

A photograph of a wind farm at sunset. The sun is low on the horizon, casting a warm, golden glow over the scene. Several wind turbines are visible in the background, their silhouettes against the bright sky. In the foreground, rows of solar panels are laid out in a grid pattern, reflecting the light from the sun. The overall atmosphere is serene and highlights renewable energy.

Probabilistic Forecast Use in Market Operations

Jeff Lerner, ENFOR A/S
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2022 ESIG METEOROLOGY & MARKET DESIGN FOR GRID SERVICES WORKSHOP

Session 3: Integration of Probabilistic Forecasts into the EMS and MMS – Status and Prospects

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Integration of Probabilistic Forecasts in TSO Operations Outline

- **Why Probabilistic Forecasting and Why Now?**
- **Current Use Case Example for Island System**
 - **EirGrid TSO – system attributes**
 - **Ramping Margin Reserves requirement**
 - **Probabilistic Ramp Forecast Product**
 - **Operator Use of Ramp Forecast Product**
- **Thoughts About Future Use of Probabilistic Forecasts**

ENFOR – What We Do

- HQ in Denmark – spin-off from the Technical University of Denmark (2006)
- Offices in Hungary, India and Iceland
- Delivers software systems and services for **operational energy forecasting and optimization**
- Operational track record of more than 25 years

2022 Operational Forecasted Capacity

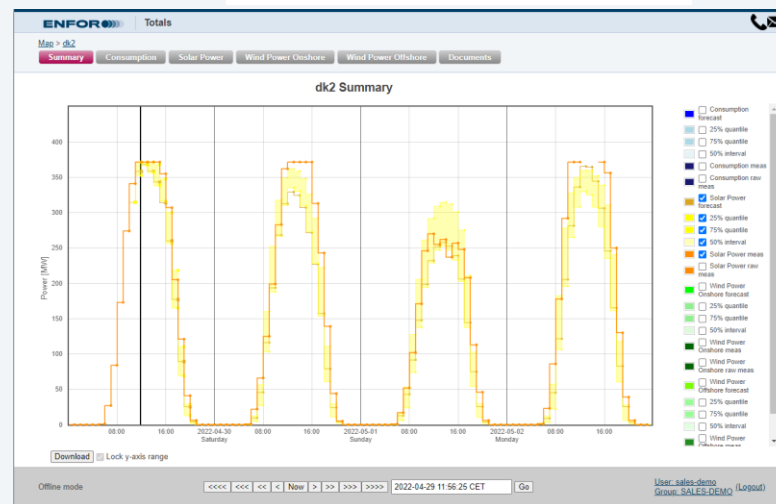


>50GW

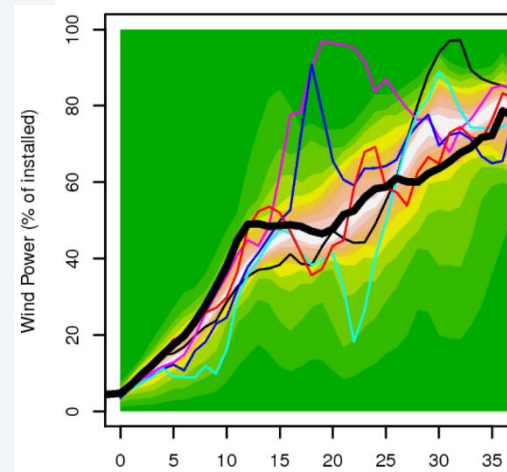


>150GW

Solar Power Forecast



Wind Ramp Event Forecast



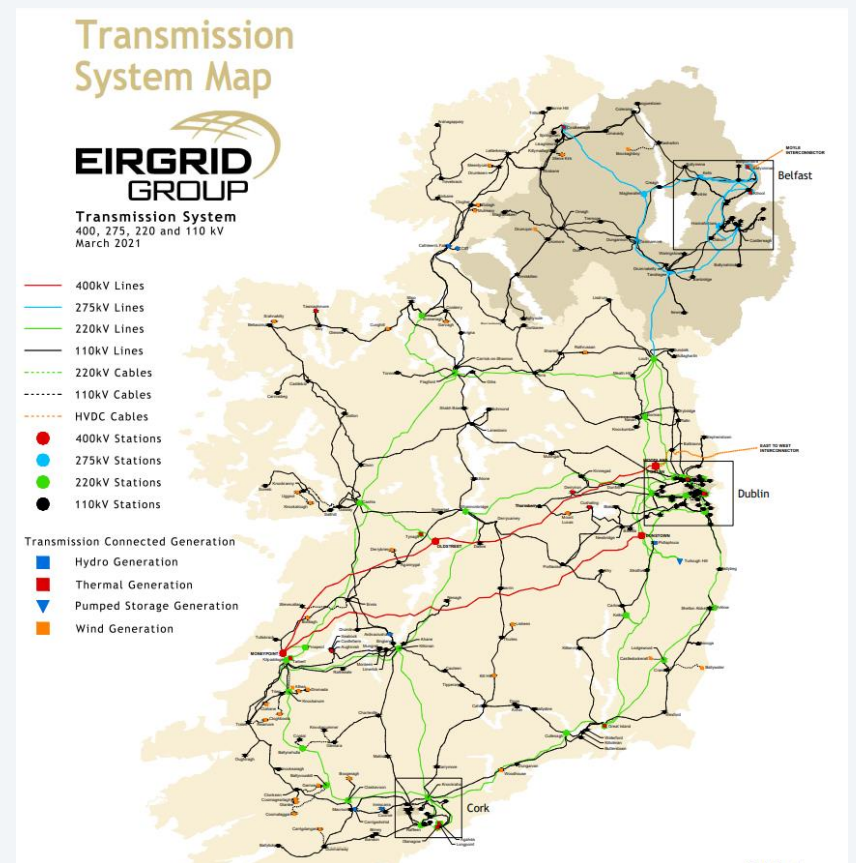
Why Probabilistic Forecast and Why Now?

- **Increased penetration levels of variable generation leads to greater need for quantifying forecast uncertainty**
- **Any weather-driven event can benefit from understanding the likelihood of occurrence. Ex:**
 - **Dynamic capacity of transmission line**
 - **Load forecasting**
 - **Grid congestion / Rapid ramp events**
 - **Electricity price forecasting**
- **There's a learning/refinement process with incorporating probabilistic forecasts, so better to start sooner than later!**

Current Use Case Example for Island System

EirGrid TSO – System Attributes

- Winter Peak Demand: ~7 GW
- Summer Night Minimum Demand: ~3 GW
- 2021 Fuel Mix:
 - Gas (46%)
 - Wind (31%)
 - Coal (11%)
 - Hydro (2%)
 - Solar (0.5%)
- Installed Wind Capacity: 5,683 MW
- Installed Solar Capacity: 250 MW
- Maximum Wind Output: 4,471 MW (12 Feb 2022)
- 2 Interconnects:
 - East-West (500 MW DC) Ireland-Wales
 - Moyle (500 MW DC) N. Ireland-Scotland
- ~40% load met by Renewables in 2021



From: <https://www.eirgridgroup.com/site-files/library/EirGrid/EirGrid-Group-Transmission-Map-March-2021.pdf>

Current Use Case Example for Island System Ramping Margin (RM) Reserves requirement

- Wind Forecast Errors are significant portion of system demand
- EirGrid must maintain a minimum level of ramping capability from online or offline generation and demand units
- Forecast Error Risks are explicit in operational scheduling
- EirGrid RM Definition

The increased MW output or reduction in demand, a unit can provide, within a given time period of receiving a dispatch instruction and maintaining that MW output for a further specified period after the initial given time period has elapsed.

- Three categories: RM1, RM3, and RM8

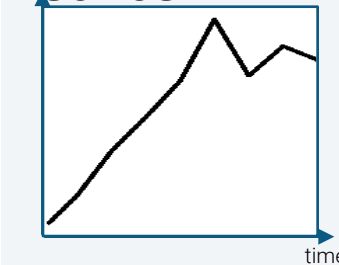
Classification	Category	Delivered within	Maintained for
Ramping Margin	Ramping Margin 1 (RM1)	1 Hours	2 Hours
	Ramping Margin 3 (RM3)	3 Hours	5 Hours
	Ramping Margin 8 (RM8)	8 Hours	8 Hours

From: https://www.sem-o.com/documents/general-publications/Ramping_Margin_Requirements_in_Scheduling.pdf

Probabilistic Ramp Forecast Product

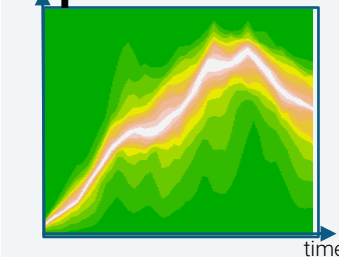
- At each forecast update time, 1000 forecast scenarios generated from probabilistic wind power forecasts
 - Conditioned on latest information including NWP ENS forecast guidance
 - Respect quantiles and correlation between time-points and regions (NI/ROI)
 - Generate independent scenarios respecting the above and therefore probability of specific ramp events can be found by $\frac{\#events}{\#samples}$
- A *plausible ramp down* is computed by using the 2% Probability of Exceedence from the scenario forecasts at each time step

Deterministic forecast point time series



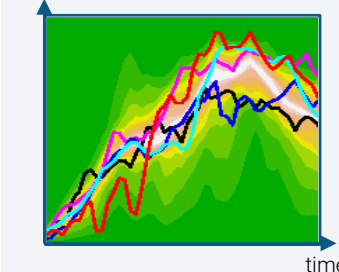
- Trading
- O&M

Ensemble forecast for generating quantiles and uncertainty bands



- Optimizing trading strategies
- Operational risk assessment

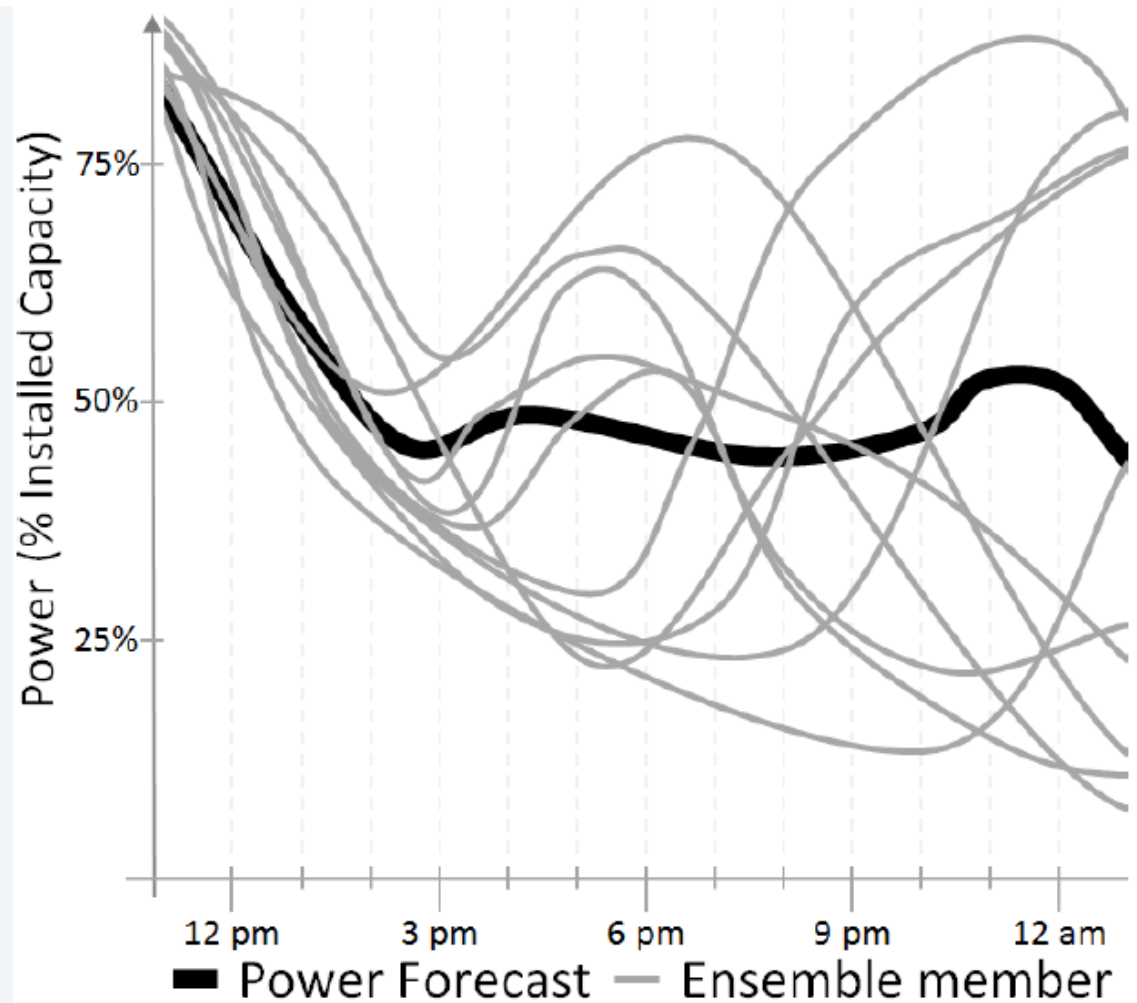
Scenario Generation



- Optimizing storage strategy or other state dependent issues

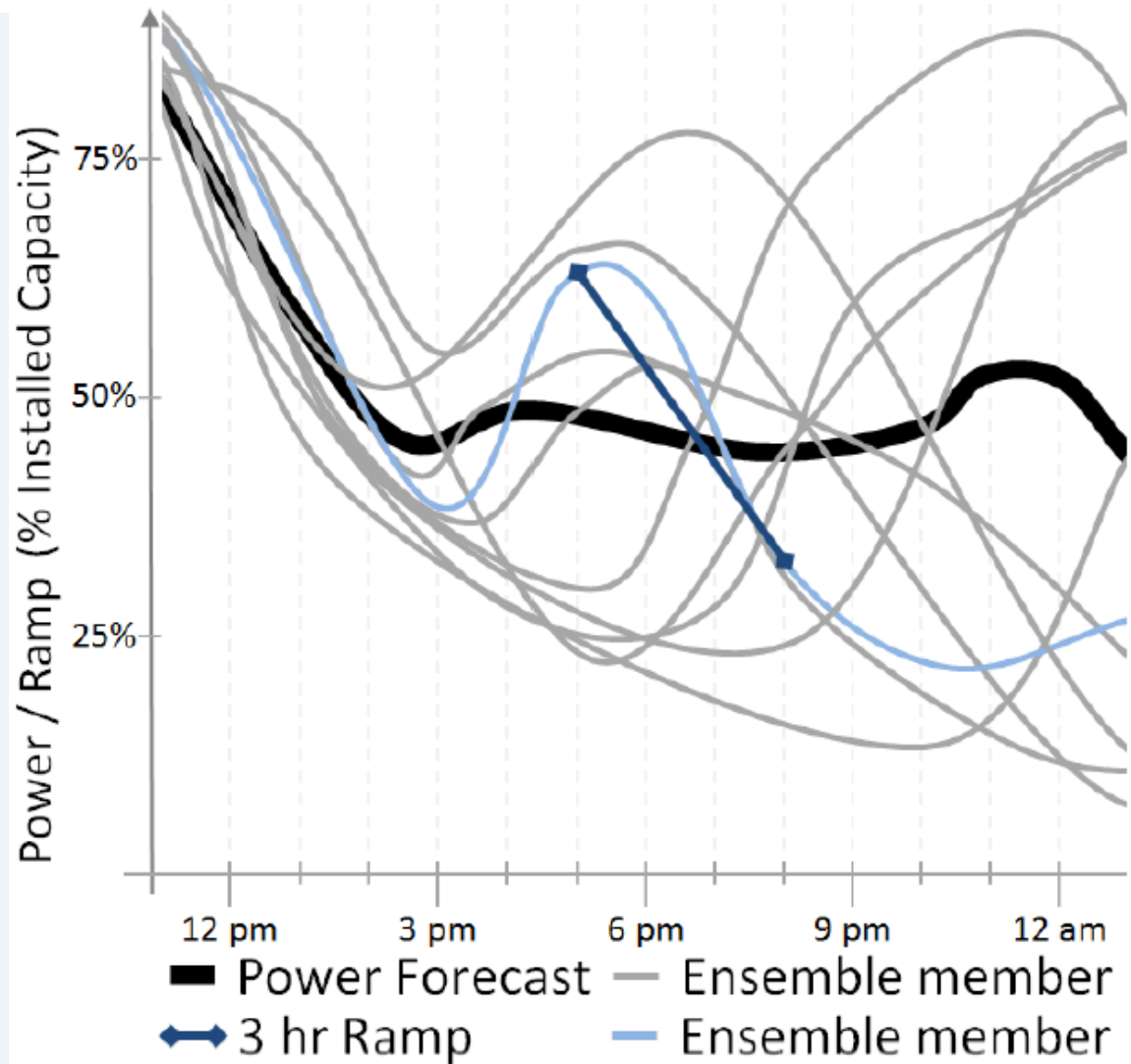
Ramp Forecast Product – Simplified Illustration

12-hour deterministic
and 10 ensemble
members / scenarios



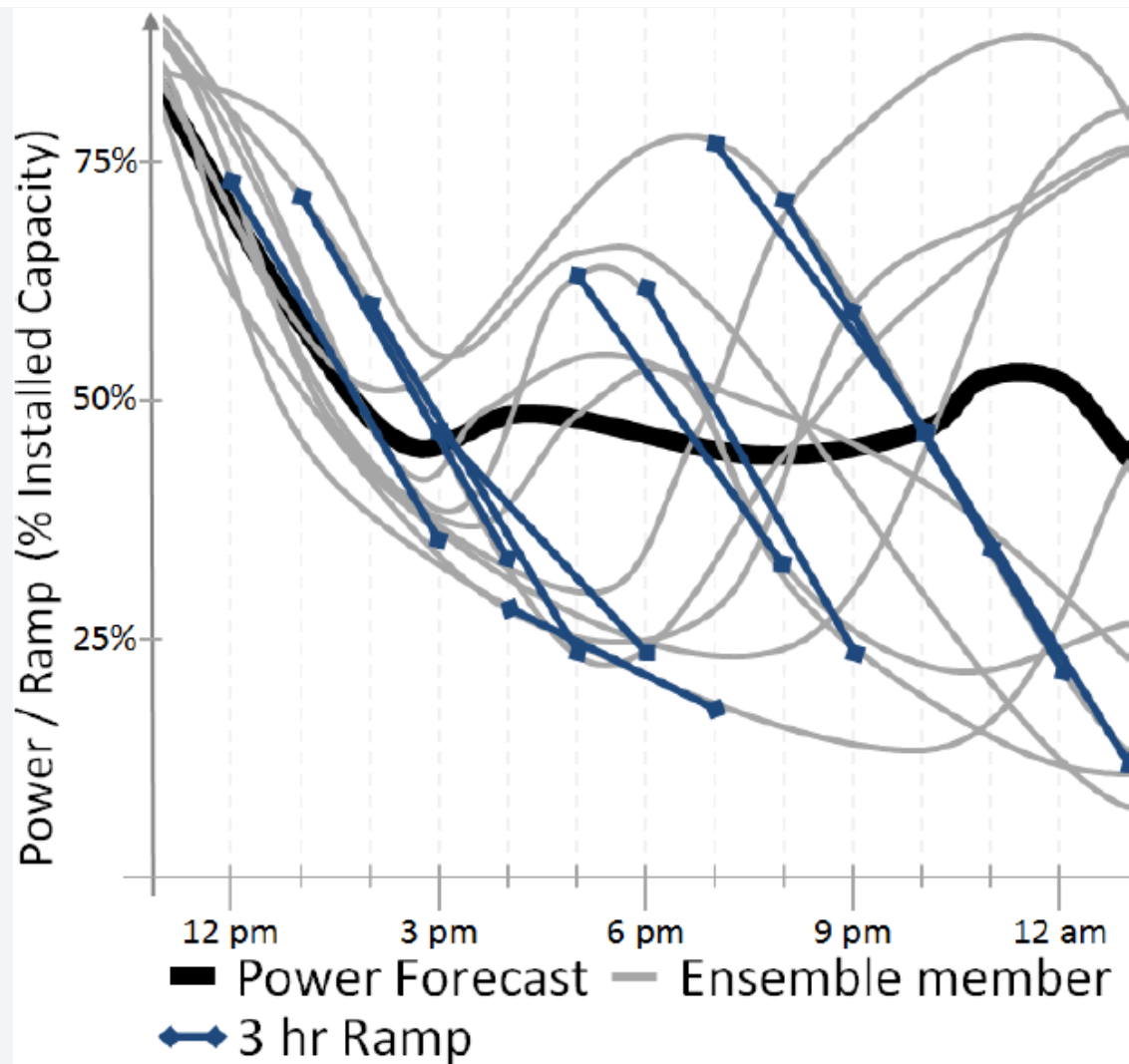
Ramp Forecast Product – Simplified Illustration

Maximum 3-hour ramp down may be calculated from ensembles



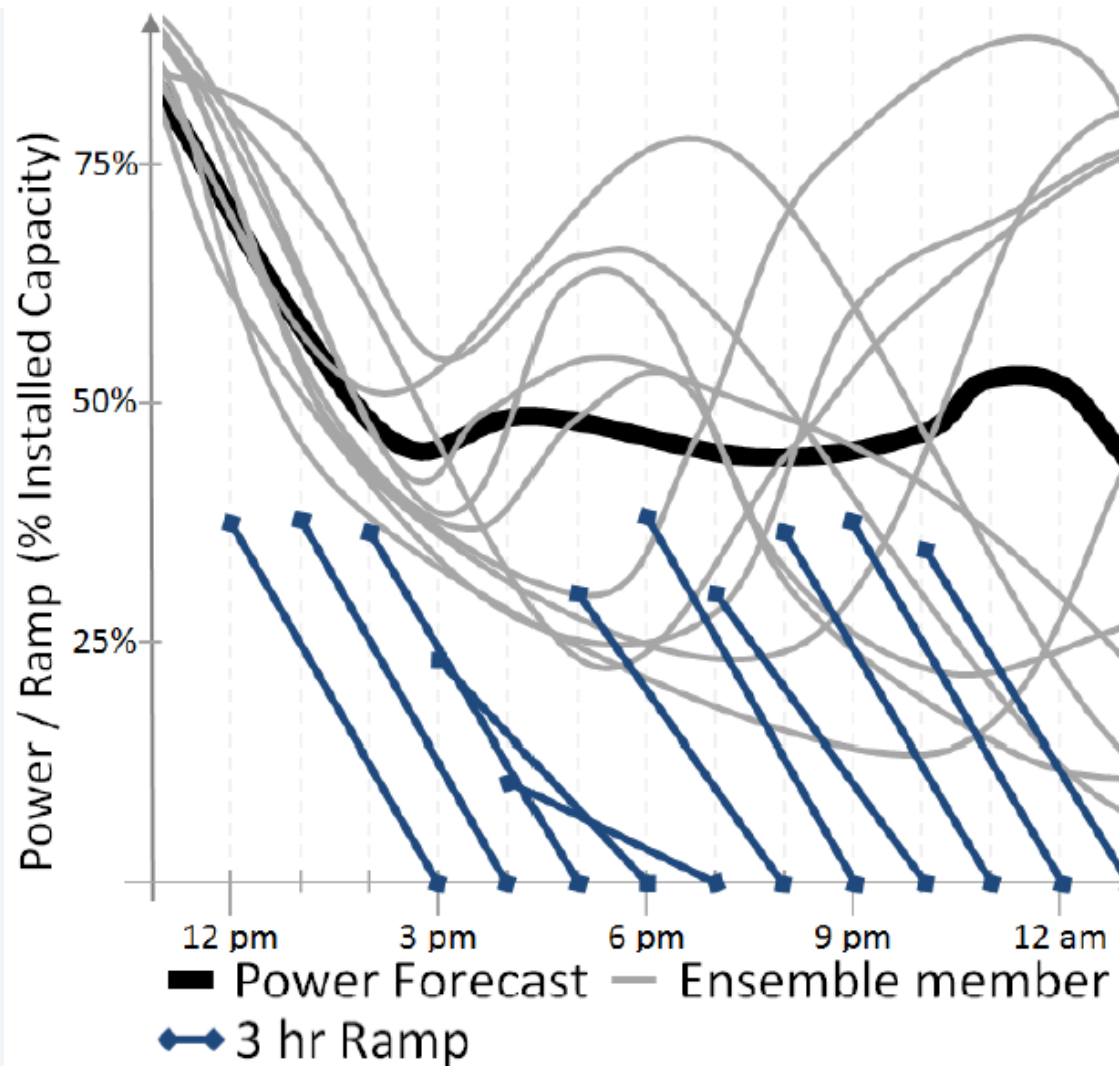
Ramp Forecast Product – Simplified Illustration

For each forecast interval, maximum ramp down calculated from ensemble of forecasts



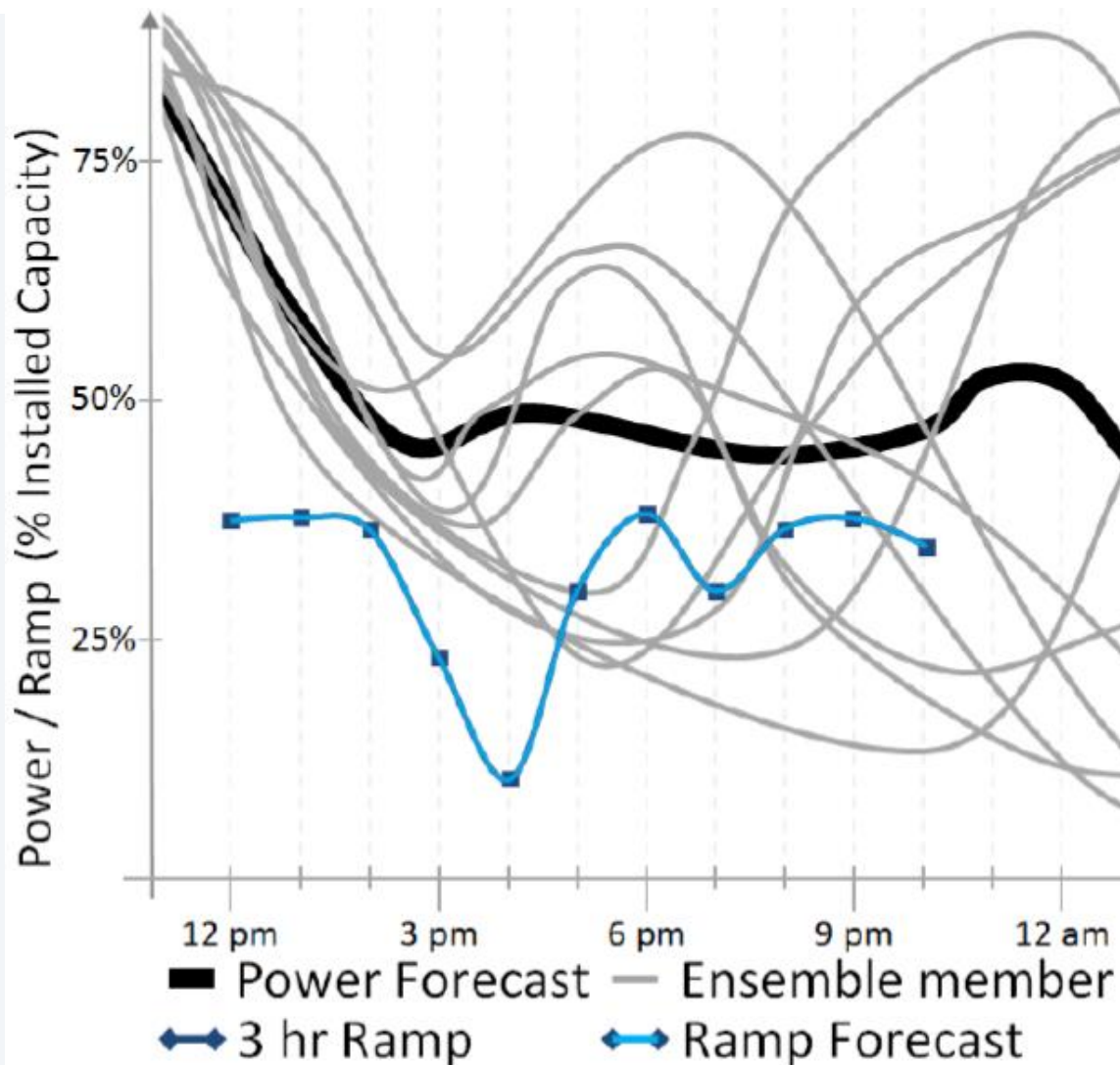
Ramp Forecast Product – Simplified Illustration

Composite of 3-hour maximum ramp down assigned at each forecast time step



Ramp Forecast Product – Simplified Illustration

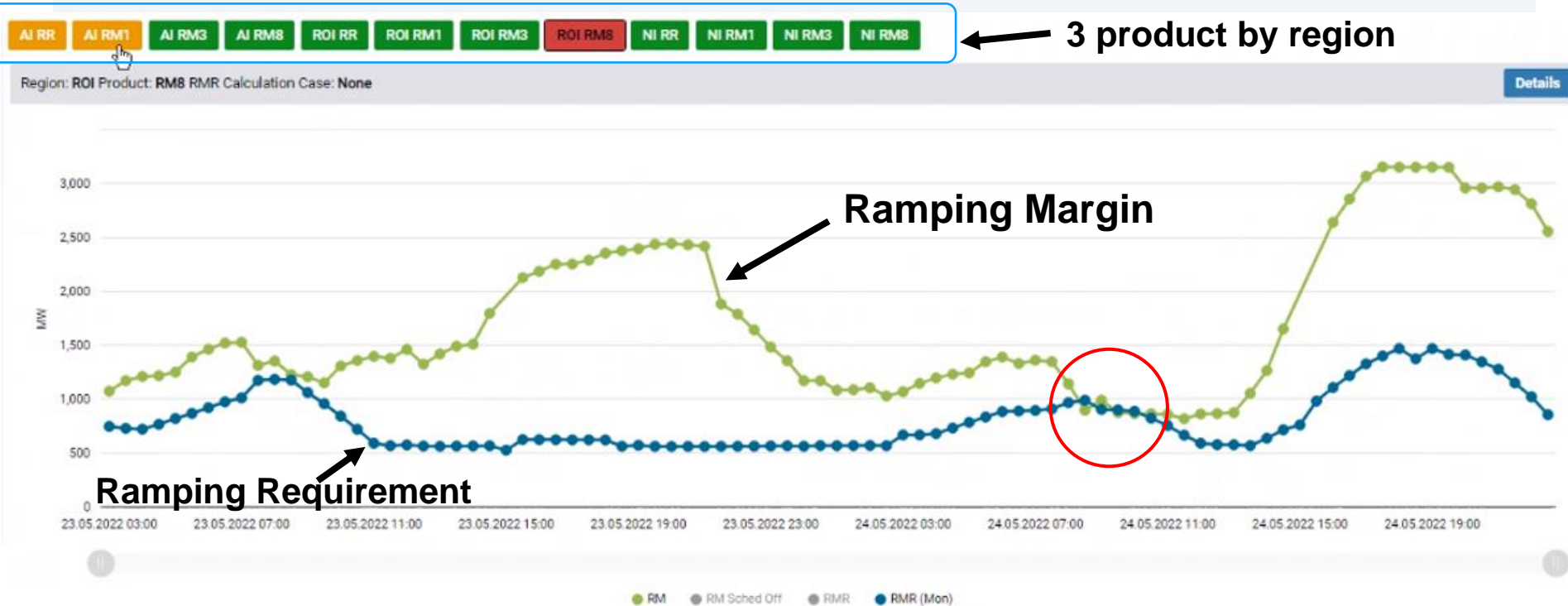
3-hour ramp forecast generated



Ramping Margin Reserve Product Description

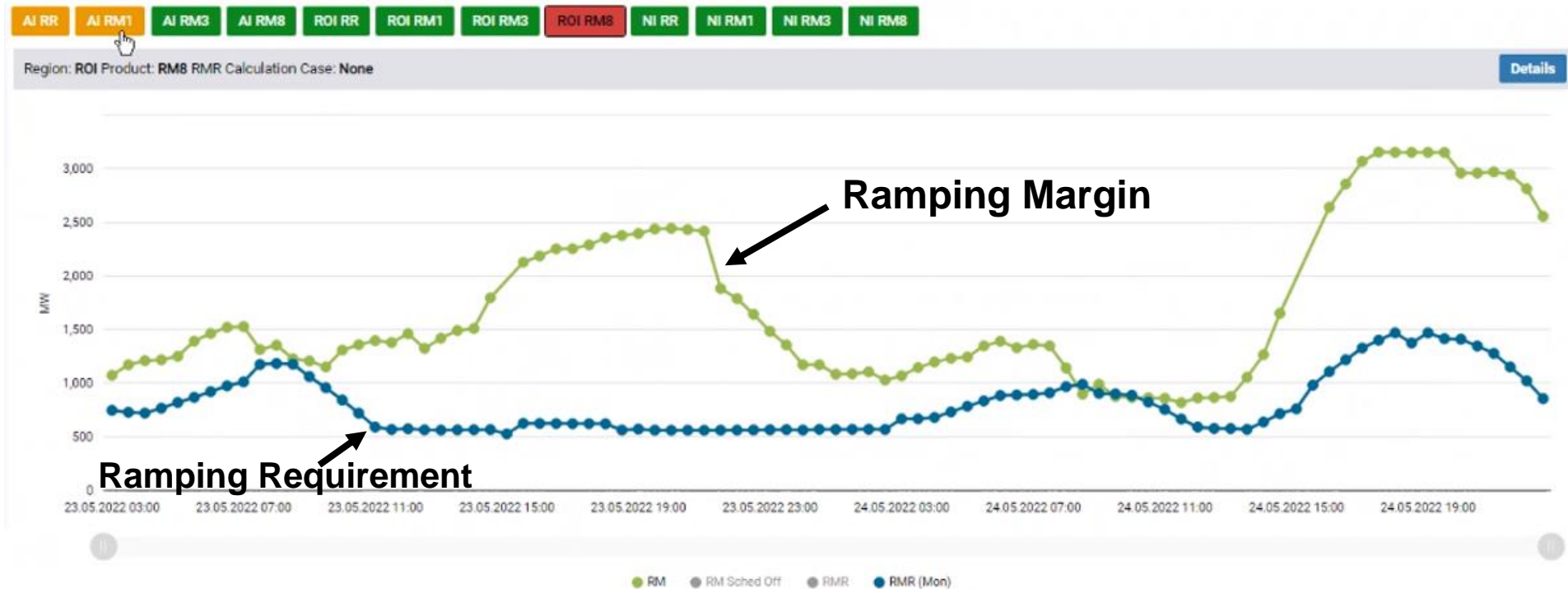
- Ramping reserves required to meet supply shortfalls (ramp-up capacity)
- Three different horizons allows for response to forecast error changes and the varying notice times required by standby units
- 3 Ramping Margin Reserves: 1-hour, 3-hours, and 8-hours horizon
- Short-term forecasts: 36-hour lead time, updated 15-minutely
- Long-term forecasts: 120-hour lead time, updated every 6 hours
- The *Ramping Reserve Requirement* considers the difference in the deterministic wind production ramp forecast and the probabilistic ramp forecast
- Ramp forecast product designed to cover most probable ramp events thus lowering operating costs

Current Use Case Example for Island System Operator Products and Decision Support Tool



- Ramping Requirement is an expression of the Forecast Uncertainty
- SCUC optimization model run outputs ramping margin time series
- Three different ramp horizons allows for various standby units to response to forecast error changes
- Operator is alerted to stoplight buttons when Ramping Margin and Ramping Requirement (uncertainty) get within pre-defined thresholds

Current Use Case Example for Island System Operator Products and Decision Support Tool



Ramping Margin Requirement (RMR)* is expressed as

$$RMR_{t(R)} = LSI_{(t+R)} + LFE_{(t+R)} + \max(RR_{(t+R)}, Uncert_{t(R)}) + Tie_{uncert} - IC_Cap_{(t+R)}$$

LSI = largest single infeed (~500 MW conv. generator)

LFE = load forecast error

RR = replacement reserve

Uncert = VG uncer. forecast

t= sched. Intvl

R=margin category

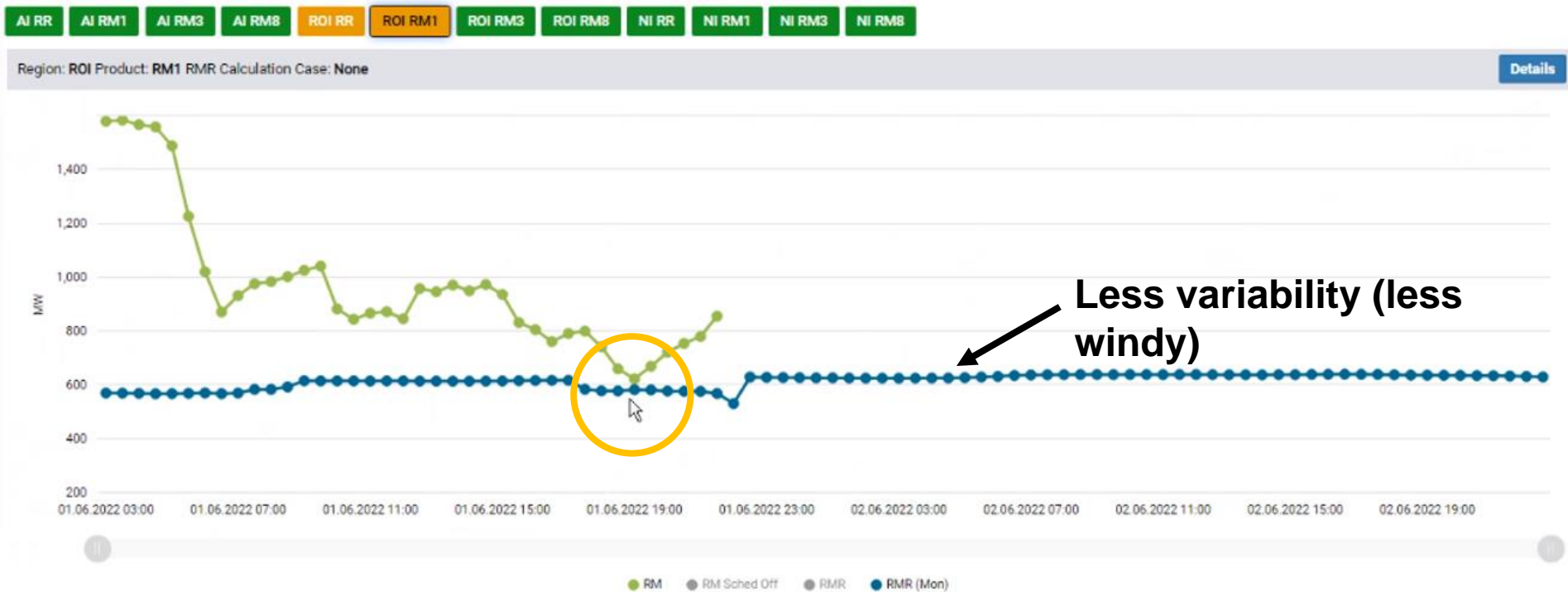
Tie = Tie line uncert.

IC_Cap = interconn. capability

*From: https://www.sem-o.com/documents/generalpublications/Ramping_Margin_Requirements_in_Scheduling.pdf

Current Use Case Example for Island System Operator Products and Decision Support Tool

- Operator is alerted to stoplight buttons when Reserve Margins and uncertainty get within pre-defined threshold
- System under-frequency and forecast error event detection will trigger release of RM-reserves
- Automated Ramping Margin Reserves incorporated starting 2020



Thoughts about Future Probabilistic Forecast Use by TSOs/ISOs

- **Increase in Demand Response technologies introduces new state dependent variables that can be modeled**
- **Expand the number of weather-driven grid reliability events**
 - **Probability of Extreme temperature events**
 - **Lost solar power generation from aerosols**
- **Additional external information can be integrated into probabilistic forecast scenarios**
 - **Interconnected system renewable generation**
 - **State of storage (e.g., pumped hydro or battery state of charge)**

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Thank You For Your Attention



Jeff Lerner, Customer Solutions Manager

contact@enfor.dk

Phone: +45 45 350 350