The GARPUR Quantification Platform

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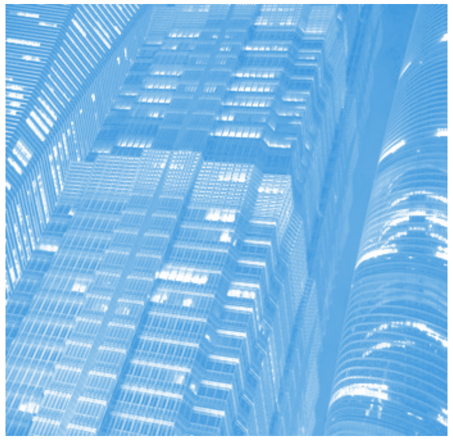
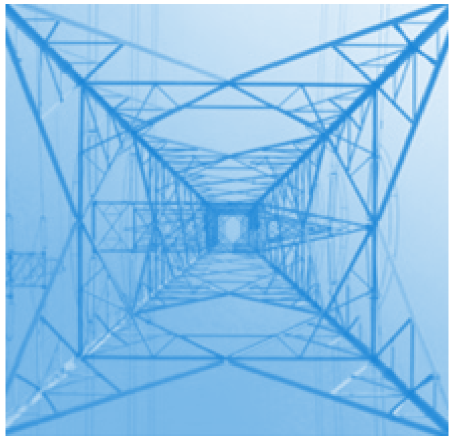
OUTLINE

Reliability criteria

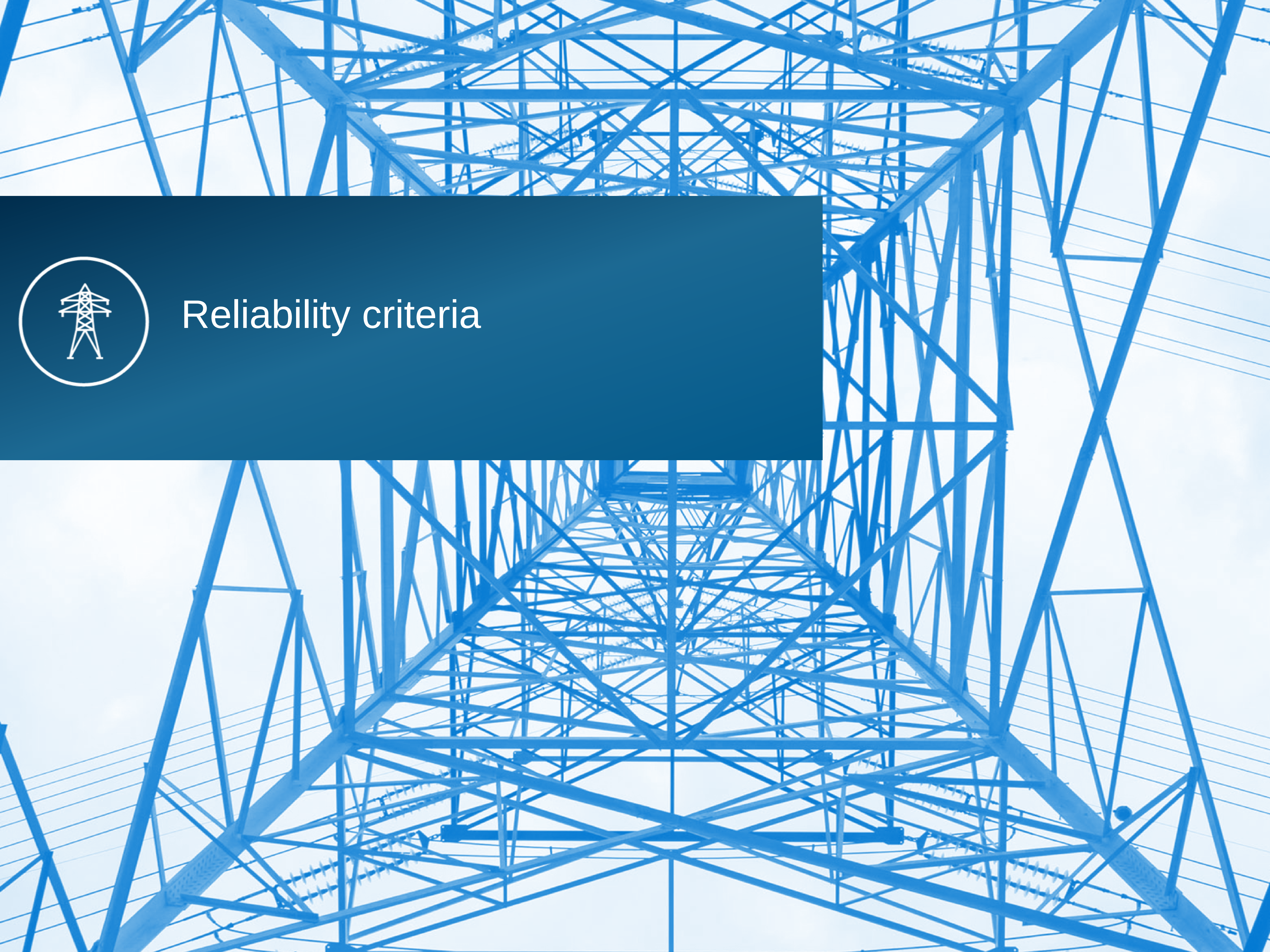
The Garpur RMAC



The “Garpur Quantification Platform” – GQP:
- Architecture
- Modules



Conclusions / lessons learned



Reliability criteria

Reliability criteria

- Why compare reliability criteria?
  - Current N-1 criterion (or derivations) is not perfect
  - All contingencies treated equally, only single events,…
  - When considering criteria, the manner in which they are calculated and managed is important (reliability assessment and control)
  - New criteria will not be accepted until it can be sufficiently shown that they are in general superior

What is N-1?

- An edge case of probabilistic reliability
  - All N-1 contingencies have equal occurrence
- In reality, the definition is still not unique
  - What is considered as N-1?
    - E.g. transmission tower vs. circuit
    - Substations
      - Substation as a whole?
      - Bus bars, breakers, transformers differently?

Comparing probabilistic reliability criteria

- Why is it difficult?
  - Different reliability assessment methodologies could lead to different values of the reliability indicators.
  - Each reliability criterion leads to different decisions
  - Each reliability decision comes at a cost: to individual stakeholders and to society as a whole
  - Social welfare is seen as an ideal indicator
  - Evaluating reliability assessment methodologies and comparing reliability criteria is extremely complex and multifaceted.

Comparing criteria through the quantification platform

- The Garpur Quantification Platform should be able to:
  - Consider TSO reliability control actions
  - Evaluate the cost-benefit of the reliability criterion based on detailed real-world test cases
  - Demonstrate new reliability assessment methodologies, new calculation methods, etc. through a clear and open framework and a modular design
  - Support pilot testing within WP8, where the GQP is tested on RTE case study
- The GQP is not intended to be run real-time or to replace existing computational tools at the TSO side

The Garpur RMAC

The Garpur RMAC

- Evaluation time frame: day-ahead, and real-time (intra-day)

- Socio-economic objective is to find a minimum between

    - Cost of actions needed to be taken against contingencies vs impact of contingencies (for TSO & society)

- Reliability management: decision on which contingencies will be secured against versus which ones will be discarded

- Reliability control: which actions need to be taken for the contingencies to be secured against

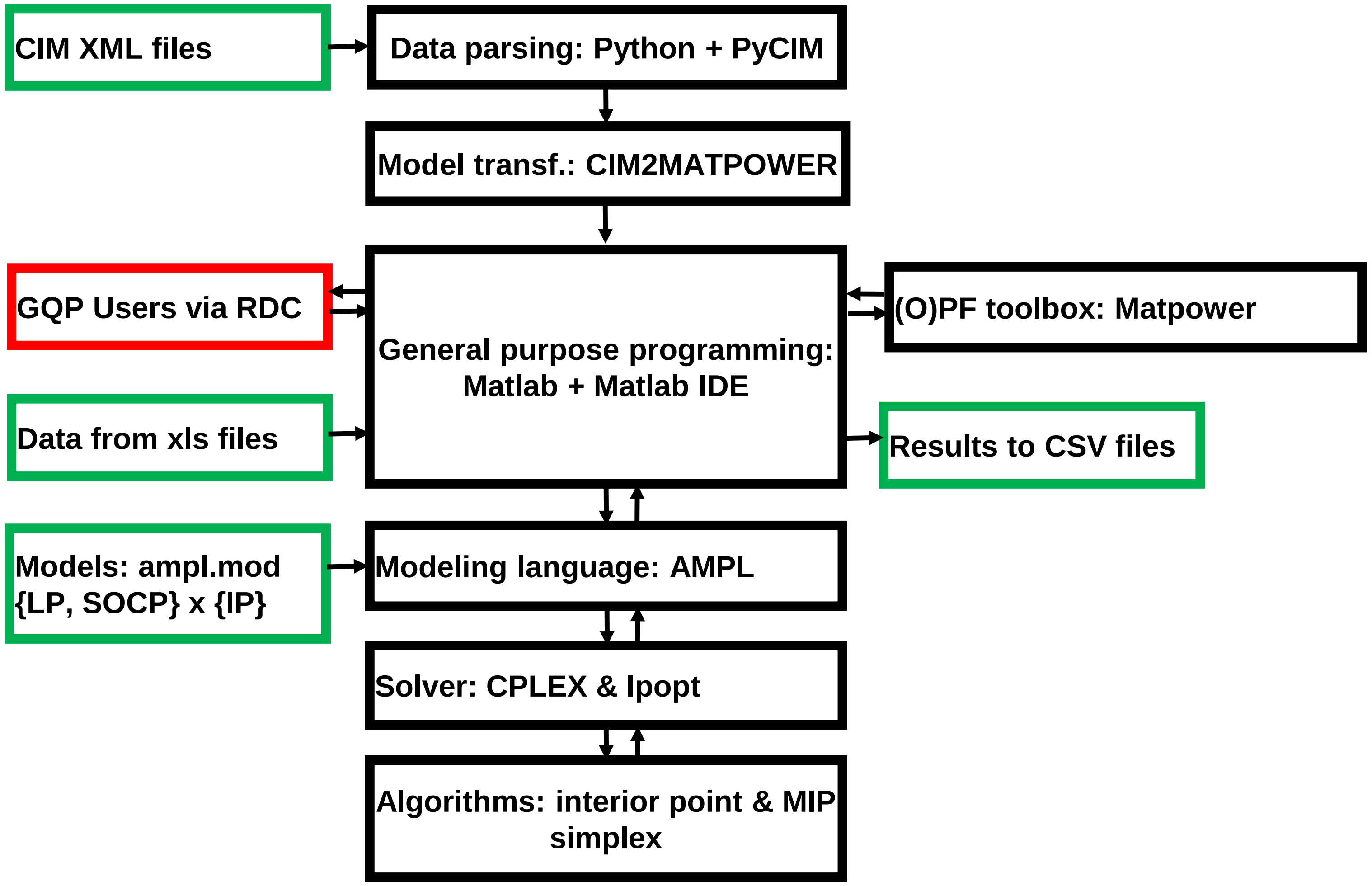
The “Garpur Quantification Platform” – GQP:

- Architecture
- Modules

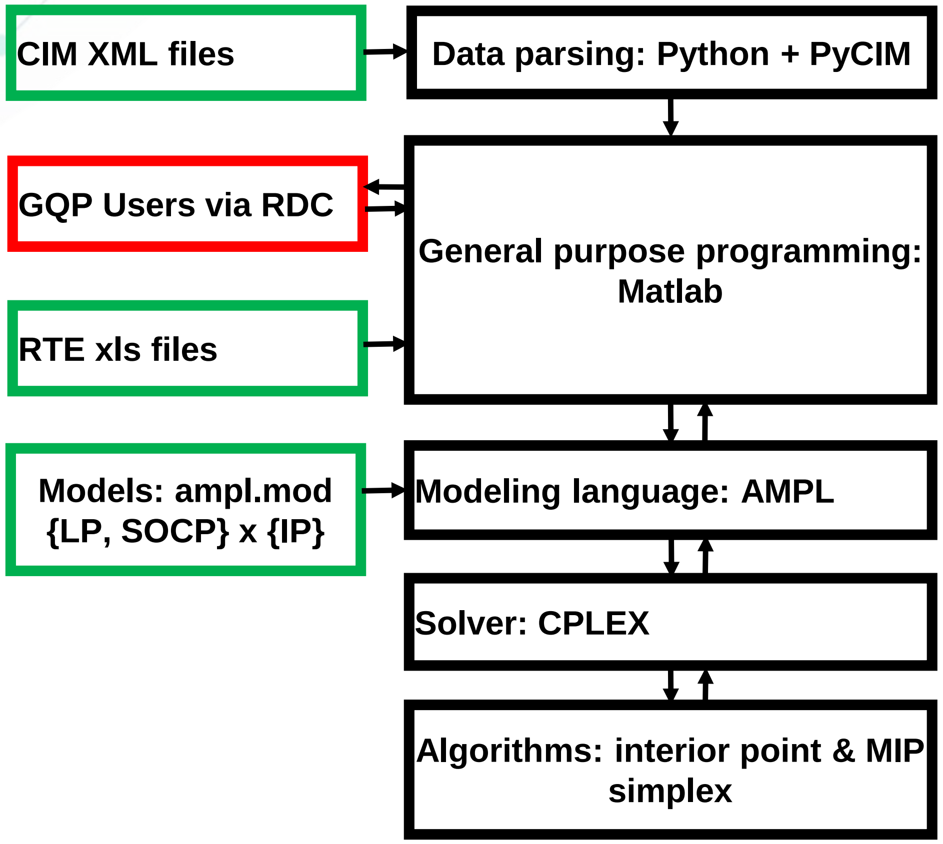
The GQP version of the RMAC

- Which costs / risk are considered?
  - Cost of preventive generation actions
  - Risk of corrective generation actions
  - Risk of load shedding
  - Blackout risk
    - Due to infeasible trajectories after contingency
    - Due to failure of corrective actions (proxy)

Architecture for simulating operation



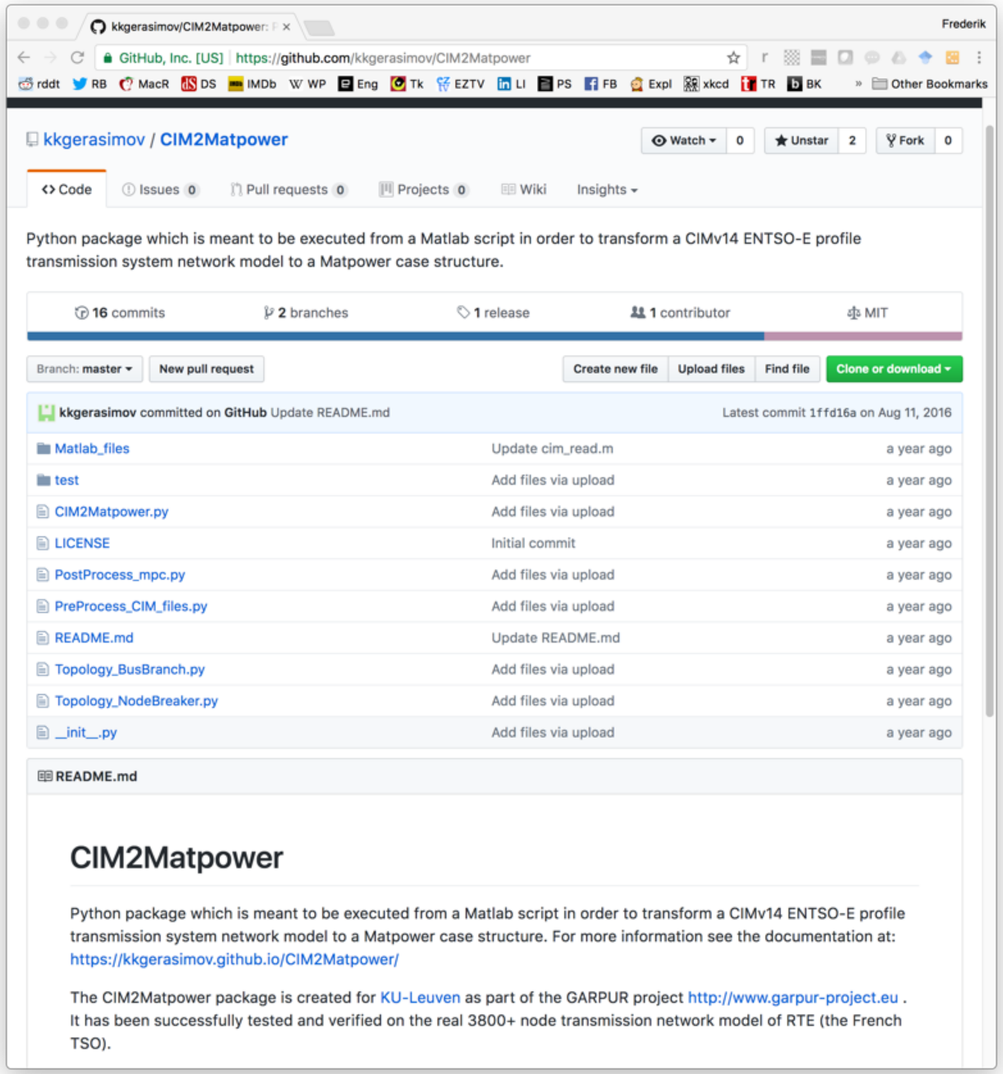
Architecture for simulating operation



- Access to GQP via remote desktop
- General purpose code written in Matlab
- Interfacing with AMPL and Python
- Well-described data models
- Validated w.r.t. Matpower

CIM import

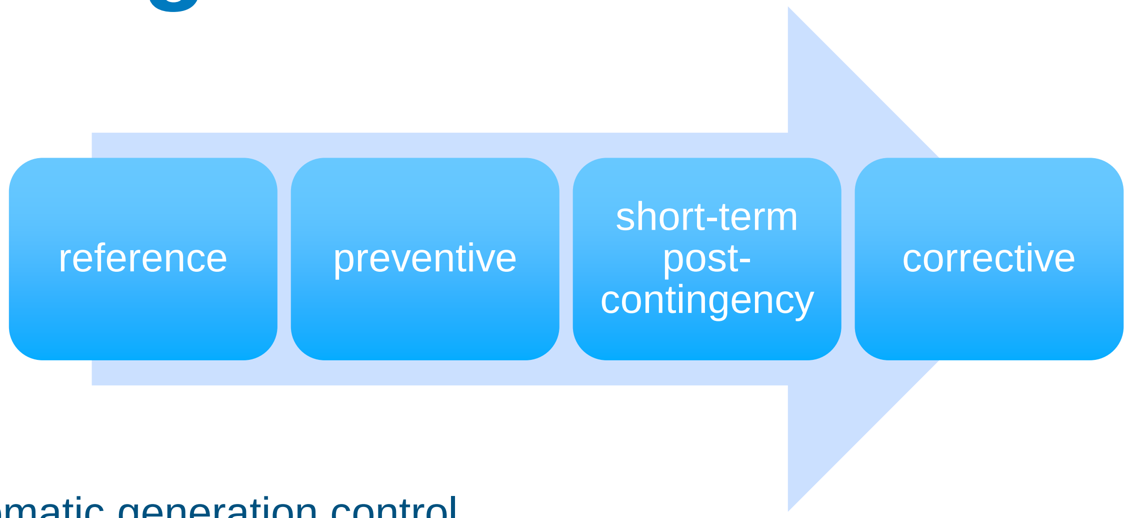
- CIM ’14 parser based on PyCIM
  - Bugfixes contributed to the project
- CIM2Matpower
  - Validated through power flow against RTEs own parser
  - Based on abandoned (’11) open-source project, but we gave our improvements back to the community
  - https://github.com/kkgerasimov/CIM2Matpower



RMAC Through Security-Constrained OPF

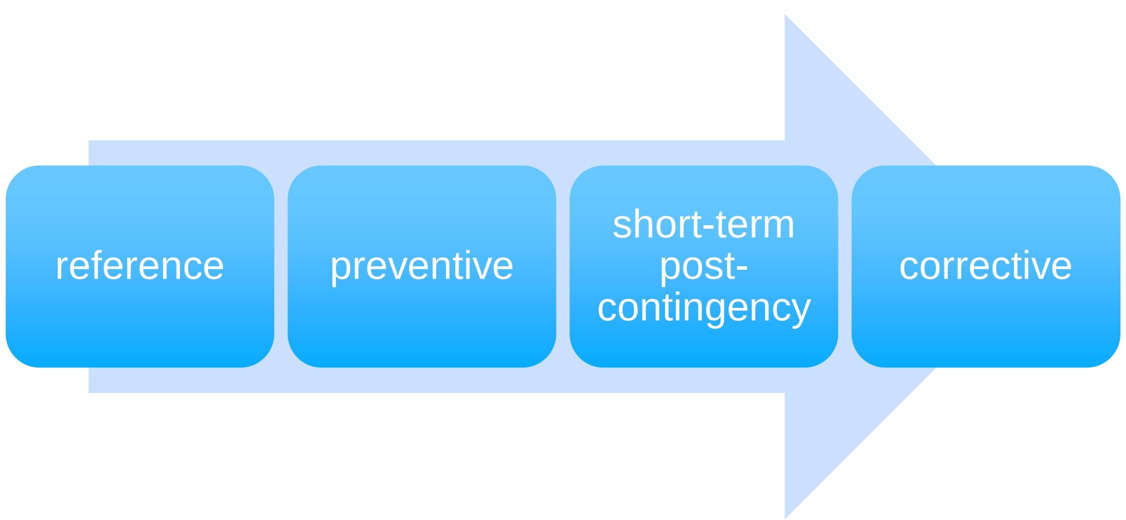
- Reliability management through SCOPF =
  - extensions towards stochastic programming
    - probability of contingencies
  - preventive, corrective *and short-term post contingency* stages
    - proxy for dynamic stability
  - failure of corrective actions
  - discarding of contingencies
    - accepting black-out risk by not securing this contingency

SCOPF stages

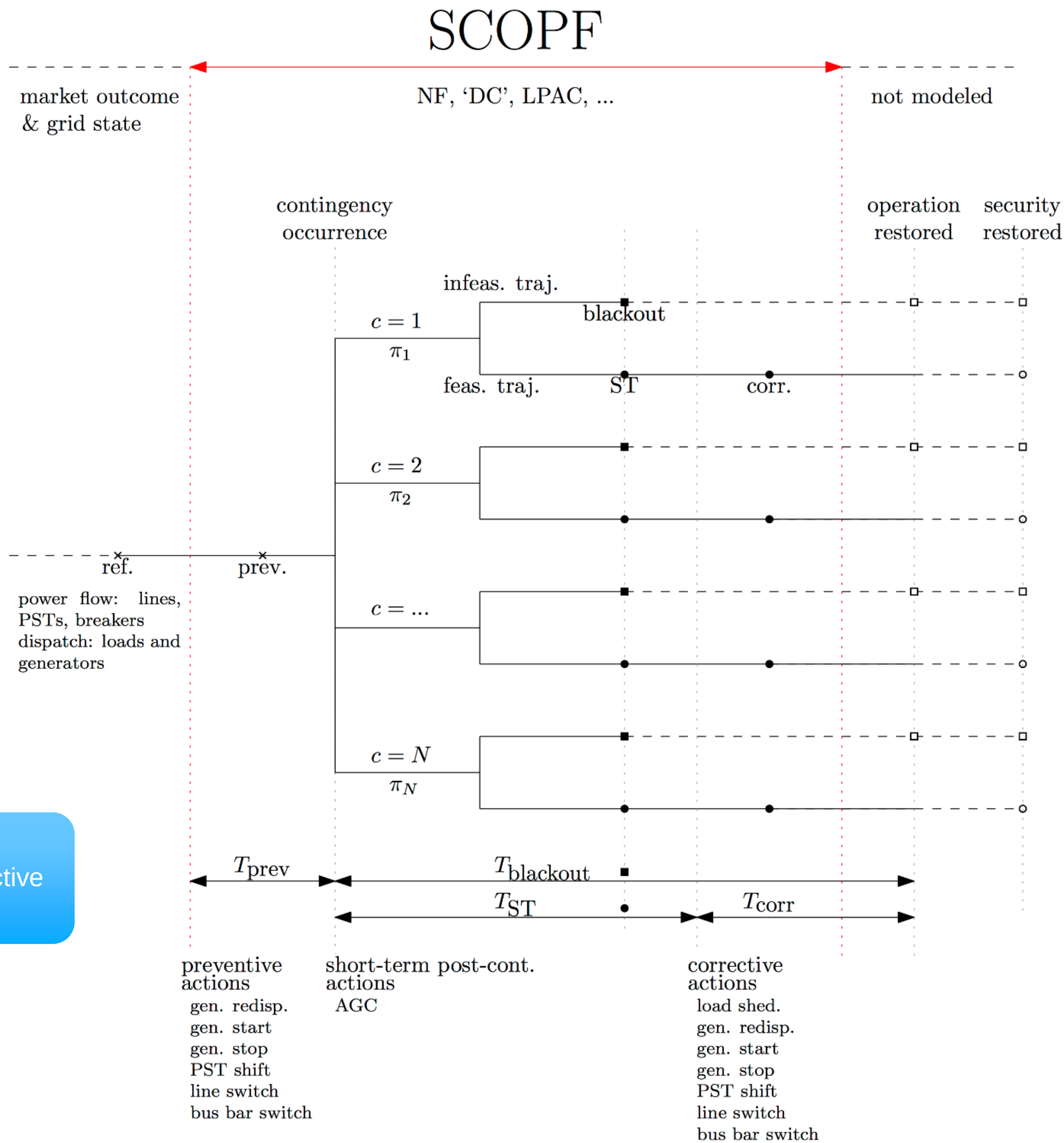


- Preventive stage
  - Generator redispatch, switching and PST shifts
- Short term post contingency stage: No actions except automatic generation control
    - actions only defined by equality, through proportionality factors describing the sharing of the change of dispatch
    - implies that preventive stage solution reserves a margin for AGC ’actions’
  - Short-term line ratings
- Corrective stage
  - **Load shedding,** Generator redispatch, PST shifts, line switching
  - Long-term line ratings

Stages



reference
preventive
short-term post-contingency
corrective



SCOPF
market outcome & grid state
NF, 'DC', LPAC, ...
not modeled
contingency occurrence
operation restored
security restored
infeas. traj.
blackout
$c = 1$
π_1
feas. traj.
ST
corr.
$c = 2$
π_2
$c = \ldots$
$c = N$
π_N
ref.
prev.
power flow: lines, PSTs, breakers
dispatch: loads and generators
T_{prev}
T_{blackout}
T_{ST}
T_{corr}
preventive actions
gen. redisp.
gen. start
gen. stop
PST shift
line switch
bus bar switch
short-term post-cont. actions
AGC
corrective actions
load shed.
gen. redisp.
gen. start
gen. stop
PST shift
line switch
bus bar switch

Objective

$$K^{\text{cost}}(\mathcal{C}) = \underbrace{k^{\text{prev}} \cdot K^{\text{prev}}}_{\text{preventive cost}} + \underbrace{k^{\text{corr}} \cdot K^{\text{corr}}(\mathcal{C})}_{\text{corrective risk}} + \underbrace{k^{\text{blackout}} \cdot K^{\text{blackout}}(\mathcal{C})}_{\text{blackout risk}}$$

- Specific cost components can be considered or ignored
    - Risks depend on the specific contingencies considered in the contingency set

Objective

$$K^{\text{prev}} = \underbrace{\underbrace{k^{\text{redispatch}} \cdot K^{\text{prev,redispatch}}}_{\text{redispatch}} + \underbrace{k^{\text{start/stop}} \cdot K^{\text{prev,start/stop}}}_{\text{start/stop}}}_{\text{units}}$$
$$+ \underbrace{\underbrace{k^{\text{switch}} \cdot K^{\text{prev,switch}}}_{\text{switch}} + \underbrace{k^{\text{shift}} \cdot K^{\text{prev,shift}}}_{\text{shift}} + \underbrace{k^{\text{ratio}} \cdot K^{\text{prev,ratio}}}_{\text{TF ratio}} + \underbrace{k^{\text{gridloss}} \cdot K^{\text{prev,gridloss}}}_{\text{losses}}}_{\text{lines}}$$

- Preventive costs and corrective risk are composed the same way
  - generators: redispatch cost, startup / shutdown cost
  - lines/transformers: switching cost, PST shifting, OLTC tapping, losses

Scalability

- Scalability depends on binary variables
  - and amount of contingencies considered
- Amount of binary variables depends on the modelling features
  - Indicator variables for actions used in failure of corrective actions
  - Contingency discarding
  - Topological actions
- Linearization and convexification offer computational shortcuts w.r.t. including binary variables in OPF problems

Working with real data: issues

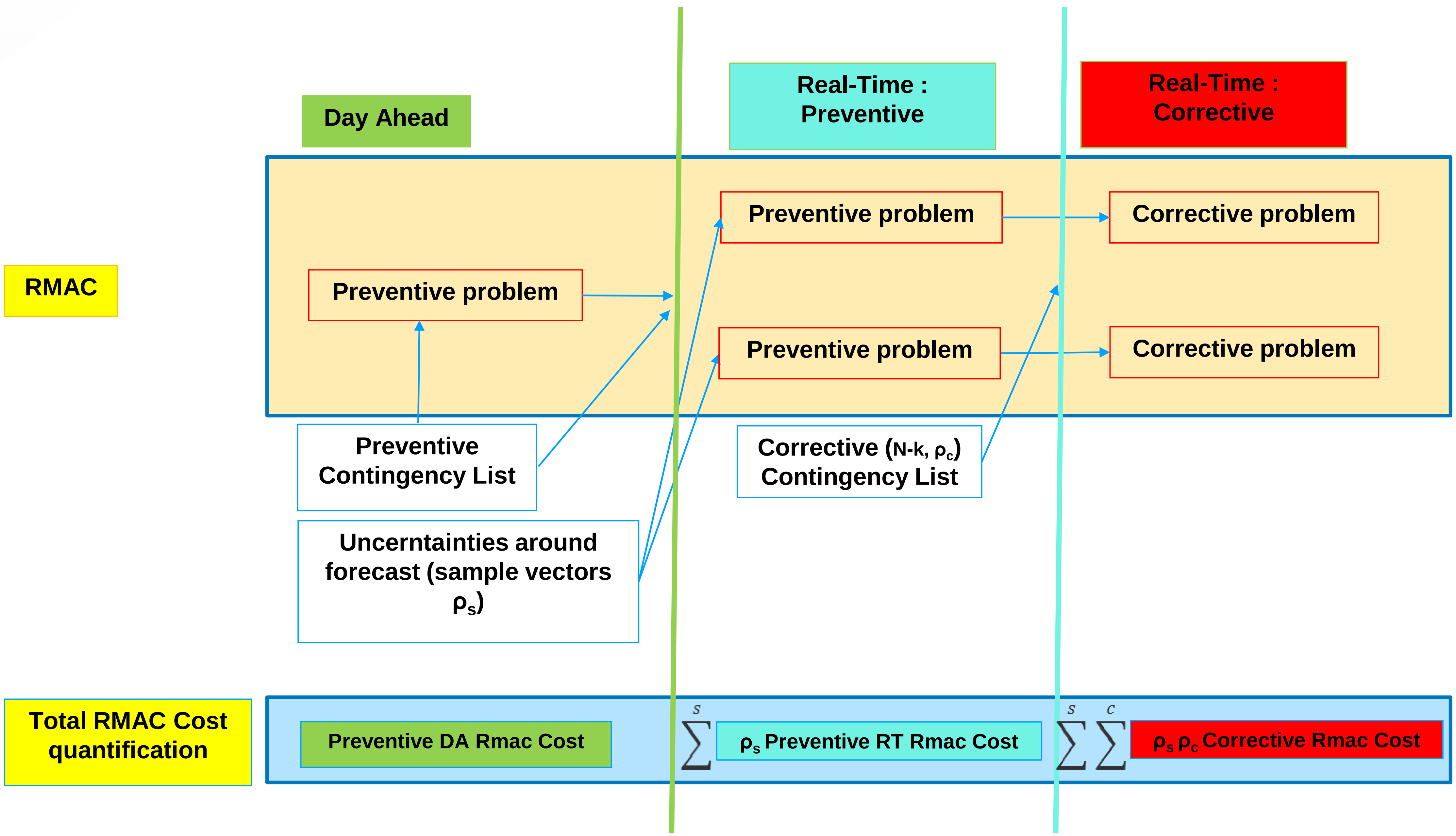
- Generator reference values outside of supplied bounds
- Negative generators and loads -> effect on variable bounds and cost model
- Removal of trivially infeasible N-1 contingencies
    - Contingencies that result in trivial infeasibilities without load shedding
    - e.g. radial feeder fails with only a load connected
- Lines without flow bounds
- Non-physical or “strange” impedance values, e.g. equivalent nodes
- Islands, wrong status, multiple reference buses, ...

Working with real-life processes

- Modeling real-life reliability management approach
  - Different contingencies taken into account day-ahead vs real-time
  - Different flexibilities considered
  - Different uncertainties realized

N-1 and RMAC in reliability management process

3 step approach



Conclusions / lessons learned

Conclusions

- PST shift actions can be used both preventively and correctively, and offer more flexibility and have limited impact on the computational tractability.

- The inclusion of topological actions in the reliability management increases the computation time significantly.

  - In order to include topological actions in the SCOPF, better convexification techniques than the DC power flow approach need to be used in order to achieve feasibility of the nonconvex AC problem.

- In case acceptability constraints are not very tight, the impact on the risk of increasing failure rates of corrective actions is rather limited. Nevertheless, with tight acceptability constraints, increasing failure rate of corrective actions can increase the occurrence of contingency discarding.

- The full potential of the GARPUR approach is not realized when decomposing the reliability management problem into separate preventive and corrective problems

  - however solving it as a single problem is too computationally demanding in realistic situations

Future work

- Adding uncertainty related to renewables
- Improving computational tractability
  - Algorithms for large-scale mixed-integer optimal power flow problems
- Adding more power system details (HVDC, statcom, …)
- Publishing test cases and data models
- Computationally explore RMAC in system development
- New GQP incorporating lessons learned
  - More user-friendly, faster, variety of new interfaces

THANK YOU FOR YOUR ATTENTION!

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