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

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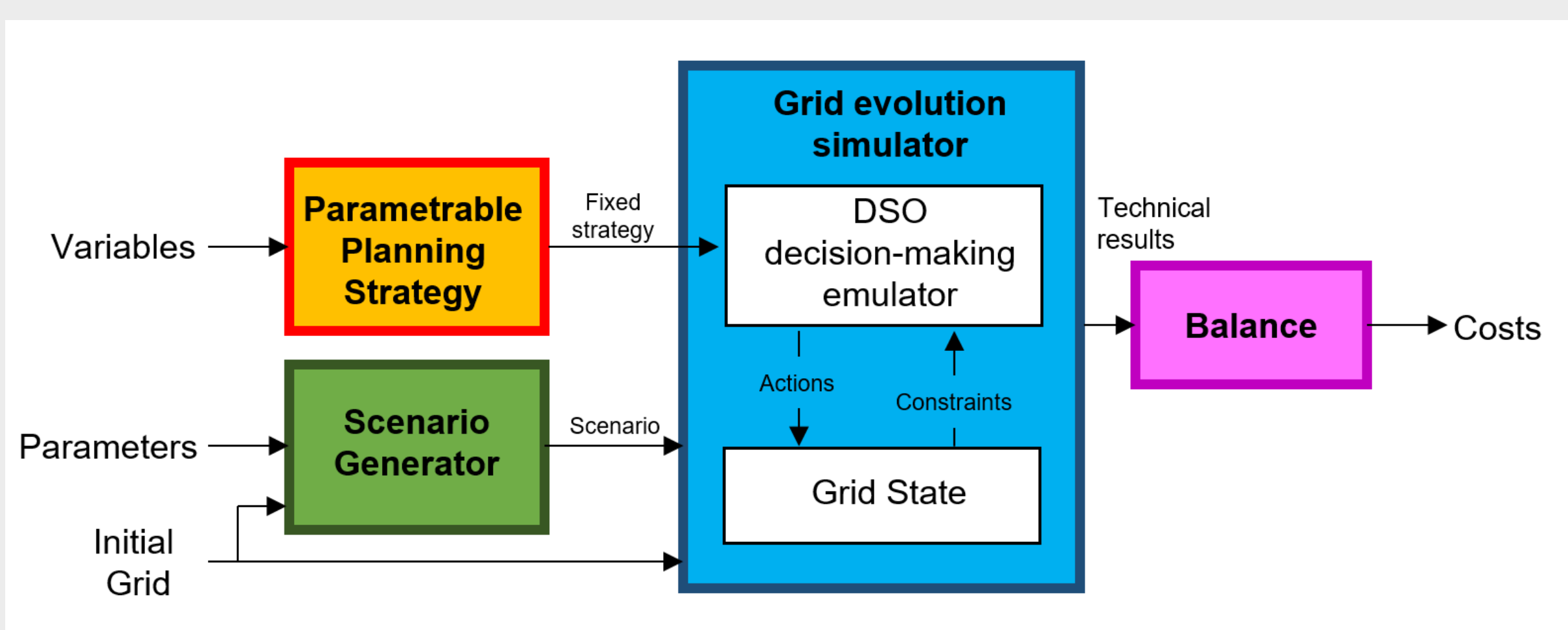
OPTIMISATION OF MULTI-YEAR PLANNING STRATEGIES TO BETTER INTEGRATE RENEWABLE ENERGIES AND NEW ELECTRICITY USAGES ON THE DISTRIBUTION GRID

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**?

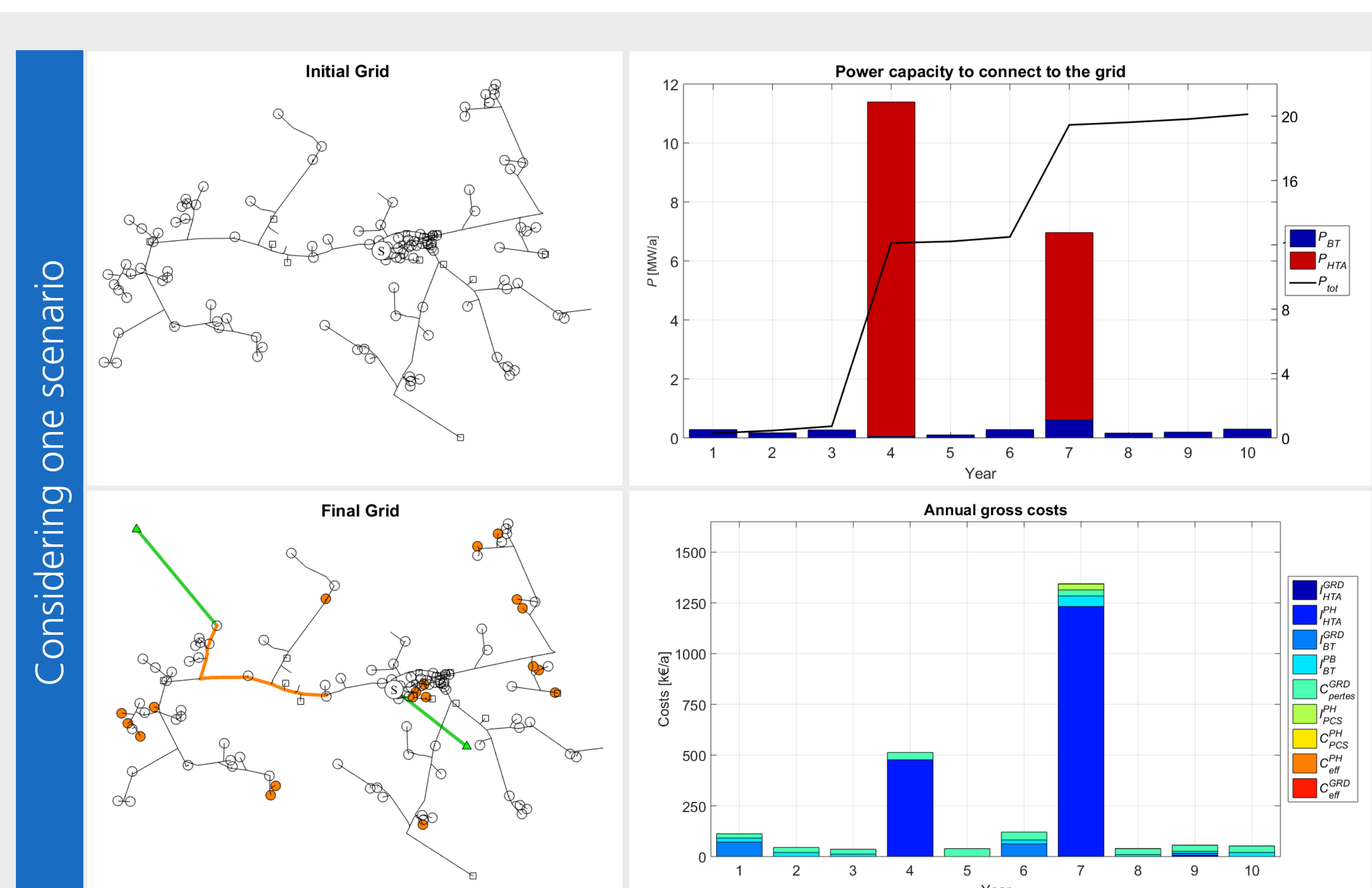
2. DECISION TOOL

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

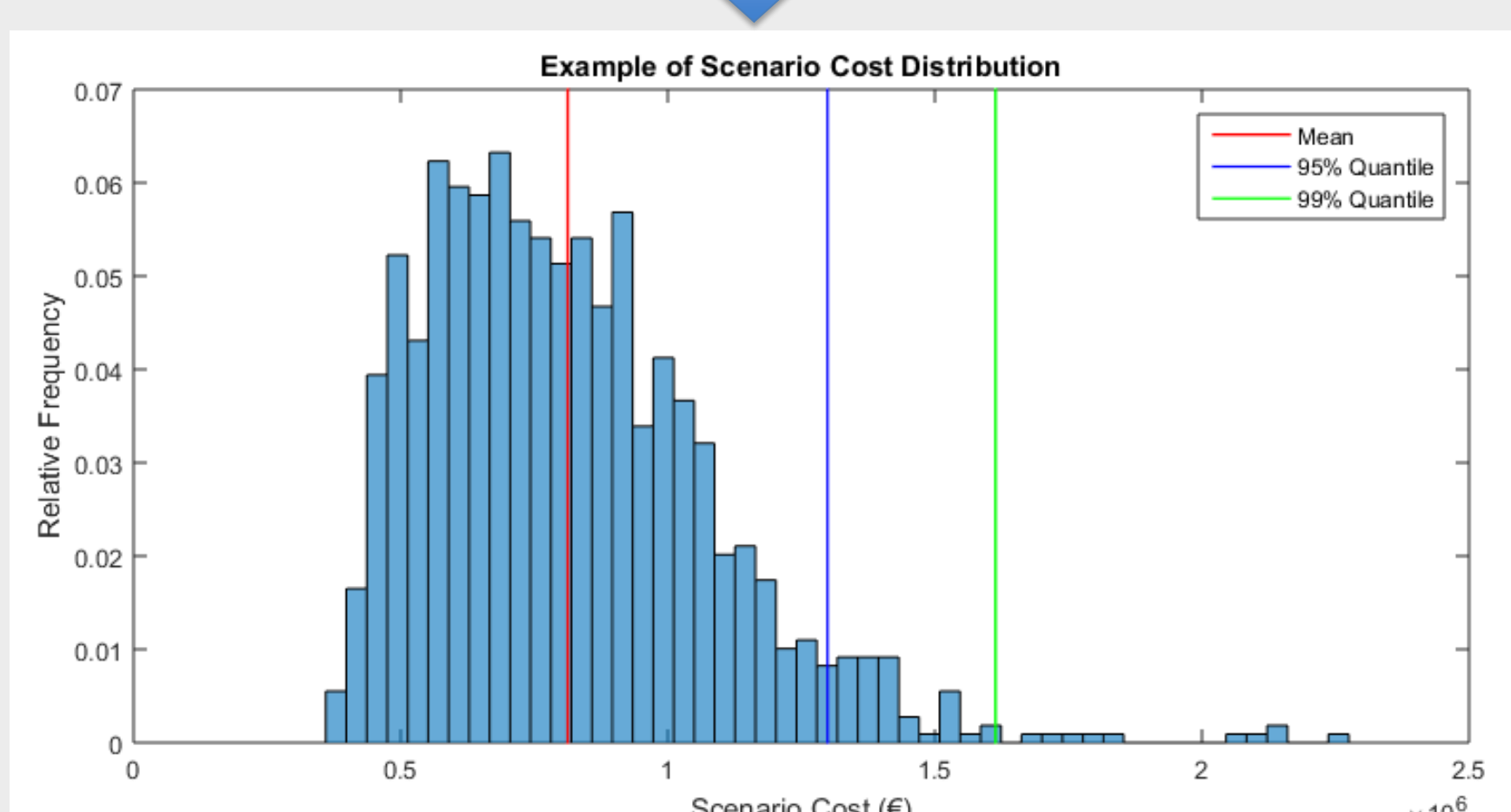


- **Scenario generator**: creates realistic random scenarios of RE's arrivals and the consumption and production profiles
- **Strategy planning**: defines the decision tree used by the Distribution System Operator (DSO)
- **Simulator**: simulates the evolution of the grid
- **Balance**: computes the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

- For a prescribed planning strategy:



Considering different realistic scenarios

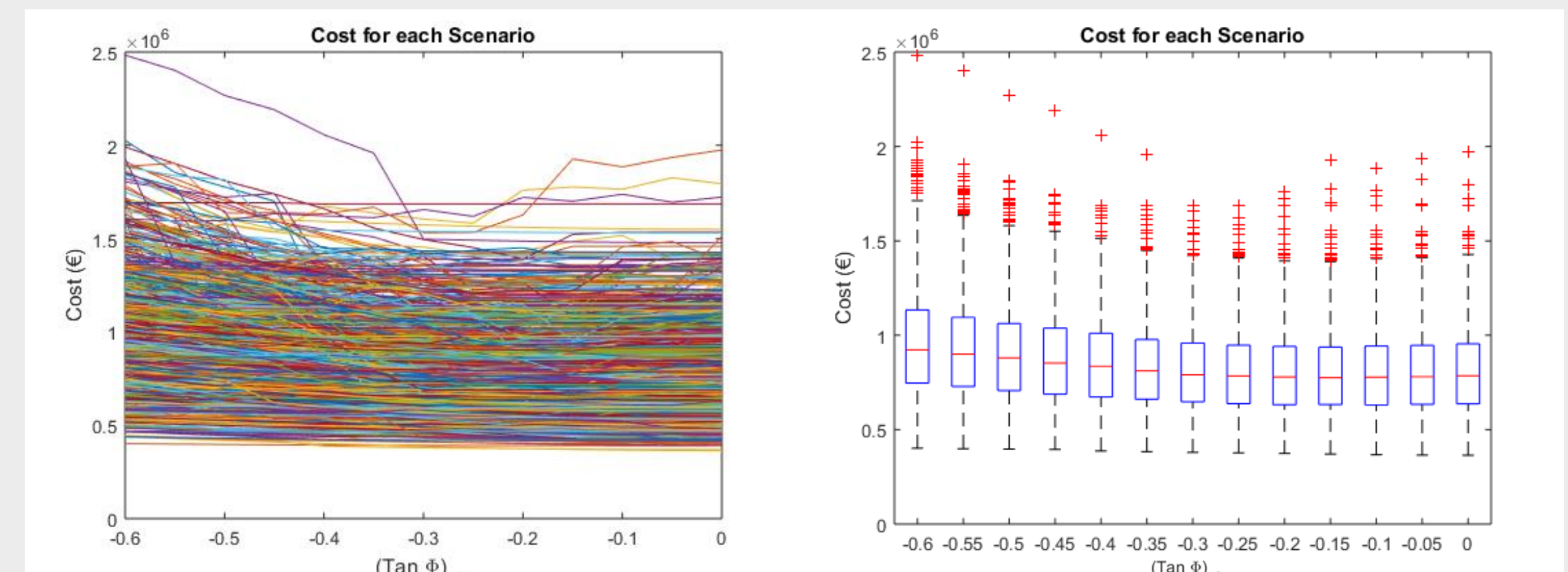


Significant variation in cost!

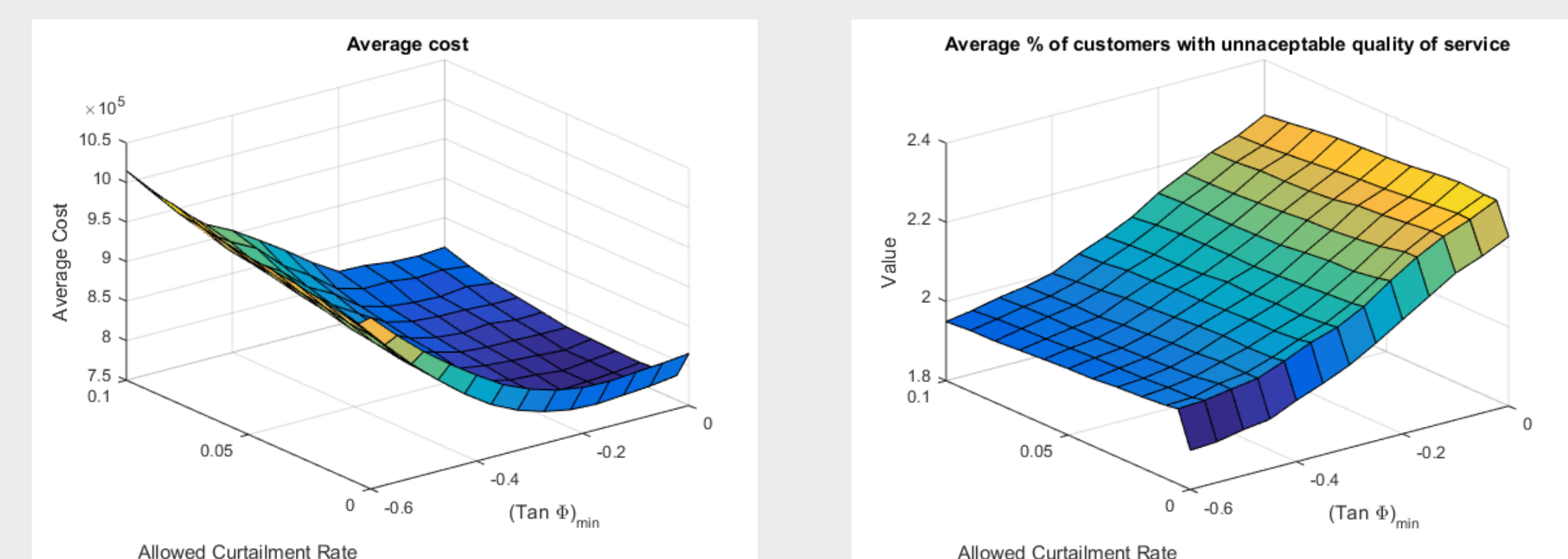
- In PARADIS, **planning strategies** are defined using **parameters** (up to about 10 parameters)

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

Possible impact of extreme values!



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: $\min_x q_\alpha(x)$, 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 $Z_1(x), Z_2(x), \dots$
- Robust optimisation: e.g., $\min_{x \in \mathbb{X}} q_\alpha(x + \varepsilon)$, with ε a random perturbation of the parameters
- Quasi-optimal regions:

$$\Gamma = \{x \in \mathbb{X}, q_\alpha(x) \leq q^* + \Delta; q^* = \min_{x'} q_\alpha(x')\}$$

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

$$\Gamma = \{x \in \mathbb{X}, q_\alpha(x) \leq q^*; q^* = \inf\{z \in \mathbb{R}, P_{\mathbb{X}}(x' \in \mathbb{X}, q_\alpha(x') \leq z) \geq \beta\}\}$$

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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