Stochastic dispatch optimization using Lidar-based power forecasts

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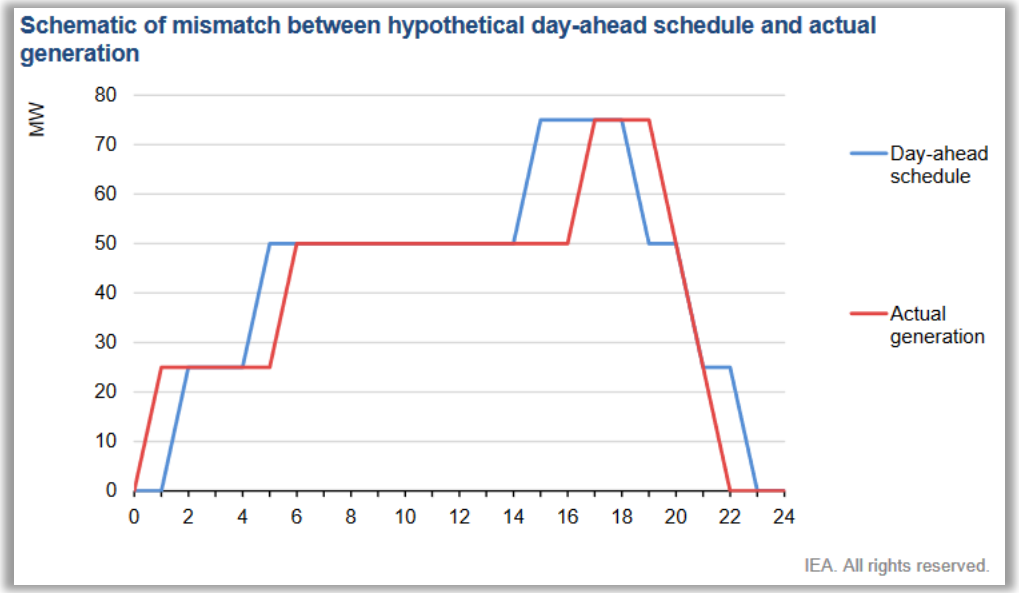
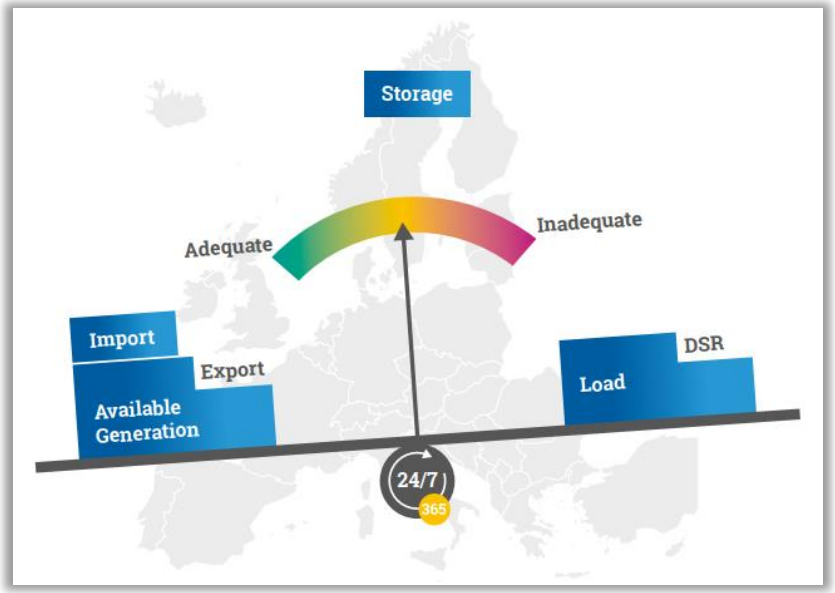
DLR

Uncertainty is inherent to the management of power systems

Planning the operation



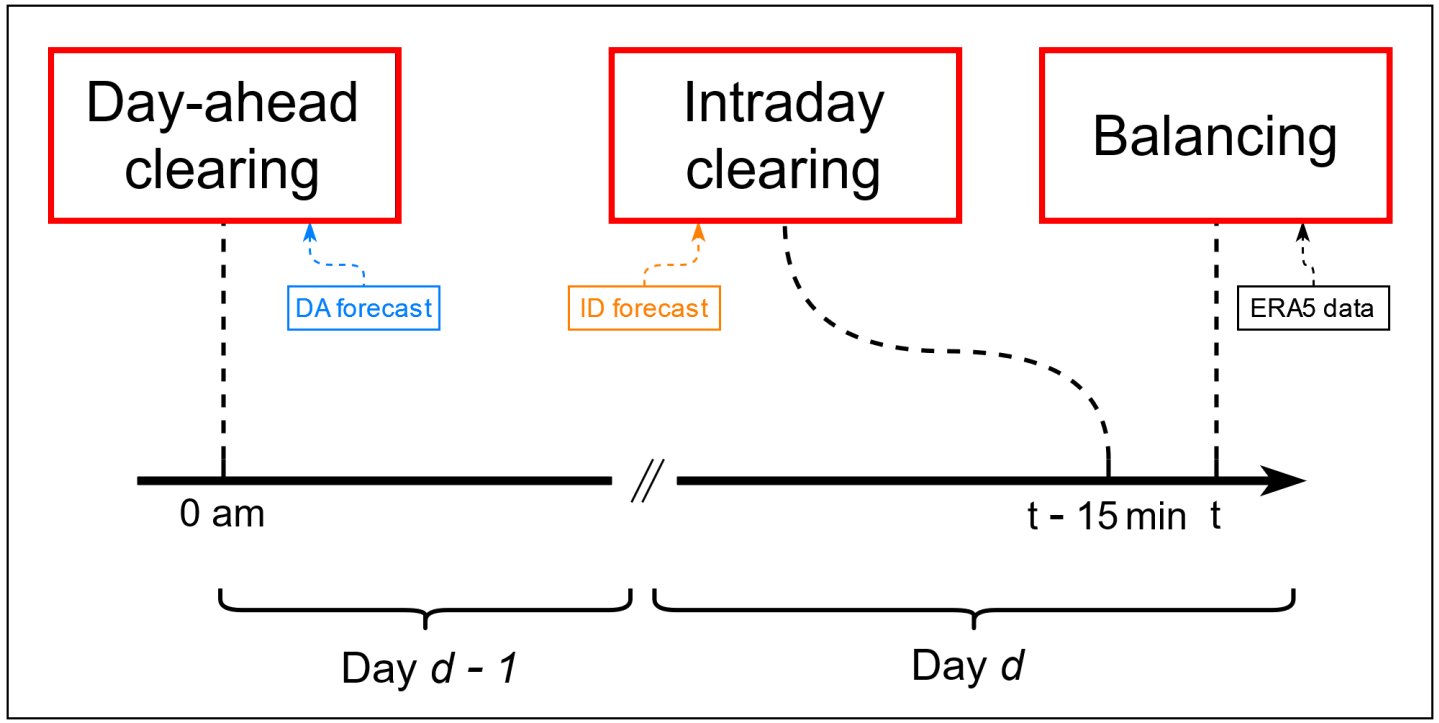
Operating the system



(1) IEA (2020), Electricity security matters more than ever, in *Power Systems in Transition*, Paris: IEA. https://www.iea.org/reports/power-systems-in-transition
(2) ENTSO-E (2023), *European Resource Adequacy Assessment*, Brussels: ENTSO-E. https://www.entsoe.eu/outlooks/eraa/2023/eraa-downloads/

Management of the power system

Simulations in ProPower



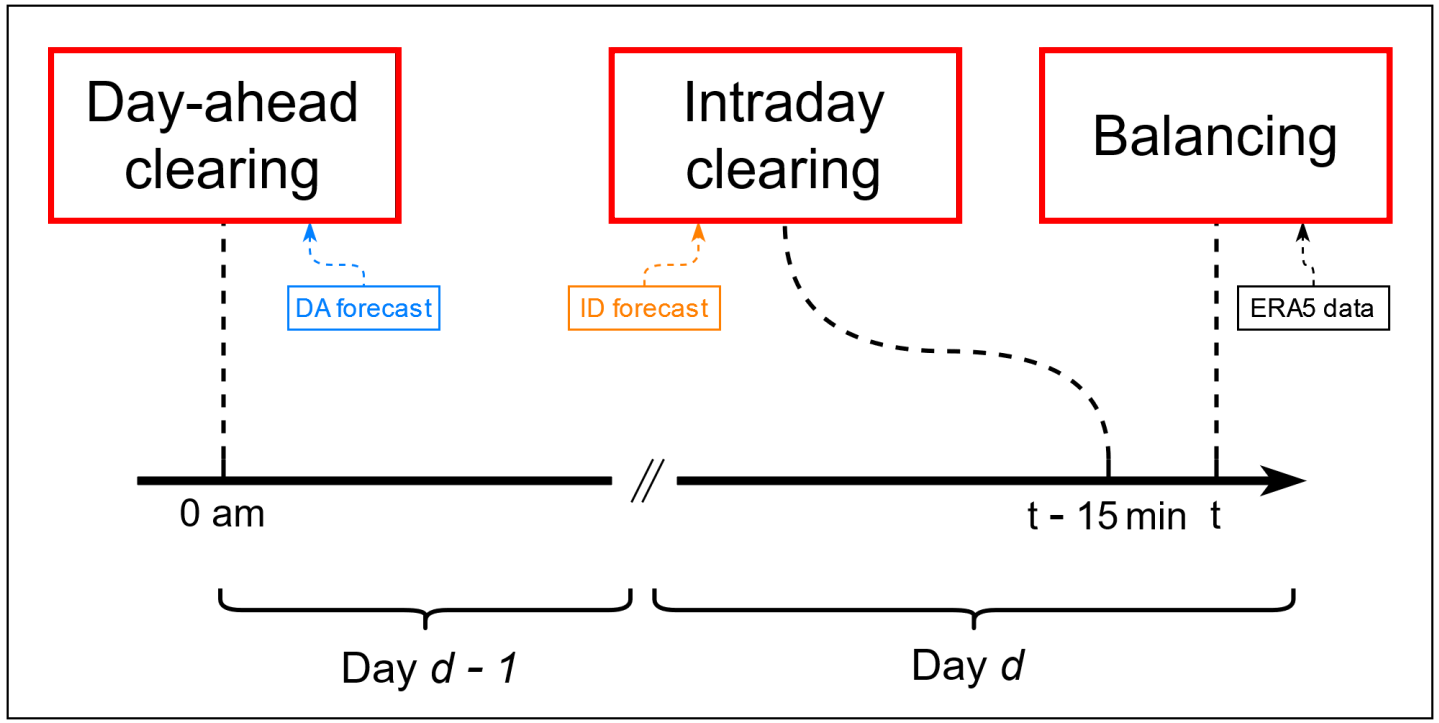
Determine **preliminary schedule of generation** (= Dispatch)

Adjusting the dispatch using forecast updates

Balancing the difference of dispatch and observed feed-in

Modelling the management

Simulations in ProPower

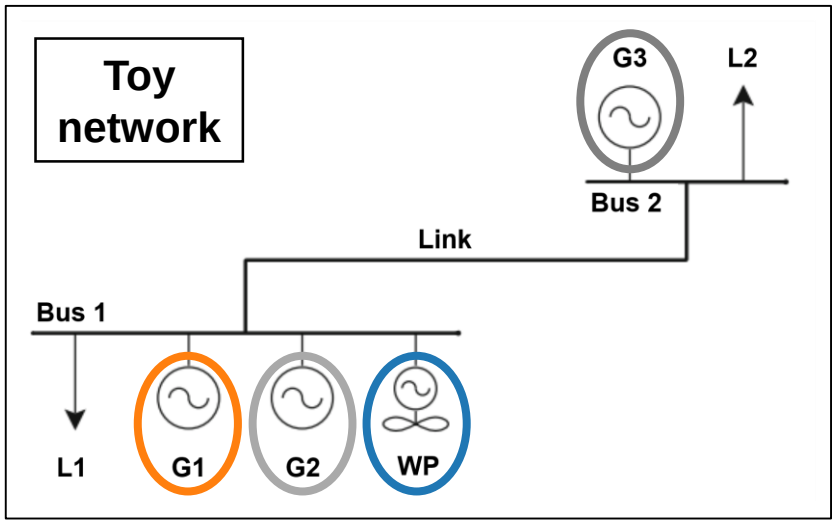


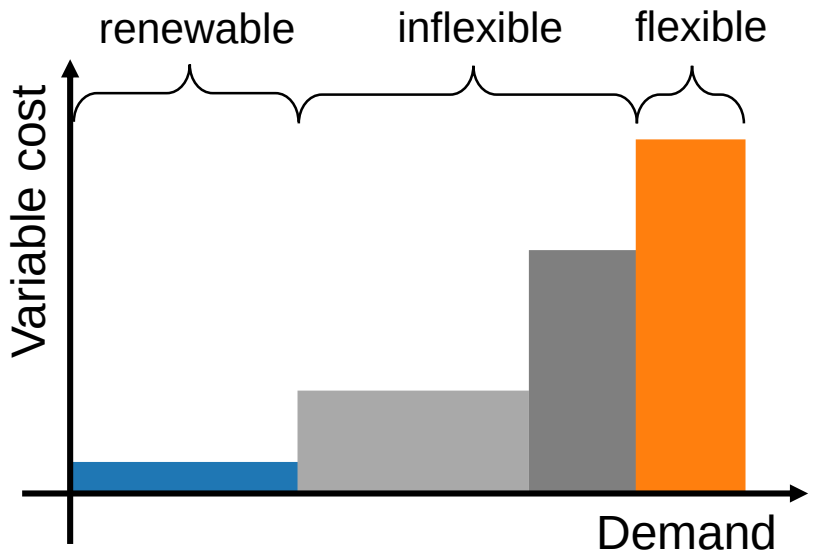
min Day-ahead dispatch costs

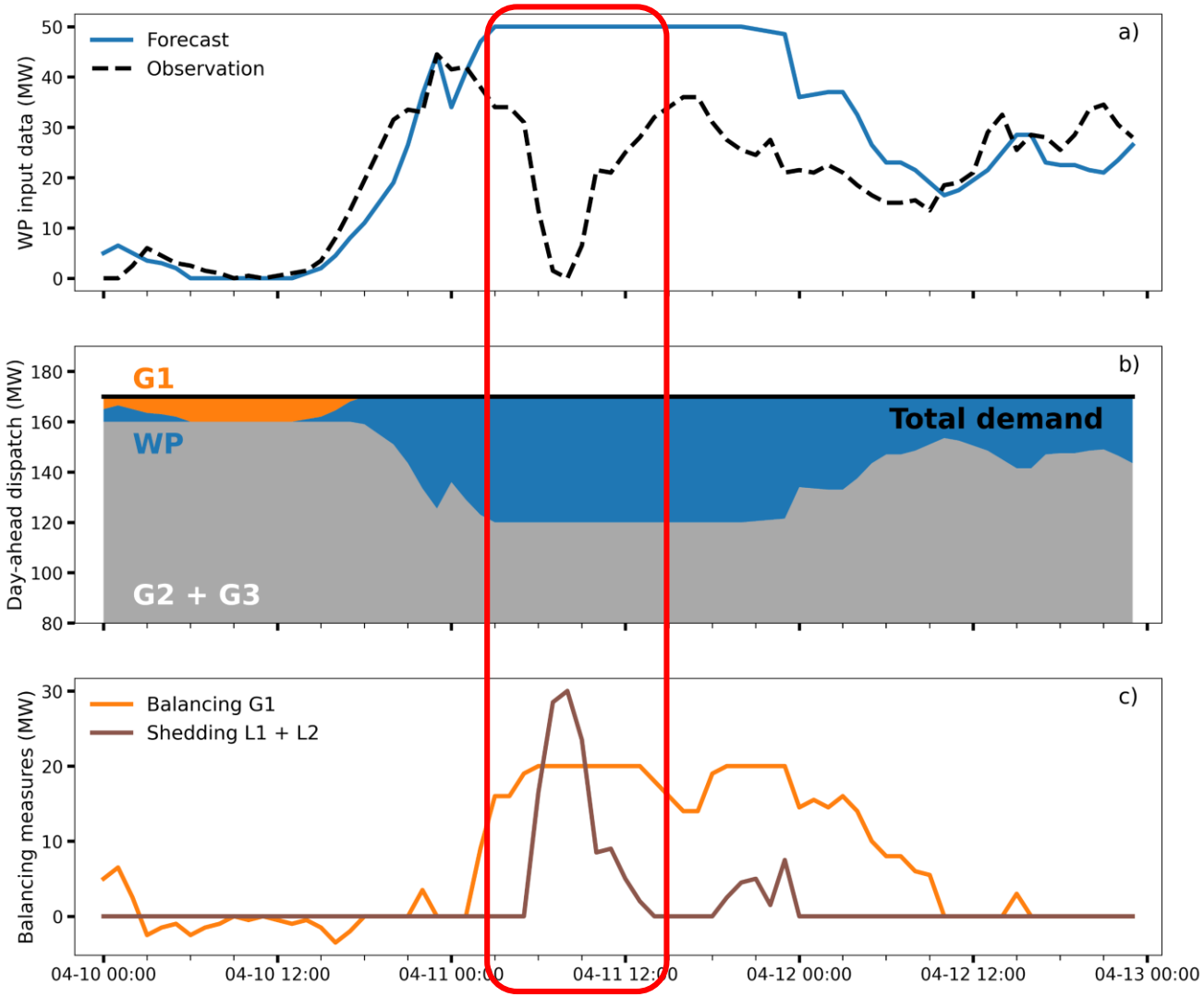
min Intraday correction costs

min Balancing costs

Simple example: 2-bus network with single wind farm

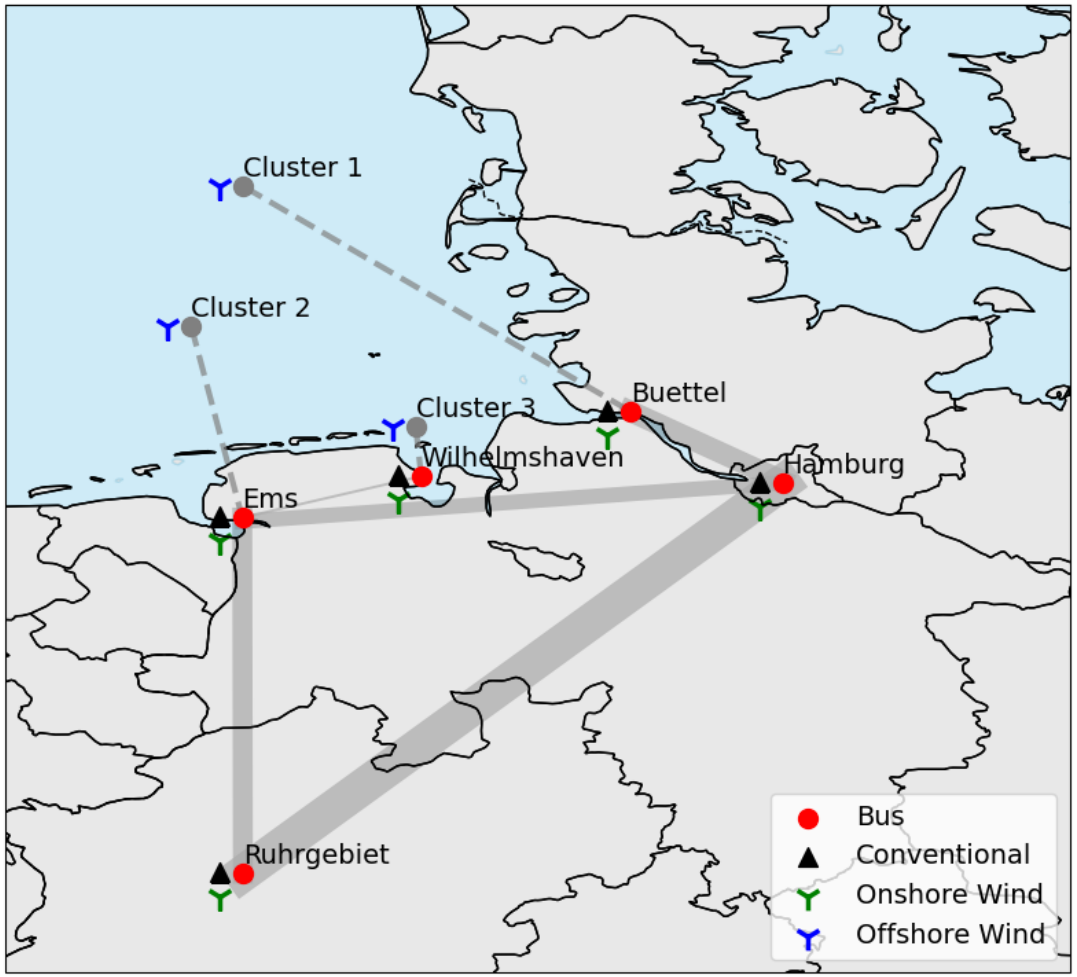






WindRamp-Network

- Grid topology used in *WindRamp* project
- 8.4 GW base load, 21.4 GW peak load
- 6.6 GW flexible and 15.4 GW inflexible conventional generators
  - Flexible generators (i.e. gas turbines) with limited ramping (+ 20% of installed capacity) in balancing
- 25 GW on- and offshore wind farms
- Analysis of 2022



Topology of the network. Demand hubs in Hamburg and the Ruhrgebiet. Wind farms in the North Sea. Transmission grid congestion in the North.

Using Lidar forecasts instead of NWP[1] products

- Employing Lidar forecast (from ForWind) at largest offshore cluster (7.1 GW) in 15 min intraday clearing
- System performance is greatly enhanced
  - System costs -15%
  - Activation of upward balancing -20%
  - Load shedding -40%
- Analyzing 18292 15-minute intervals from 2022 provided

		ECMWF[2] forecast	Lidar
$E_{\text{Wind}}^{\text{delivered}}$	(TWh)	18.7	18.7
E^{+}	(TWh)	1.4	1.1
E^{-}	(TWh)	0.3	0.4
E^{shed}	(TWh)	0.5	0.3
C^{total}	(M€)	660	560
$\langle \text{RMSE} \rangle_{g,t}$	(GW)	1.9	1.4

System indicators

$E^{\text{delivered}}$	E^{+},E^{-}	E^{shed}	C^{total}	$\langle \text{RMSE} \rangle_{g,t}$
Delivered energy	Balancing energy	Shedded energy	Total system operating costs	System RMSE in intraday

[1]NWP: Numerical weather prediction
[2]ECMWF: European Centre for Medium Range Weather Forecasts

How do Lidar forecasts and persistence compete?

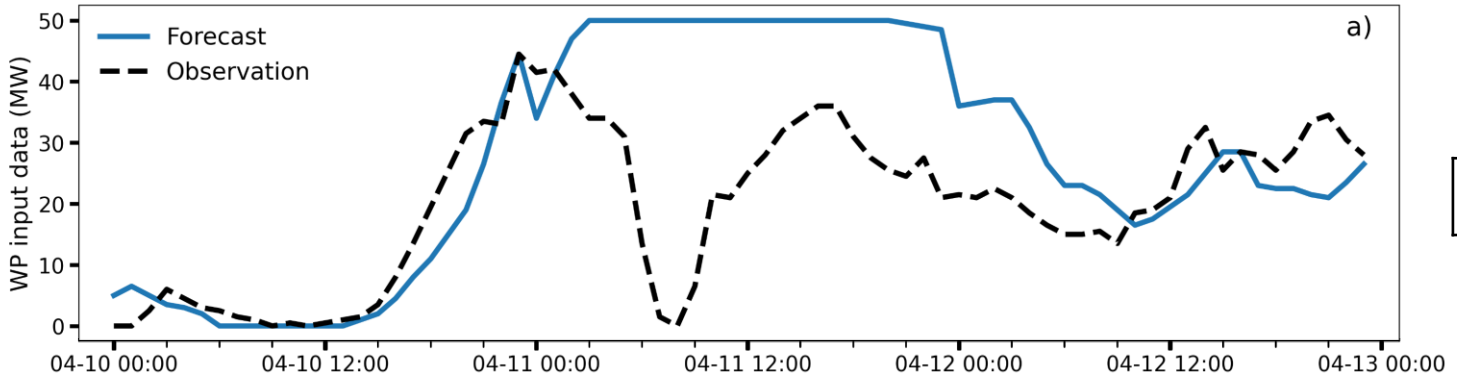
- The annually, averaged performance of Lidar forecast and persistence is very similar
- Analyzing of ramp events not conducted in the system context is limited by data availability
- 7192 15-minute intervals from 2022 available for analysis

Lidar forecasts

		Not calibrated	Calibrated	Persistence
$E_{\text{Wind}}^{\text{delivered}}$	(TWh)	10.70	10.70	10.70
E^{+}	(TWh)	0.64	0.64	0.64
E^{-}	(TWh)	0.21	0.19	0.19
E^{shed}	(TWh)	0.17	0.16	0.17
C^{total}	(M€)	305.1	303.6	304.5
$\langle \text{RMSE} \rangle_{g,t}$	(GW)	1.85	1.75	1.80

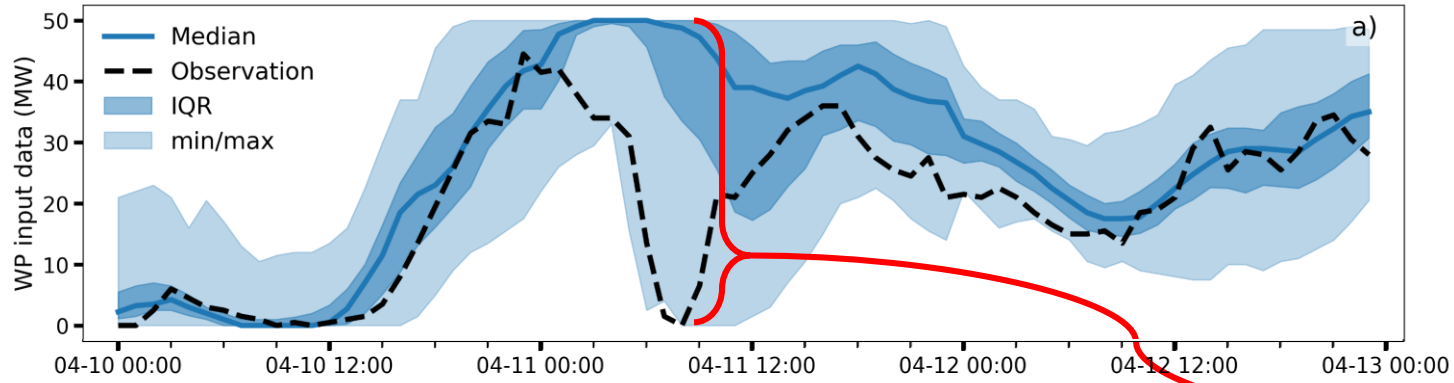
$E^{\text{delivered}}$	E^{+},E^{-}	E^{shed}	C^{total}	$\langle \text{RMSE} \rangle_{g,t}$
Delivered energy	Balancing energy	Shedded energy	Total system operating costs	System RMSE in intraday

Recent: Integrating uncertainty into planning



Deterministic clearing

min Day-ahead dispatch costs



Stochastic clearing

min Day-ahead dispatch costs
+ expected balancing costs

Ensemble members

(3) J. M. Morales et al., “Electricity market clearing with improved scheduling of stochastic production”, *European Journal of Operational Research*, vol. 235, pp. 765-774, 2014. doi.org/10.1016/j.ejor.2013.11.013

The use of forecast uncertainty in planning

- Utilizing forecast uncertainty has several advantages
  - Increased use of wind energy (+2%)
  - Decreased system operating costs (-42%)
  - Decreased activation of flexibilities
- Analysis of 18292 15-minute intervals from 2022
- Lidar forecasts employed at largest wind farm cluster

		Deterministic	Stochastic
$E_{\text{Wind}}^{\text{delivered}}$	(TWh)	18.7	19.1
E^{+}	(TWh)	1.4	0.5
E^{-}	(TWh)	0.3	1.2
E^{shed}	(TWh)	0.5	0.0
C^{total}	(M€)	660	380

$E^{\text{delivered}}$	E^{+},E^{-}	E^{shed}	C^{total}
Delivered energy	Balancing energy	Shedded energy	Total system operating costs

Conclusion

- The use of Lidar forecasts is advantageous from a system perspective
  - Reduced activation of flexibility (i.e. gas turbines or load shedding)
  - Increased delivery of wind energy
  - Use at large wind farms increases system impact
- Employing probabilistic power forecasts in power systems management reduces system operating costs
- Outlook
  - Analyzing impact of ramps on activation of short-term flexibilities
  - Integrating further clearings

Acknowledgements

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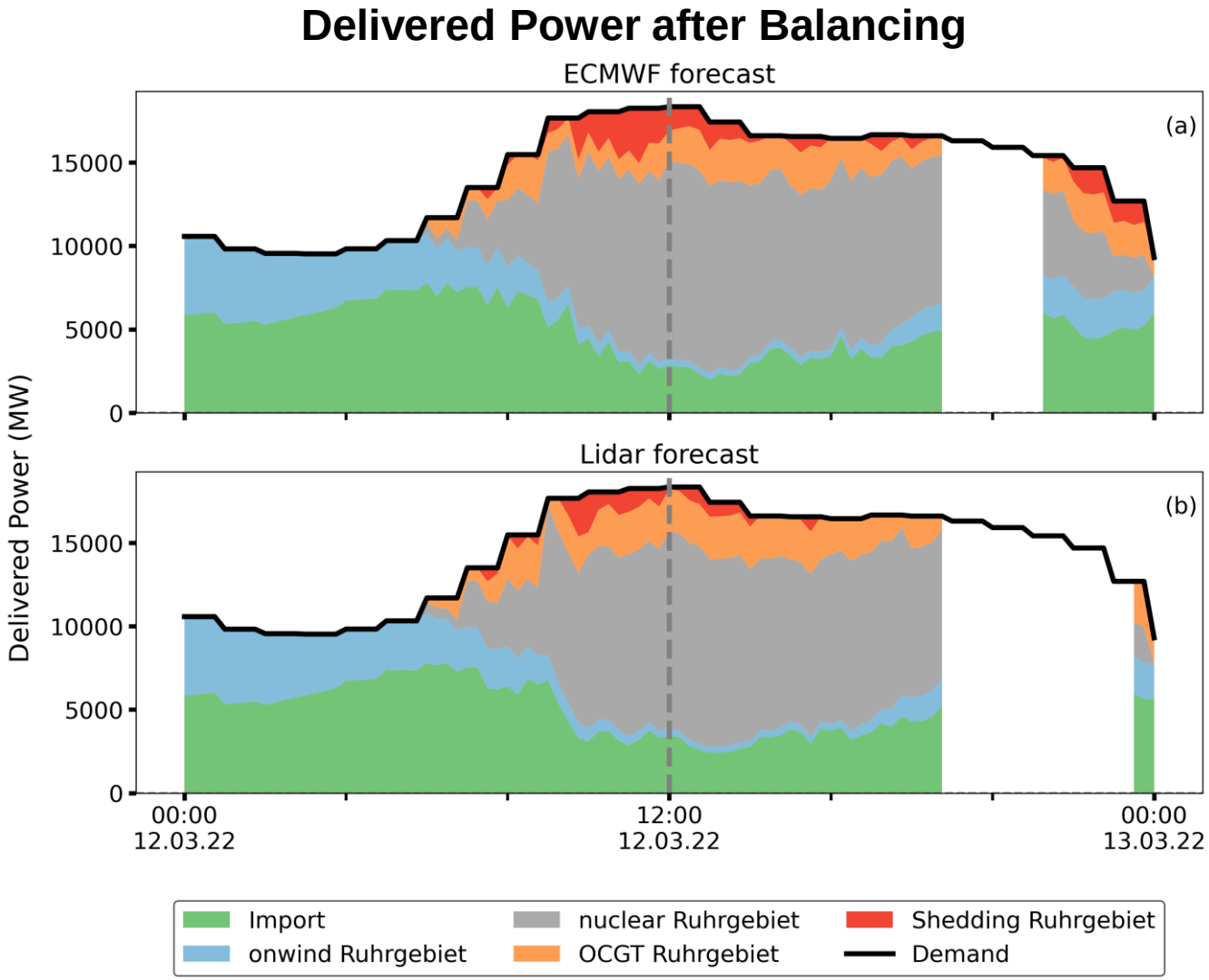
Backup: Ramps ECMWF vs Lidar forecast



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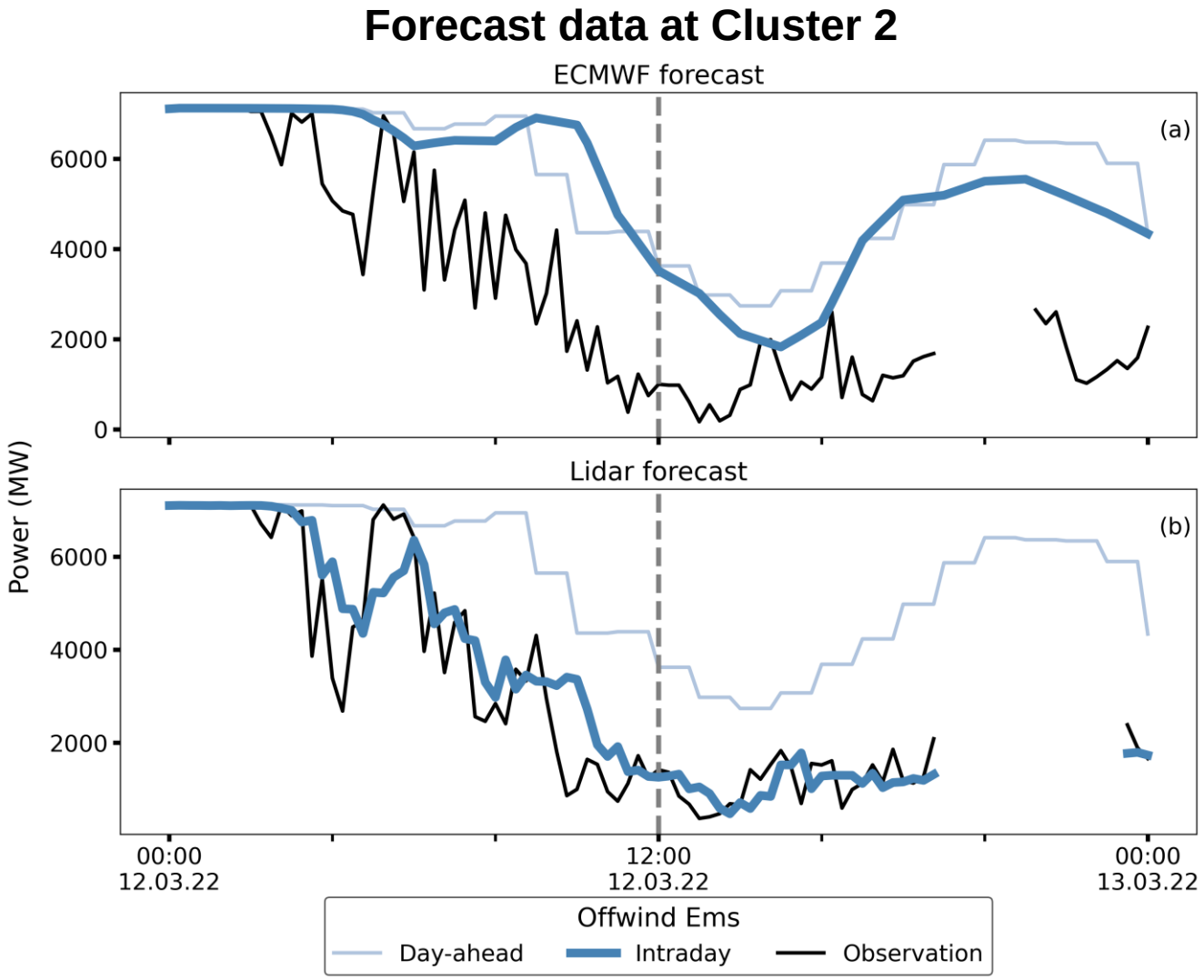

Backup: Ramps ECMWF vs Lidar forecast