THE ROLE OF AI IN HYDROPOWER OPTIMIZATION

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SINTEF Energy Research

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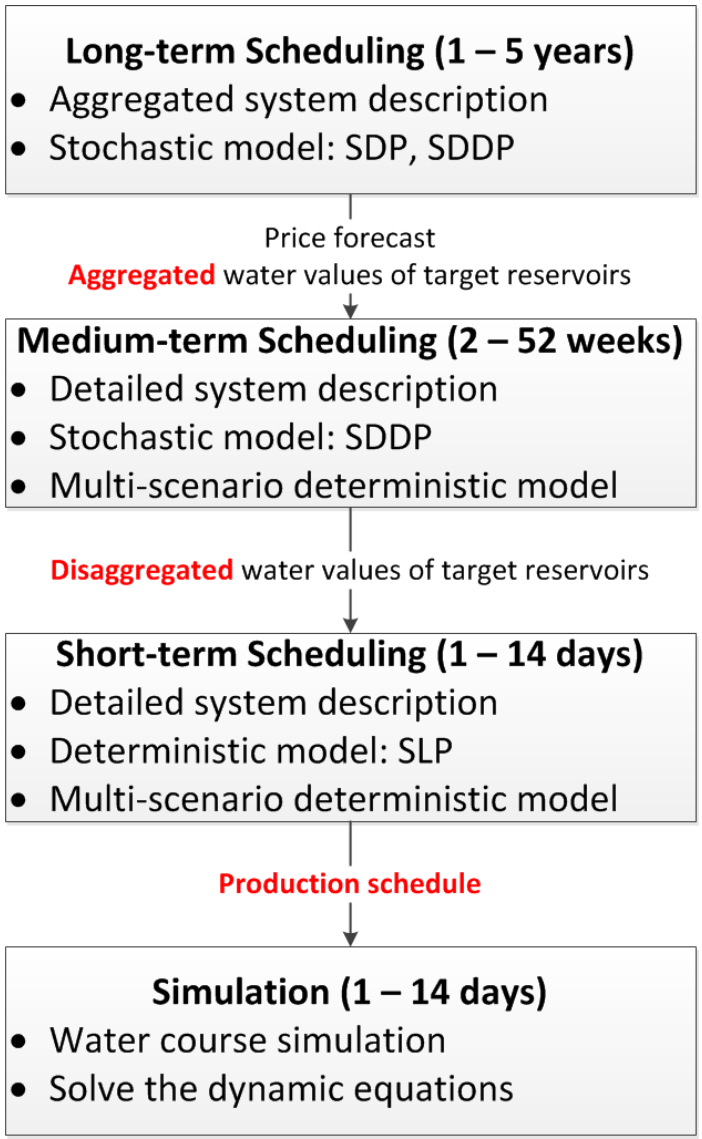
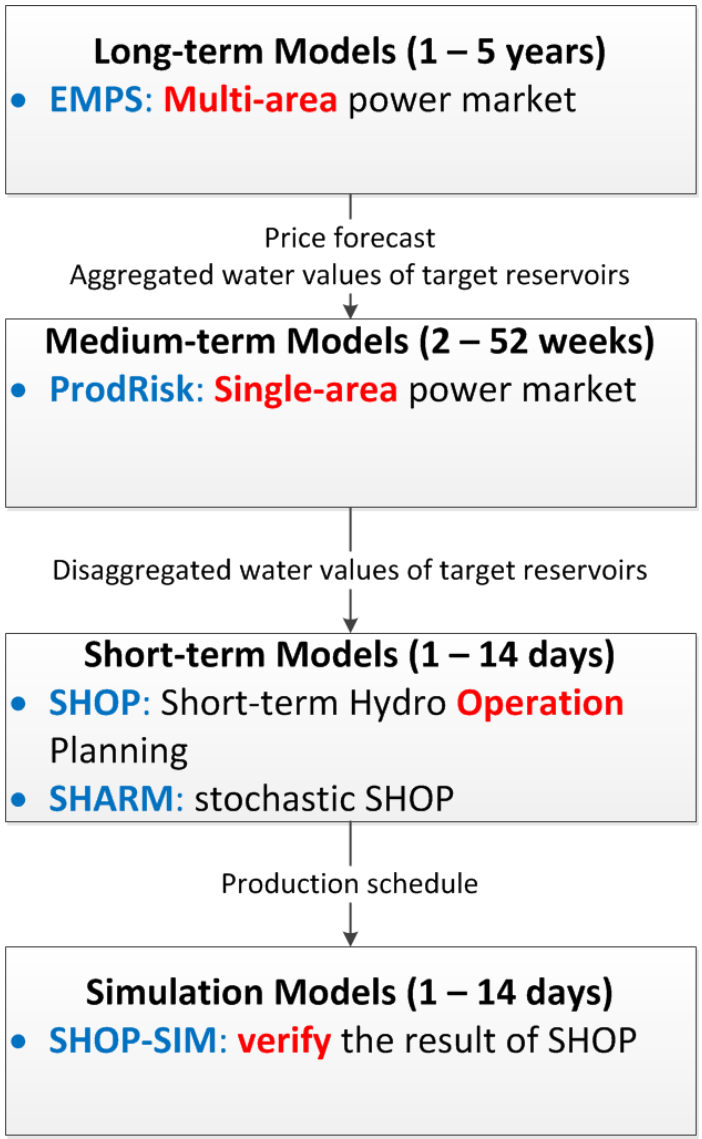
Overview of hydropower scheduling process





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SHOP user map

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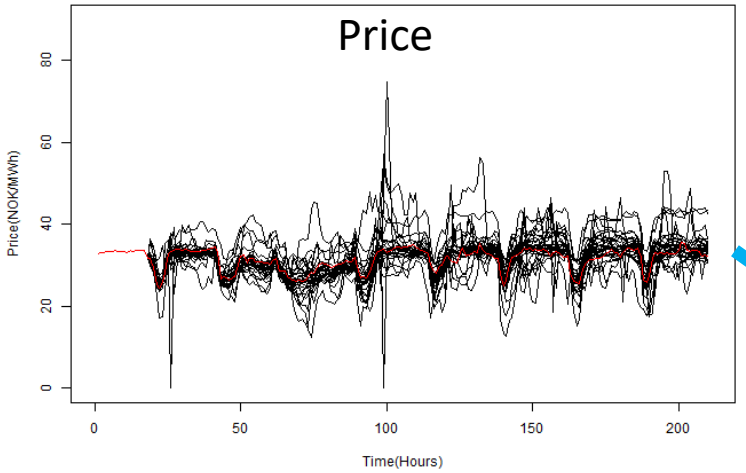
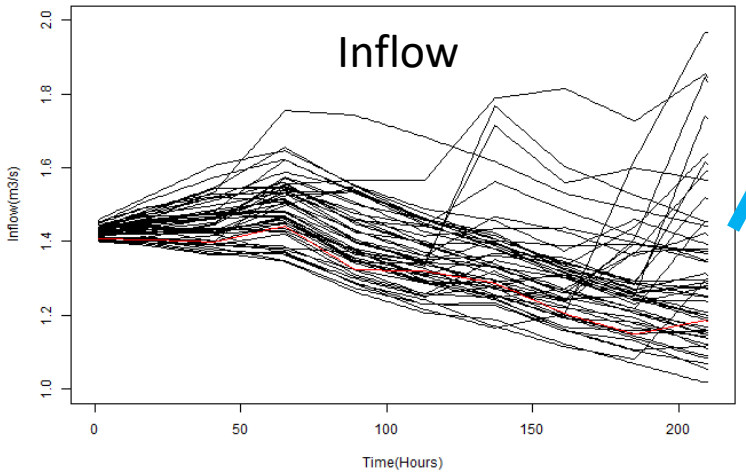
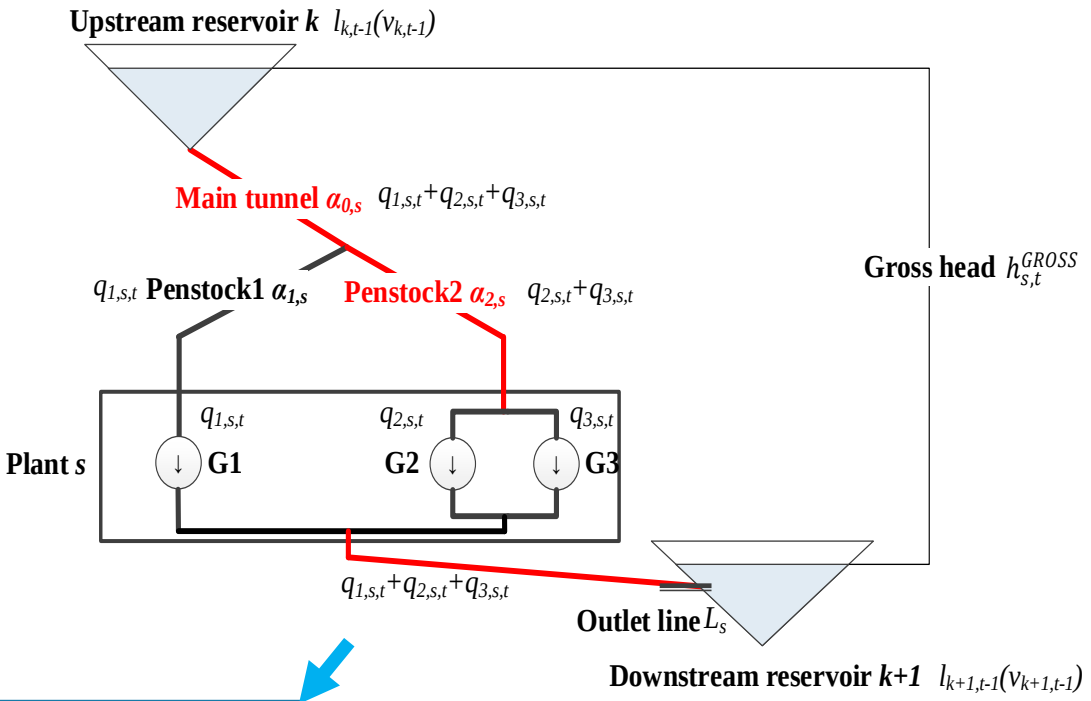
Short-term Model: SHOP

- The objective function of the program is to optimize use of the available resources:
  - maximize the profit within the period of consideration by exploiting the options of buying and selling in the markets
  - Include start/stop cost of units and end value of reservoirs
- Constraints
  - Storage limits of the reservoir and operational limits of controllable spillage
  - Head optimization and flow-related head losses
  - Needle combinations (pelton) and forbidden operating zones
  - Non-convex production function
  - Coupling to long-term/mid-term strategy
  - Environmental constraints (ramping, minimum discharge)
  - Physical flow relationships (time delay, pressurized tunnel systems, hydraulic short circuit)
  - Market-specific delivery constraints (symmetry, buffer capacity, droop, min delivery, rotating requirements, etc)

Use of SHOP







SHOP:
Optimal production schedule for next day

Strategy from long-term model

- Cost-effective energy
- Flood control
- Fulfil environmental restrictions
- Balance other renewables

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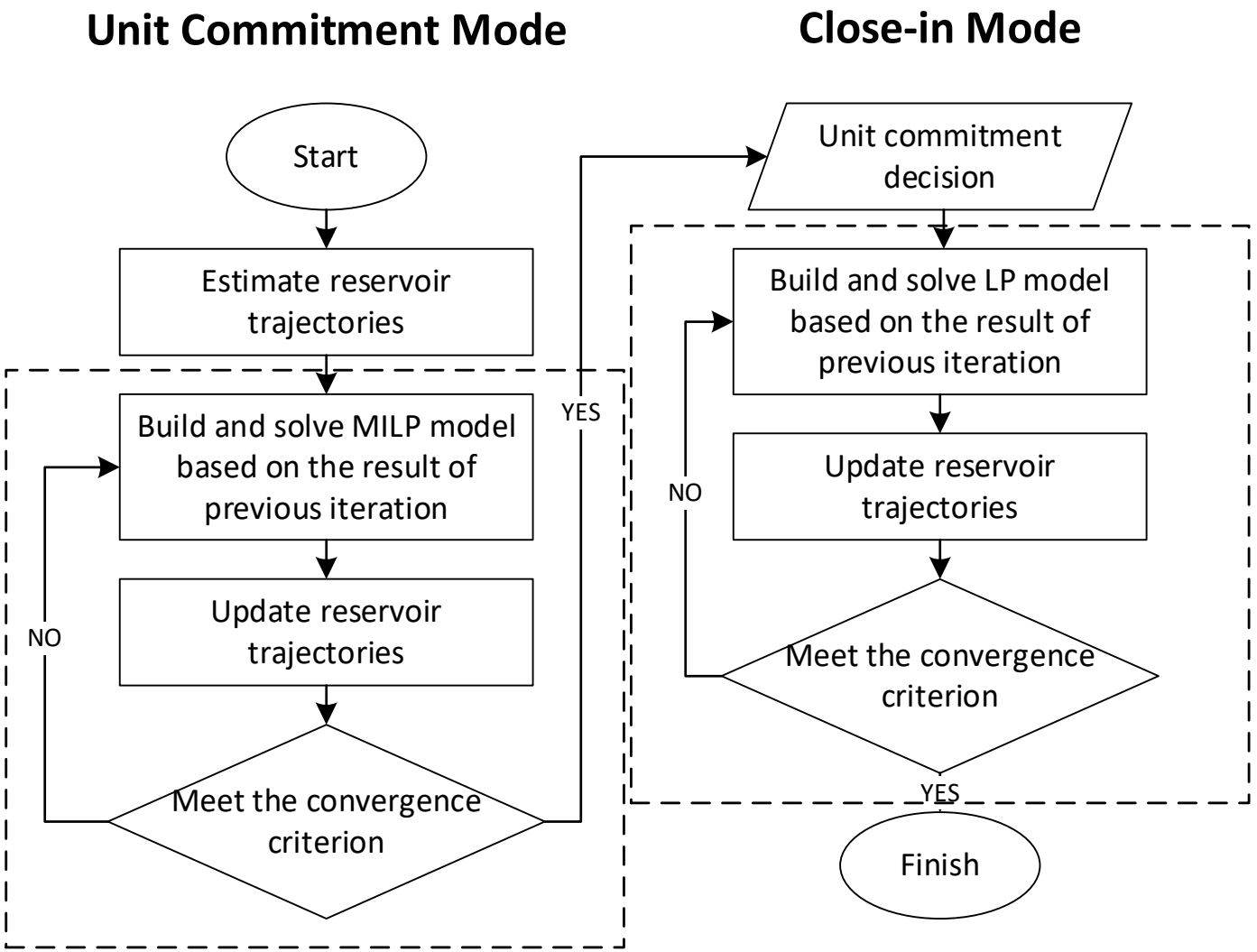
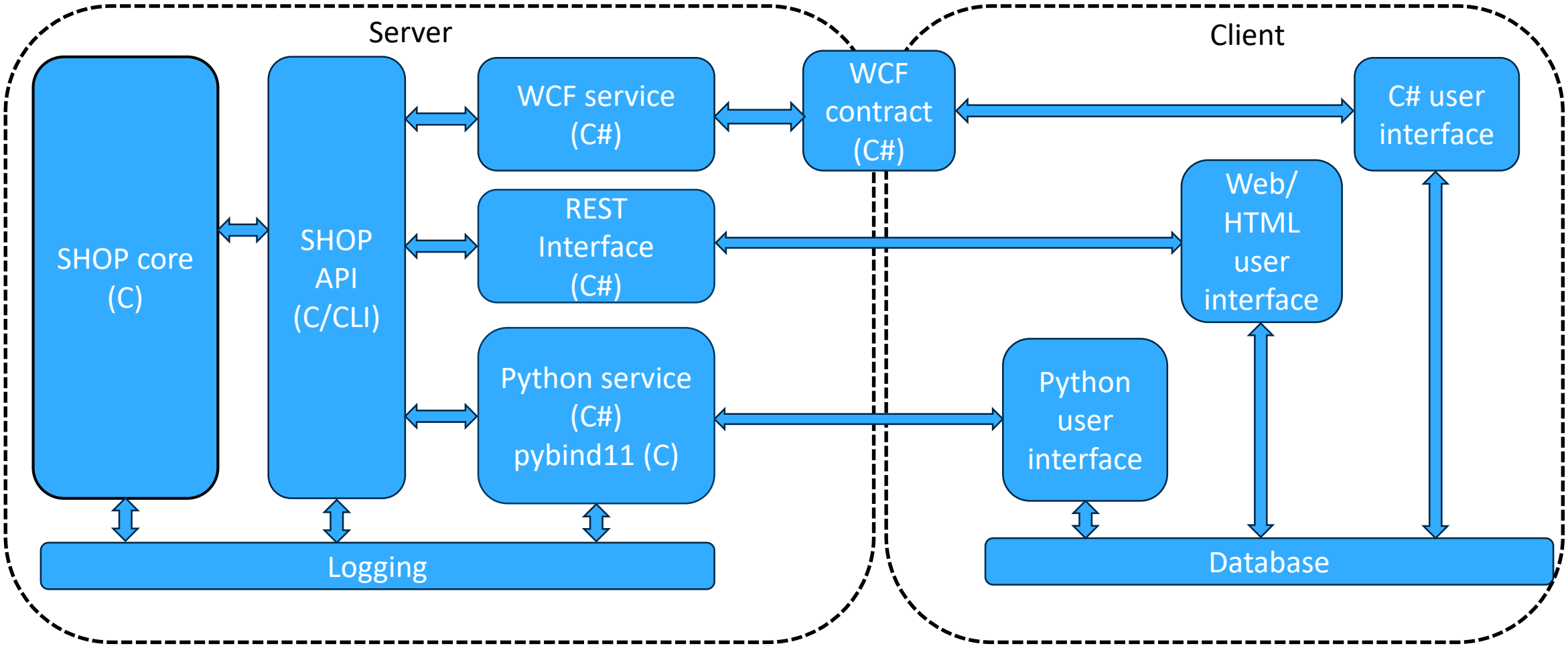
Optimization methodology



Integration



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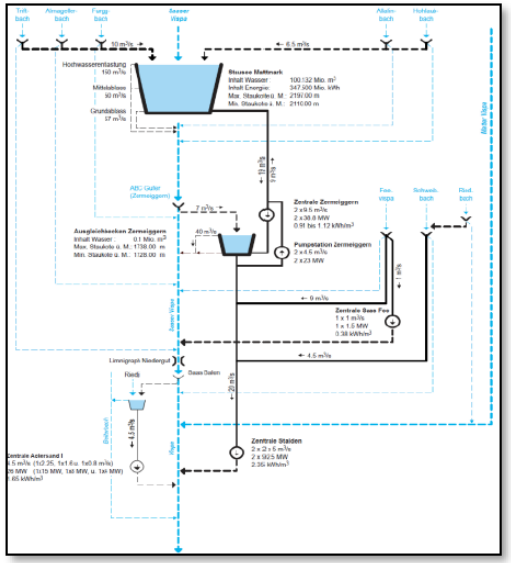
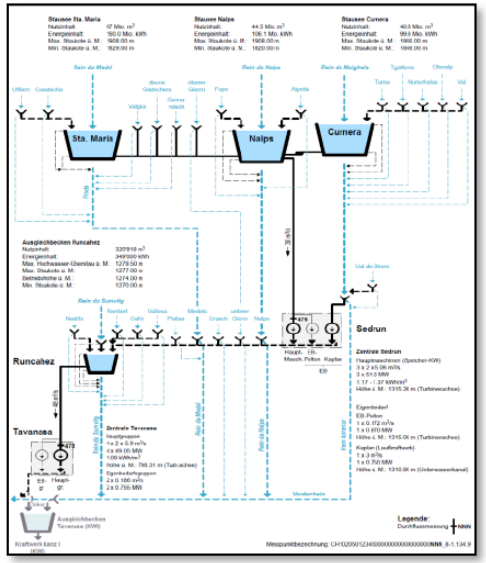
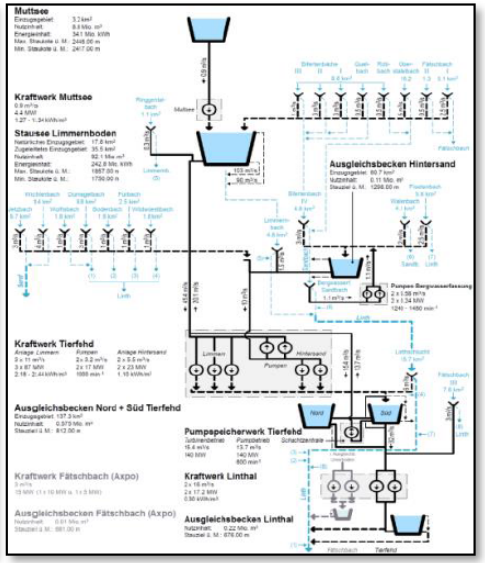
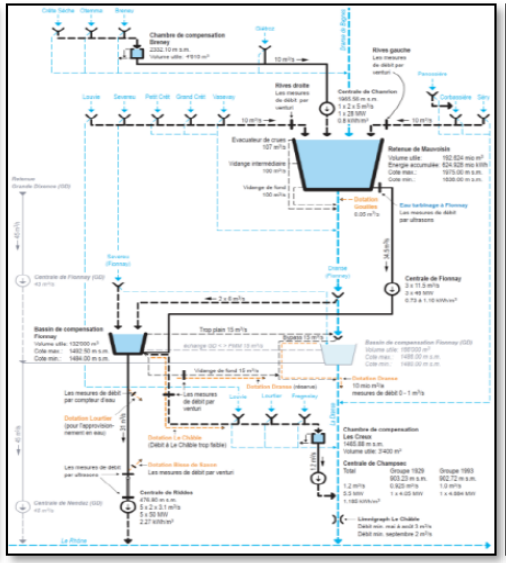
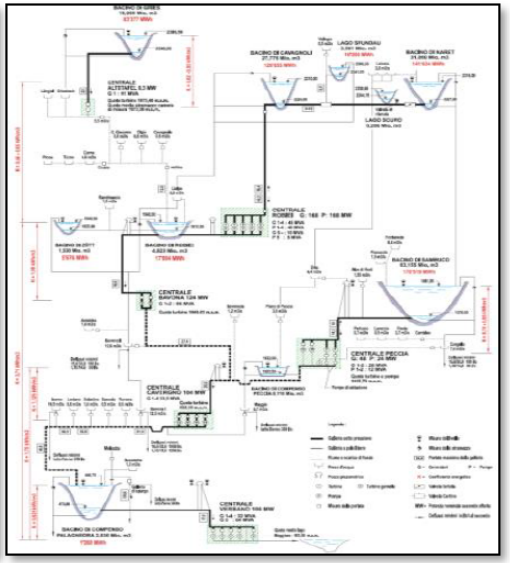
Use case example: Axpo (Switzerland)











Long-term optimization(s)

Long-term & Short-term

	Opp-Cost	Auction	Reserve-Distribution	Marginal Costs	DA-Bidding	Auction	Optimization	Checks / Simulation	ID - trading	Reserve Distributor	Control
Time	W-1			D-1			D			h-1	real time

Week-Ahead | Day-Ahead | Intraday

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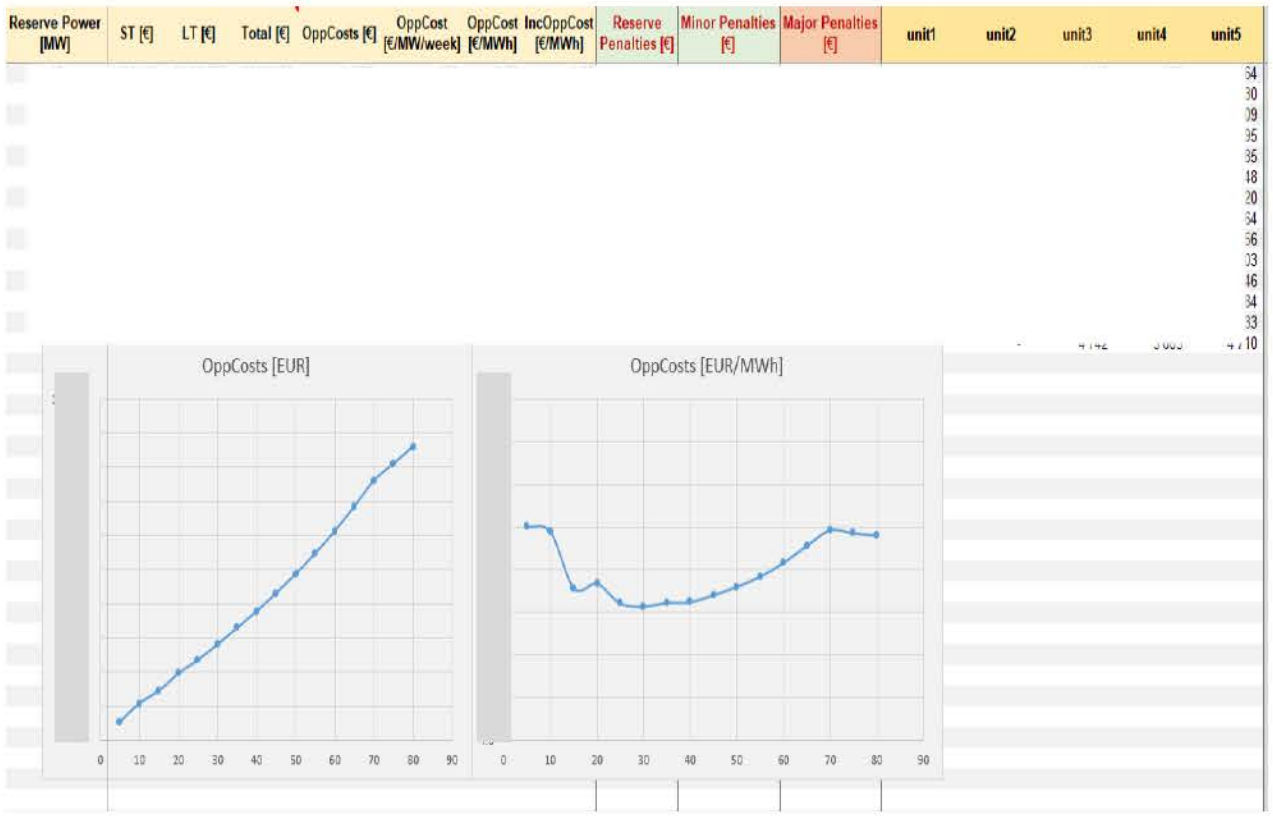
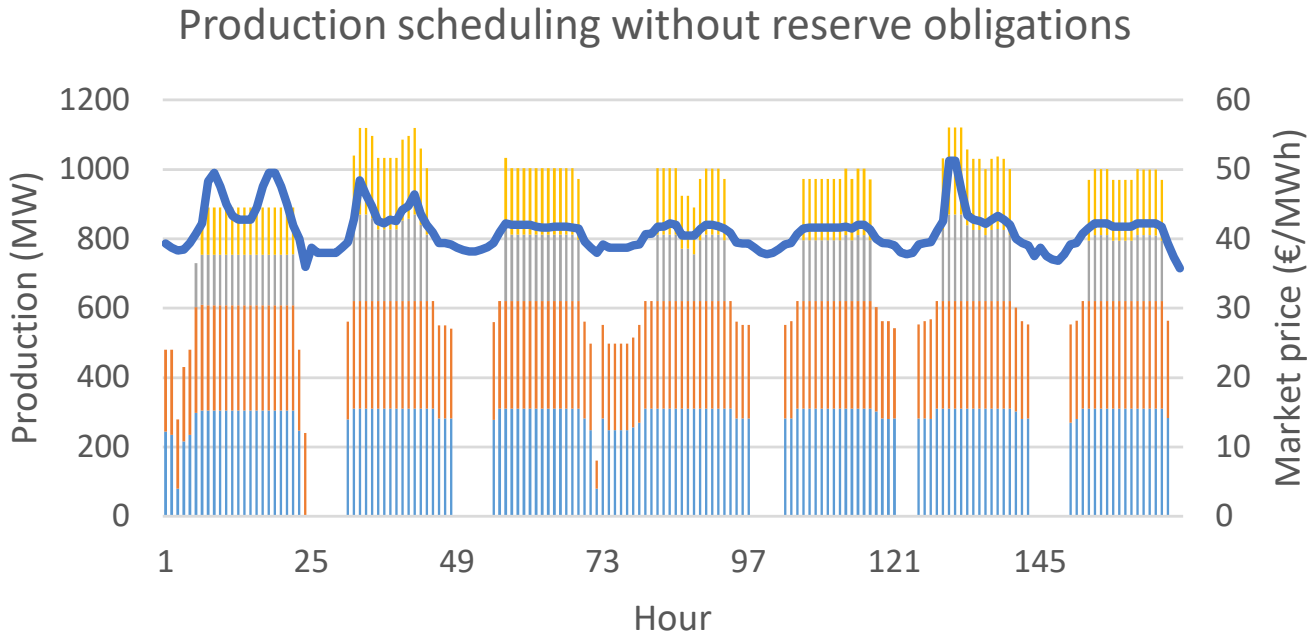
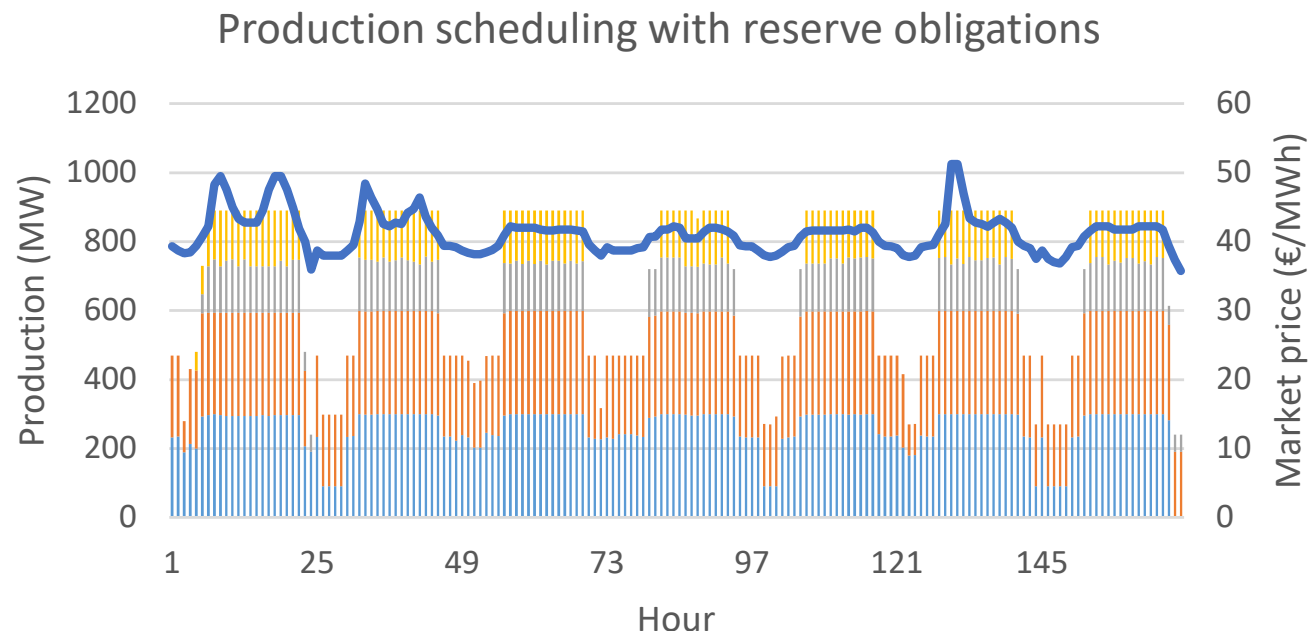
Pricing of secondary reserve (FRR-UP)



Currently modeling: Energy (DA+ID), FCR-N U/D, FCR-D, FRR U/D, RR U/D

Scheduling with reserve obligations





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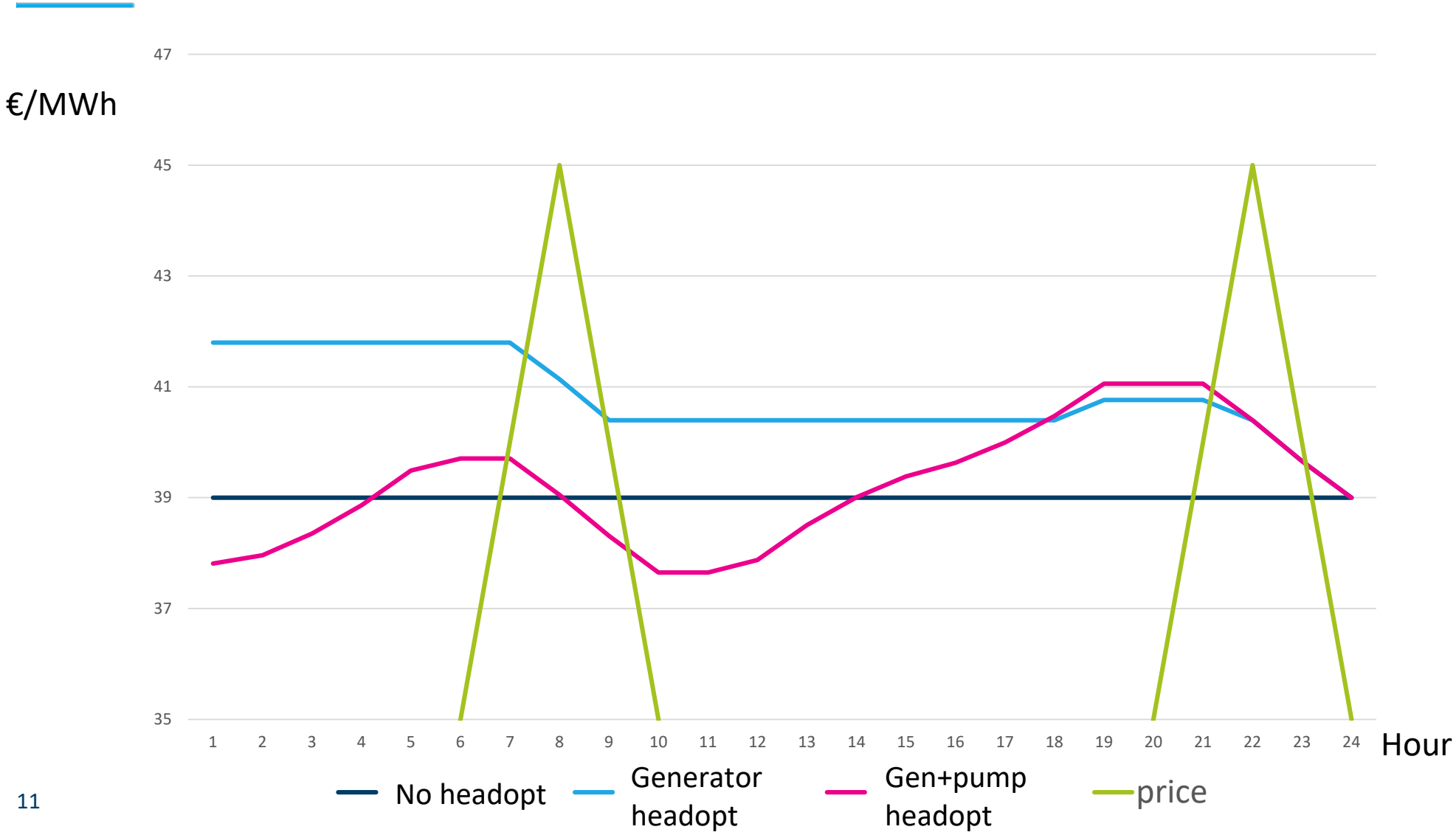
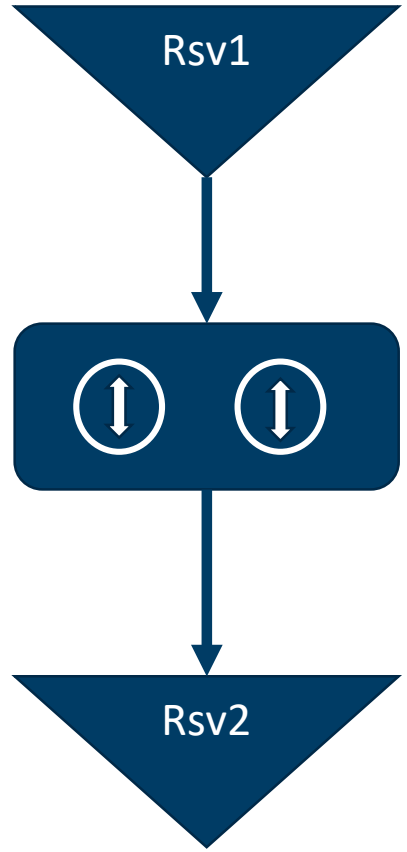
Head optimization

$$p = q \cdot g \cdot h \cdot \eta$$





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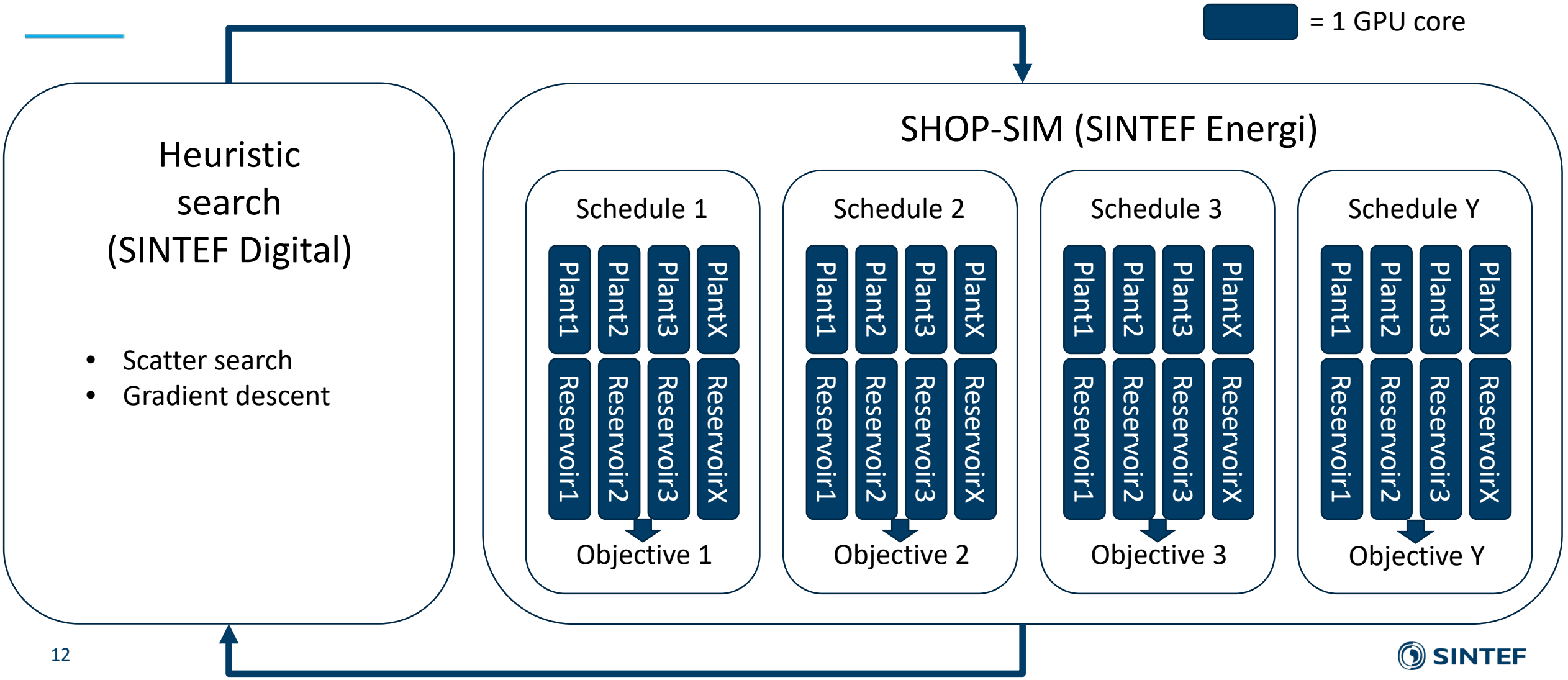
GPU-accelerated simulation-based optimization



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Overview of AI applications

AI Methods Compared	Objectives	Input
-Multiple Linear Regression -Neural Networks	Rainfall estimation	Rainfall
-Auto Regressive Moving Average -Artificial Neural Networks -Adaptive Neural-based Fuzzy Inference System -Genetic programming -Support Vector Machine	Discharge time series	River flow discharging
-Neural Networks -Support Vector Regressions -Multiple Linear Regressions	Streamflow forecasting	Weather and climate inputs
-Artificial Neural Networks -Fuzzy clustering	Streamflow forecasting	Streamflow time series
-Artificial Neural Networks -Support Vector Machine	Streamflow forecasting	Streamflow data

MonitorX - Background

- Measurements/data available already today
→ Potential data sources for different purposes
- Today these data are not much used for maintenance decisions
→ Potentially large benefit when using these data

Decarbonisation

Decentralization

Digitalization ← MonitorX

Predictive maintenance

Smartgrid

Prosumers

Generation → Transmission → Distribution → Wholesale trading → Retail

Smart production planning

Virtual power plants

Operation (O)

Maintenance (M) ← MonitorX

Forskningsrådet

MonitorX 2015-2019 — Optimal utilization of hydropower asset lifetime by monitoring of technical condition and risk (Optimal levetidsutnyttelse av vannkraftanlegg basert på overvåking av teknisk tilstand og risiko)

MonitorX - Aims

internet of things
machine learning
internet of services
big data
cyber-physical systems
industry 4.0
data mining
predictive maintenance

Results

- Model and algorithms for fault detection (and optimal lifetime utilization)
- Demonstrate practical application in selected power plants (cases)

Benefits

- Reduced maintenance costs by … :
  - … avoiding (catastrophic) faults …
  - … avoiding unnecessary component replacements …
  - … prioritizing the most critical components for maintenance …
  - … optimized maintenance …
- … through early warnings of ageing and potential faults.

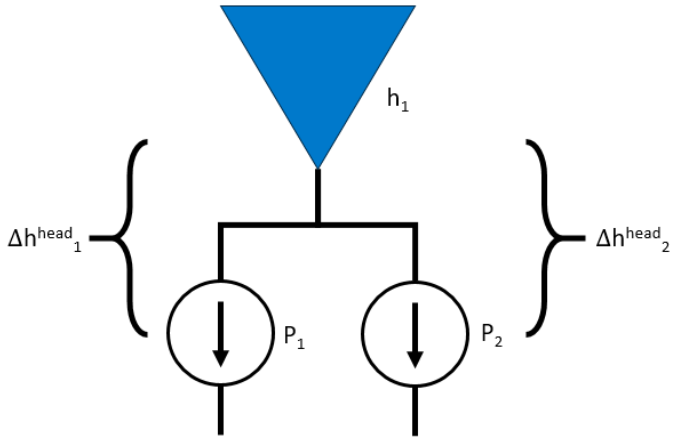
Knowledge gain

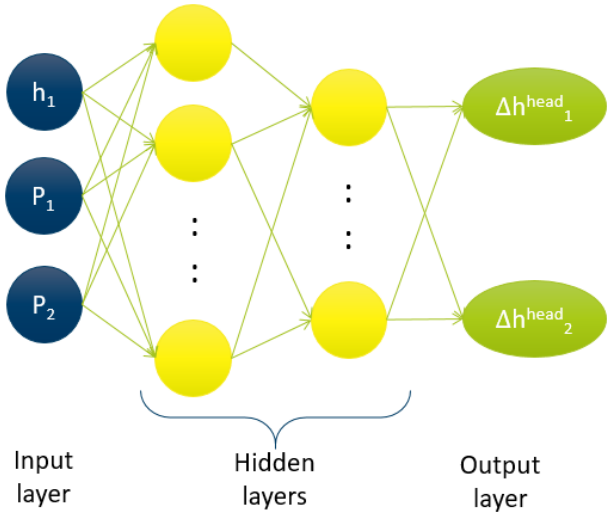
- How can operators utilize the mentioned **concepts and methods** for plant maintenance?
- What are possibilities, challenges & restrictions?
- How can monitoring data be used to carry out maintenance more predictive?

Testing through cases is important part of the project

Problem/case identification and description → Modelling & algorithm and prototype development → Testing / demonstration

Modeling of hydropower plants





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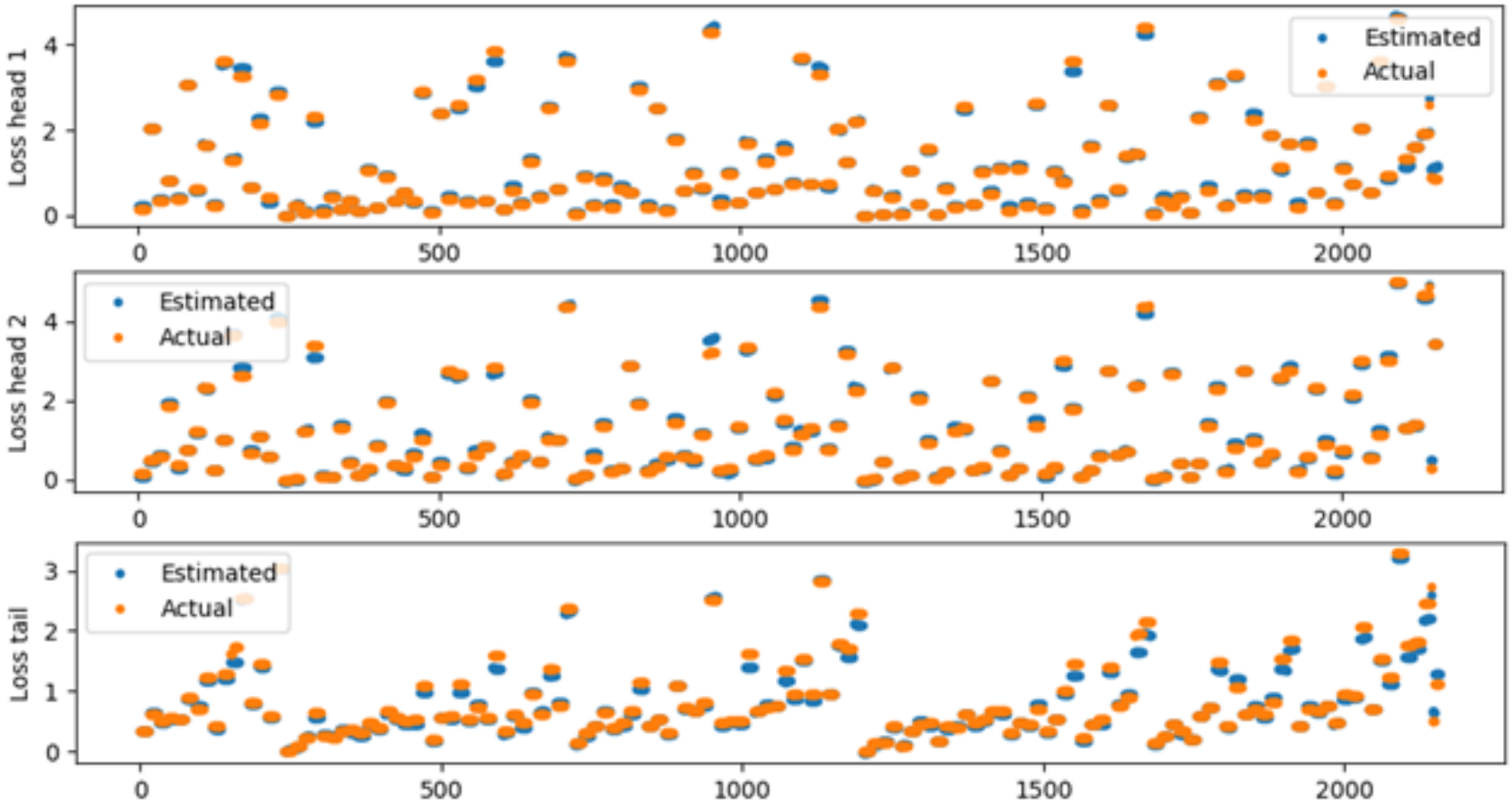
Estimation quality



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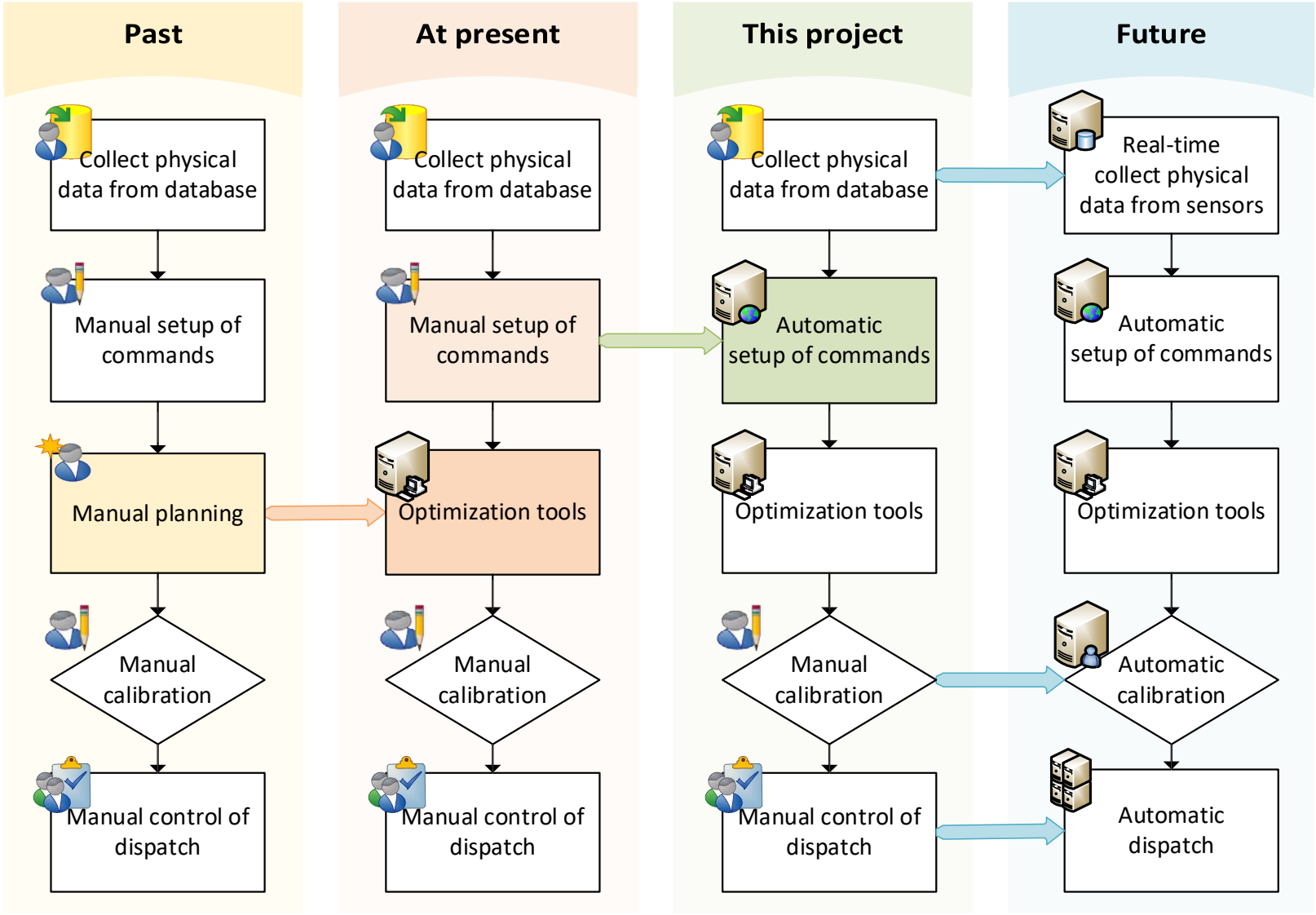
iScheduling – context based optimization



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Teknologi for et bedre samfunn