



Preventing definition of flexibility actions for solving technical problems in electrical grids using uncertainty forecasts

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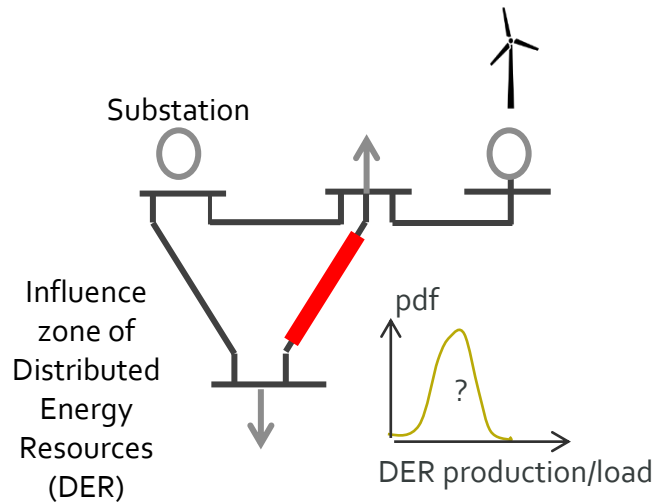
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Objectives

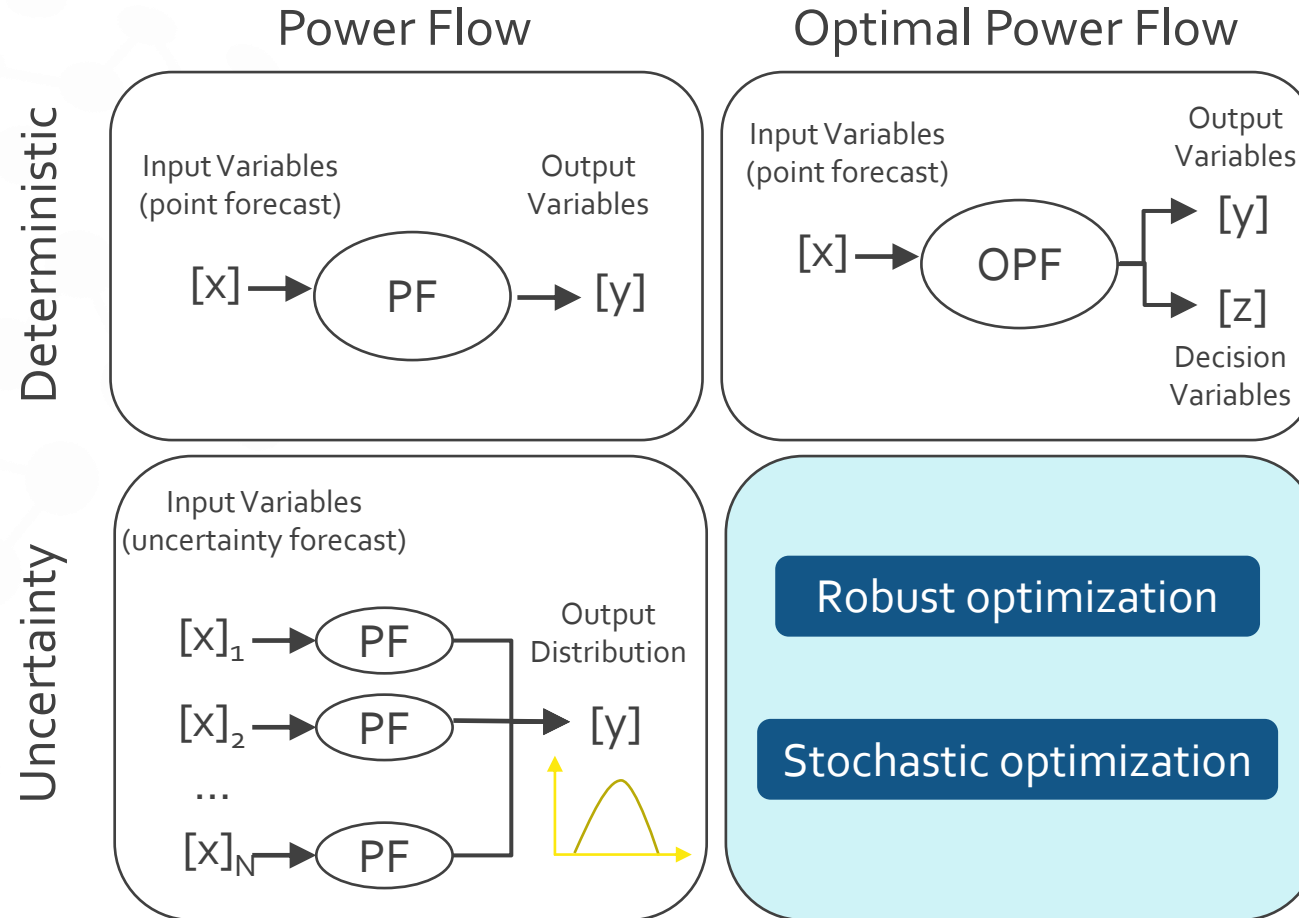


Flexibility: demand response, RES with capacity to increase/ decrease its operating point + grid resources (network reconfiguration, shunt elements, OLTC)

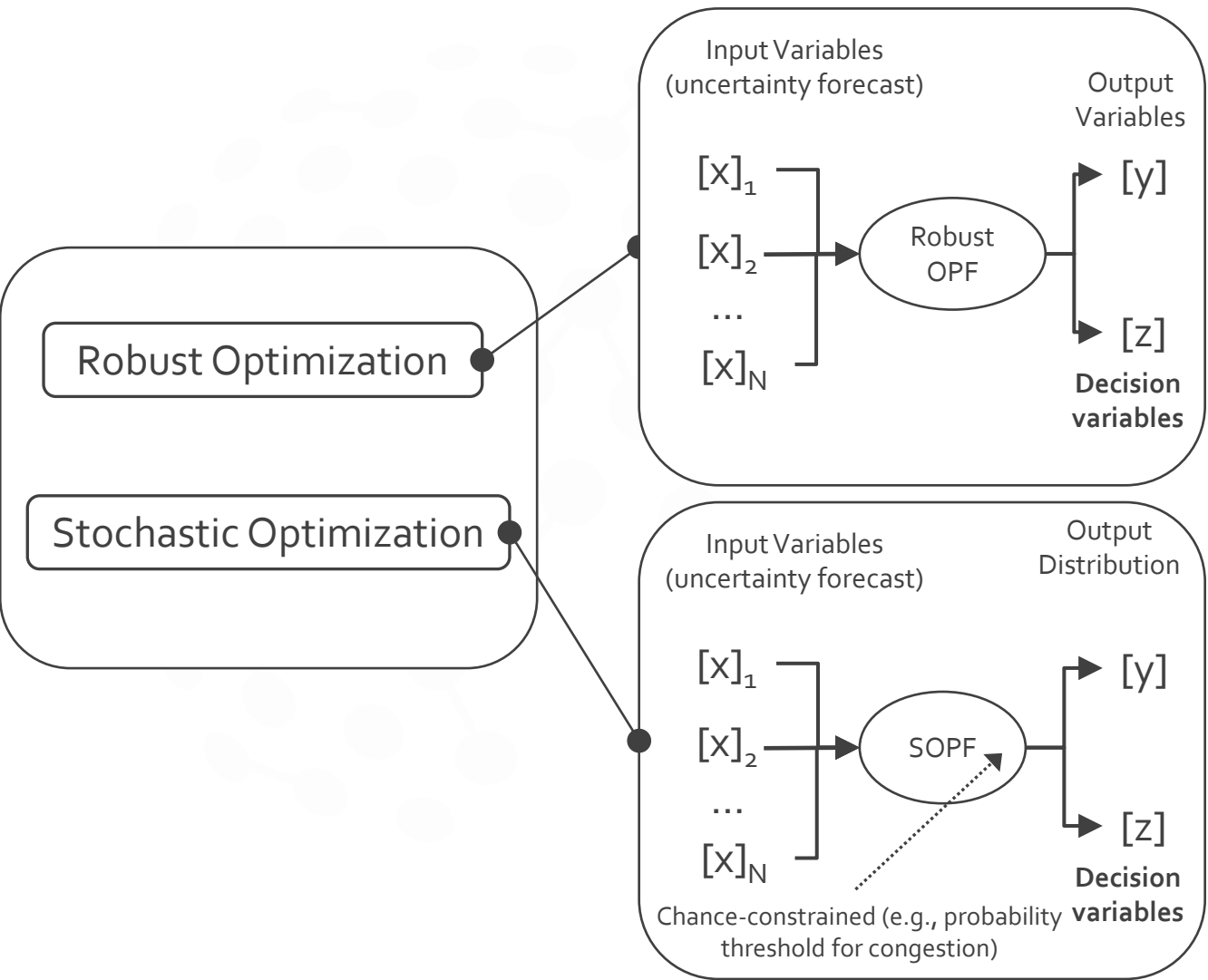
GOALS

- Define preventive actions (flexibility “booking”) under RES and load **forecast uncertainty**
- Propose a methodology to find the **“decision moment”** to “book” flexibility under uncertainty
- Supply the human operator with a **limited set of flexibility options**

Predictive management solutions



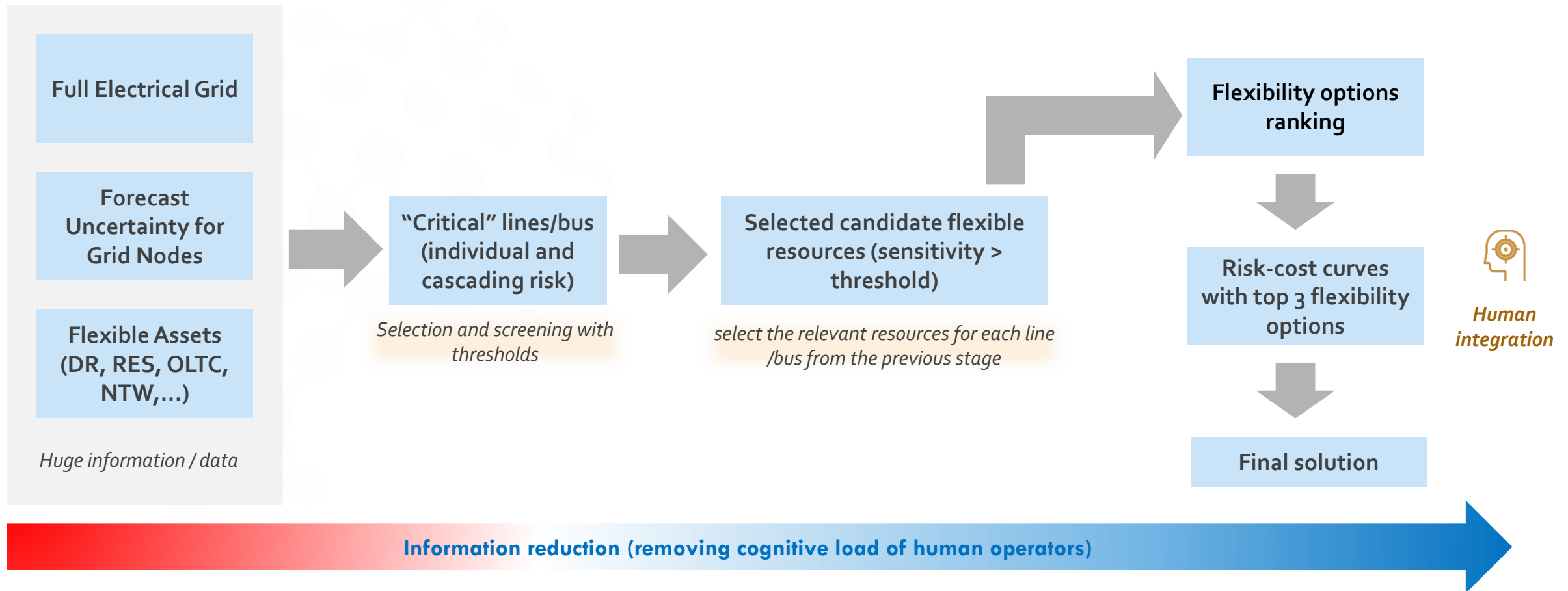
Academic state-of-the-art



- [+] Deliver optimal solutions
- [+] Explicit modelling of objective functions and constraints
- [-] High computational time to get decisions
- [-] Perceived as a “black-box” by operators
- [-] Delivers only one solution (limited interaction)

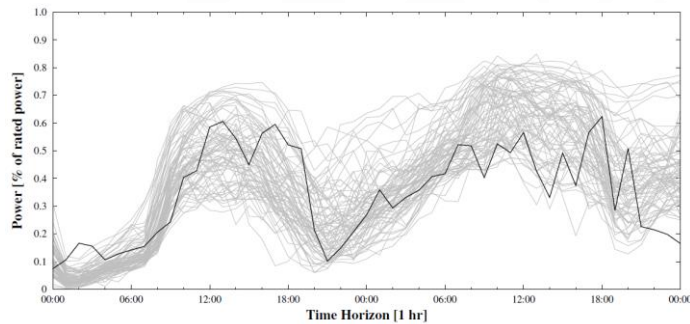
- ❑ Provides information about cause and effect → “interpretability”
- ❑ Multi-criteria information & iterative process (no optimization and “navigation” across solutions)

Smart4RES approach



Building blocks: Scenarios & sensitivities

Spatial scenarios generated with a Gaussian copula and marginal probability distributions



For each scenario compute sensitivity indices relating

$P, Q \sim$ Branch current ⁽¹⁾
 $P, Q \sim$ Node voltages ⁽¹⁾
NTW reconfiguration \sim Branch current (Z-bus + graph theory)

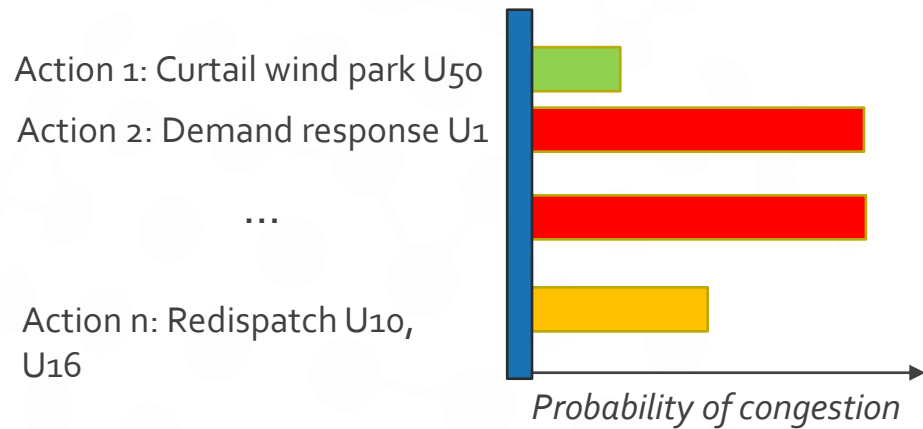
For each flexibility option a set of metrics are computed to characterize its *effectiveness*

- Expected flexibility cost
- Probability of congestion / voltage problem
- VaR of flexibility cost
- VaR of severity
- Expected severity

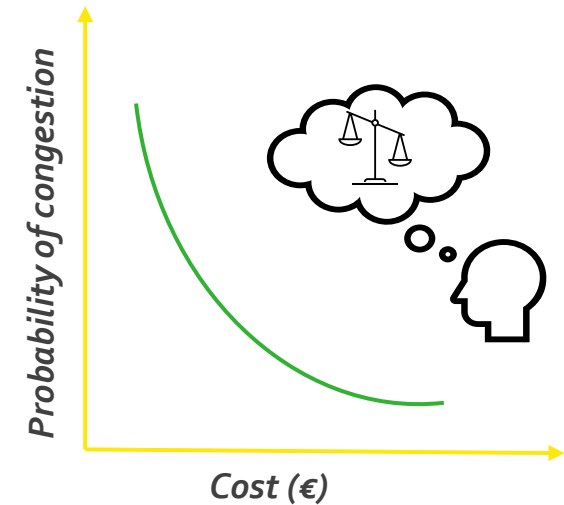
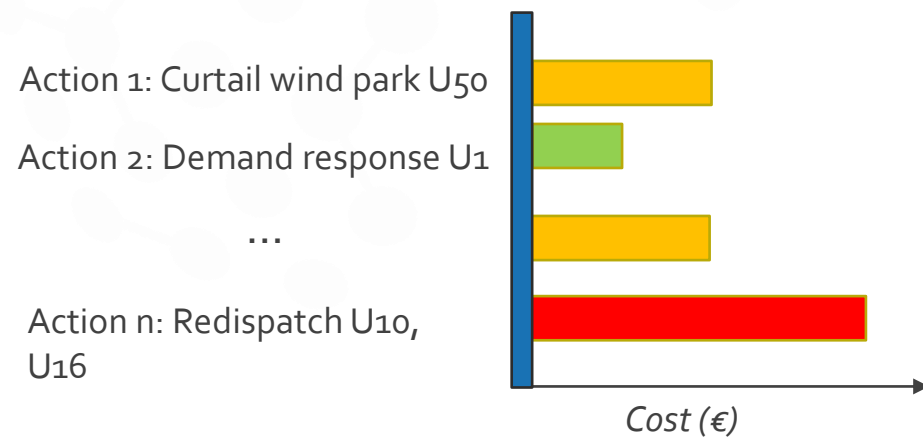
(1) Christakou, K., et al. (2013). Efficient computation of sensitivity coefficients of node voltages and line currents in unbalanced radial electrical distribution networks. IEEE Trans. on Smart Grid, 4(2), 741-750

Building blocks: Flexibility ranking and risk curves

Flexibility options ranking with TOPSIS

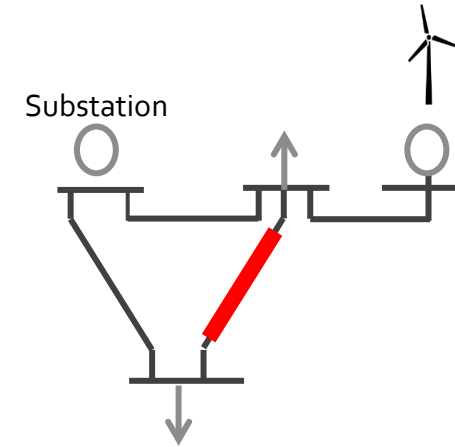


Combine top-3 flexibility options

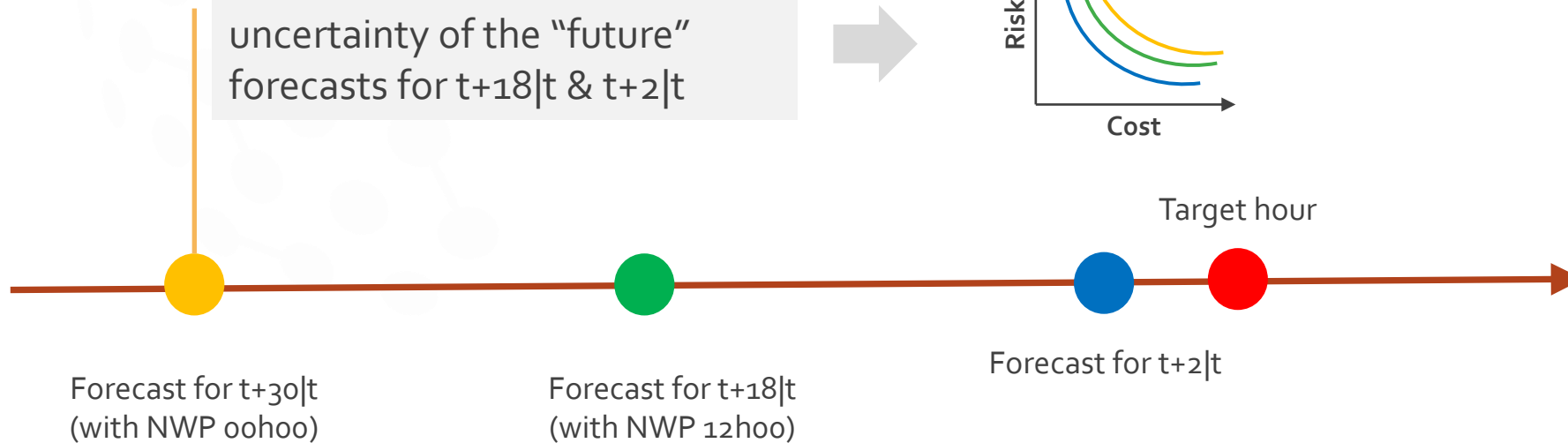
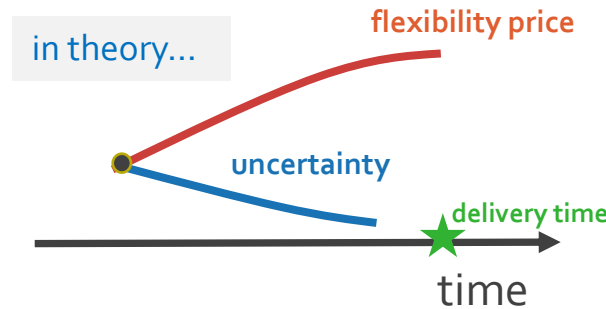
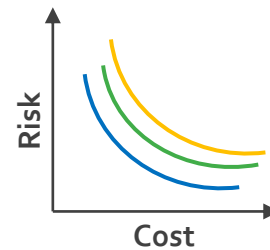


Rethink the decision problem

Probability of a congestion forecasted with NWP (ohoo) for day D+1 (lead time: $t+30$)
 > Decide now (i.e., "reserve" flexibility option) or wait for next forecast?

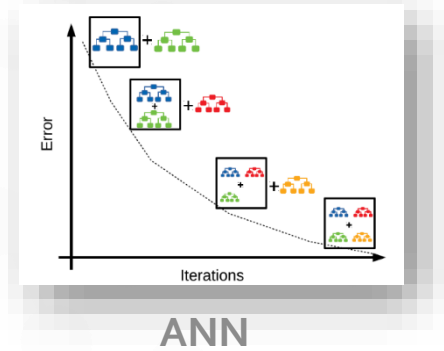


meta-forecast: forecast the uncertainty of the "future" forecasts for $t+18|t$ & $t+2|t$

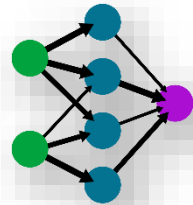


Building blocks: Meta-forecasting model

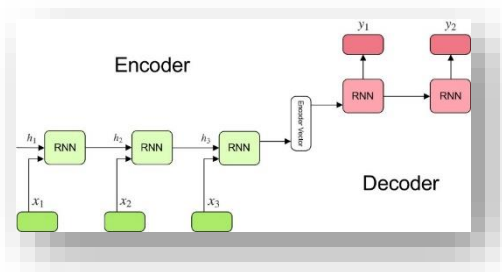
Gradient Boosting Trees



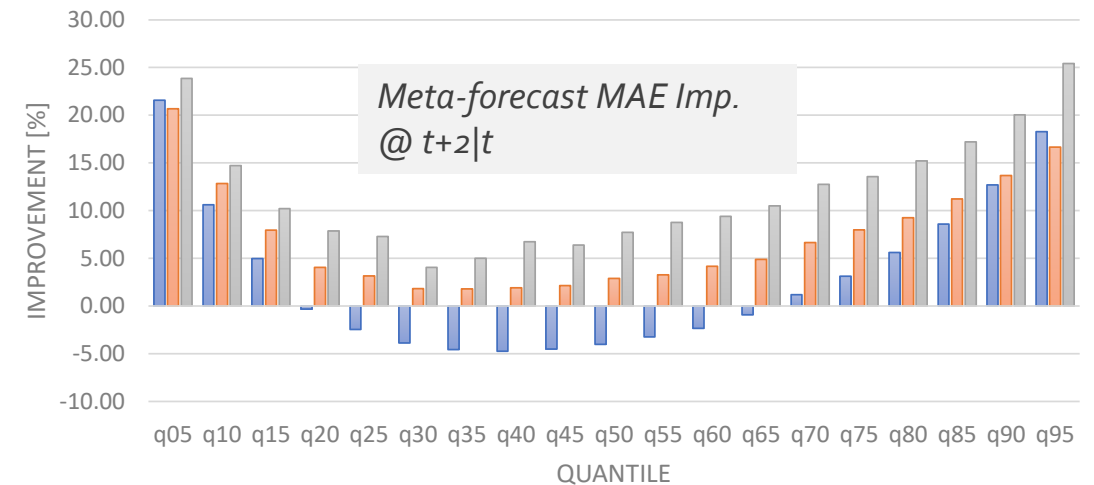
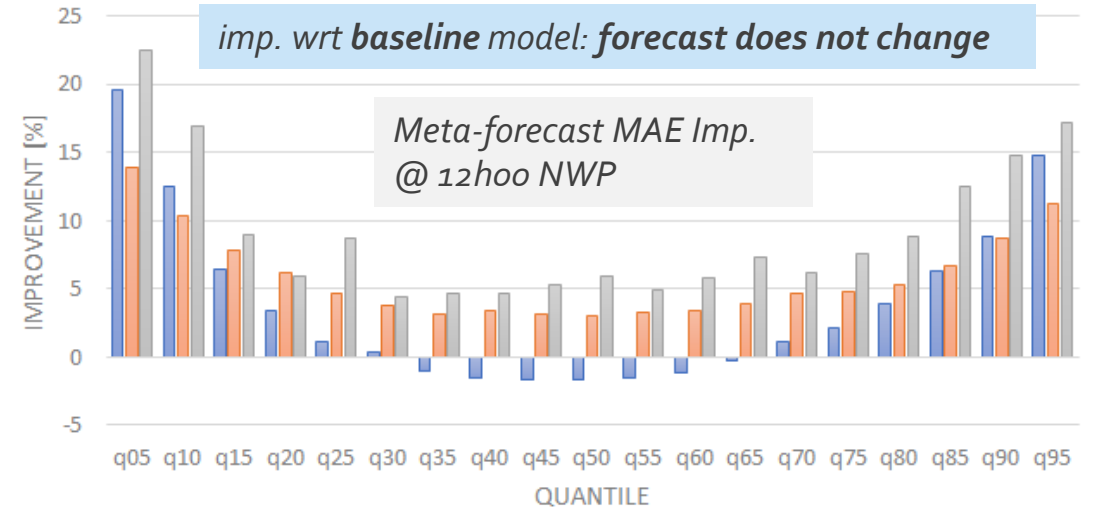
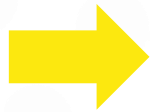
ANN

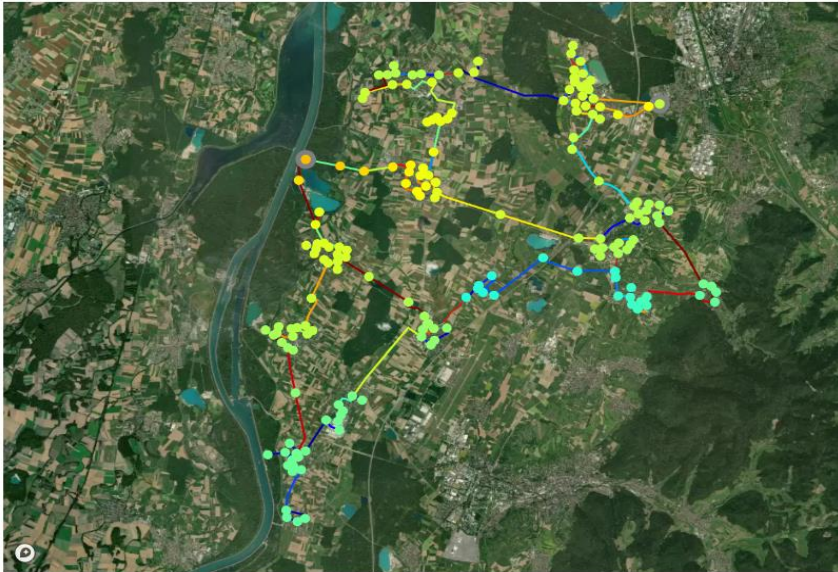


RNN



Forecasted generated with ohoo NWP
+
Features characterizing level uncertainty (IQR, forecasted quantiles, stdev.)





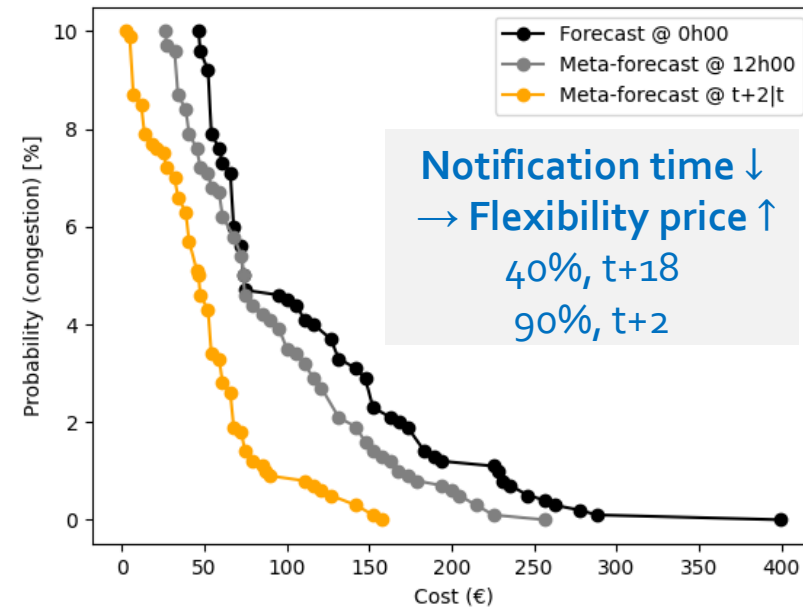
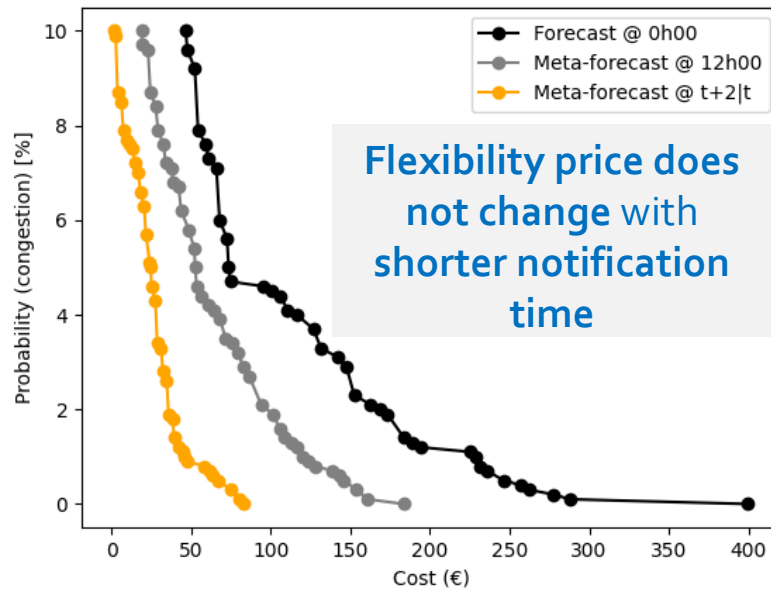
- ❑ **Modified Oberrhein MV network**
- ❑ **Load time series:** Measurements from Iowa Distribution Test Systems⁽¹⁾
- ❑ **RES time series:** French dataset (Smart4RES) + ECMWF NWP data
- ❑ Rated power of wind power plants and consumption values adjusted to create technical problems in 1-year of data
- ❑ Only wind power forecast uncertainty is used (perfect forecasts for load)
- ❑ Flexibility prices randomly sampled between 10 and 30 €/MWh

(1) Z. Wang, "Iowa Distribution Test Systems", Available: <http://wzy.ece.iastate.edu/Testsystem.html>

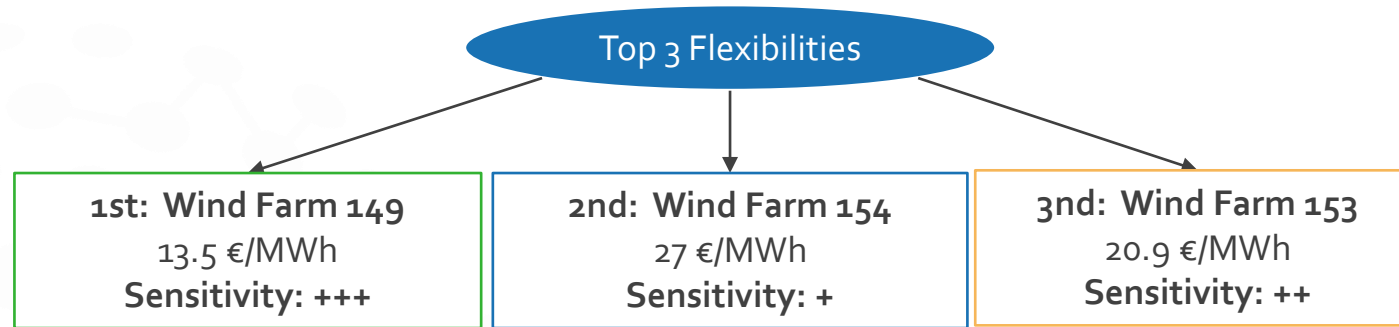
Results: Congestion case 1

False negative case (not detected by a point forecast) for one line

Point forecast: 87.7% of line loading
Real: value 170% of line loading



Results: Congestion case 1



Action for probability threshold = 5%			
Forecast/ actions	Action 1 (wind farm 149)	Action 2 (wind farm 154)	Action 3 (wind farm 153)
ohoo	11.2%	9.5%	9.91%
12hoo	8.47%	6.95%	6.56%
t+2	8.41%	2.91%	7.09%

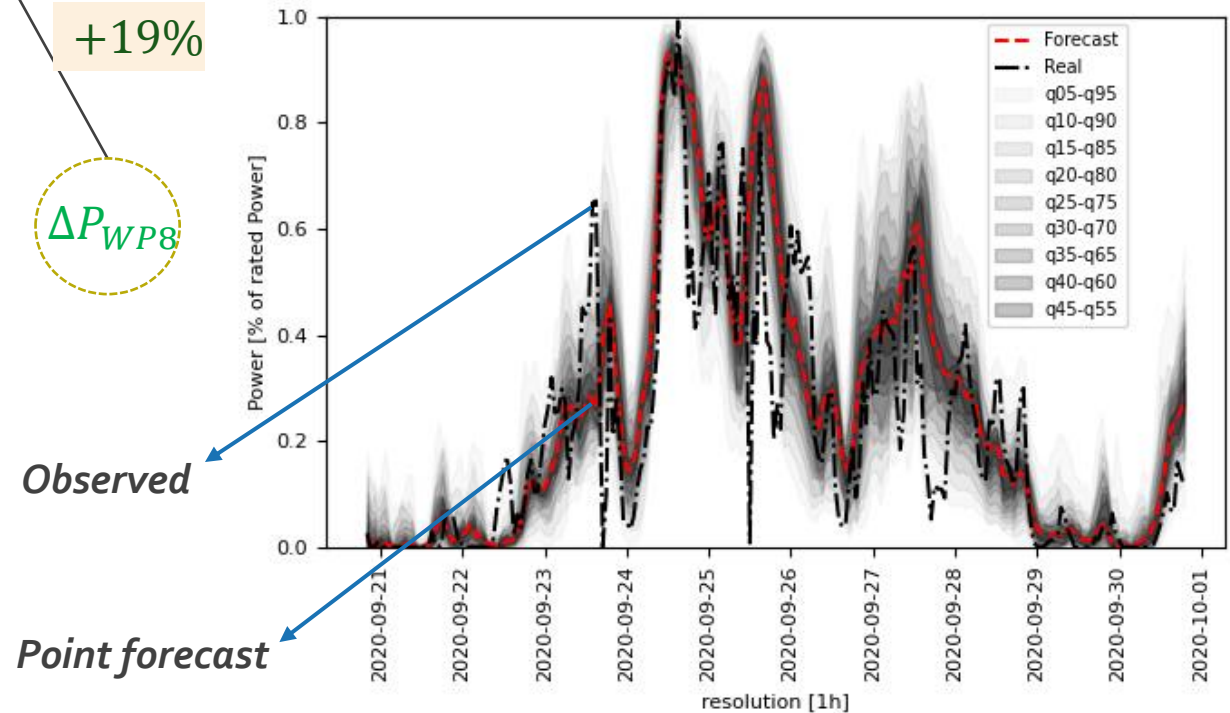
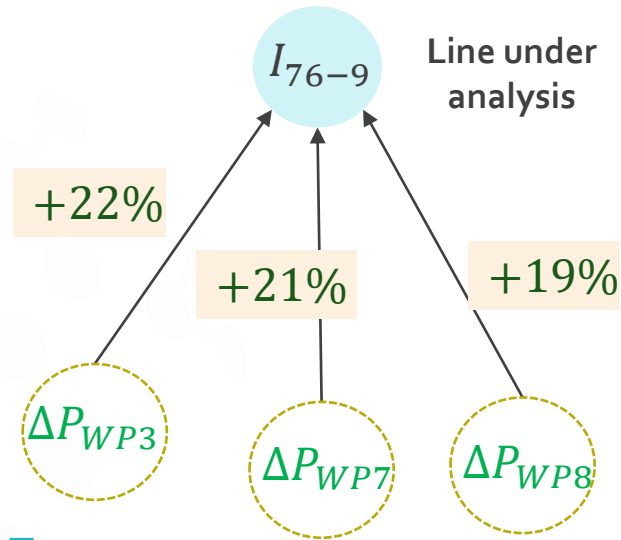
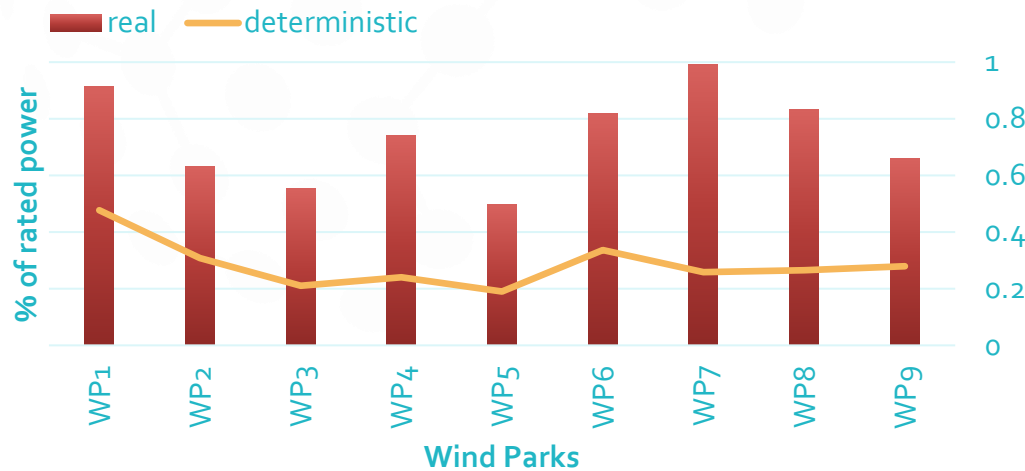
Impact of the action: Congestion solved if the probability threshold is 5%, 1%, 0.1%

Results: Congestion case 1

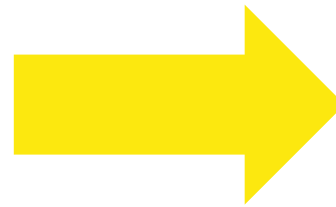
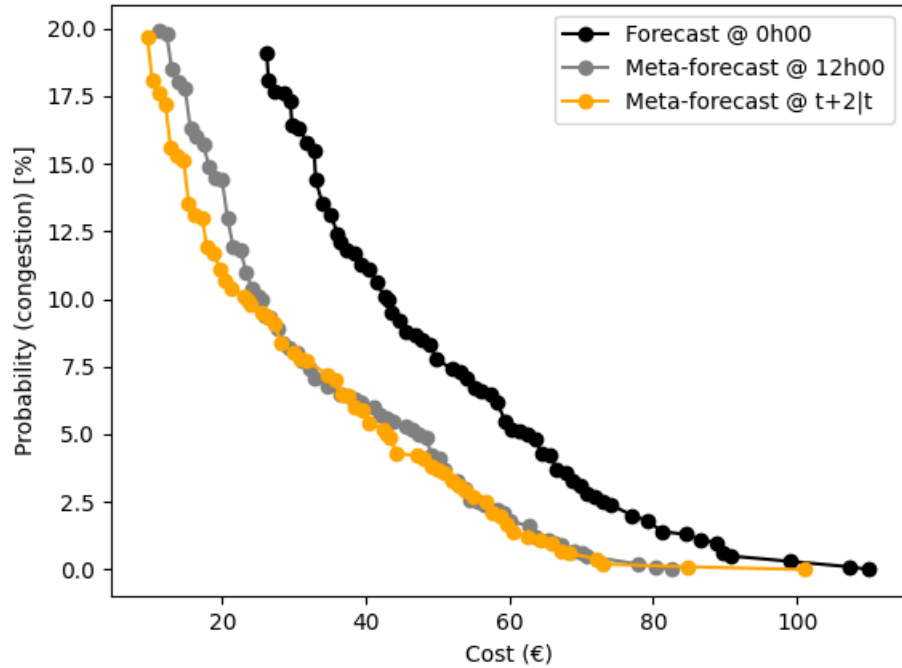
A high forecast error originated deviations in line loading (overload of 170%)



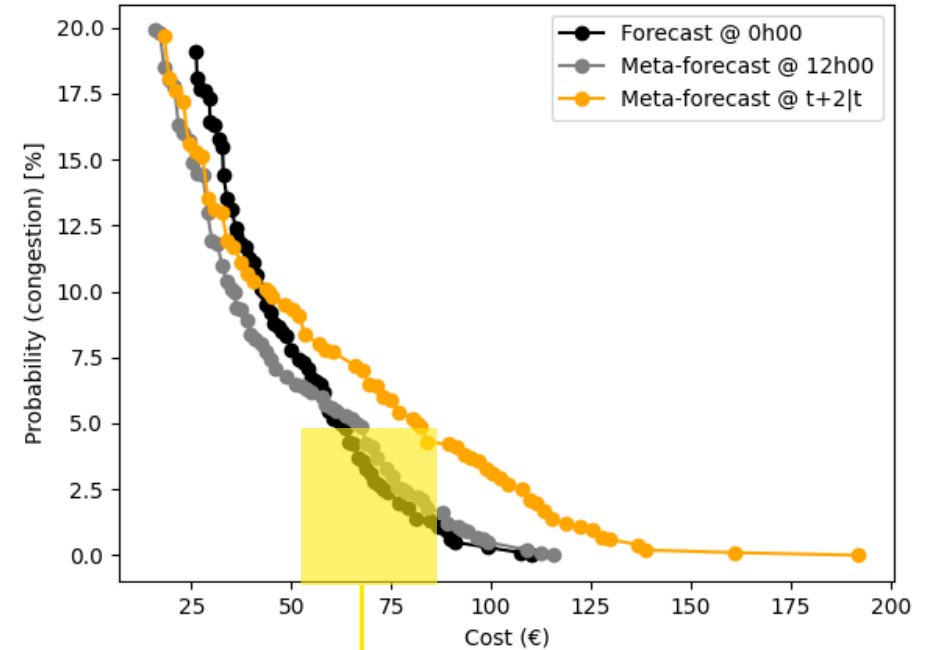
Day 12, hour 7



Results: Congestion case 2



*Increase in flex. price
over time: 40%
increment at 12h00
and 90% increment at
t+2*



for these thresholds it is better to buy flexibility now and not wait for a forecast update

- This method brings the following advantages
 - **Higher interpretability** → **contribute to increase adoption by human operators** of information from forecast uncertainty & advanced forecast products (e.g., NWP ensembles)
 - **High capacity** and **flexibility for parallelization**
 - Can be combined with existing rules for grid operation
- The **main limitation is the lack of an optimization engine**...yet under uncertainty optimality is a “fuzzy” concept
- **Future work**
 - Improve the meta-forecasting approach (integrate weather ensemble data)
 - Formulate interaction with human decision-maker (e.g., confidence-based decision making)
 - Design a methodology and metrics to measure decision quality under uncertainty



THANK YOU !



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