frac{h_x}{h_1} \right)^\alpha \quad (6)$$

Where v_x is the extrapolated wind speed at the hub height h_x . v_1 and h_1 are references obtained from the reanalysis database (any wind speed at any known height). α is the wind shear coefficient, calculated according to the following equation:

$$\alpha = \frac{\ln \left(\frac{v_2}{v_1} \right)}{\ln \left(\frac{h_2}{h_1} \right)} \quad (7)$$

Where v_1 , v_2 , h_1 and h_2 are known wind speeds references from the reanalysis database. Then, we apply Equations (6) and (7) for each hour of the historical data to obtain the wind speed, at each hour, at the required height h_x .

3. Final considerations

The tool can provide a VRE synthetic hourly historical record in any location of the world, based on reanalysis databases. Which is a powerful tool to provide input data to statistical models that may generate future synthetic scenarios for the VREs without having actual measurement data.

References

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