Optimisation of multi-year planning strategies to better integrate renewable energies and new electricity uses in the distribution grid

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ELECTRICAL SYSTEMS

OPTIMISATION OF MULTI-YEAR PLANNING STRATEGIES TO BETTER INTEGRATE RENEWABLE ENERGIES AND NEW ELECTRICITY USAGES ON THE DISTRIBUTION GRID

CentraleSupélec
L2S Laboratoire des Signaux & Systèmes
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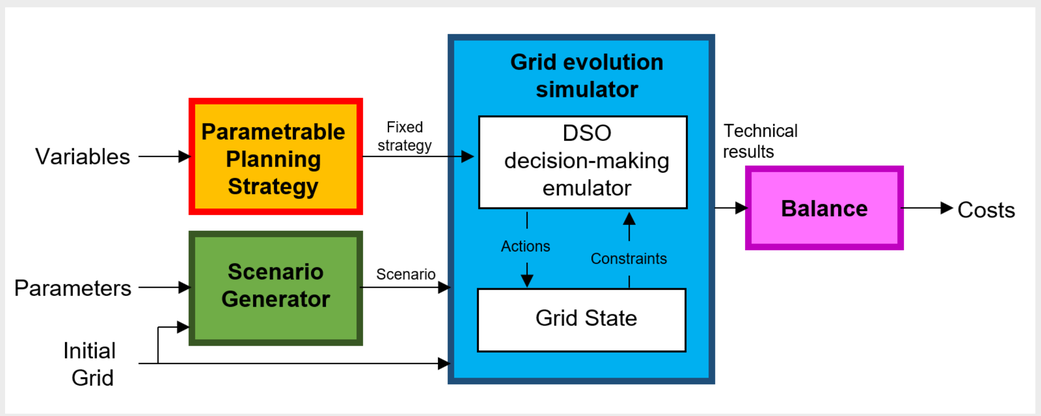
1. CONTEXT

- Future of electricity distribution: new usages in the distribution grid, e.g., electric vehicles, distributed energy generation, local storage units…
- How to adapt the grid to these new usages at lowest cost?

2. DECISION TOOL

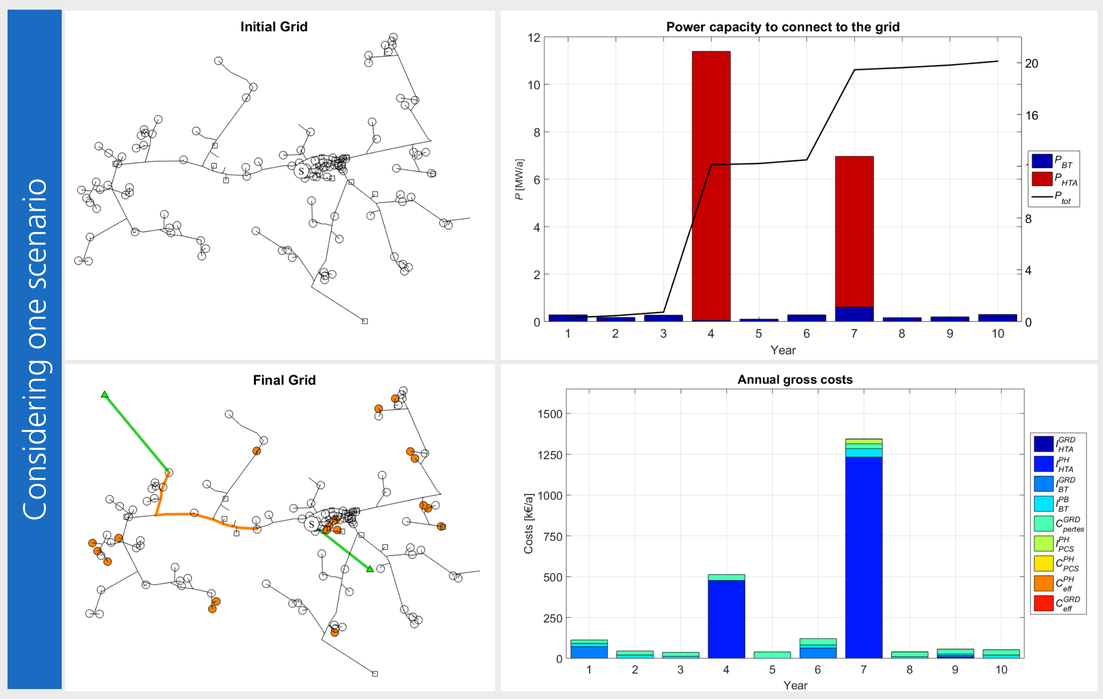
- PARADIS (EDF R&D and CentraleSupélec/L2S, [DUT15]) is a tool to simulate planning strategies for different scenarios



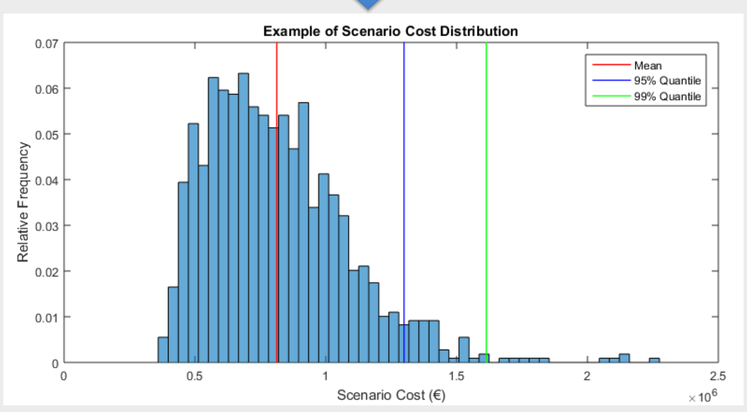
- Scenario generator: creates **realistic random scenarios** of RE's arrivals and the consumption and production profiles
- Strategy planning: defines the **decision tree** used by the Distribution System Operator (DSO)
- Simulator: simulates the **evolution of the grid**
- Balance: computes the **final costs** of the planning strategy

- For a prescribed planning strategy:

Considering one scenario



Considering different **realistic scenarios**

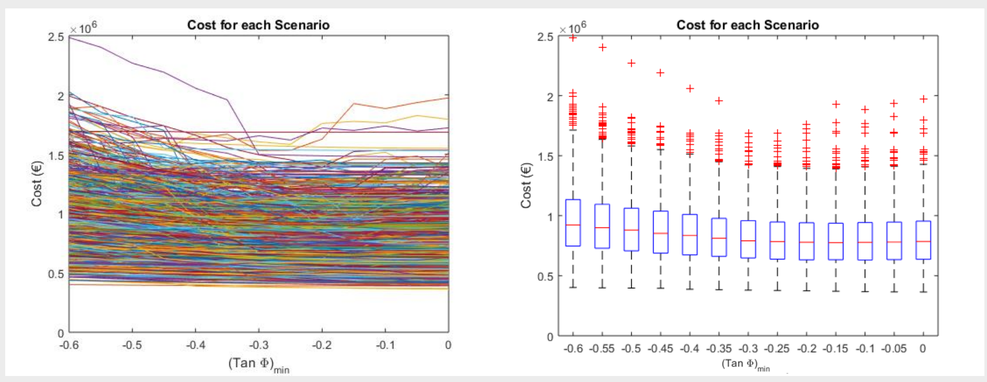


Significant variation in cost!

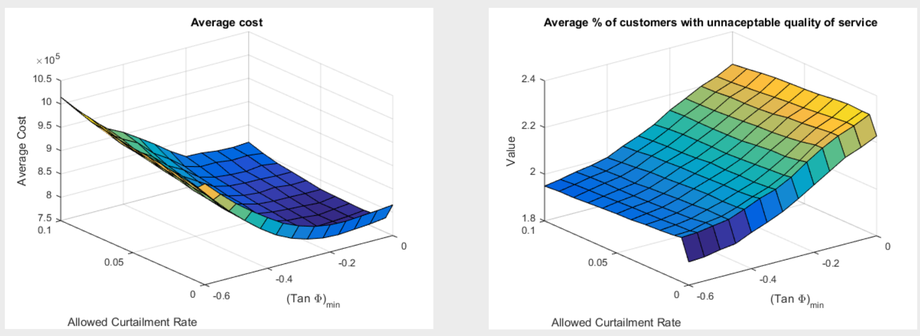
- In PARADIS, planning strategies are defined using parameters (up to about 10 parameters)

Possible impact of extreme values!

One-parameter strategy ($\tan\phi$)



Two-parameter strategy ($\tan\phi$ and curtailment)



Conflicting Objectives!

3. PLANNING STRATEGIES

Main characteristics of the problem

- Expensive simulations (e.g., 5 minutes for one simulation)
- Continuous parameters
- Stochastic simulator (scenario-based)
- Conflicting objectives
- Impact of extreme values

Different formulations of the problem

- Mono-objective optimisation: $\min_x \mathrm{q}_\alpha(x)$, with $q_\alpha(x)$ an α-quantile (or superquantile) of the cost $Z(x)$.
- Multi-objective and/or constrained optimisation with more than one cost function $Z_1(x)$, $Z_2(x)$, …
- Robust optimisation: e.g., $\min_{x\in\mathbb{X}} q_\alpha(x+\varepsilon)$, with ε a random perturbation of the parameters
- Quasi-optimal regions:

$$\Gamma = \left\{x \in \mathbb{X}, q_\alpha(x) \le q^\star + \Delta; q^\star = \min_{x\prime} \mathrm{q}_\alpha(x')\right\}$$

with Δ a constant that defines the accepted level of quasi-optimality, or

$$\Gamma = \left\{x \in \mathbb{X}, q_\alpha(x) \le q^\star; q^\star = \inf\{z \in \mathbb{R}, P_{\mathbb{X}}(x' \in \mathbb{X}, q_\alpha(x') \le z) \ge \beta\}\right\}$$

4. RESEARCH IDEAS

- Bayesian Optimization!
- And other ideas:
  - Scenario min-max optimisation [CAR15]
  - Quantile estimation [LAB16]
  - Reliability-based design optimisation [DUB11]
  - Bayesian algorithms for best arm identification [RUS16]
  - Informational approach to global optimisation [VIL09]

SOME REFERENCES

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[CAR15] A. Caré, S. Garatti and M.C. Campi, "Scenario min-max optimization and the risk of empirical costs",. SIAM Journal on Optimization, 25, n° 4, pp. 2061-2080, 2015.
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