Sensitivity of Electricity System to perturbation of Capacity Factor of Wind and PV



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Introduction

•Integration of renewable energy sources is crucial for the decarburization of electricity supply systems. the potential of dispatchable renewable technologies is limited so, variable renewable (VRE) sources such as wind and solar PV are preferred. •Optimal installed capacity of VRE estimated based on their Capacity Factor (CF) which is dependent on the meteorological variables such as wind speed and irradiation. CF dataset contains errors that could stem from, errors in the meteorological dataset, power curve, or downscaling method.

•The goal of this study is to find out how the electricity system both optimal and installed energy system is to perturbation of CF of PV and Wind in different generation events.

Model and data

Model

• Electricity system used in this study is EOLES model, which is dispatch and investment optimization model. It minimize total system cost by satisfying hourly demand.

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• A version of EOLES used in this study contains following technologies: Onshore Wind, Solar PV, run-of-river and lake-generated hydroelectricity, nuclear, biogas combined with closedcycle gas turbines and lost load.

Data

Simulation performed for 9 years, from 2012 to 2020. CF of PV and Wind are from hourly observation provided by RTE. CF time Seri divided to nine quantile and at each time one of them is perturbed.





Technology	Installed Capacity (GW)
Onshore Wind	82
PV	39
Run of River	7.5
Lake	13
Nuclear	34
CCGT	22
PHS	5.2 (volume 135 (GWh))
Battery	0

- Average annual demand: 437 TWh/year.
- Share of Nuclear is between scenario N2 and N03 and it is consistent with French government's position

Experiments

Experiments are divided into two main categories

Dispatch Optimization: How uncertainty in the production of the PV and wind can influence the operation and cost of an energy system that has already been installed

Investment and Dispatch optimization: How uncertainty in the production of the PV and wind can influence the installed capacity, system operation as well as operation and investment cost of the optimal energy system.

Sensitivity measurement: Sensitivity is measured using a quantity called Elasticity is calculated by dividing the relative change in the chosen output.

Comparing the sensitivity of the total system cost in Dispatch optimization & Investment and dispatch optimization

•Higher sensitivity of cost to perturbation of CF of PV and the wind is observed in the first quantile, while it reduces as we approach the last quantile. This observation is related to the increased presence of time steps with negative residual demand as we move toward the last quantile. Since the price of electricity is zero during these time steps, perturbing the capacity factors of PV and Wind does not significantly affect the system cost.

•In the Dispatch optimization, The cost exhibits higher sensitivity to negative perturbations due to the need for expensive reserves (Lost Load) to compensate for the lack of renewable generation. On the other hand, positive perturbations result in excess installed capacity of peak producers.





Sensitivity of the Installed Capacity of technologies in Investment and dispatch optimization

Sensitivity of Installed Capacity of technologies to perturbation in CF of the PV



• We observe a remarkable sensitivity in CF perturbations within the first quantile, reaching up to 8 for PV and wind systems. This heightened sensitivity can be attributed to the high price levels associated with this quantile. Perturbing the CF disrupts the zero profit condition, a constraint of the optimal solution. Consequently, significant changes in installed capacities are required to uphold the zero profit condition within the optimal solution.

Sensitivity of Installed Capacity of technologies to perturbation in CF of the onshore wind



- In the PV perturbation test, there is a substitutability effect, between the installed capacity of PV and nuclear power. In the majority of quantiles, the installed capacity of wind power exceeds the reference case. In sensitivity tests to CF Wind, there is substitutability observed between wind power and nuclear power, as well.
- Conclusion:
- The initial quartile exhibits a significant level of sensitivity, indicating that special consideration must be given to the accuracy of the CF calculations for this quantile throughout the entire process of selecting raw datasets, choosing power curves, and applying bias correction.
- By employing renewable technologies with higher CF values in the first quantile, the sensitivity of the energy system to CF variations can be reduced.