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

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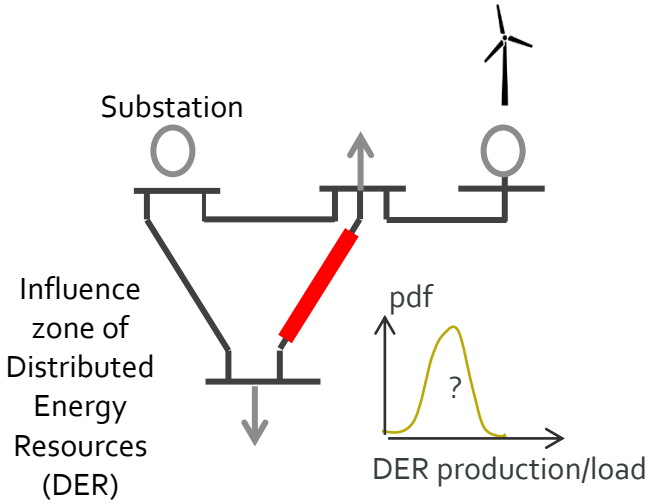
Objectives



DSO/TSO

1. Assessment of grid technical constraints using by RES and load forecasts

Flexibility Market

2. Booking of flexibilities options

DSO/TSO

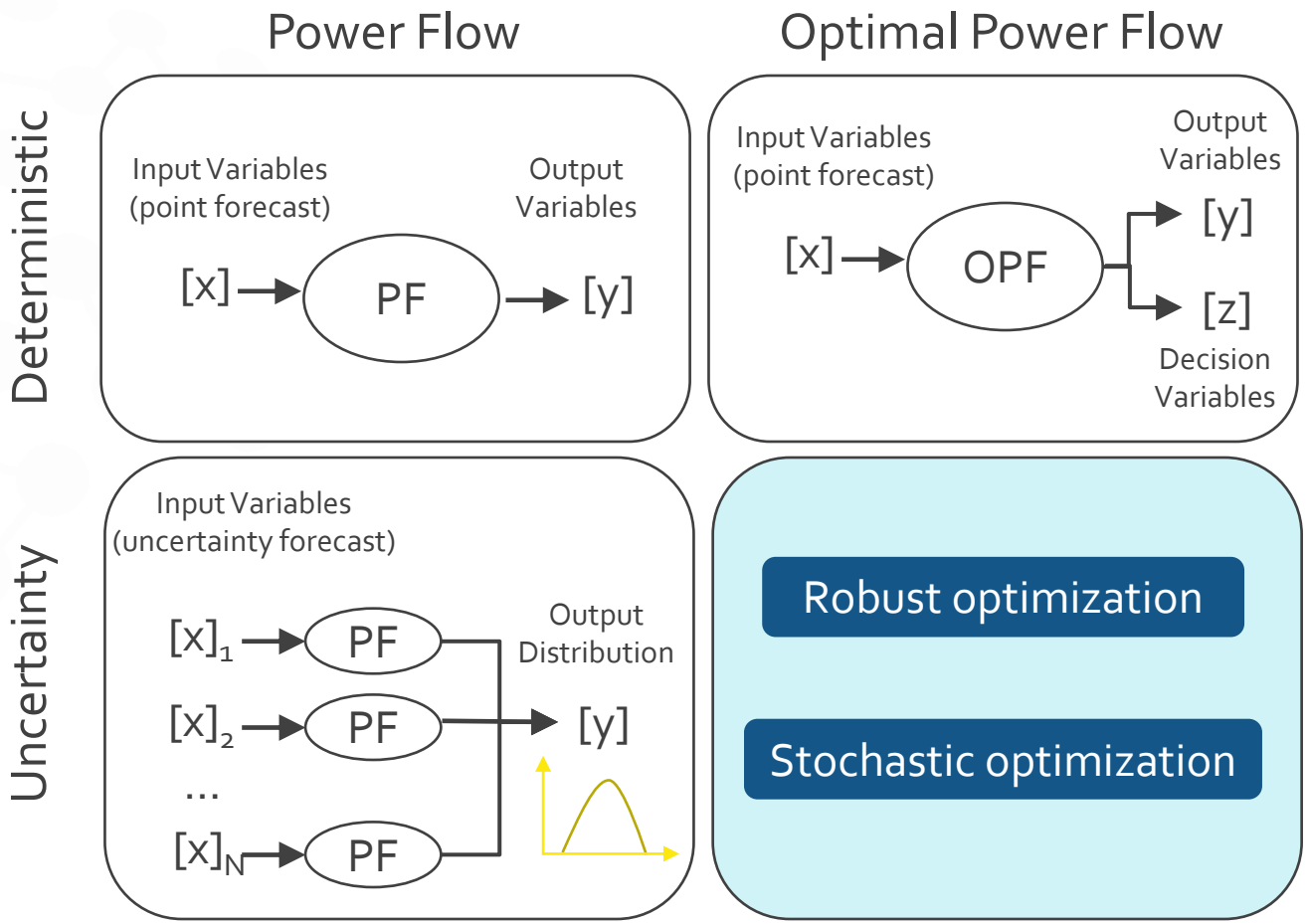
3. Activation of flexibilities (DER, NTW reconf., etc.)

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

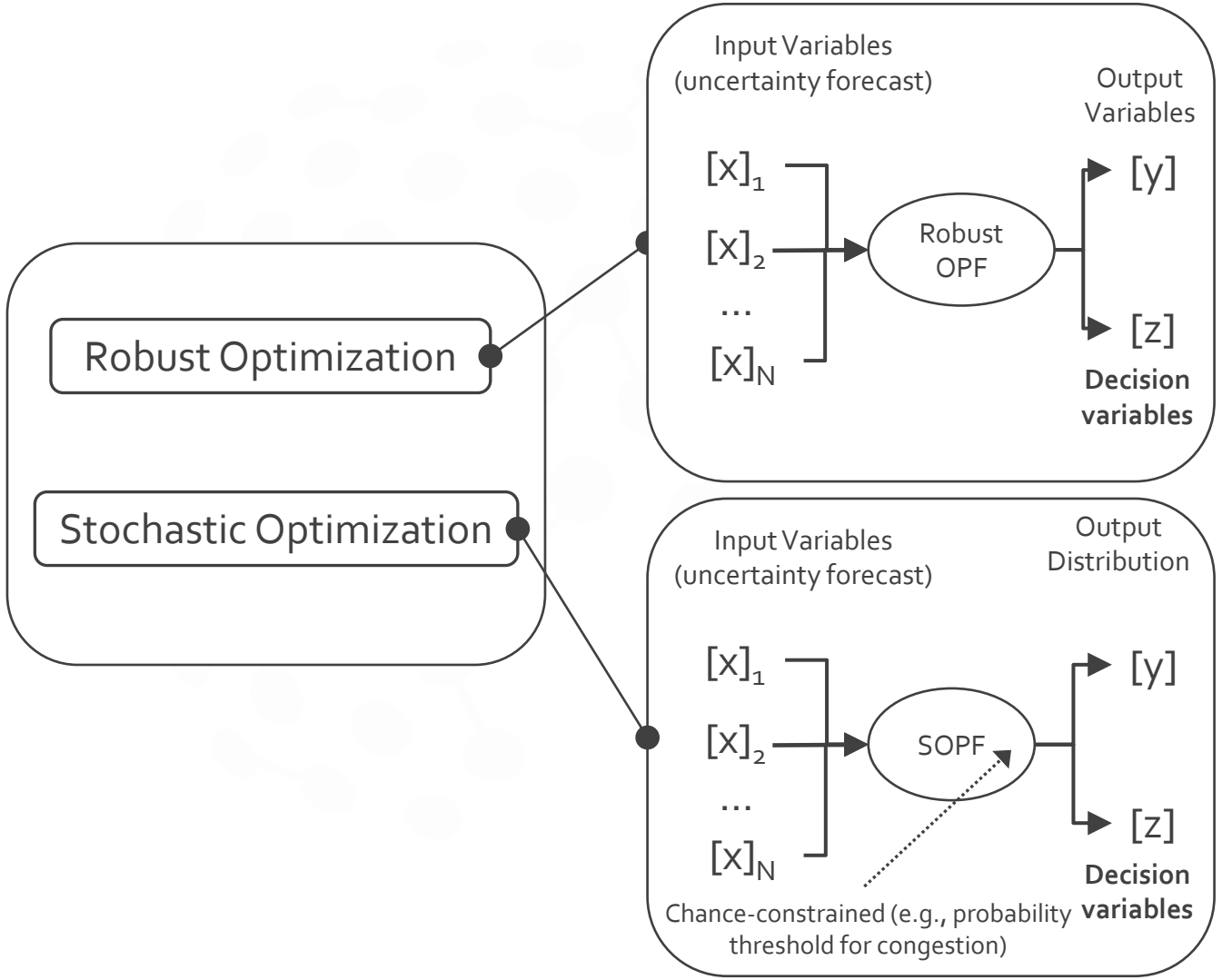
GOALS

- 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

Full Electrical Grid

Forecast Uncertainty for Grid Nodes

Flexible Assets (DR, RES, OLTC, NTW,…)

Huge information / data

"Critical" lines/bus (individual and cascading risk)

Selection and screening with thresholds

Selected candidate flexible resources (sensitivity > threshold)

select the relevant resources for each line /bus from the previous stage

Flexibility options ranking

Risk-cost curves with top 3 flexibility options

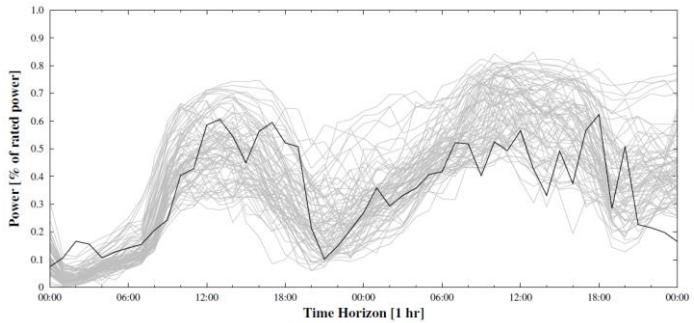
Final solution

Human integration

Information reduction (removing cognitive load of human operators)

Building blocks: Scenarios & sensitivities

Spatial scenarios generated with a Gaussian copula and marginal probability distributions



For each scenario compute sensitivity indices relating

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

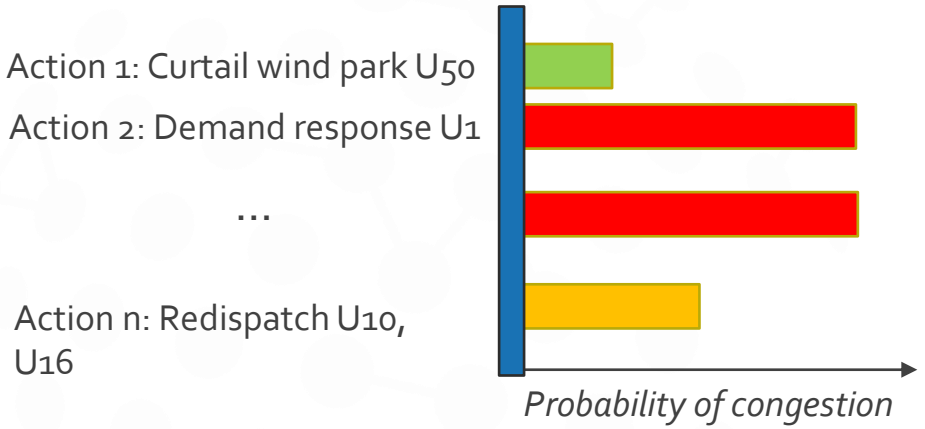
For each flexibility option a set of metrics are computed *to characterize its* ***effectiveness***

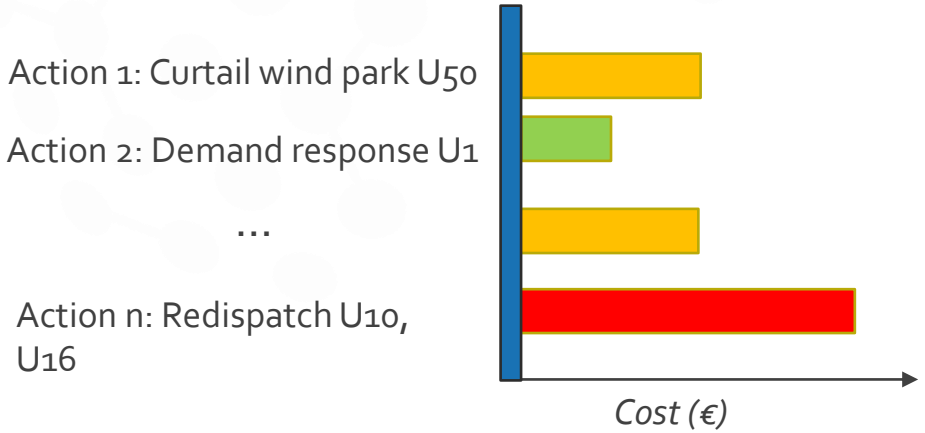
- **Expected flexibility cost**
- **Probability of congestion / voltage problem**
- **VaR of flexibility cost**
- **VaR of severity**
- **Expected severity**

(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

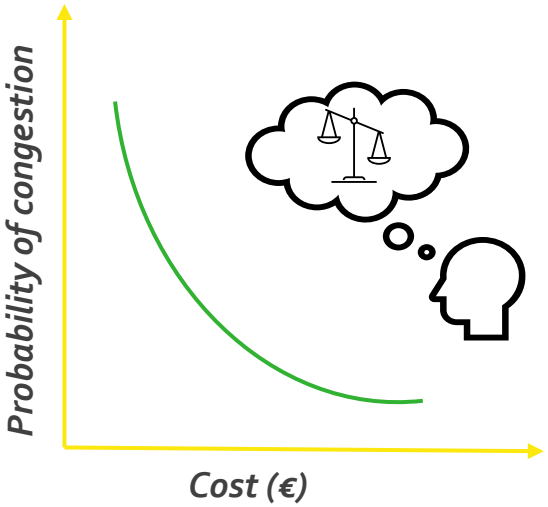
Building blocks: Flexibility ranking and risk curves

Flexibility options ranking with TOPSIS



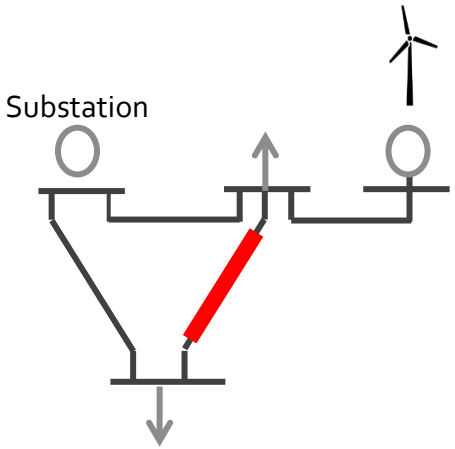


Combine top-3 flexibility options

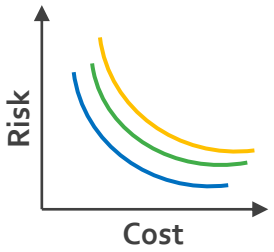


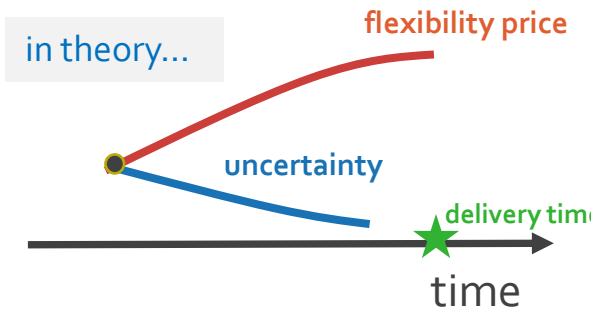
Rethink the decision problem

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





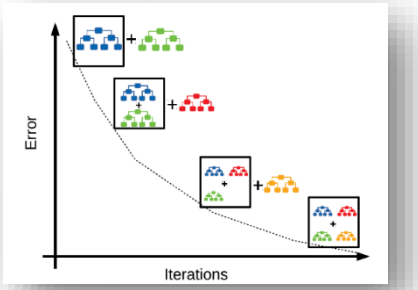
Building blocks: Meta-forecasting model

Forecasted generated with ohoo NWP

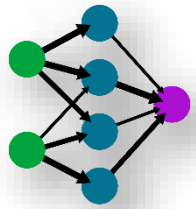
+

Features characterizing level uncertainty (IQR, forecasted quantiles, stdev.)

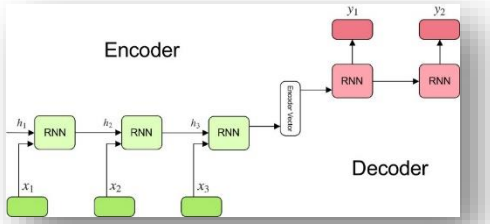
Gradient Boosting Trees



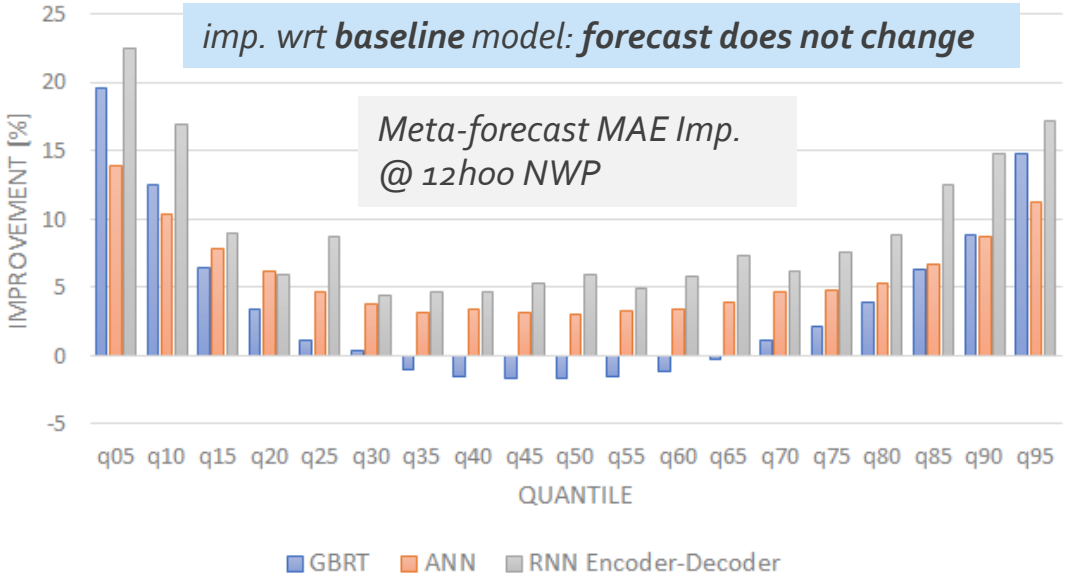
ANN

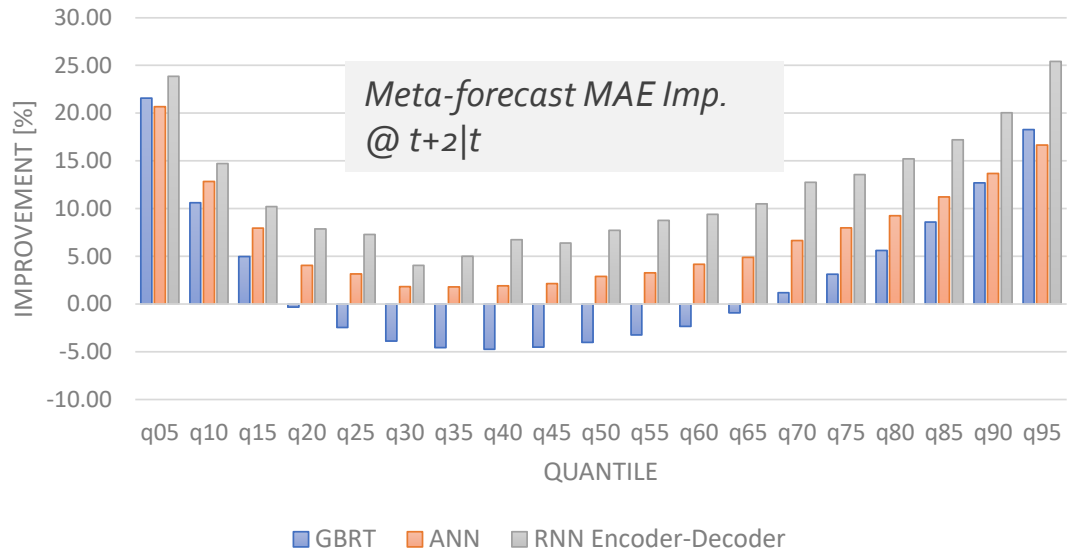


RNN

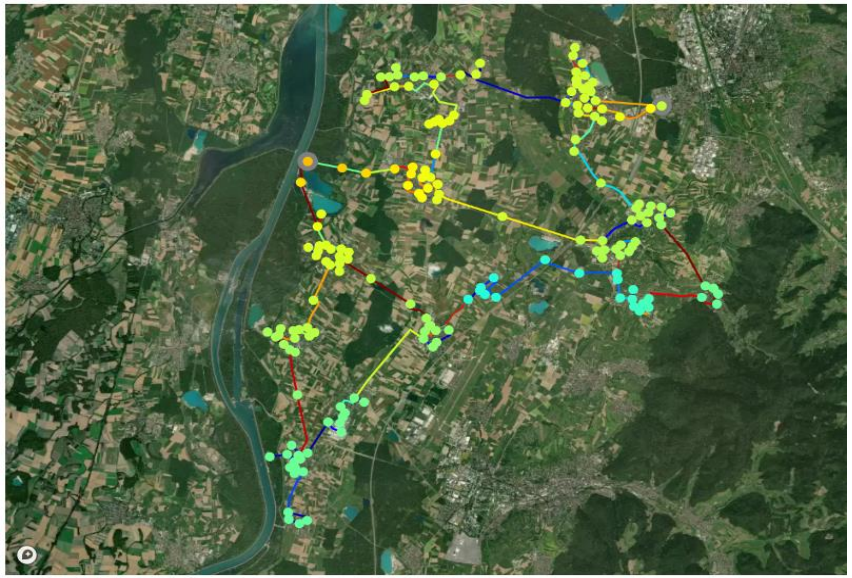


*imp. wrt **baseline** model: **forecast does not change***





Case-study



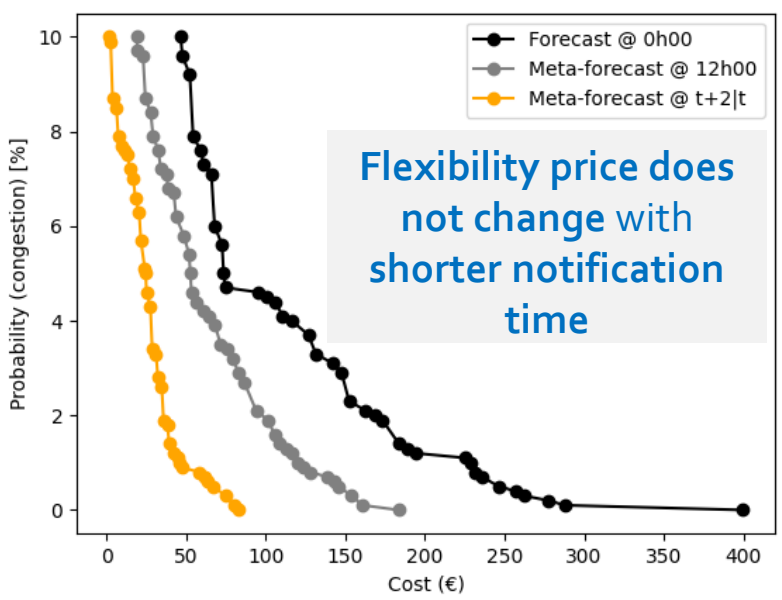
- **Modified Oberrhein MV network**
- **Load time series:** Measurements from Iowa Distribution Test Systems(1)
- **RES time series:** French dataset (Smart4RES) + ECMWF NWP data
- Rated power of wind power plants and consumption values adjusted to create technical problems in 1-year of data
- Only wind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

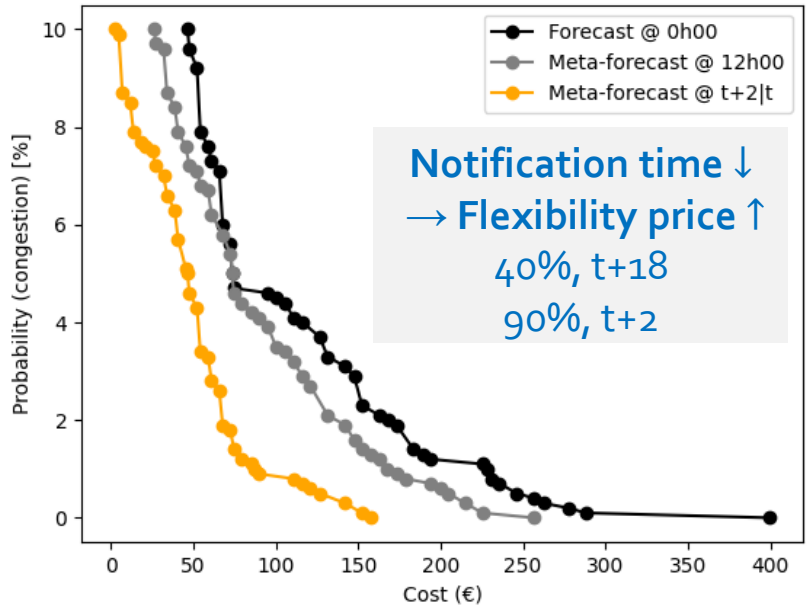
(1) Z. Wang, "Iowa Distribution Test Systems", Available: http://wzy.ece.iastate.edu/Testsystem.html

Results: Congestion case 1

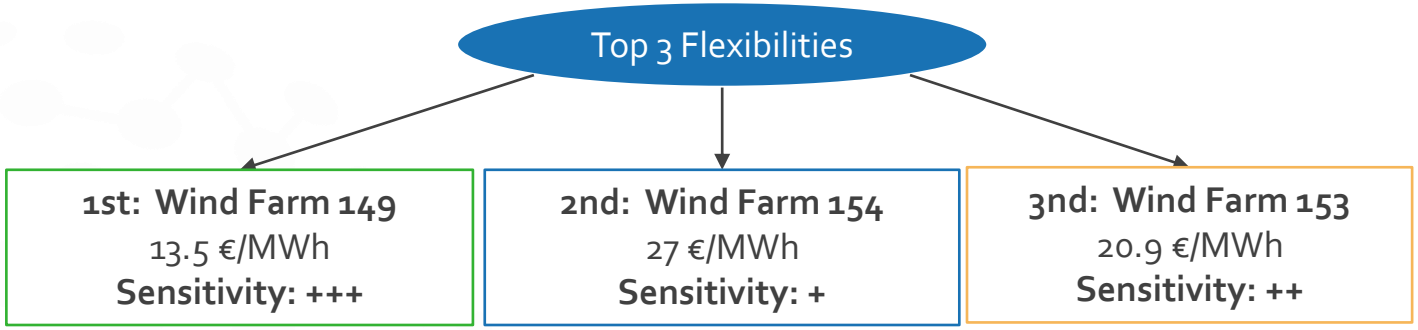
False negative case (not detected by a point forecast) for one line

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





Results: Congestion case 1

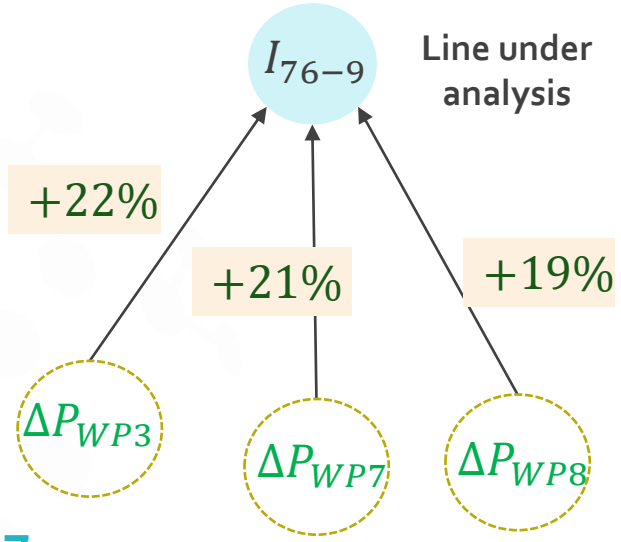


Action for probability threshold = 5%			
Forecast/ actions	Action 1 (wind farm 149)	Action 2 (wind farm 154)	Action 3 (wind farm 153)
0h00	11.2%	9.5%	9.91%
12h00	8.47%	6.95%	6.56%
t+2	8.41%	2.91%	7.09%

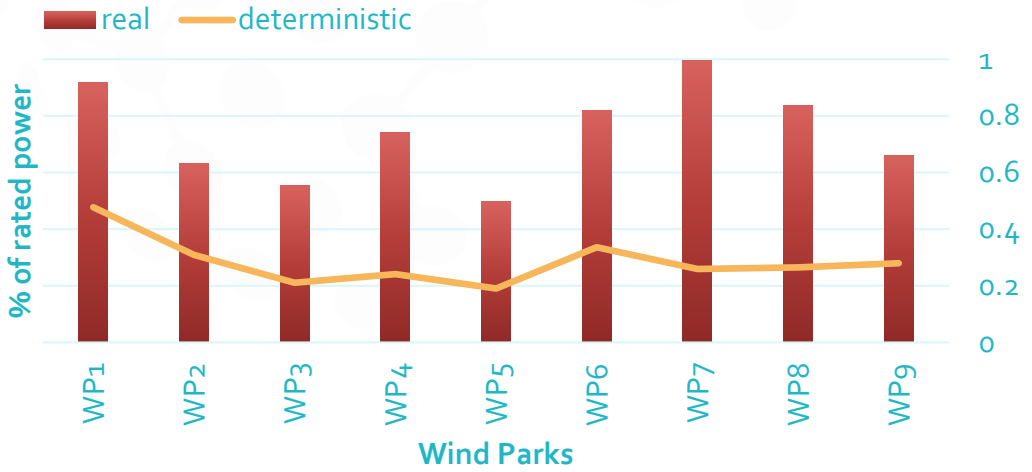
Impact of the action: Congestion solved if the probability threshold is 5%, 1%, 0.1%

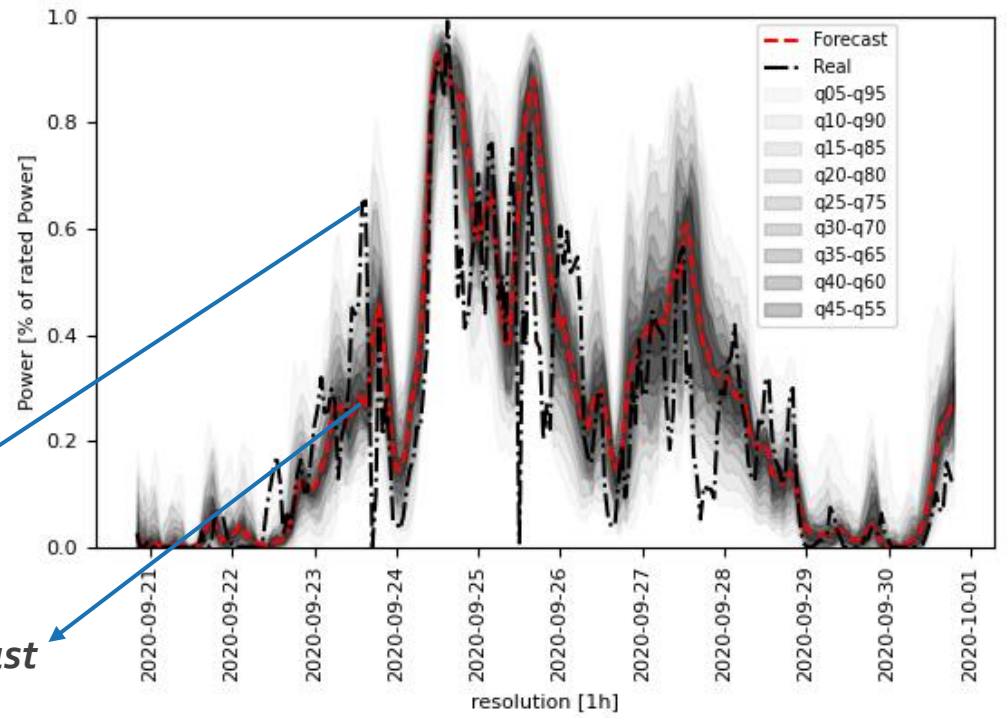
Results: Congestion case 1

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

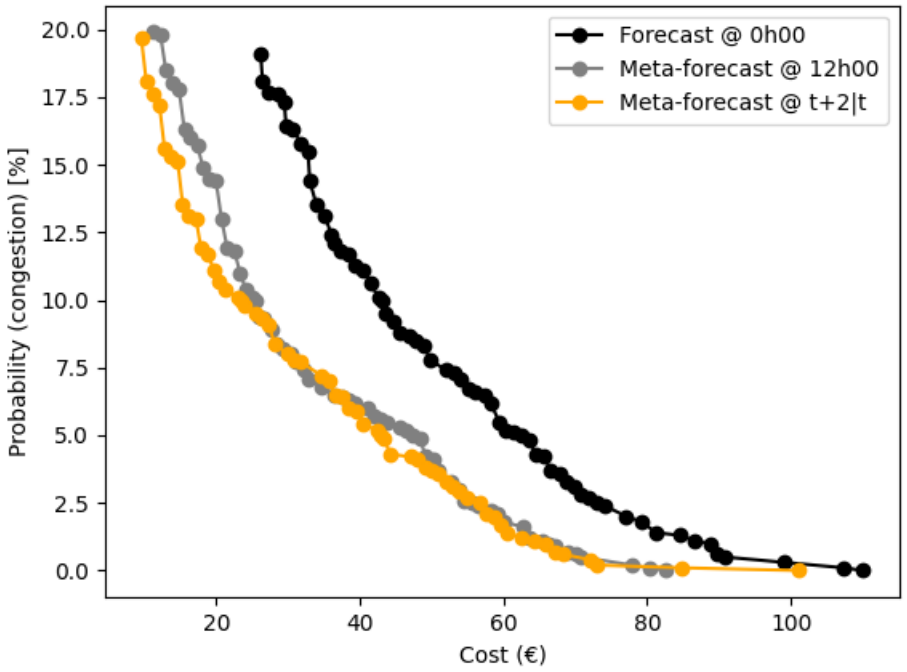


Day 12, hour 7

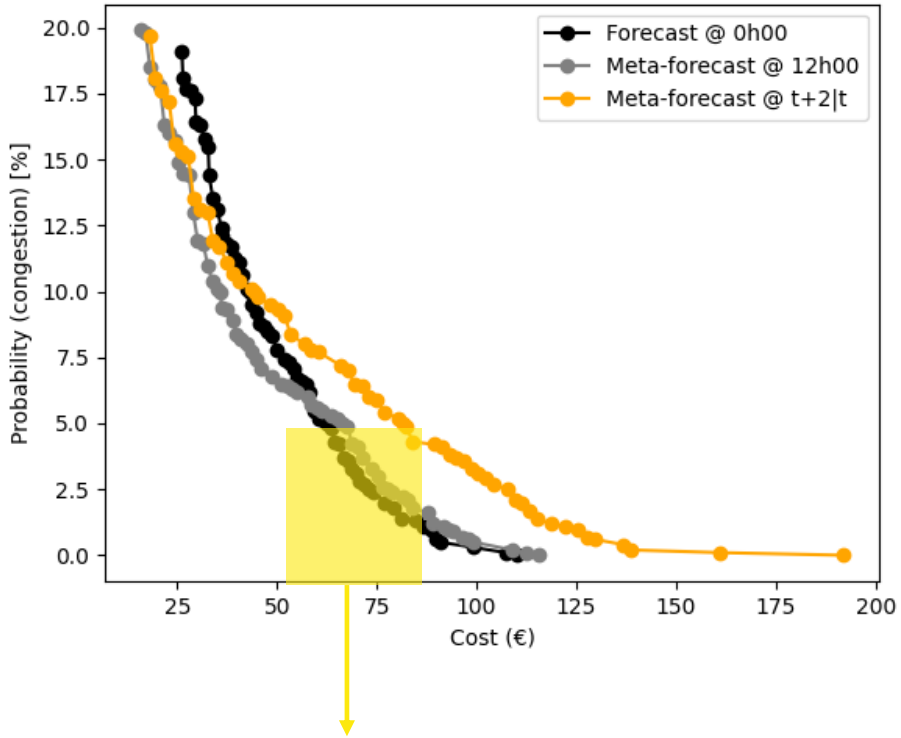




Results: Congestion case 2



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

Conclusions and future work

- 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

Smart4RES

THANK YOU !

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