Introduction

PJM system operation is facing increased uncertainty due to extreme weather events and higher renewable penetration. To ensure grid reliability, it is necessary to establish an uncertainty framework, which quantifies uncertainty for the next operating day, so that markets and operations can proactively factor the appropriate level of uncertainty and secure necessary reserves correspondingly, so that energy and reserve prices are consistent with system needs and conditions.

Uncertainty Components

Load and renewable (wind and solar) forecast accuracy, generation performance and interchange are the main uncertainty components that system operation faces when securing the appropriate level of reserves for the next operating day.

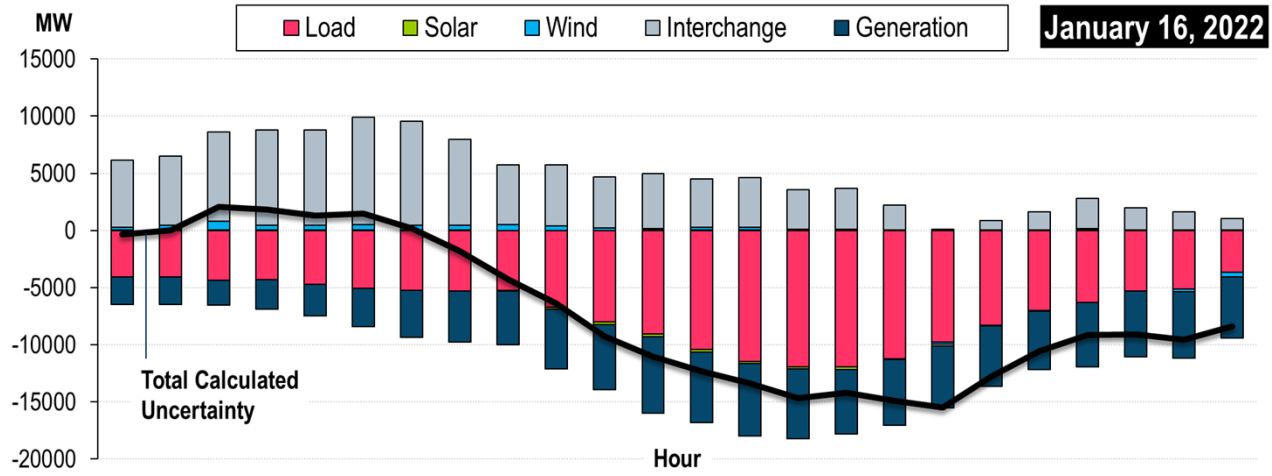
Reliability Assessment Commitment (RAC) runs daily between 14:30 and 15:30. 14:00 Day-ahead forecast is used in RAC run. Choosing 14:00 Day-ahead forecast aligns with the timing of the RAC run. The difference between 10:00 and 14:00 is covered by RAC. Using PJM RTO wind and solar power forecast gives better overall prediction compared to using wind and solar DA bid-in values. And generation tripping and de-rating that happen before 15:00 are accounted for by the RAC process. The following hourly uncertainty components were collected for the historical days since March 2018:

- Load Forecast Error (LFE)
  - LFE = Load Forecast – Actual Load
  - Load Forecast used is the 14:00 Day-ahead Load Forecast.
- Wind Power Forecast Error (WFE)
  - WFE = Wind Power Forecast – Actual Wind Power
  - Wind Power Forecast used is the 14:00 Day-ahead Wind Power Forecast.
- Solar Power Forecast Error (SFE)
  - SFE = Solar Power Forecast – Actual Solar Power
  - Solar Power Forecast used is the 14:00 Day-ahead Solar Power Forecast.
- Interchange Error (IE)
  - IE = DA Interchange – Actual Interchange
  - DA interchange is the 14:00 Day-ahead scheduled interchange.
- Generation Loss due to tripping or de-rating (GenLoss)
  - Generation Loss data was collected from GADS, which has more accurate unit tripping and de-rating information as compared to eDart. The tripping and de-rating happened after 15:00 the previous operating day, and within the operating day is considered as generation uncertainty for the operating day.

The **total uncertainty** is then calculated as the summation of all the above independent uncertainty components for the corresponding hour, i.e.:

Total Uncertainty = LFE – IE – WFE – SFE – GenLoss

The following figure shows an example of total calculated uncertainty for Jan. 16, 2022, and the contribution of each uncertainty component. The main components contributing to the negative total uncertainty were generation loss (blue bar) and under-forecasted load (pink bar). For example, for HE18, total uncertainty = LFE (-9,794) – IE (192) – WFE (145) – SFE (-15) – GenLoss (5,383)= -15,499 MW.



Uncertainty Forecast

Due to the complex data structure, high non-linearity between the individual impacting factors and forecast target (total uncertainty), and no explicit mathematical model available to represent the relationship between total uncertainty and the individual factors, PJM chose to use machine learning (ML) methods to forecast total uncertainty for the next operating day, with the following impacting factors as input variables. Season, month, day and hour are used as features.

- Load forecast
- Wind power forecast
- Solar power forecast
- Cloud cover
- Dew point
- Wind speed
- Effective temperature
- THI
- Heat index

Seven years of historical data were collected to train ML models for underlying relationship, patterns and trends. Once ML models were trained, the models are then able to predict the total uncertainty (in megawatts) for each hour of the next operating day based on load forecast, wind and solar power forecasts, and forecasted weather conditions (cloud cover, dew point, wind speed, effective temperature, THI and heat index).