Project 03
Report

Final project

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1 Wind resource assessment based on reanalysis data

1.1 Introduction

The objective of this final project is to develop a Python Module for wind resource assessment (WRA) at a specified site in Horn1(Denmark) using ERA5 reanalysis data. Analyzing multi-year hourly wind data at two heights (e.g., 10 [m] and 100 [m]) to estimate key wind energy metrics, including wind speed distribution, wind rose, annual energy production (AEP) for NREL 5MW and 15MW reference wind turbines. The Module developed provides all the necessary tools to process, visualize, and interpret reanalysis data as required for this final project fulfillment.

1.2 Repository structure

Please, for reviewing my repository structure for Project03 check README.md file, there is completely detailed. My GitHub repository is handed in today too.

1.3 Design

1.3.1 Load and parse multiple netCDF4 data files

As part of the input files, four netCDF4 files were provided that included complete information on u and v wind speed components at 10[m] and 100[m] height. I have used the *Winddataloader* class for loading netCDF4 files using `xr.open_dataset` and `xr.concat` which are both functions from the xarray Python library. Finally I have filtered all the data provided for a specific year using .sel(time=slice(str(year), str(year))) which is a method used in the xarray library for selecting data within the yearly processing loop included in *main.py* script.

1.3.2 Computing wind speed and wind direction time series

I have calculated the wind speed using `compute_wind_speed_direction` function which calculates wind speed with $\sqrt{u^2 + v^2}$ and wind direction with the expression $np.arctan2(u, v)$.

1.3.3 Computing wind speed time series

Here, I used linear interpolation and vertical extrapolation. First, using the *WindResource* class' `__init__` method for linear interpolation for the two u and v component wind speeds at the heights provided, 10[m] and 100[m]. After I have distinguished, for calculating wind data at a specific height, depending whether the height was between the two past values or above 100[m] where the power law profile is applied.

1.3.4 Fitting Weibull distribution for wind speed

For this task, I have used the `fit_weibull_parameters` function with `scipy.stats.weibull_min.fit` function in order to estimate A and k parameters that belong to Weibull distribution for wind speed. After this is integrated in a method from *WindResource* class, which is `WindResource.fit_weibull_distribution` for a height and location data chosen.

1.3.5 Plotting wind speed distribution

In this task, I used the `WindAnalysisPlotter.plot_speed_distribution` method, which generates a histogram with the wind speeds. After is overlayed the probability density function of the Weibull distribution producing the final plots. I have sorted in subdirectories each output plot for every single year at a specific height.

1.3.6 Plotting wind rose diagram

For this case first I have installed the *windrose* library in order to get really good quality images for wind rose diagrams. The WindAnalysisPlotter.plot_wind_rose method uses this library to obtain wind speed frequencies for every year (period 1997-2008).

1.3.7 Computing Annual Energy Production(AEP)

Finally, obtain the AEP for every single year at a specific height and point within the study area defined in Horn 1. I have used `calculate_aep` method which belongs to *WindTurbine class*. This method what it does is to compute numerically integrating the product of the WT's power curve with Weibull probability distribution function through scipy.integrate.quad function. The power curves data belong to the reference wind turbines, as mentioned before, the NREL 5MW and NREL 15MW wind turbines.

1.4 Results

All the results obtained can be reviewed in my Project03 repository in the outputs directory.

From the AEP values and all the data reviewed, I can say that it is a really good area for an Offshore Wind Farm, specially for wind turbines with 15MW-18MW power(wind resource double checked with GWA also).

When running the package scripts the shape parameter k and the scale parameter A are obtained for each year, and then are used to calculate the AEP. Here I am sharing the k and A Weibull parameters obtained at 90 [m] height:

Year	k	A
1997	2.17	10.67
1998	2.55	11.41
1999	2.30	10.91
2000	2.30	11.38
2001	2.37	10.37
2002	2.40	10.72
2003	2.19	10.01
2004	2.30	10.79
2005	2.40	11.08
2006	2.30	10.57
2007	2.26	11.35
2008	2.20	10.97

Table 1: k and A Weibull parameters at 90 [m] height

And here finaly, I am just sharing the table that includes the AEP summary results for z = 90[m] height using the two NREL reference wind turbine power curves provided for this project:

Year	NREL 5MW AEP [MWh]	NREL 15MW AEP [MWh]
1997	23278.938	73566.318
1998	26284.135	83147.566
1999	24281.860	76780.007
2000	25451.671	80245.875
2001	22925.022	72823.898
2002	24011.190	76141.225
2003	21494.933	68204.304
2004	23962.580	75835.338
2005	24987.866	79054.874
2006	23342.693	73966.450
2007	25236.500	79542.551
2008	24144.841	76204.276

Table 2: AEP summary for NREL 5MW and NREL 15MW reference wind turbines