Méthodes d'optimisation dans les réseaux électriques de puissance

Nicolas Omont

3ème Concordat Genelec

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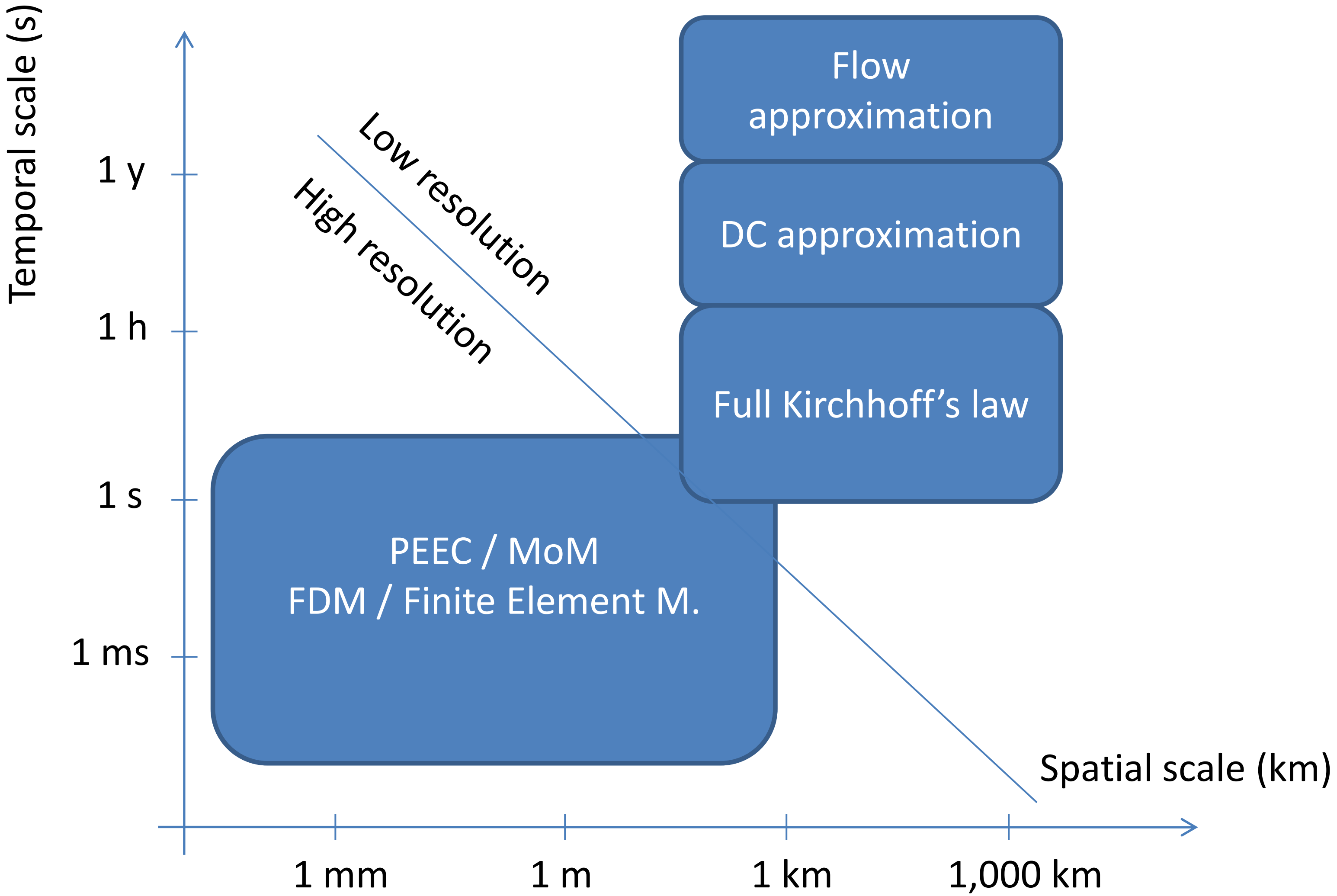
Simulation of power networks



Maxwell's equations

$$\nabla \times \vec{H} = \vec{J} + \frac{\partial \vec{D}}{\partial t}$$

$$\nabla \times \vec{E} = -\frac{\partial \vec{B}}{\partial t}$$

$$\nabla \cdot \vec{D} = \rho_v$$

$$\nabla \cdot \vec{B} = 0$$

$\vec{E}$ – Electric field intensity, $[\frac{V}{m}]$

$\vec{D}$ – Electric flux density, $[\frac{C}{m^2}]$

ρ_v – Volume charge density, $[\frac{C}{m^3}]$

ε – Capacitivity of the medium, $[\frac{F}{m}]$

$$\vec{D} = \epsilon \vec{E}$$

$$\vec{B} = \mu \vec{H}$$

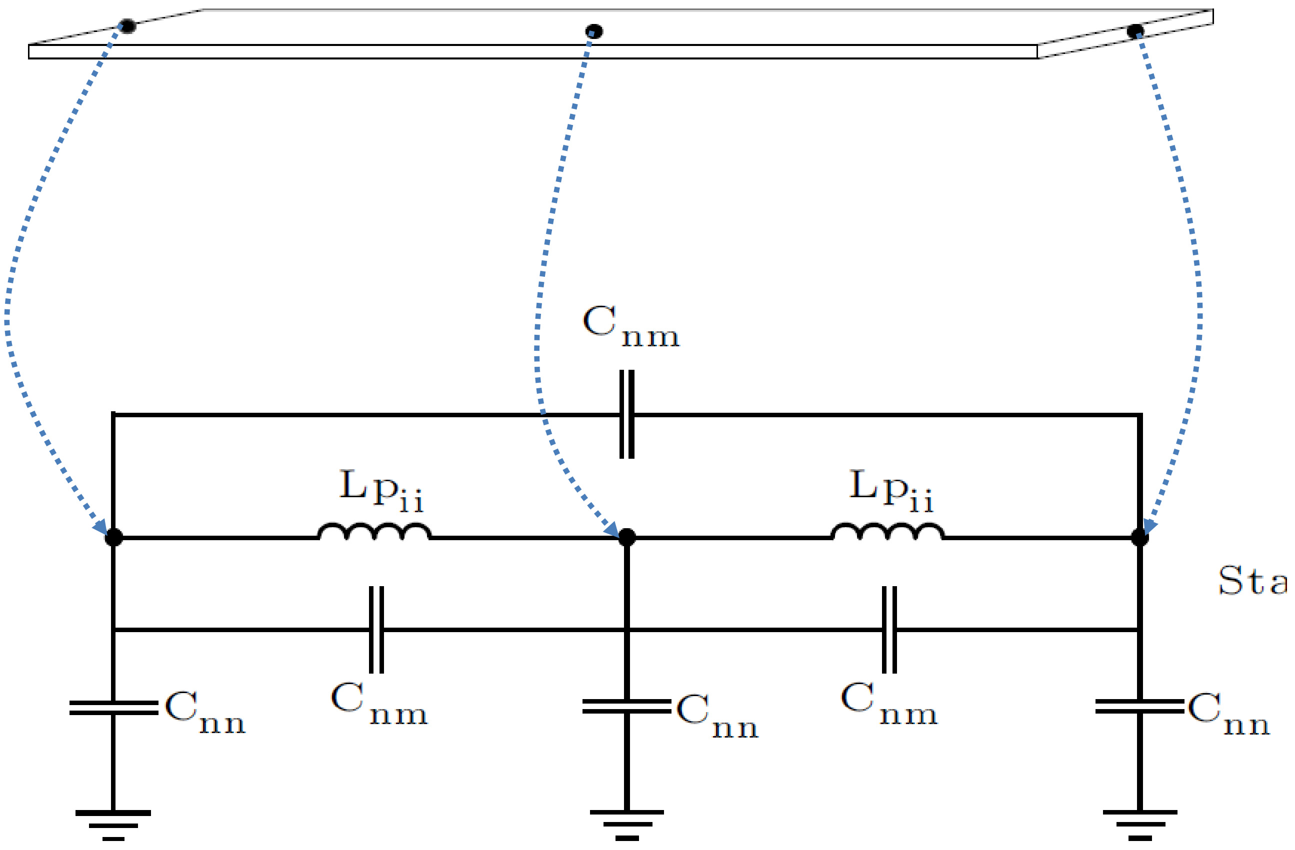
$$\vec{J} = \sigma \vec{E}$$

Credit to Jonas Ekman

PEEC (Partial Element Equivalent Circuit)

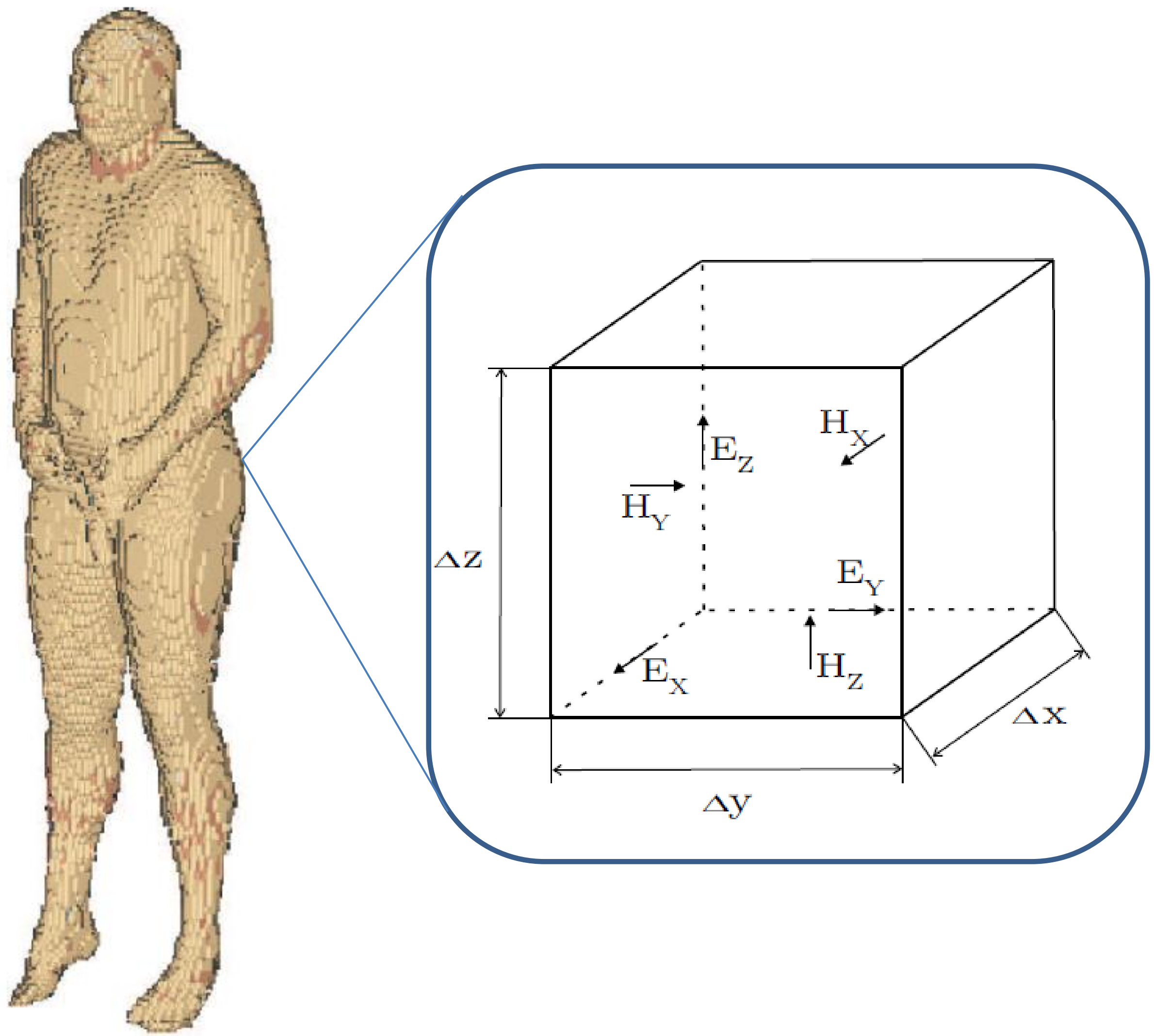
Conductor

PEEC model



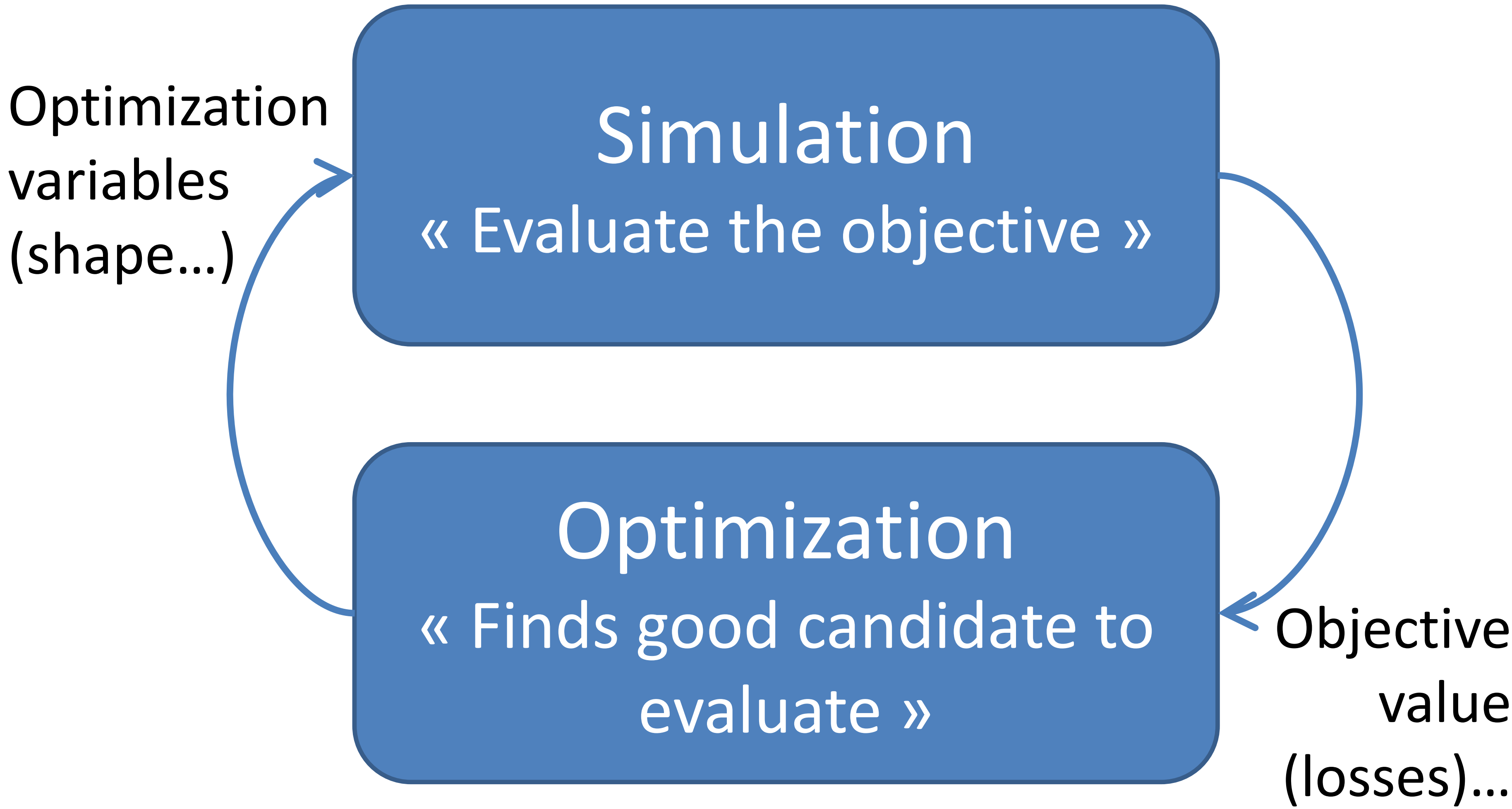
Credit to Jonas Ekman

Finite difference method



Credit to Jonas Ekman

Optimization

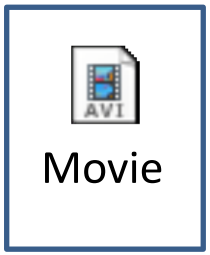


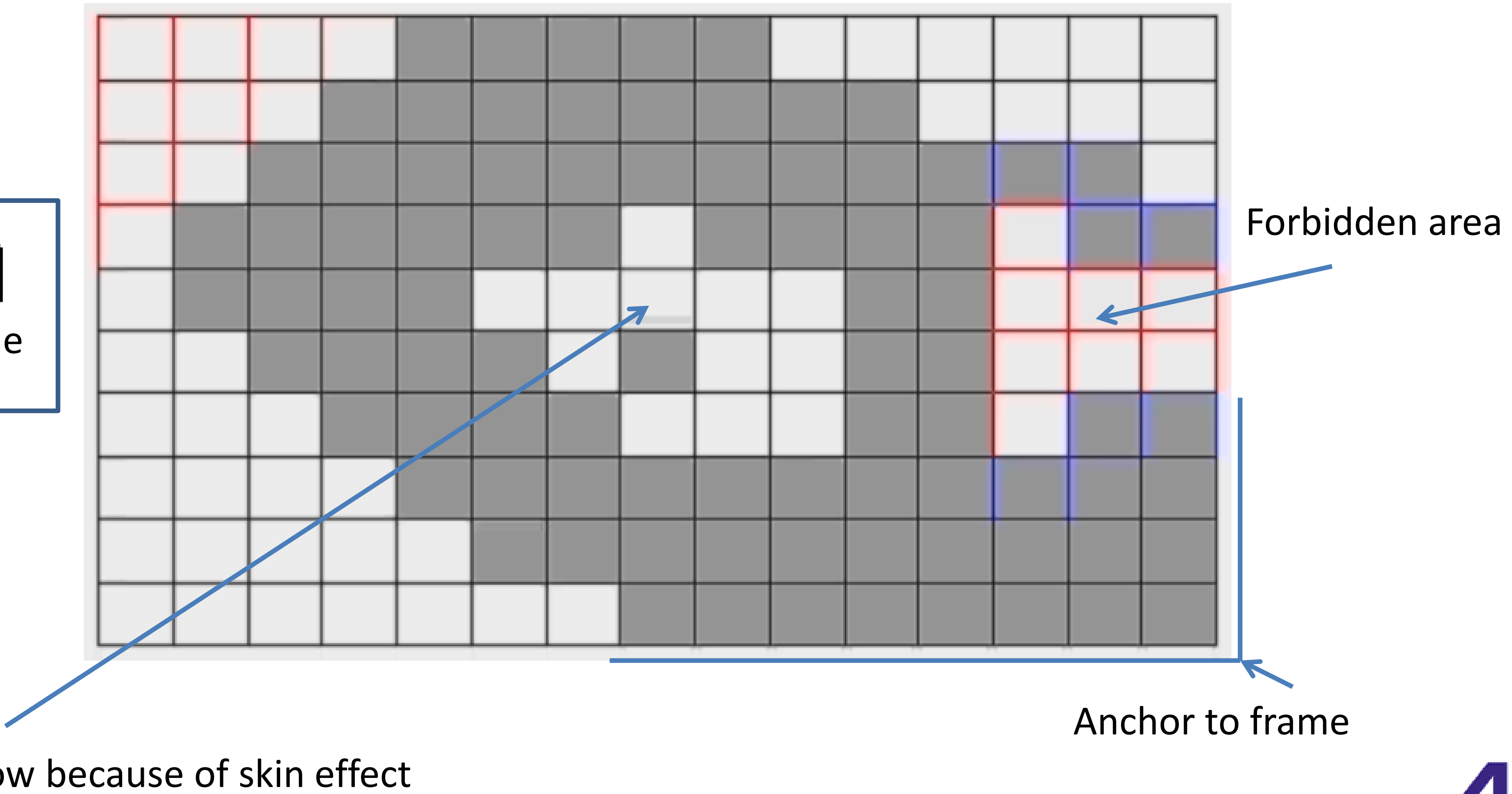
High resolution optimization model

- Why optimization is difficult with high resolution models?
  - Multiple minimums: Yes
    - Except on special problems, where global optimum can be guaranteed
  - Smoothness: Yes
    - But numerical errors may « blur » the results
  - Evaluation time: Large
    - Even on the most simple problem, at least 20 evaluations are needed.

High resolution optimization example

- Conductor shape optimization (genetic alg.)





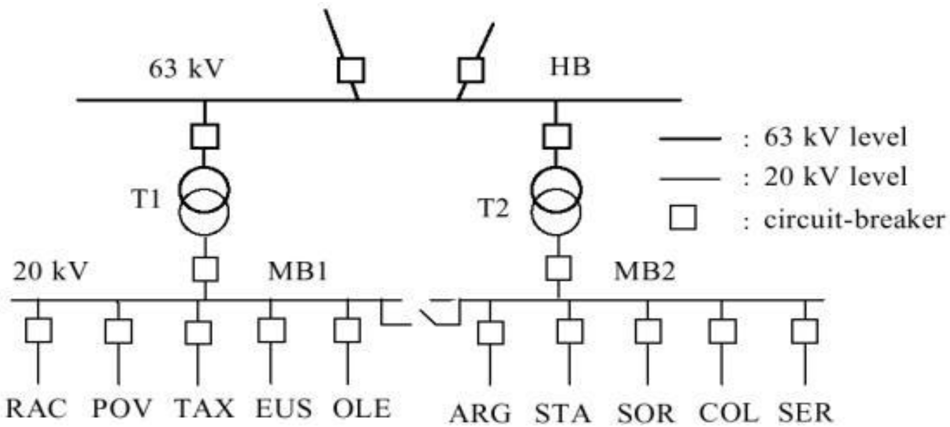
Credit to Jean-Paul Gonnet , Schneider Electric

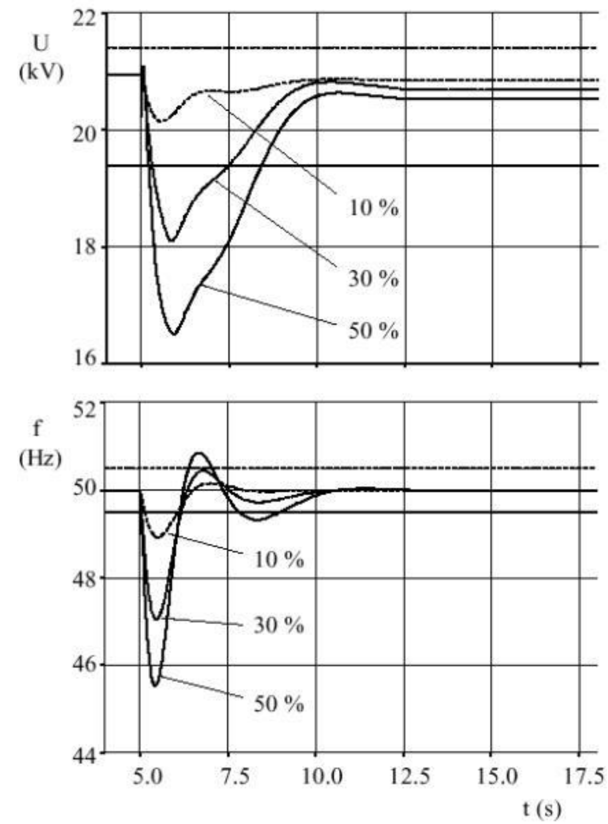
Low resolution optimization model

- How are model simplified for optimization purpose?
  - Multiple minimums: No, through linearization
    - DC approximation and flow model are linear
  - Smoothness: Yes
    - Only basic operations to evaluate the objective
  - Evaluation time: Low
    - Only basic operations to evaluate the objective

High resolution optimization examples

- Dynamic simulation



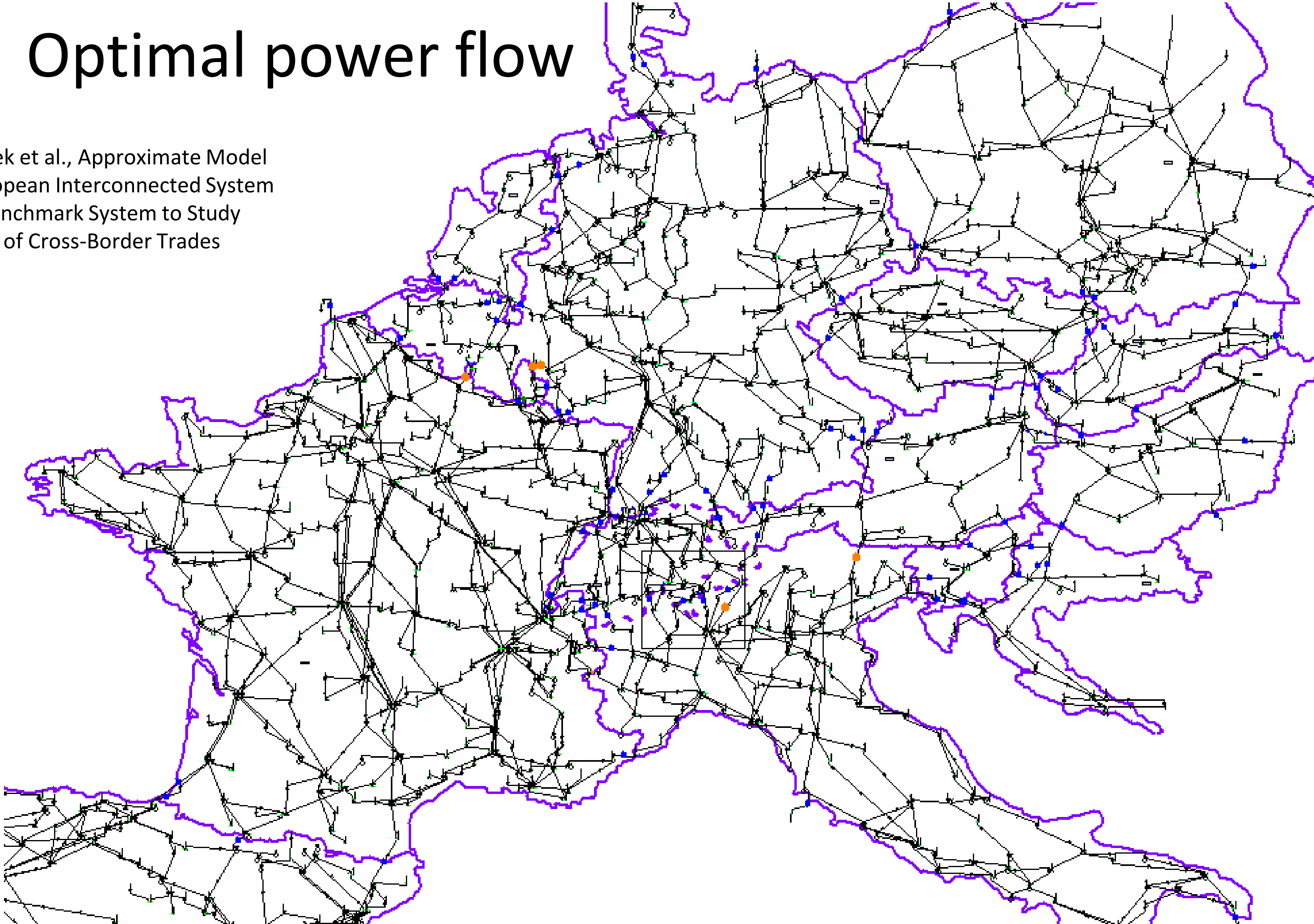


http://wwweurostag.epfl.ch/users_club/newsletter/

High resolution optimization examples

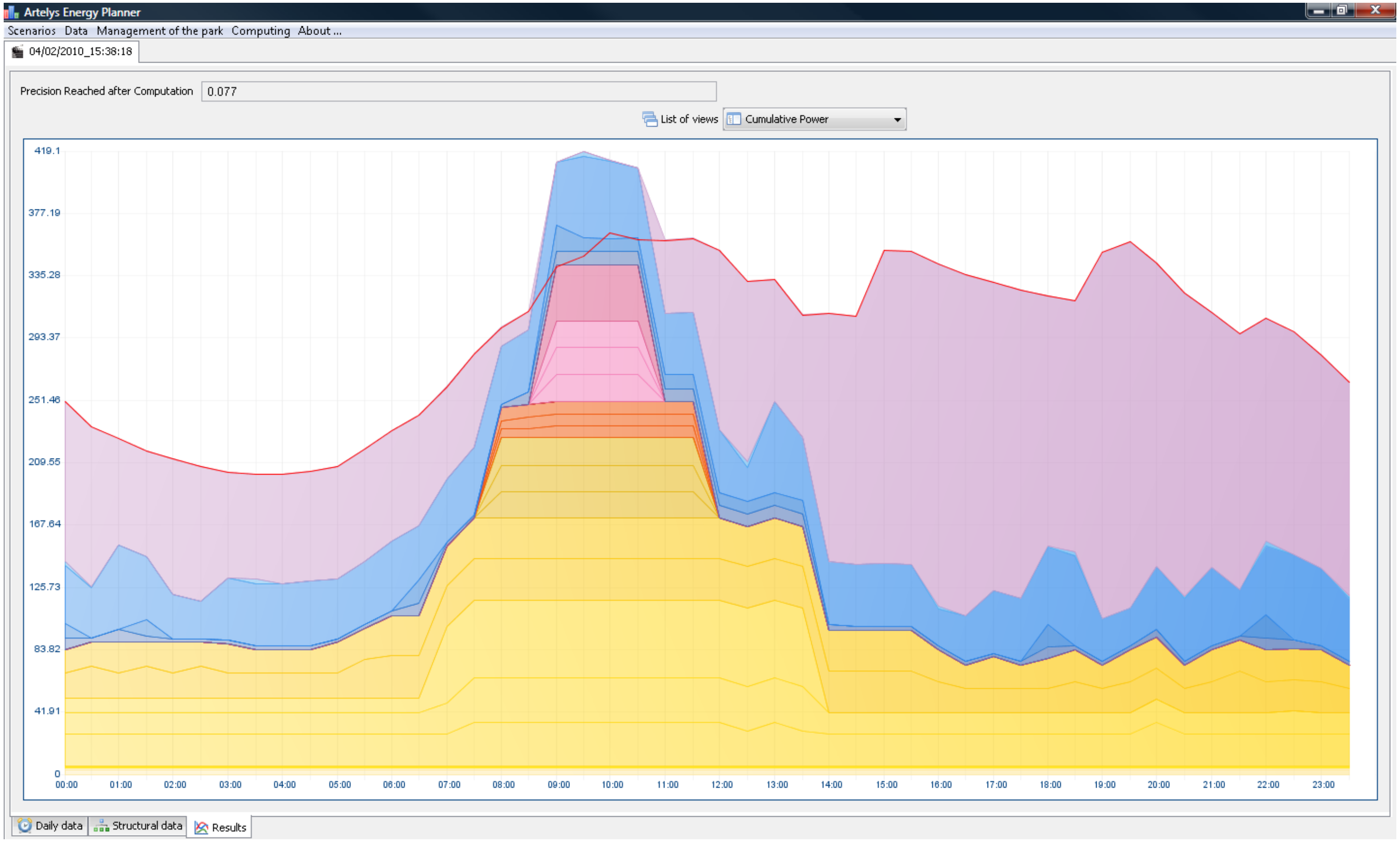
- Optimal power flow

In Bialek et al., Approximate Model of European Interconnected System as a Benchmark System to Study Effects of Cross-Border Trades



High resolution optimization examples

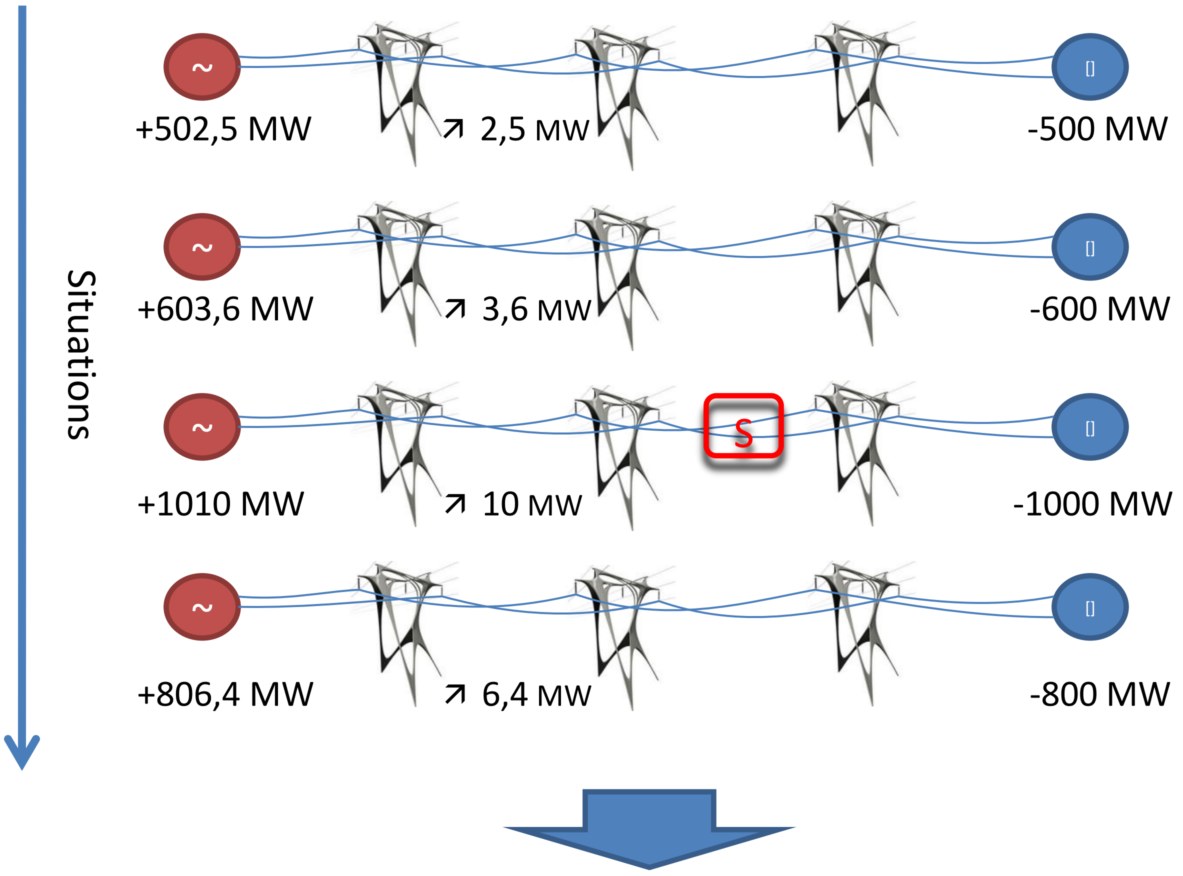
- Optimal Dispatch – Artelys Energy Planner



http://www.artelys.com/gb/platforms/crystal/EnergyPlanner.html

High resolution optimization examples

- Investment planning



Build line of 1000 MW. But how to price transport?

Conclusion

- Spatial and temporal scales ranging over 9 decades.

    Very different simulation tools

- Optimization has widespread use:
  - Design optimization (shape…)
  - Short-term optimization (fixed assets)
    - How to handle congestion on the networks.
  - Long-term optimization (investment allowed)
    - Dimensioning the network for future use.