Sonja Bouwman (KEMA)

A survey of OR models and techniques for electrical grid companies

KEMA

- Founded in 1927, KEMA is a commercial enterprise, specializing in high-grade business and technical consultancy, inspections and measurements, testing and certification (KEMA-KEUR).
- Much of the company's work centers round innovative technology. As an independent organization, KEMA supports clients concerned with the supply and use of electrical power and other forms of energy.
- We work for major utilities, heavy industries and governments, as well as electrical and electronic companies.
- We have offices around the globe, a presence in more than 20 countries and employ more than 1,500 professionals.

Contents

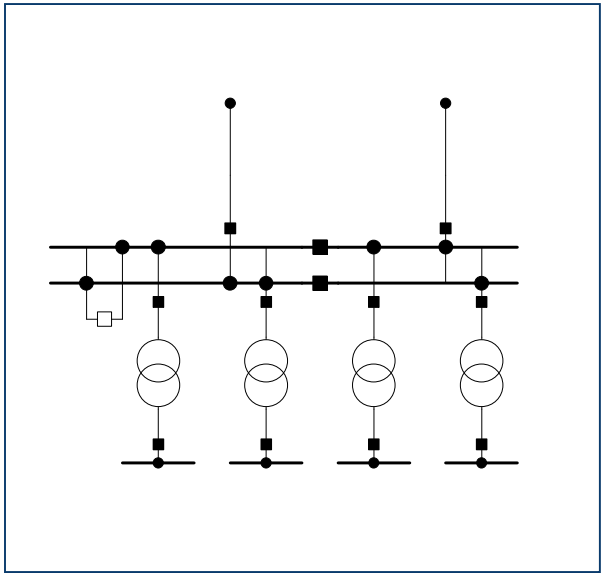
- Optimization model
- Branch & bound
- Graph theory
- Genetic Algorithms
- Decision making method
- Business Simulation
- Demand forecasting

Optimization model for replacement and maintenance strategies of transformers

in cooperation with the University of Twente

Problem description

100 25/10 kV transformers in several stations, with different conditions and ages, who possibly need replacement. How does one make an optimal replacement and maintenance plan for these stations?



Objective:

- maintain at minimum cost (including energy losses, reliability, investment and maintenance)

Constraints:

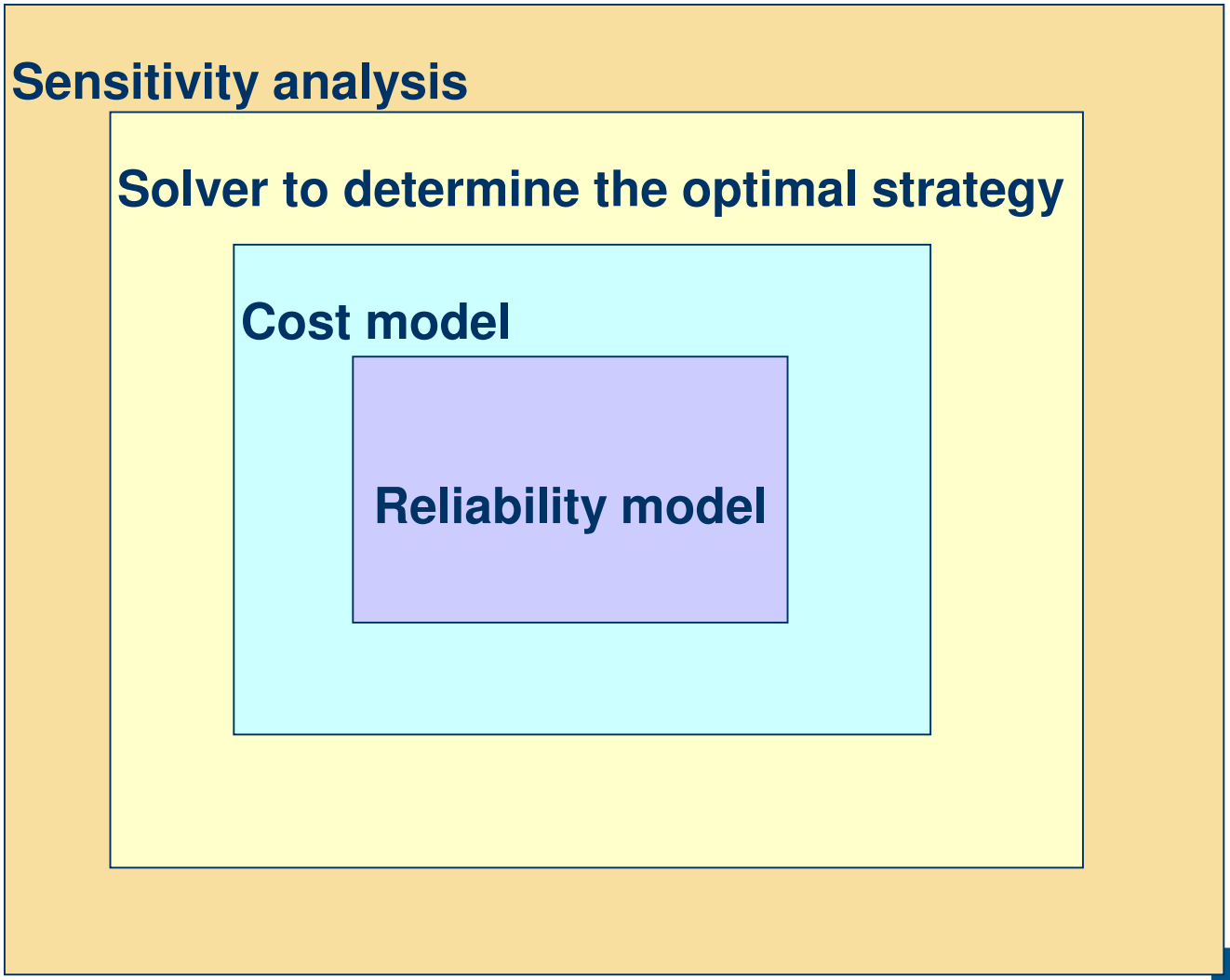
- number of replaced, refurbished or maintained transformers per year
- budget / manpower restrictions for all stations together

Alternatives:

- Options to consider, for example: “do nothing”, “perform maintenance”, “refurbish” or “replace” (each year).

KEMA

Layers of the model

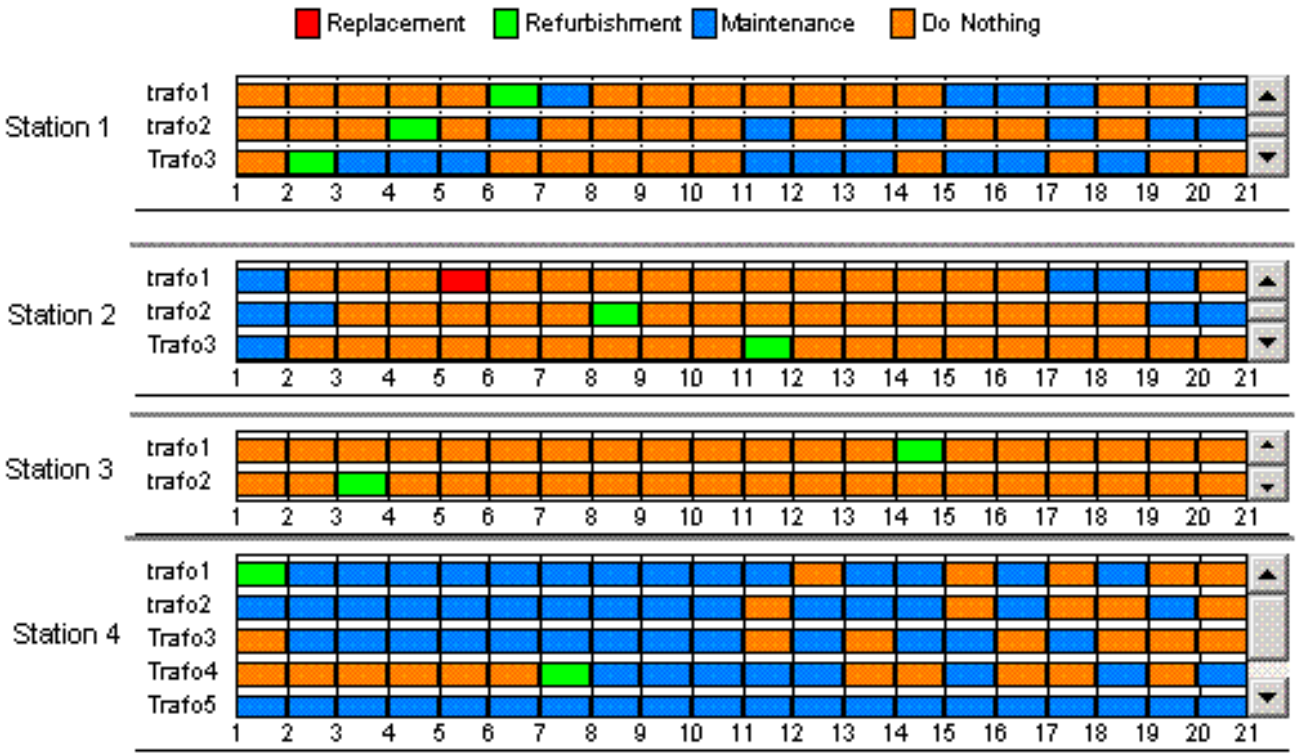


Questions that can be answered with the model:

- When do we have to replace this transformer?
- What is the optimal maintenance schedule for my transformers?
- What type of maintenance should I perform?
- How does this replacement effect my system reliability?
- What are my annual costs to obtain my choosen reliability limits
- …

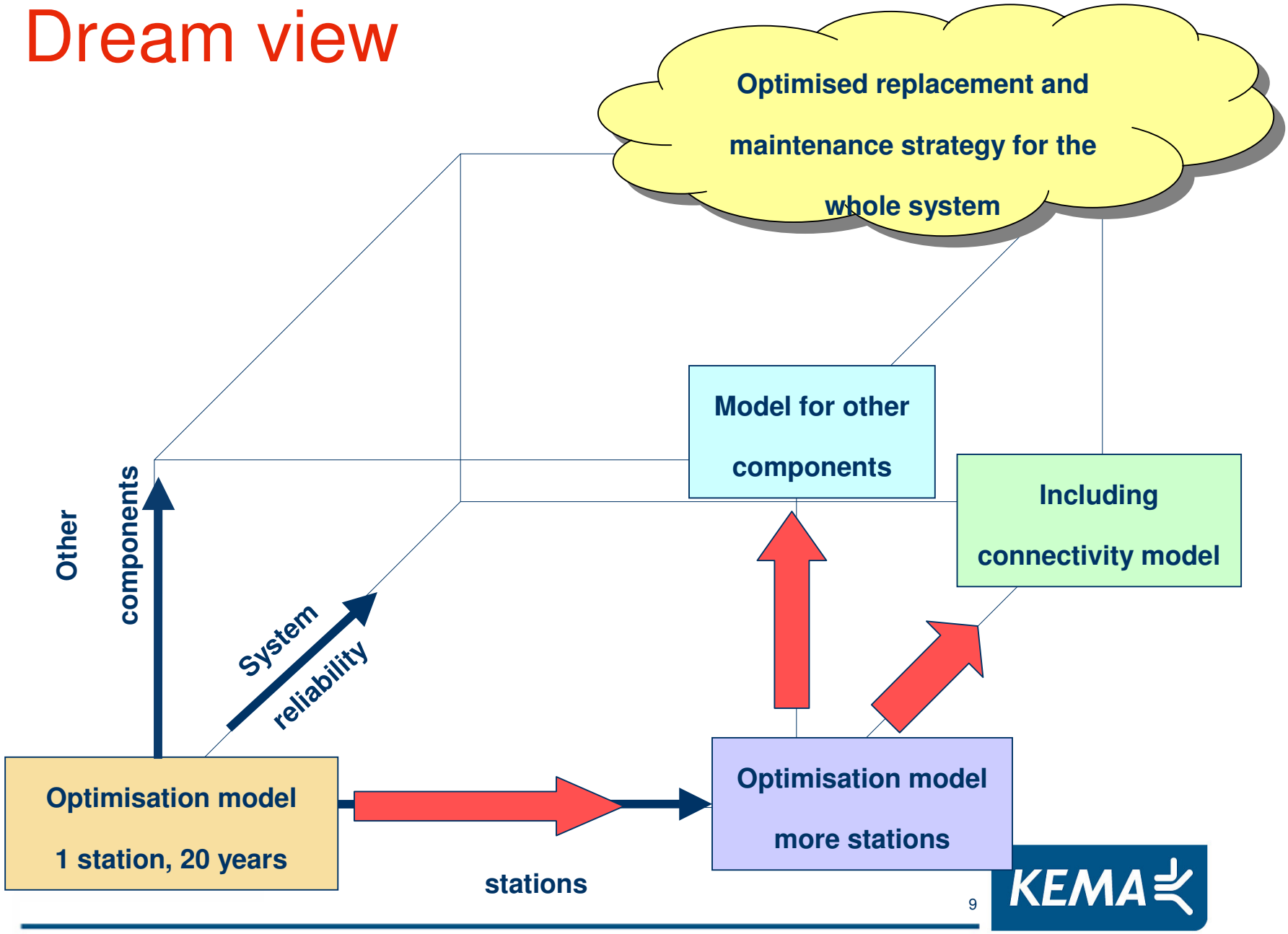
Results multi station model

- Integral optimization for a combination of substations



- Different objectives and constraints per station are possible.

Dream view

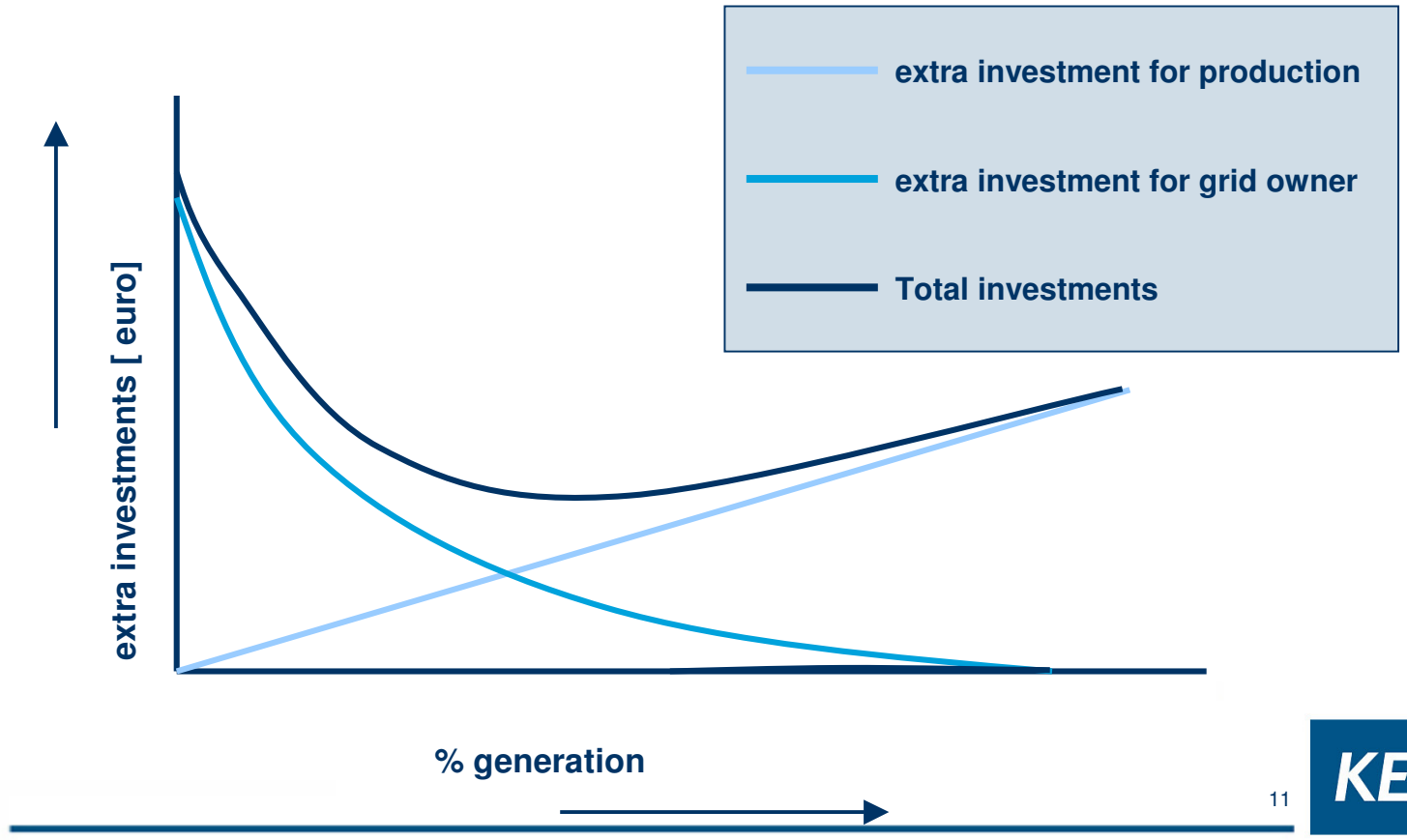

Optimised replacement and maintenance strategy for the whole system
Model for other components
Including connectivity model
Other components
System reliability
Optimisation model 1 station, 20 years
Optimisation model more stations
stations

PRIM€-method

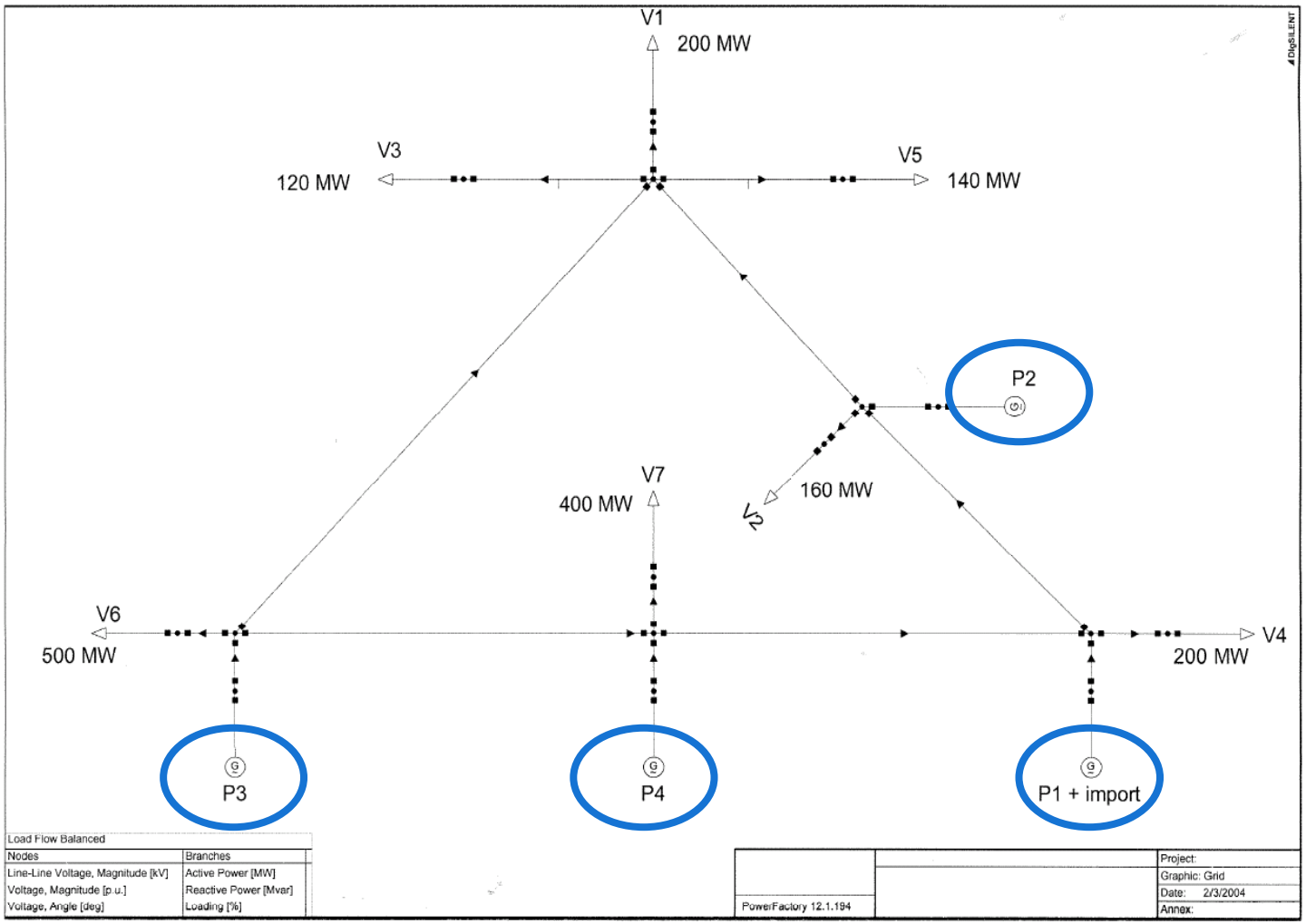
Determining worst-case scenario's of production locations for power supply network operators

Goal

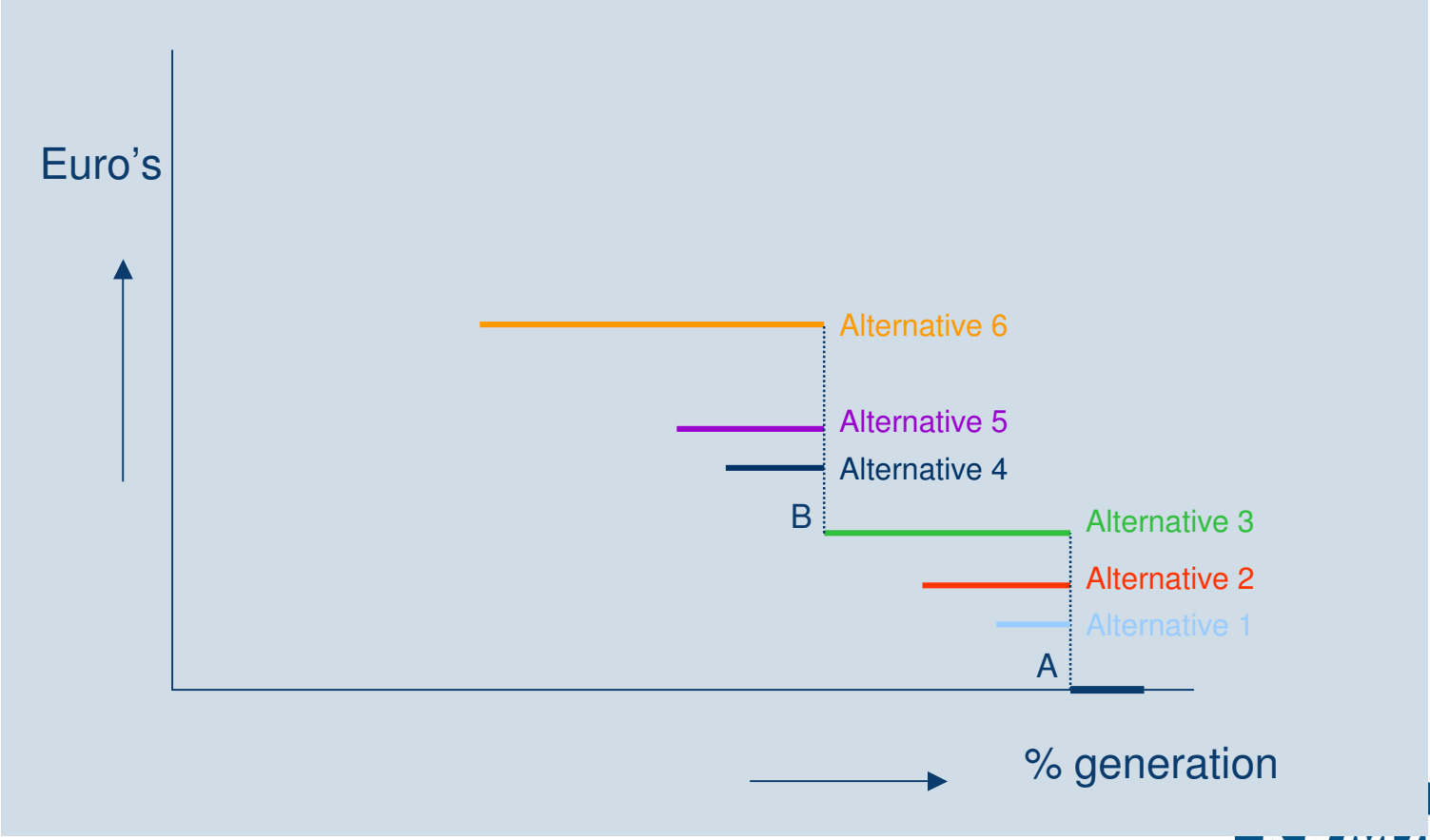
- Regional grid owners depend largely on regional production
- Less production => more import => higher cost grid owner
- Insight into the extra cost for the grid owner when production is moved outside its region.



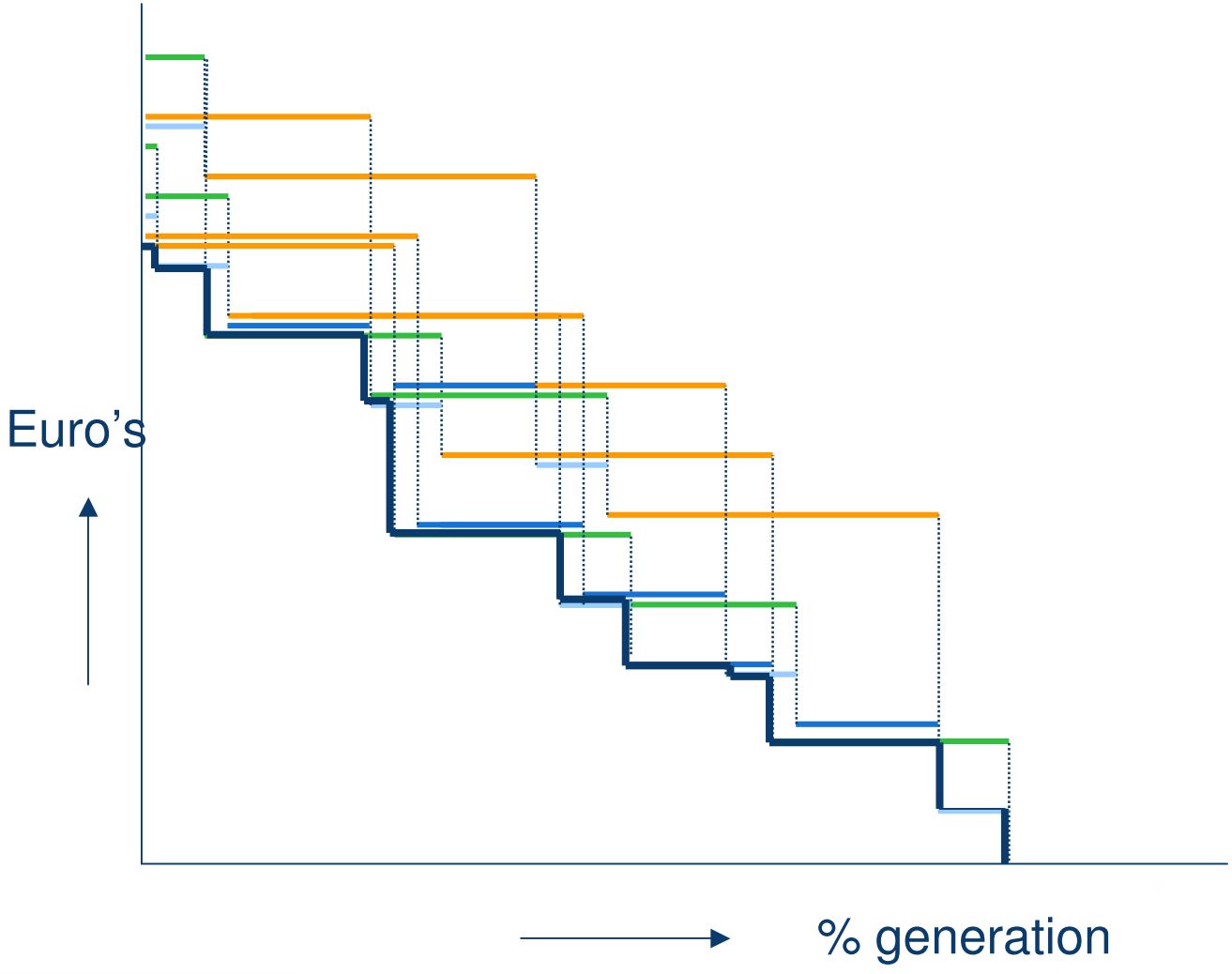
Gridstructure



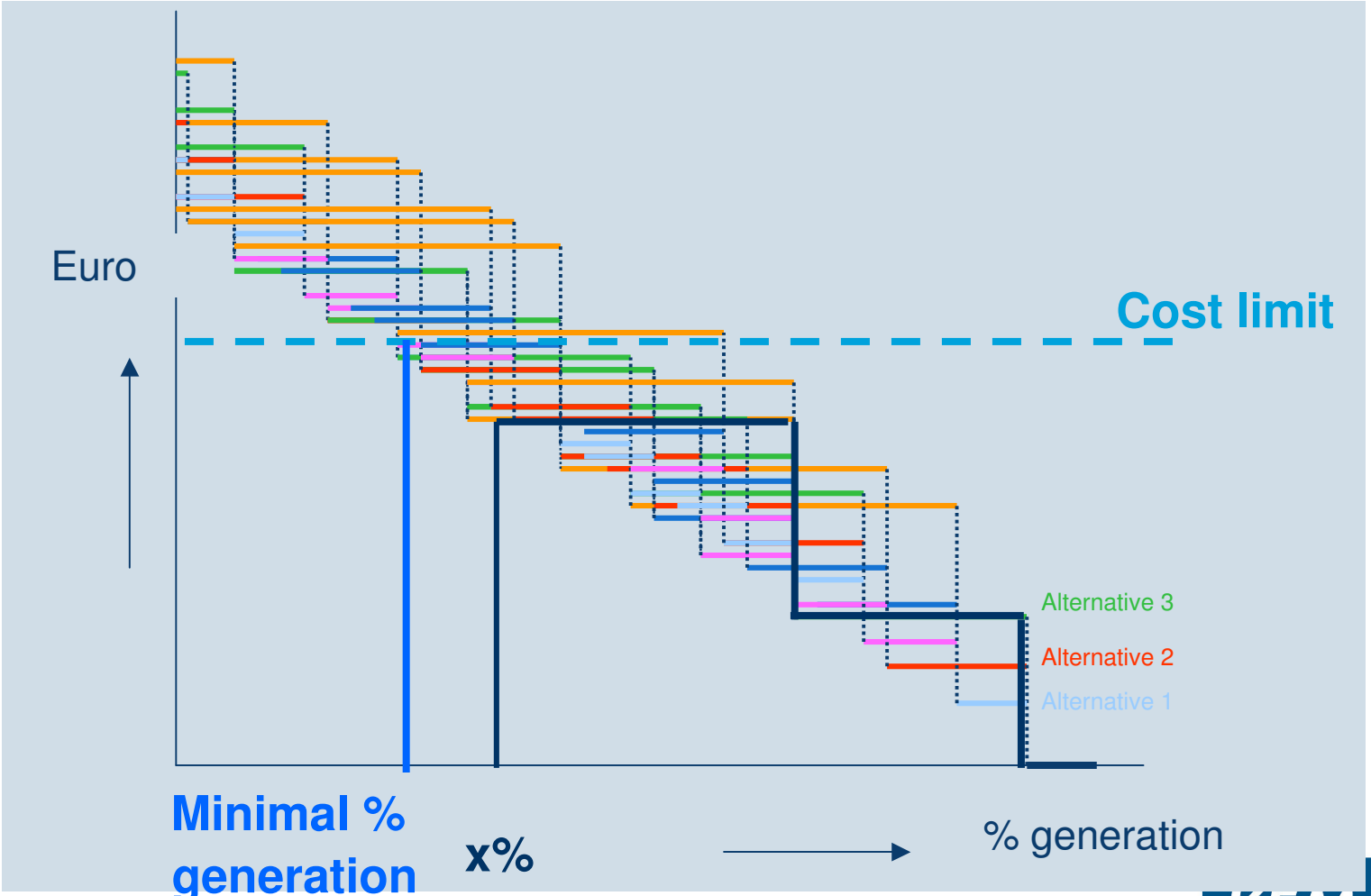
Determination graph



PRiM€ Method



PRIM€ Applications

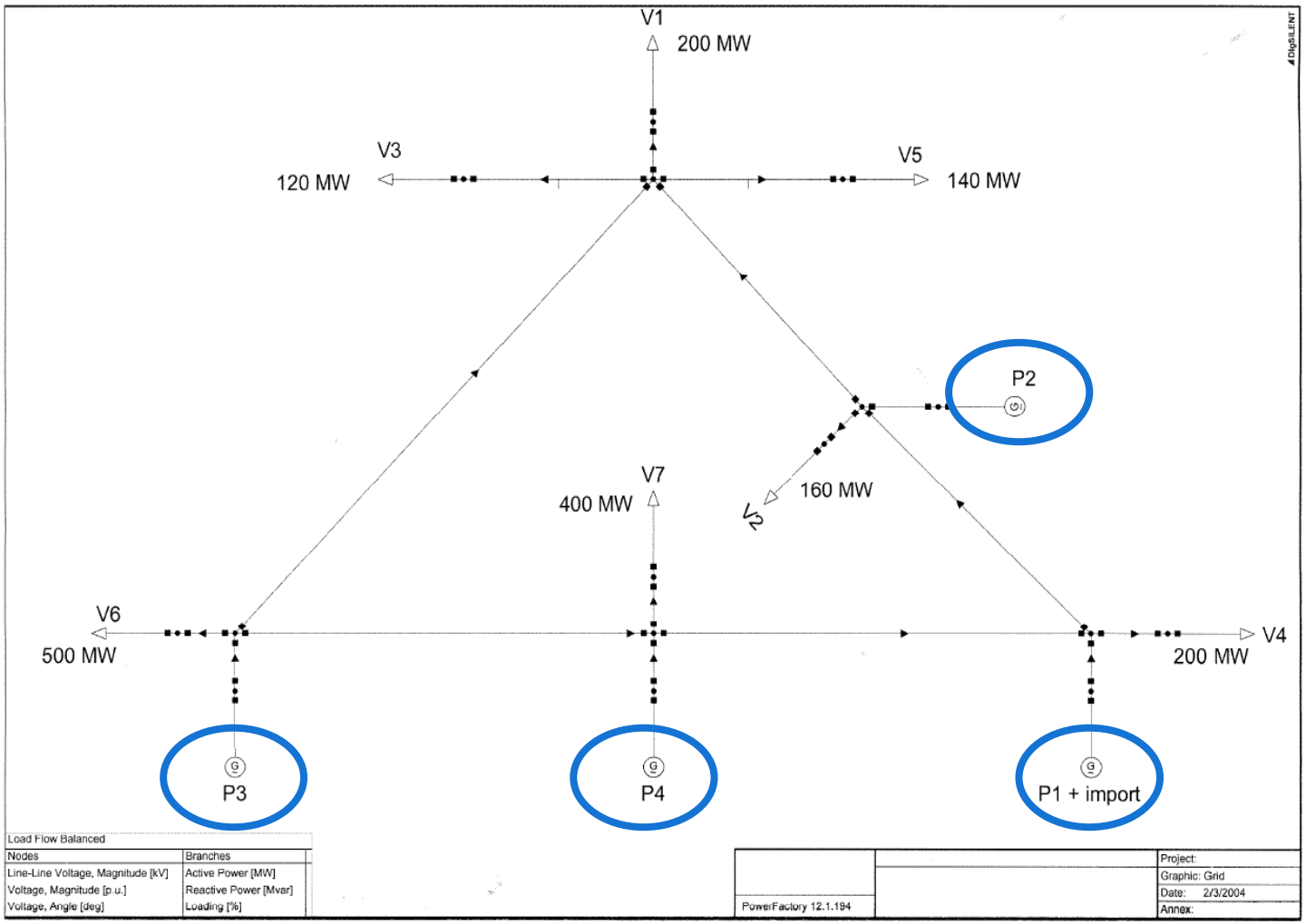


OR applications:

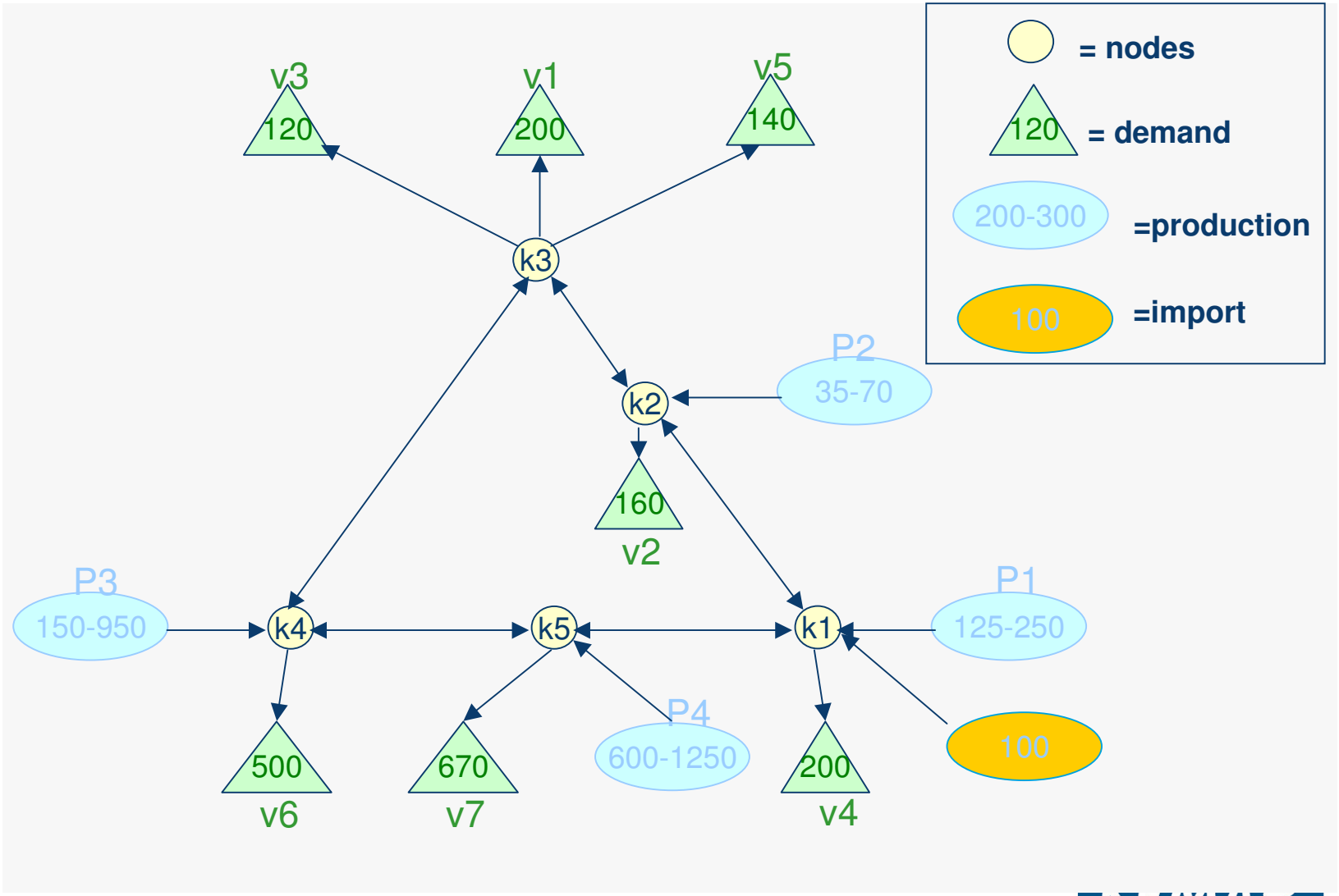
1. Is it possible to reduce the number of paths? =>
   Branch & Bound method

2. Is it possible to determine the worst case production scenarios (at a certain % of generation)? =>
   graph theory

Gridstructure



Graph structure



KEMA

GENODAL

Utilizing a Genetic Algorithm for Distribution Automation Optimization

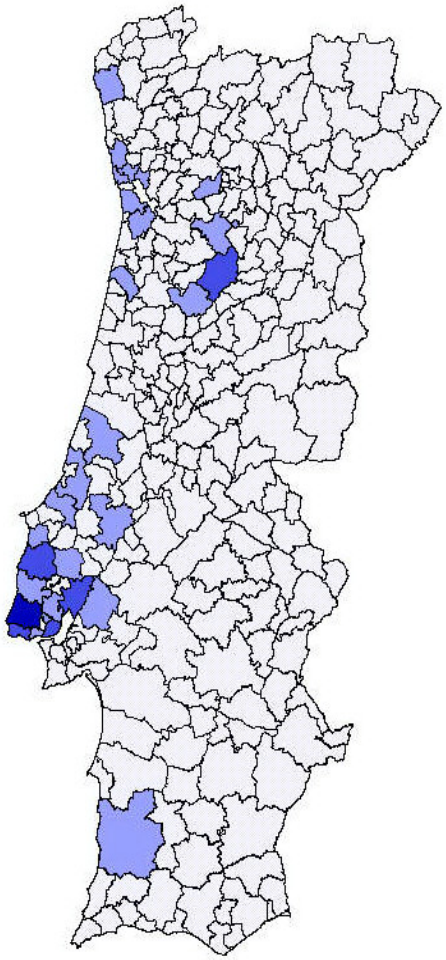
Jasper van Casteren

Portugal

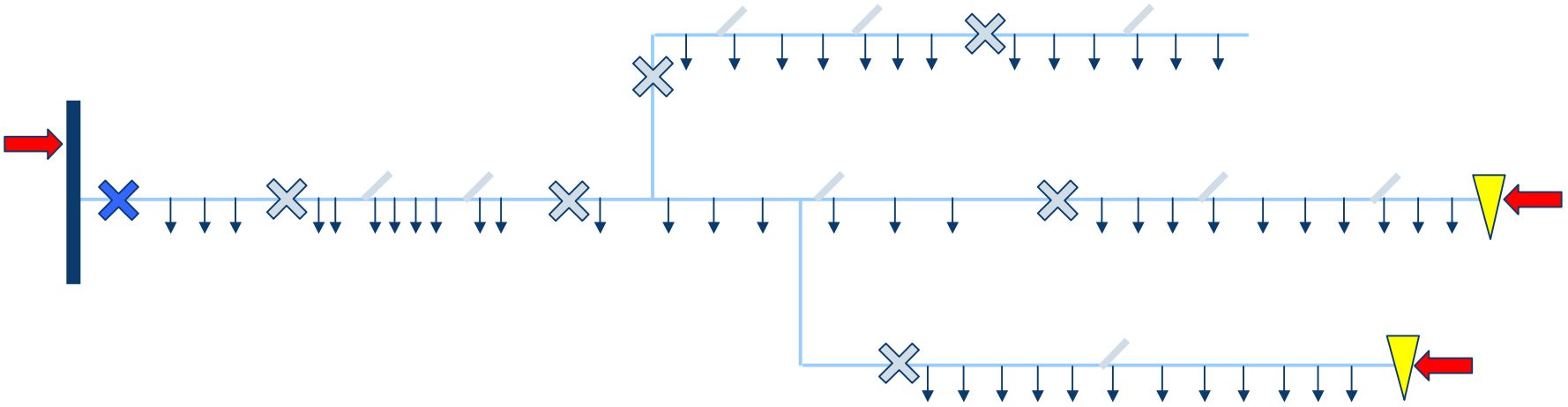
- 14 areas
- 400 substations
- 4000 feeders

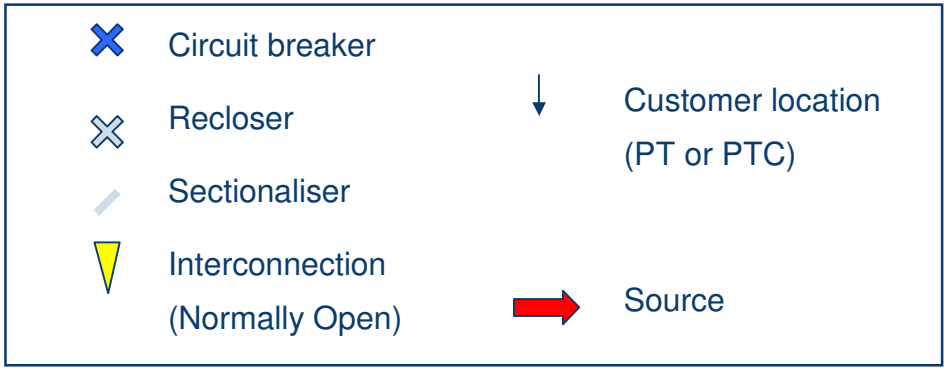
- Feeders show high END (energy not delivered) and high interruption frequencies
- Main indication: TIEPI (cust minutes lost (weighted)

- Solution : distribution automation
  - Auto-Reclosers
  - Sectionalizers

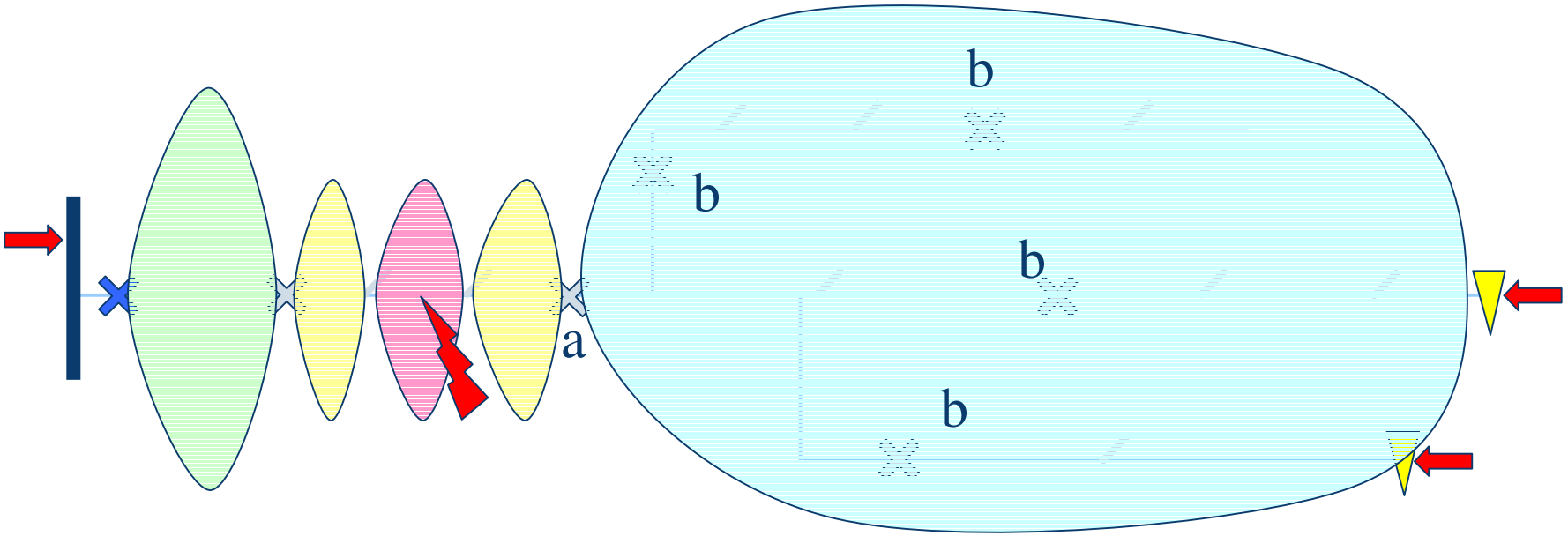


Effects of distribution automation





Effects of distribution automation



No TIEPI, no MAIFI

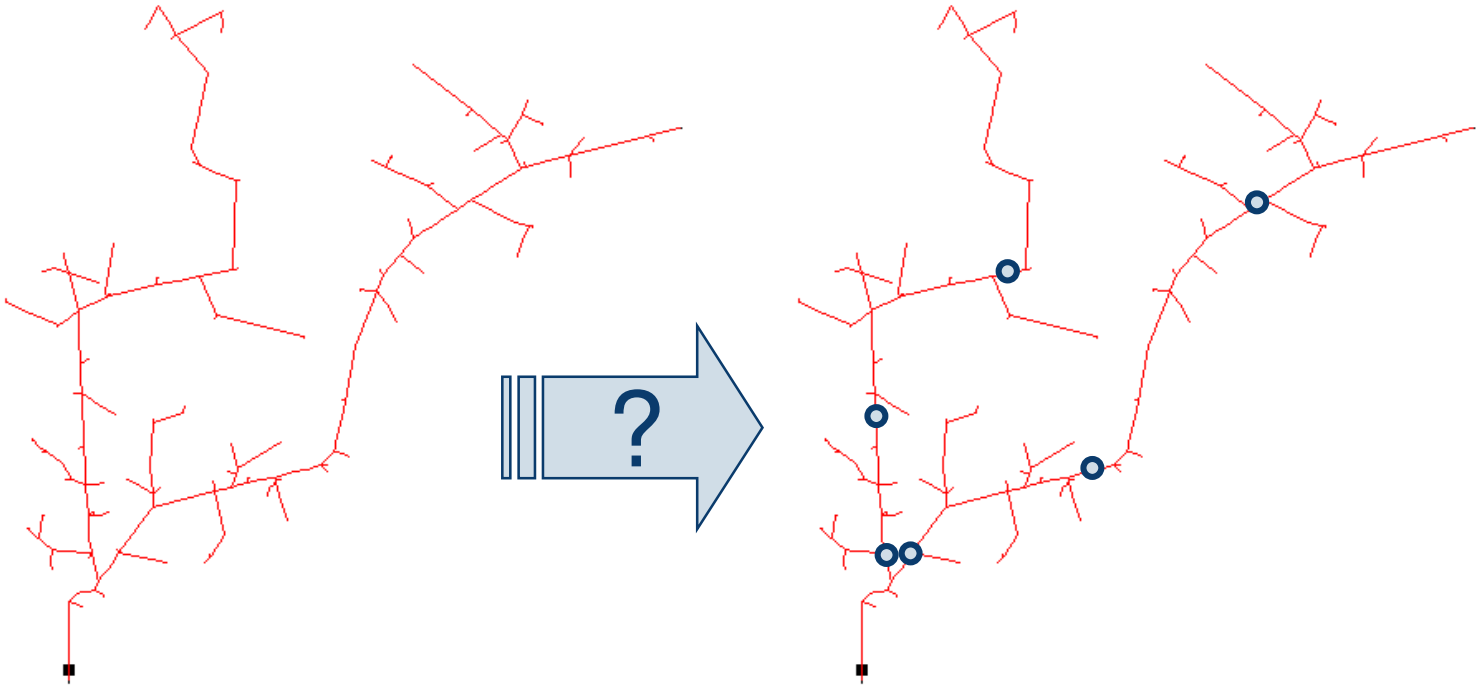
No TIEPI, MAIFI

TIEPI, no MAIFI

No TIEPI, MAIFI+

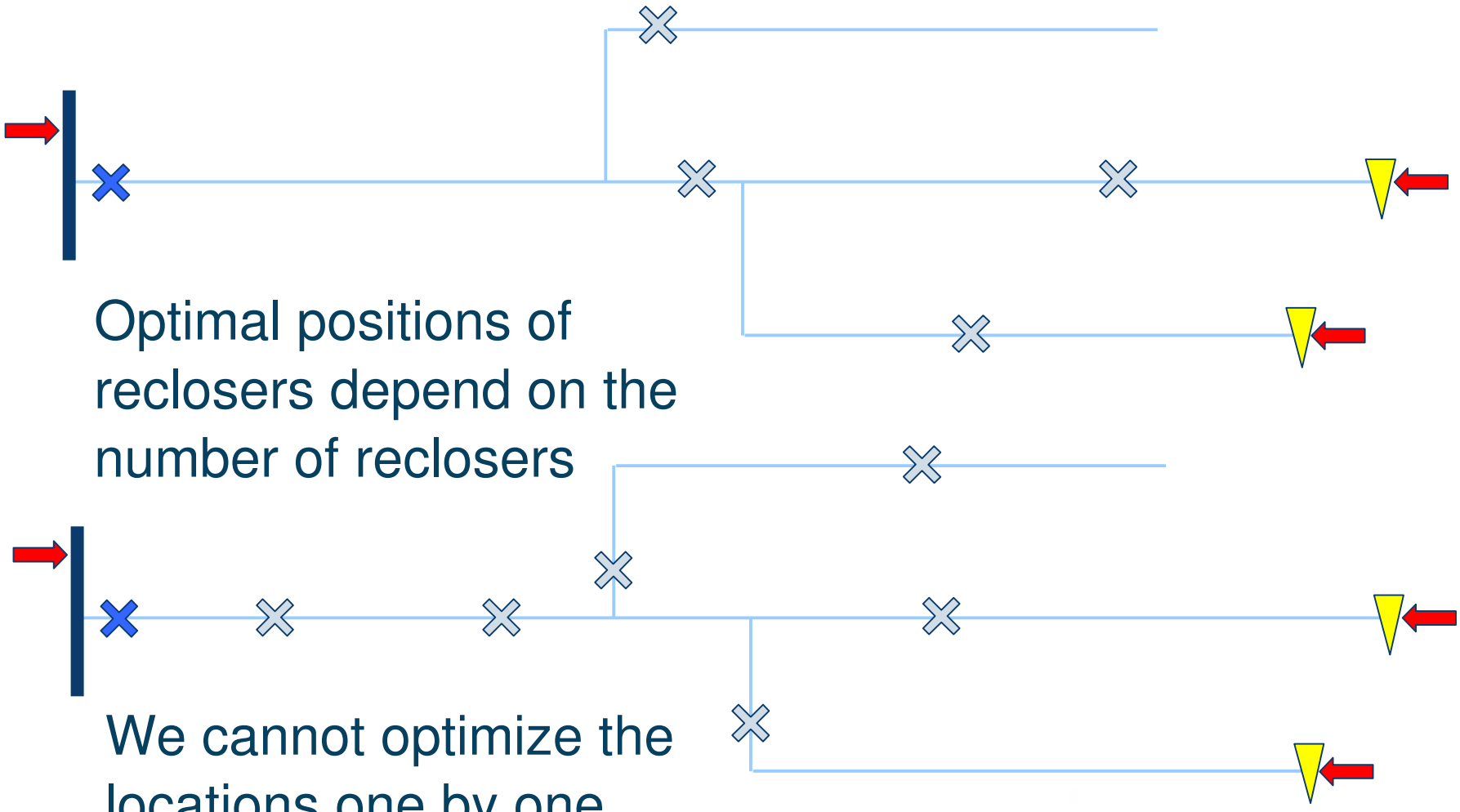
KEMA

One single feeder



- Problem:
  - how many reclosers ?
  - Where to put them ?

Combinatorial Problem



Optimal positions of reclosers depend on the number of reclosers

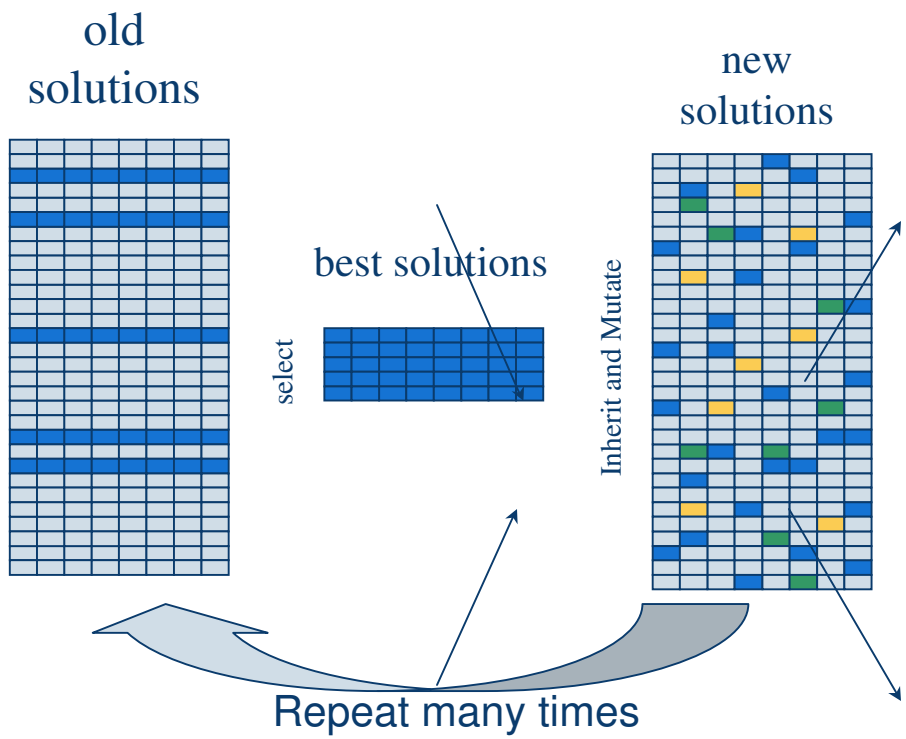
We cannot optimize the locations one by one

Defining the Problem

- Find the optimal solution using cost-benefit analyses
  - Optimize the number of DA-devices
  - Optimize the locations of DA-devices
- Thousands of feeders to optimize
- Reliability assessment determines quality of solution
- Optimizing the location is a combinatorial problem : billions of possible solutions

A Genetic Algorithm

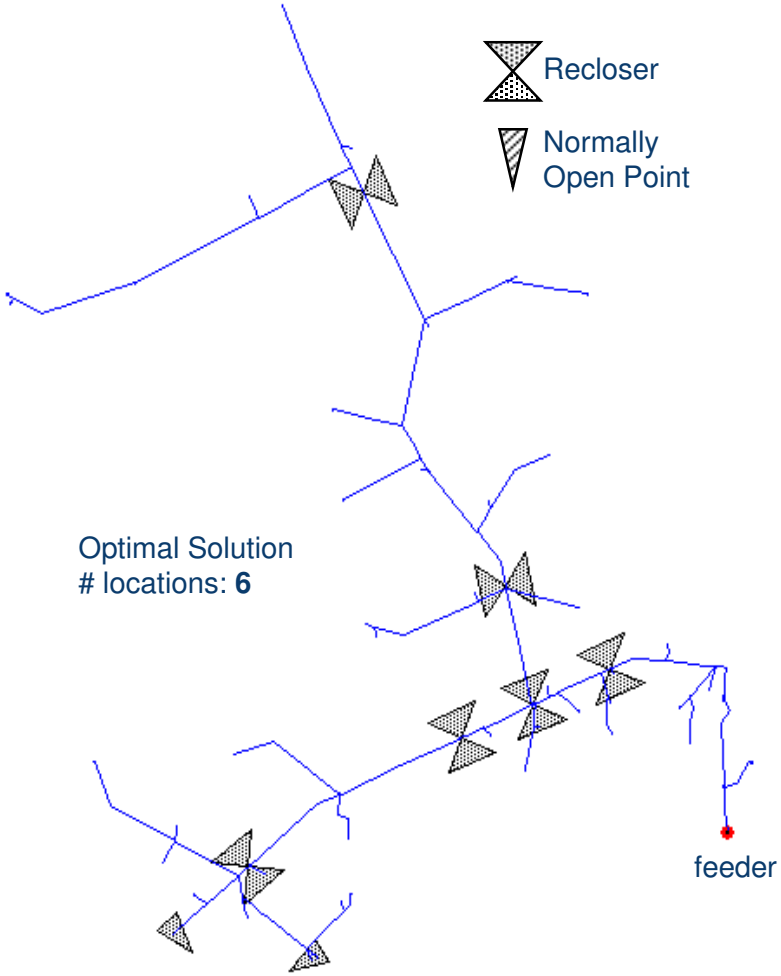
- Combinatorial problem solved by genetic algorithm
- Repeating cycle many times produces list of best solutions
- Overall best solution is the result of the optimization process.



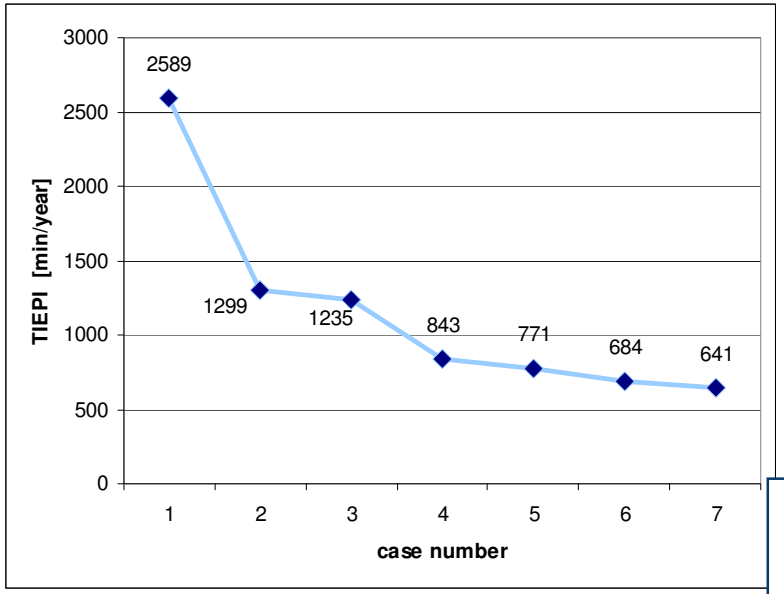
Example of a result

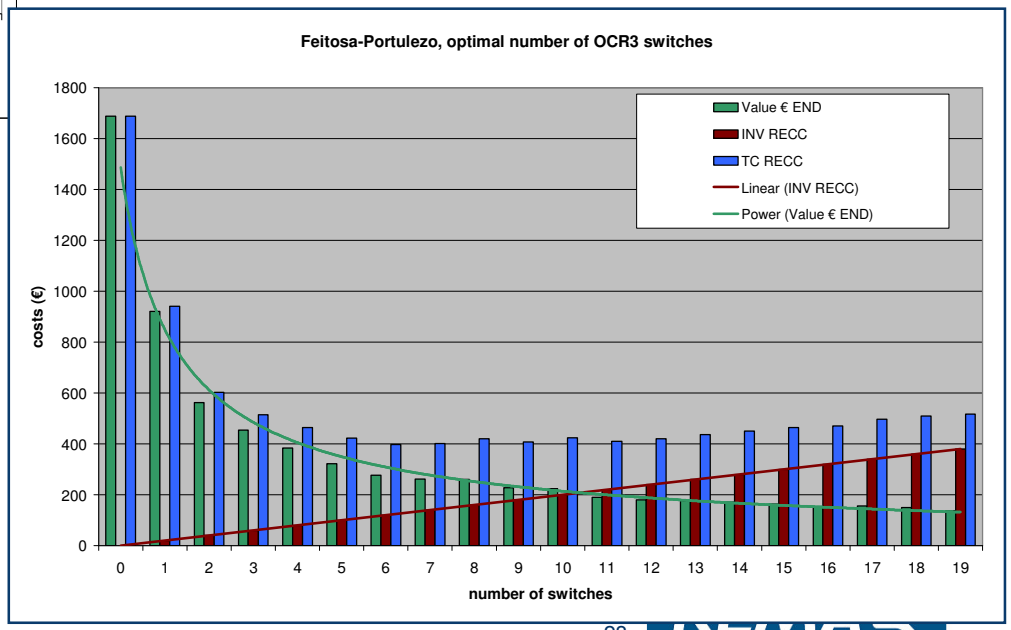
- Solutions for 1..15 numbers of reclosers are calculated.
- The optimal number of reclosers is selected.

- Total calculation time:
  - About 5 minutes.



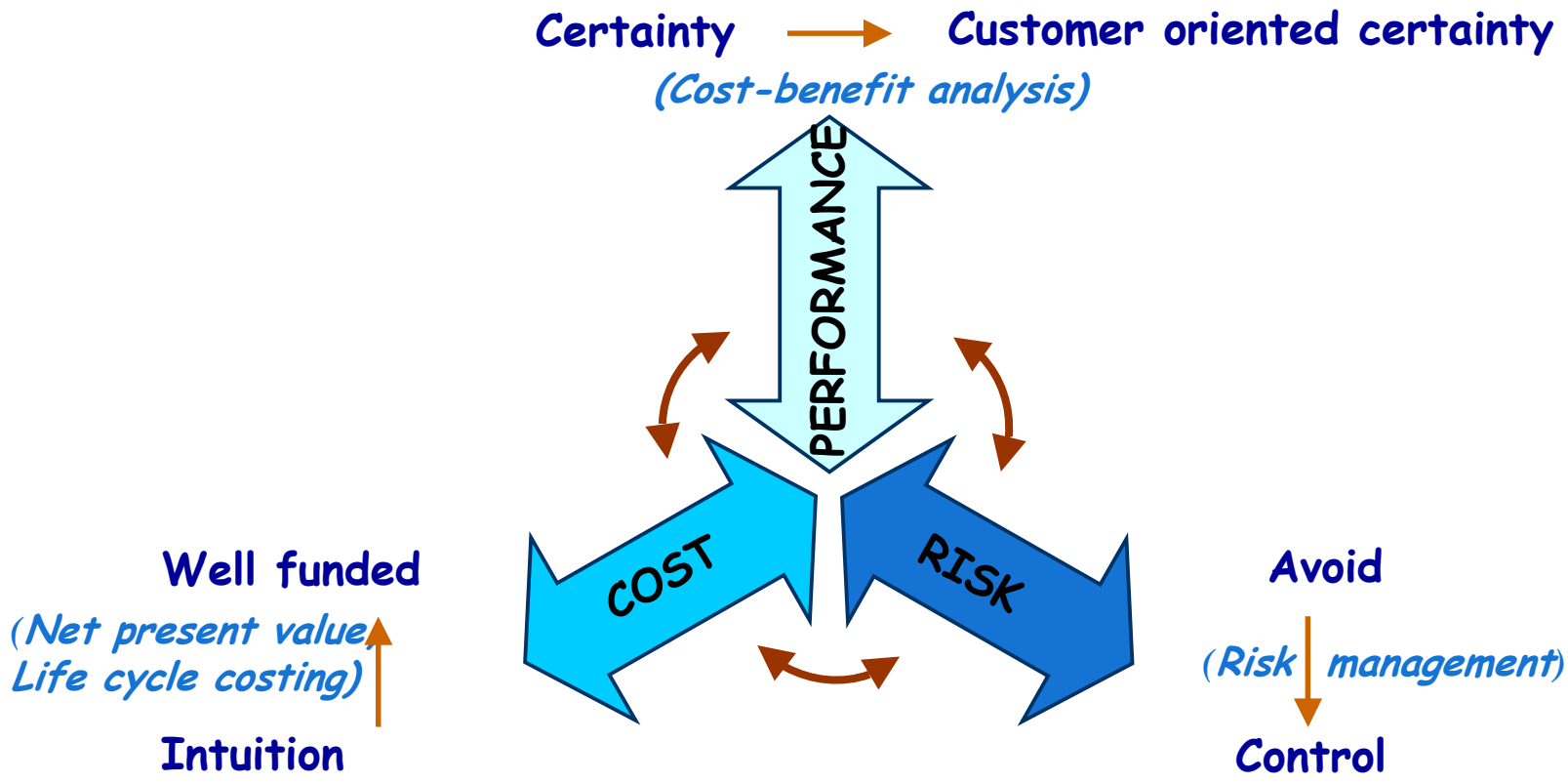
DA results, TIEPI reduction





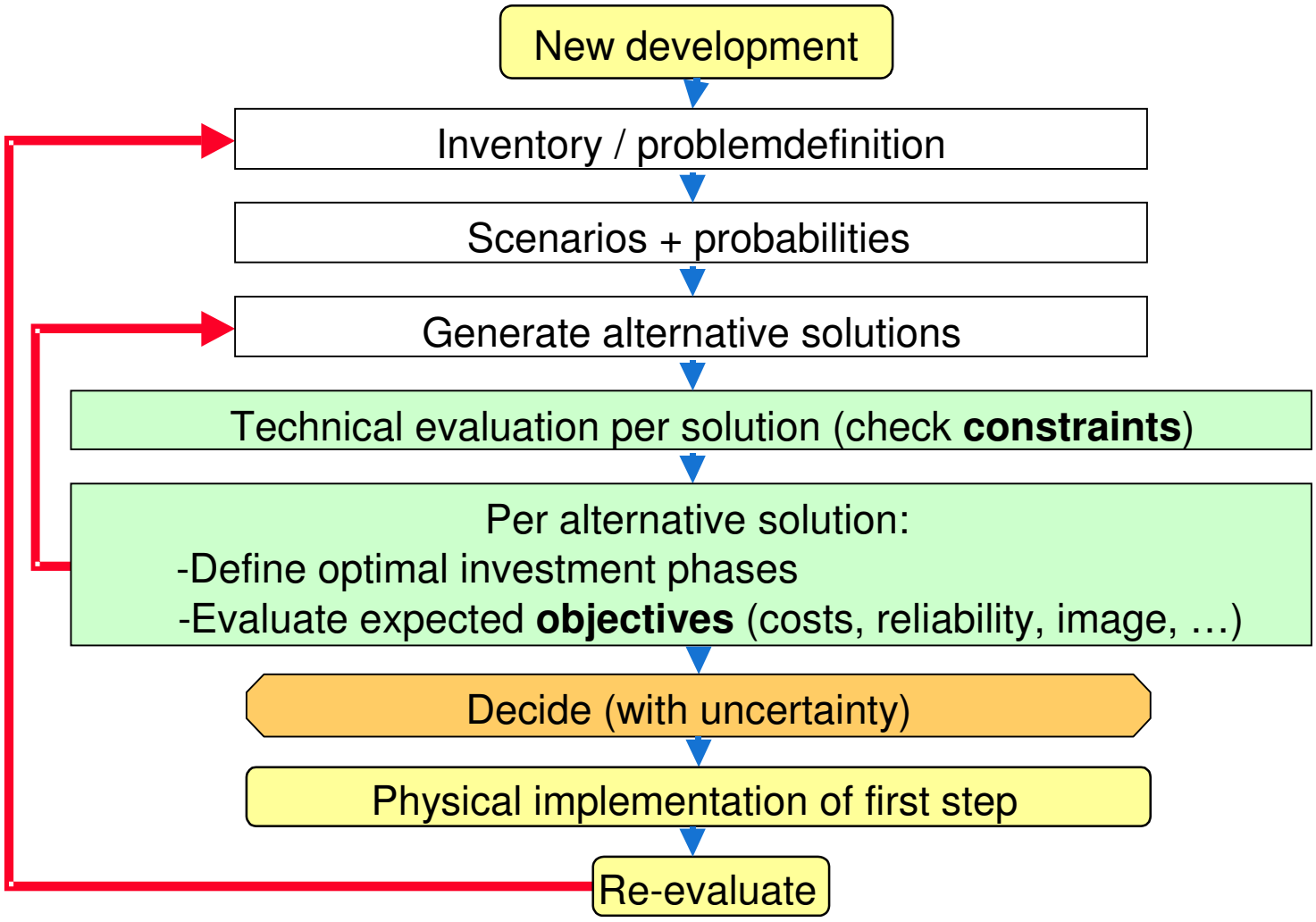
Decision making method

Changing balance of objectives



What are the aspects of a good decision?

- Objective
- Transferable
  - Consistent terminology
  - Separation between preparator and decision maker
- Transparent / verifiable
- Well founded (no more unconscious decision making)
- …


New development
Inventory / problemdefinition
Scenarios + probabilities
Generate alternative solutions
Technical evaluation per solution (check **constraints**)
Per alternative solution:
-Define optimal investment phases
-Evaluate expected **objectives** (costs, reliability, image, …)
Decide (with uncertainty)
Physical implementation of first step
Re-evaluate

Business Simulation fleXnet

Business Simulation fleXnet

- FLEXNET is a business simulation consisting of a game board plus software, supported by KEMA professionals
- FLEXNET links technology to policy and to human response.
- You can simulate planned and unplanned events and third-party developments, and see what impact they have on your own ideas and strategies. The software calculates the resulting energy and cash flows, bringing every overload and penalty to light.

Possibilities of fleXnet

- On the game board, an electricity grid is built up from a starting situation, complete with production and consumption units.
- Including new (flexible) components
- Withdrawal of subsidies
- Introduction of new regulations
- Power import
- Offshore wind farms
- Unexpected events:
  - Faults
  - Client relocations
  - Wind fluctuations

KEMA

Applications

- Training (Insight into the dynamics of the whole electricity sector)
- Testing of new legislations or new strategies
- Investigation of impact of new developments (components, systems, technologies)

Users

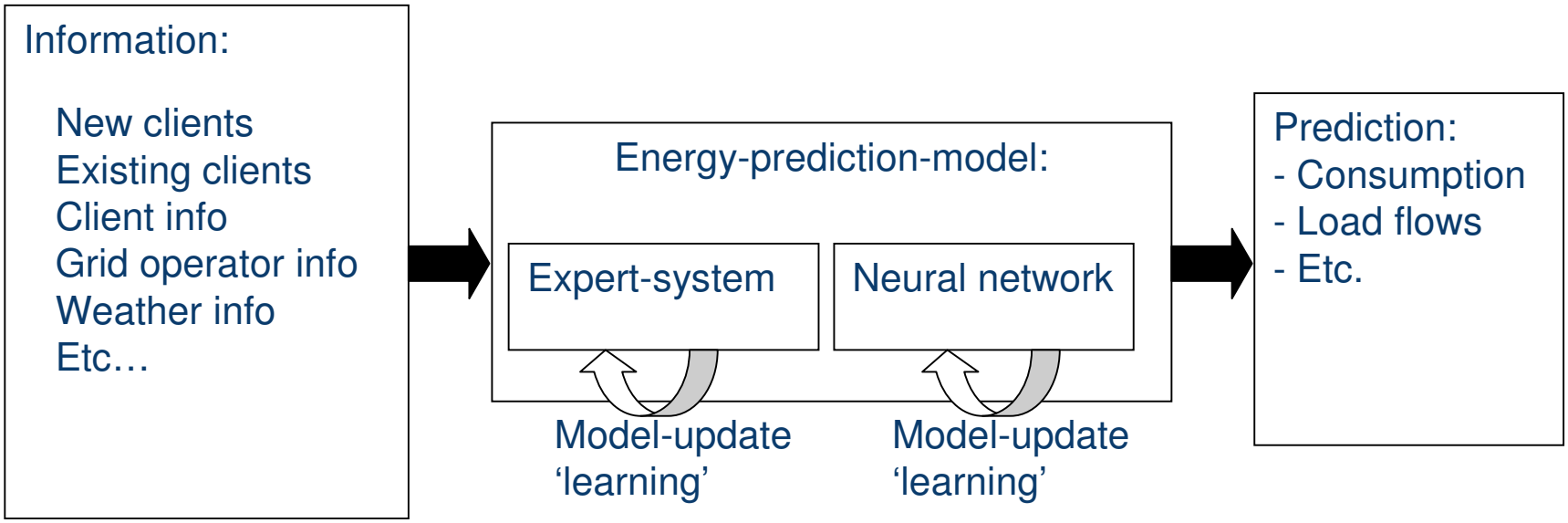
- Grid companies
- Regulators
- Power generators, consumers, traders, manufacturers
- Students, teachers, researchers

Future

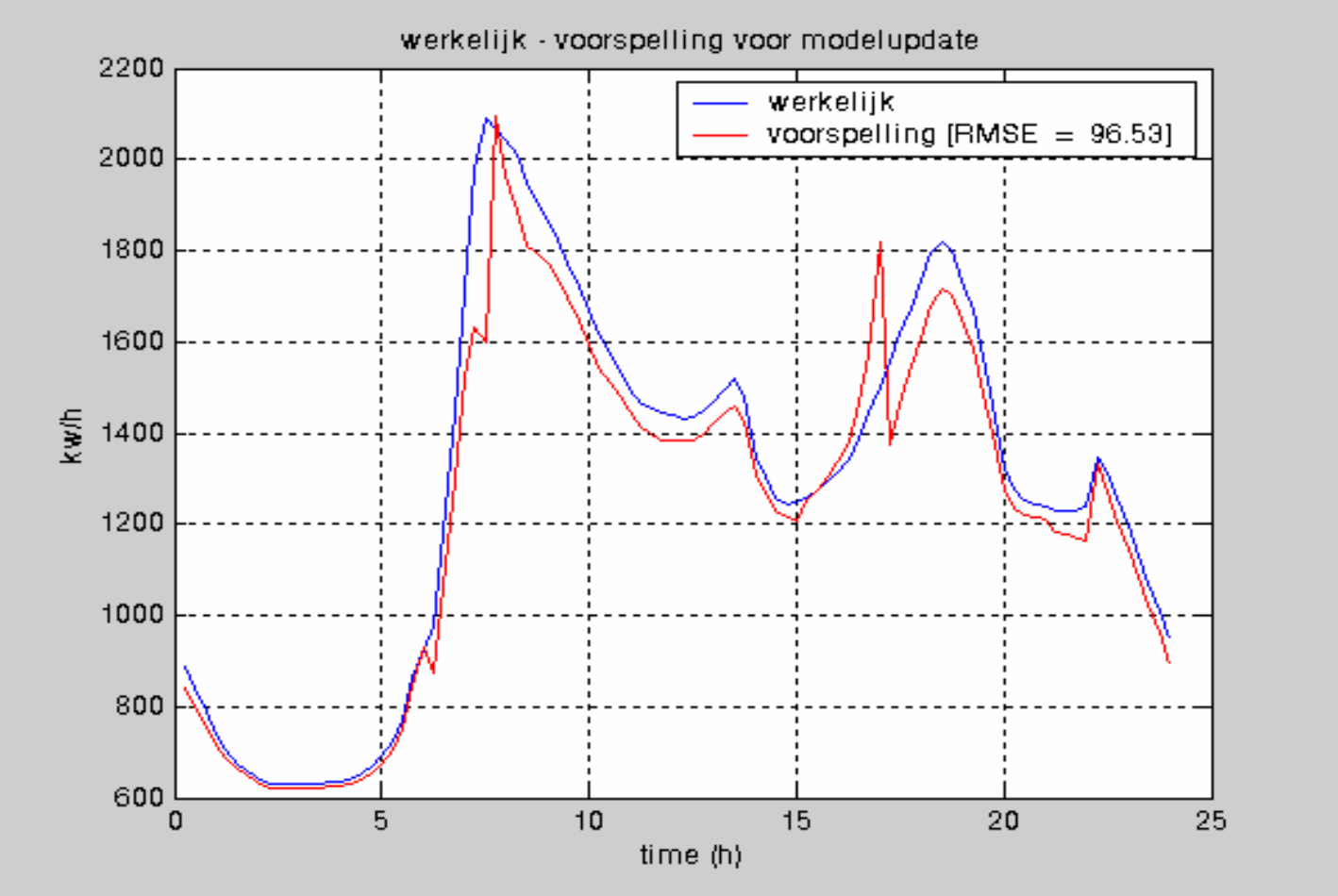
- FleXnet can only be played for several rounds, while decisions are typical long-term
- *How does a FleXnet-situation develop long-term?*
- Players have a relative short amount af time and not all knowledge
- *Which strategy is the best and how much does it differ from current solutions? What is the advantage of cooperation?*
- FleXnet can be used for several different learning goals and parties.
- *Which adjustments (before and during the simulation) can be made to obtain the different learning goals*

Demand forecasting

Energy Prediction System



Energy Prediction System Results



KEMA

Summary

- Optimization model for replacement and maintenance strategies of transformers
- Determining worst-case scenario's of production locations for power supply network operators
- Utilizing a Genetic Algorithm for Distribution Automation Optimization
- Decision making methods
- Business Simulation fleXnet
- Demand forecasting

Questions?
Remarks?
Suggestions?

Thank you for your attention