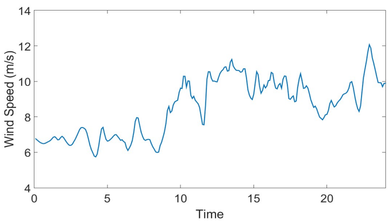
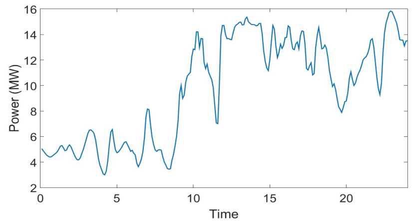
Uncertainty Quantification Approaches in Wind Energy Generation for Optimal Economic Dispatch

Arun Sukumaran Nair, Naima Kaabouch, Hossein Salehfar, Prakash Ranganathan
arun.sukumarannair@und.edu

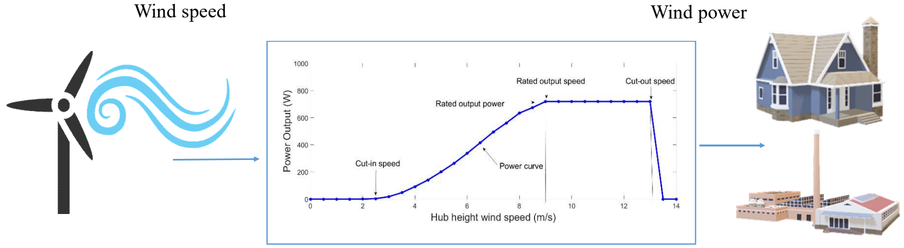
Introduction



Wind speed



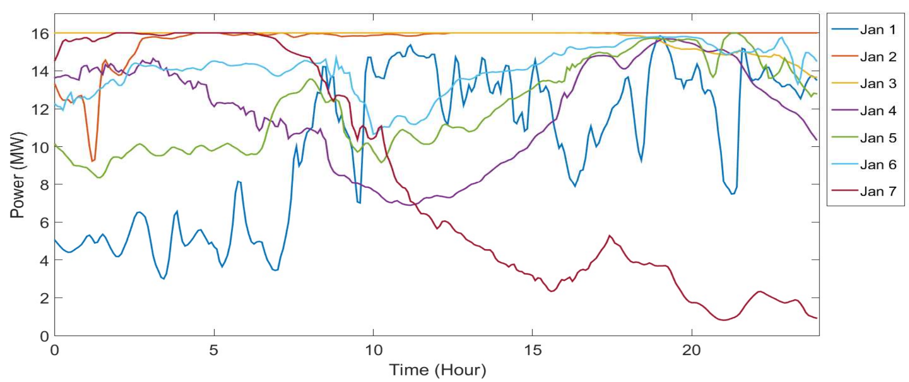
Wind power



- Wind speed
- Wind direction
- Air density
- Turbine design

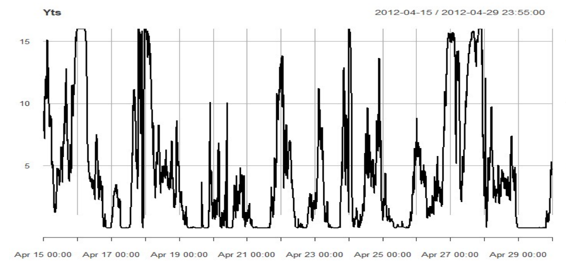
- Pumped hydro
- Battery storage
- Energy Curtailment
- Fast acting generators

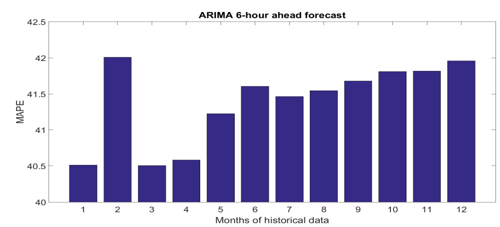
Wind Generation Uncertainty



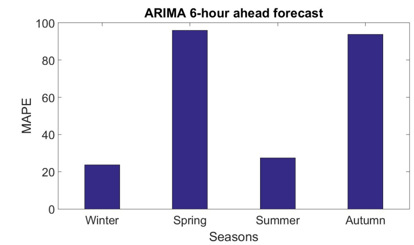
Wind power generation (Buffalo, NY, NREL Wind Generation data)

Wind Power Forecast





ARIMA 6-hour ahead forecast with 5 minute resolution



ARIMA 6-hour ahead forecast with 5 minute resolution

High-Level systematic summary of wind uncertainty quantification in economic dispatch

Uncertainty Measure	Method	Strengths/Weaknesses
Weibull distribution	Monte Carlo Simulation	+ Probabilistic results + Sensitivity and scenario analysis - Larger computational time
	Quasi-Monte Carlo Simulation	+ Reduced complexity over the MCS + Reduced number of scenarios + Improved computational time over the MCS
	Taguchi Orthogonal Arrays	+ Reduced number of scenarios + Reduced computation burden
Gaussian Mixture model	Maximum Likelihood Estimation	+ Allows constraint violation to a certain limit + Robust solutions - Often difficult to solve
Point estimate	Two-point estimation method	+ Closed-form function not required + Computation time - Uncorrelated stochastic variables are required
Probabilistic forecast	Latin Hypercube Sampling	+ Easier to evaluate than single point forecasts + Adds the probability measure
Scenario set	Roulette wheel mechanism	+ Scenario reduction techniques can be applied + Reduced computational time
Prediction interval	Bi-level Programming	+ Provides a range of values + More tractable + Neural network approaches can be utilized
	Big-M Approach	
Membership function	Fuzzy systems	+ Multi-objective optimization capability + Can handle disparate & contradicting objectives
Uncertainty budget	Markov's inequality	+ Independent on prior knowledge + Need not assume a probability distribution + The uncertain bounds are easier to construct - Results are often too conservative
Adjustable uncertainty budget	Duality theory	+ minimizes the conservation problem of Robust optimization
Dynamic uncertainty sets	Linear dynamics	+ Data-driven way to model uncertainty + can model spatial and temporal correlations in variable sources