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Reliability-based Sizing of Energy Storage for Systems with Very High Renewable Energy Penetration

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Motivation

- Jurisdictions around the globe are enforcing policies to **fight climate change**
- Share of electricity from **renewable energy resources (RERs) increasing** rapidly
- *Pros:* RERs are **clean, abundant, and cheap**
- *Cons:* **Intermittent, variable, unreliable**
- RERs need to be **firmed up** to make the grid more reliable
- **Energy storage systems (ESSs)** can be used to firm up RERs

Objective

Size ESSs appropriately **to firm-up RERs** in a system with very high RER penetration so that a desired level of **grid reliability** can be achieved.

ESS Sizing Methodology

- **Markov chains** used to model *up* and *down* states of system components
- **Monte Carlo simulation (MCS)** performed to generate outage statistics
- **ESS power capacity** calculated using **Expected Power Not Served (EPNS)**
- **Duration of ESS, t_A,** calculated using **unavailability reduction ratio $\boldsymbol{\alpha}$**

$$t_A = -\bar{r} \times \ln\alpha$$

where

$$\alpha = \frac{1 - A_0}{1 - A_1}$$

- **Energy capacity** of ESS

$$Q_S = P_L t_A$$

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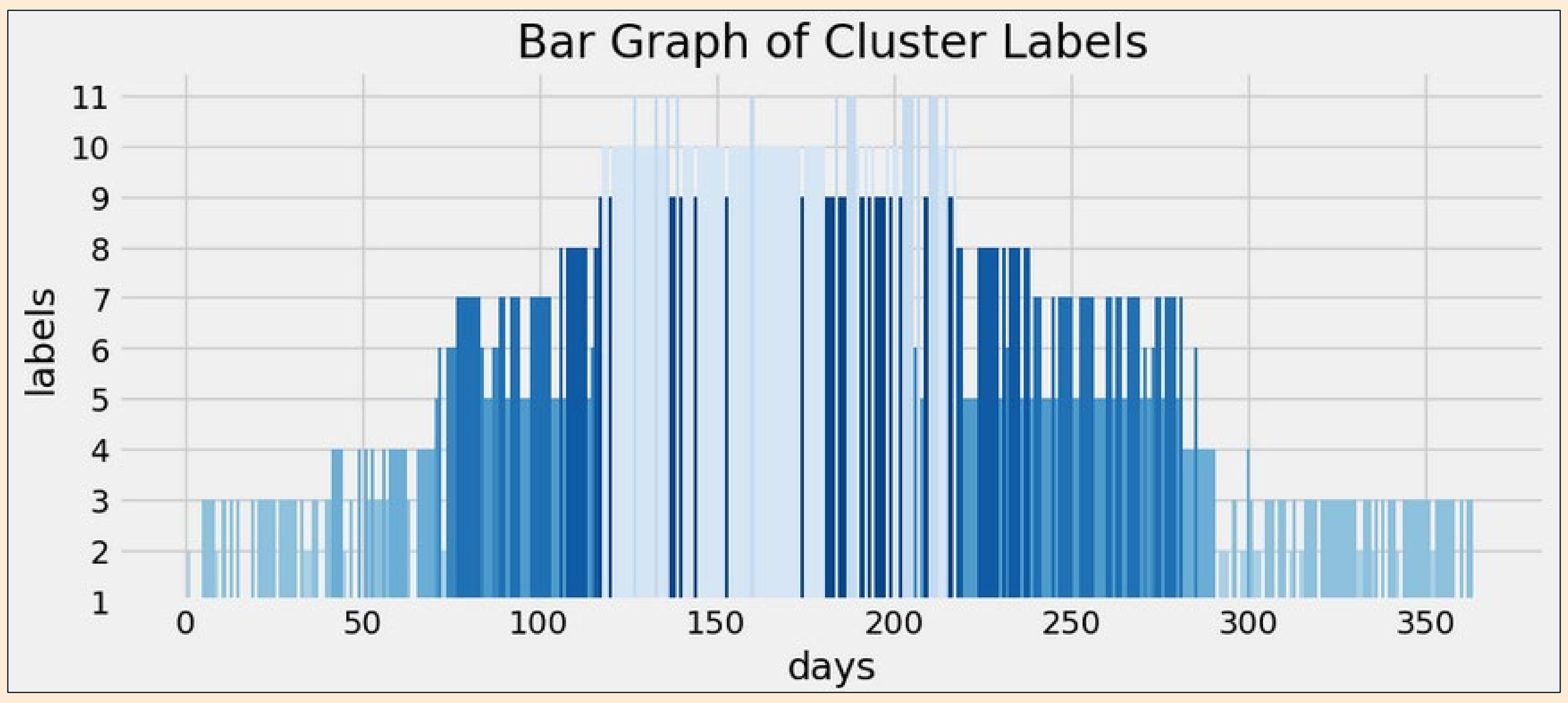
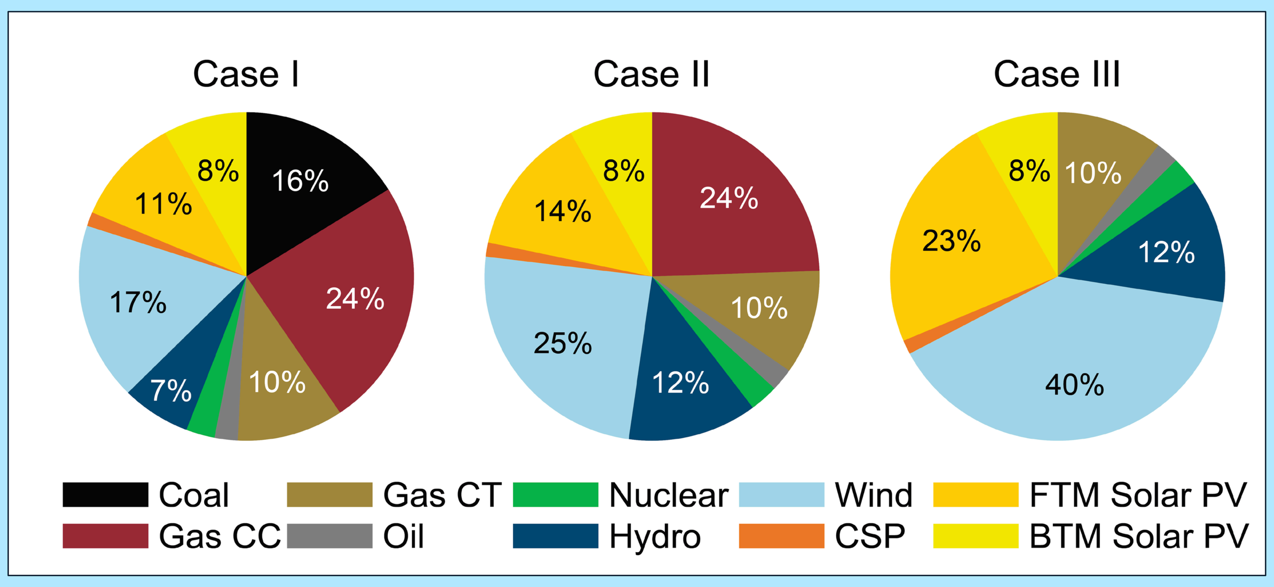
Uncertainty Modeling of Solar & Wind

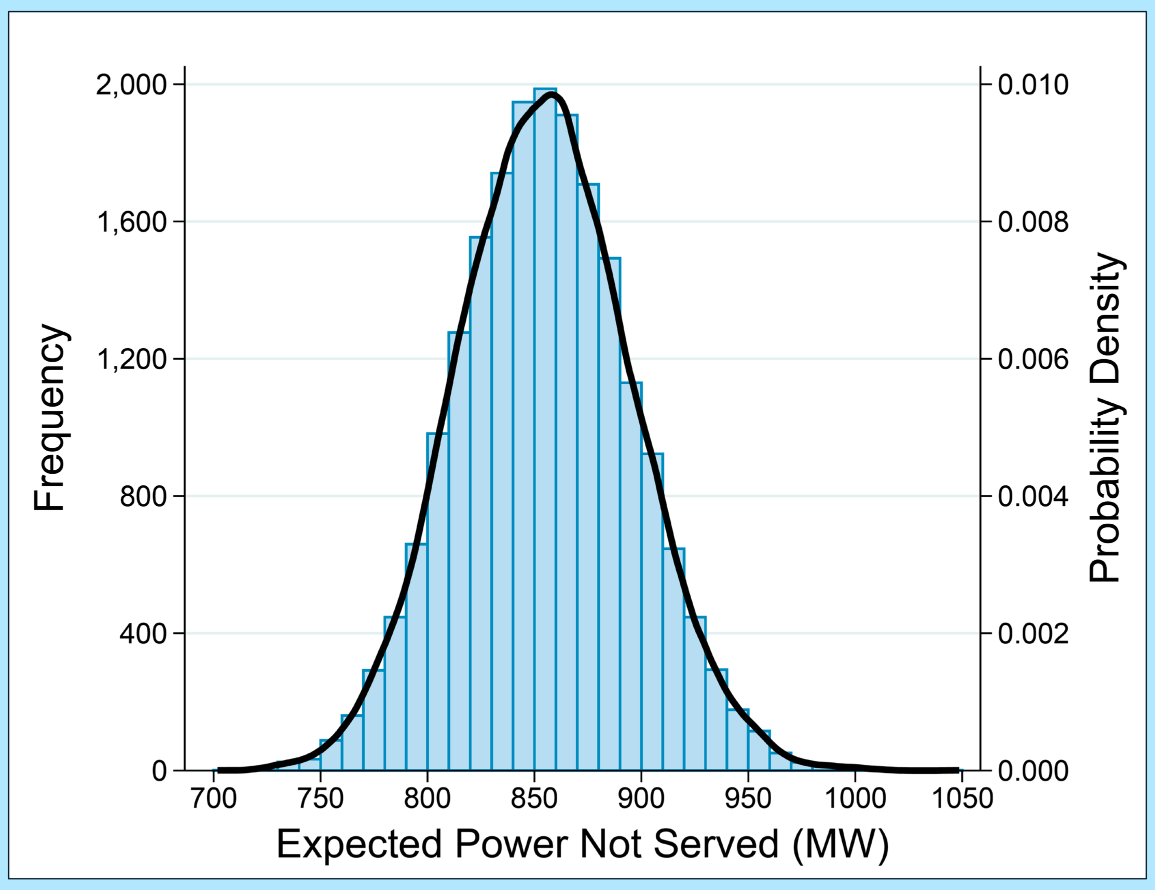
- K-means clustering used to group hourly solar generation data into similar days
- Features used: actual solar availability, theoretical solar availability under clear-sky conditions, clear-sky index, hours of sunrise and sunset
- Sampling procedure preserves spatiotemporal correlation

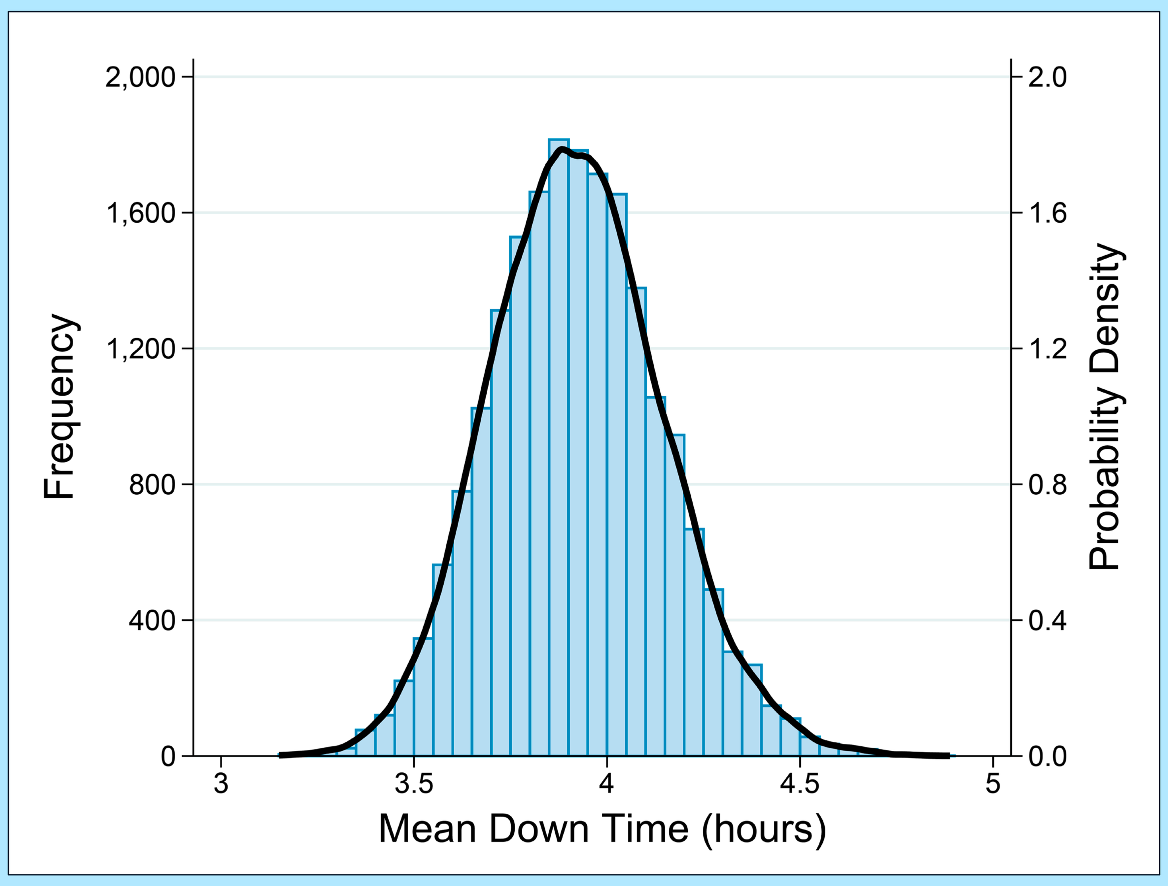


- Transition rate matrix developed to predict hourly wind speed
- Parameters of transition matrix estimated from historical data

Results







ESS SIZES FOR THE CASE STUDIES

Case No.	LOLH (h/y)	NEUE*	P_s (MW)	$\bar{r}$ (h)	α	t_s (h)	Q_s (MWh)
I	0.57	0.0003	202	1.5	0.4261	2	404
II	22	0.0200	337	2	0.0112	9	3,033
III	990	2.2569	856	4	0.0024	34	33,660

*NEUE = normalized EUE (EUE expressed as a % of the load)

System reliability gets drastically worse as RER penetration increases and consequently a large amount of ESS is required.

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