SINTEF tools for short-term scheduling

Overview of recent developments

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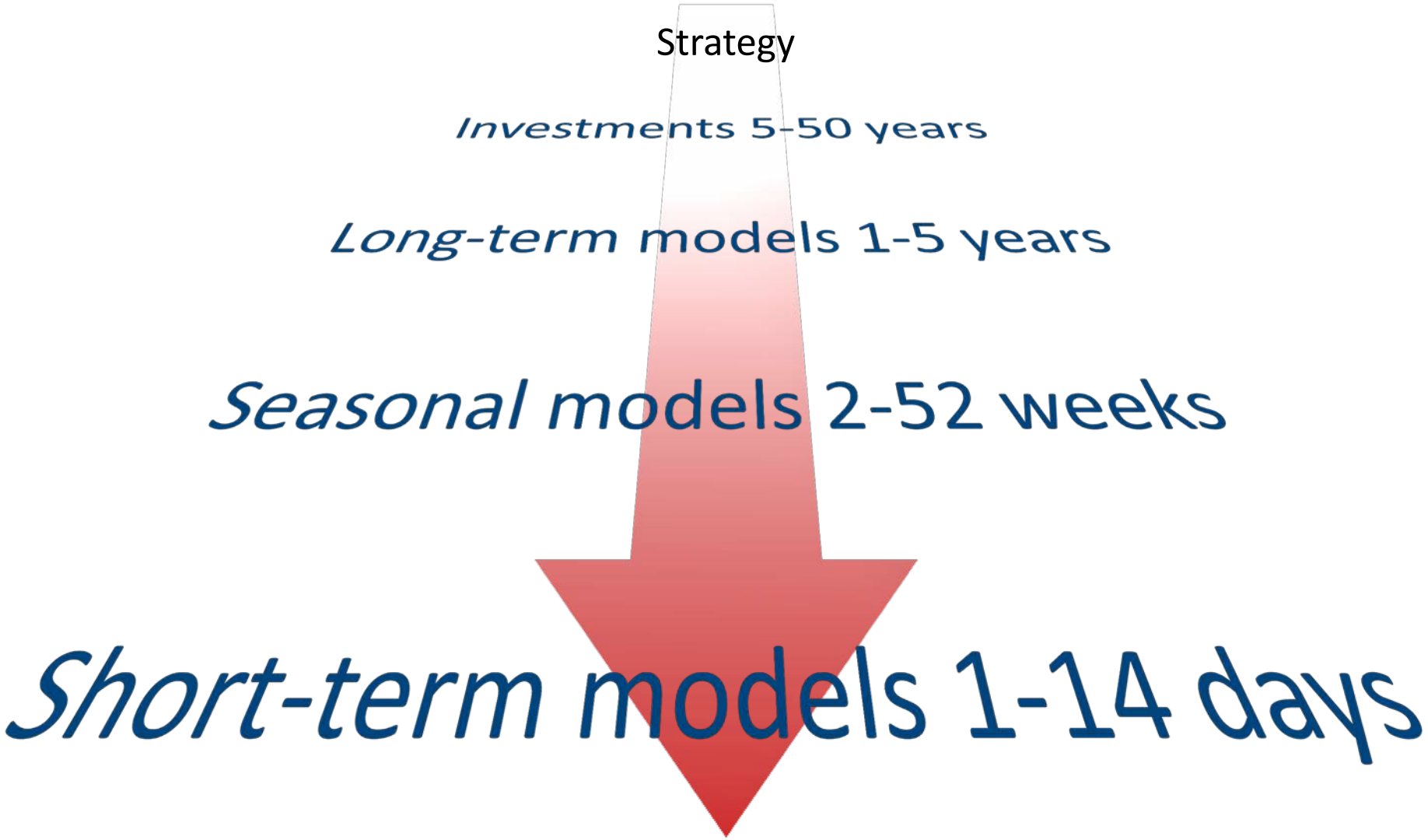
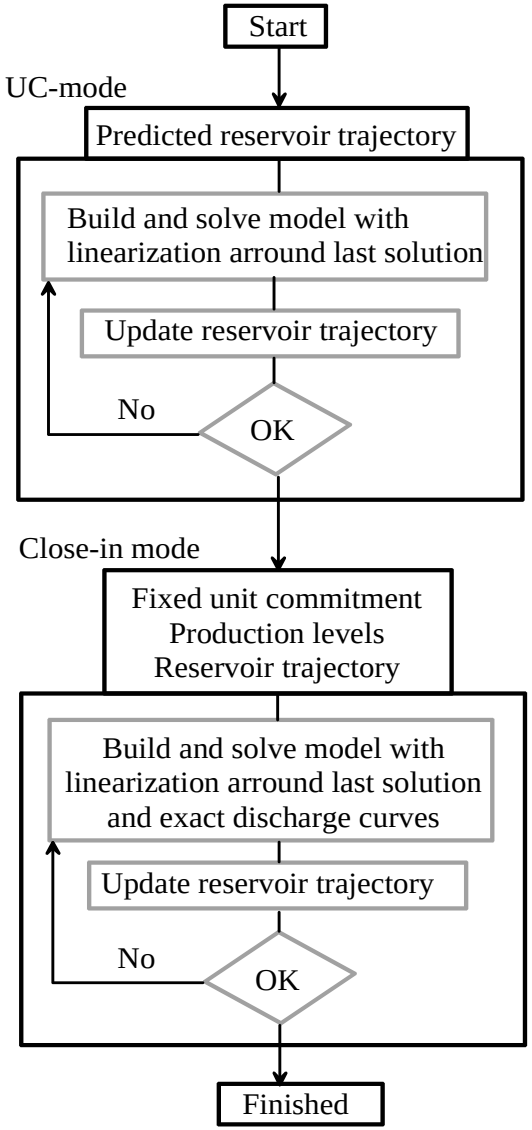
Strategy



Physical production

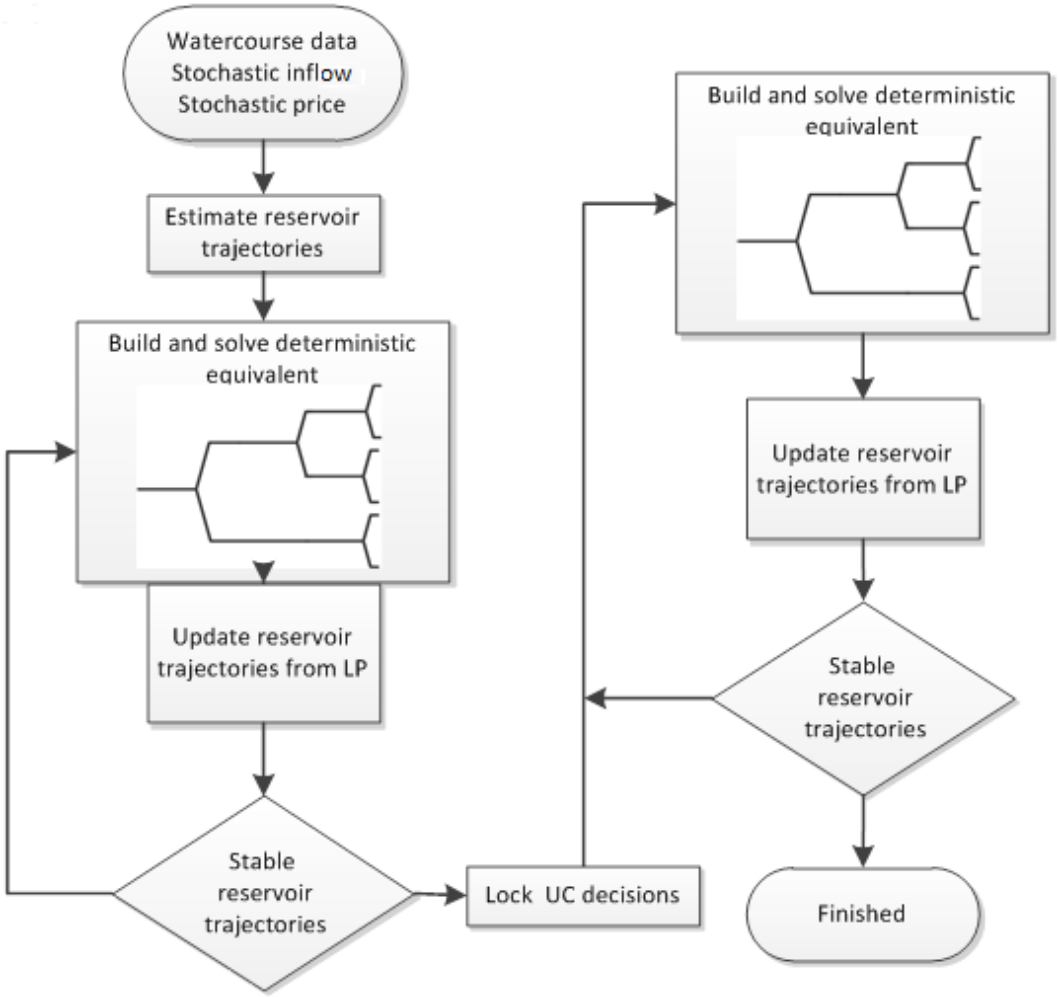
SHOP – Short-term Hydro Optimization Program

- Developed since mid 90's
- Used in about 25 generating companies, mainly in the Nordic countries, but also in Central Europe and Southern America
- Optimization horizon typically 7-14 days
- Optimization based on successive linear programming
- Supports a wide range of hydrological topologies and restrictions
- Price is input to the model
- No network constraints



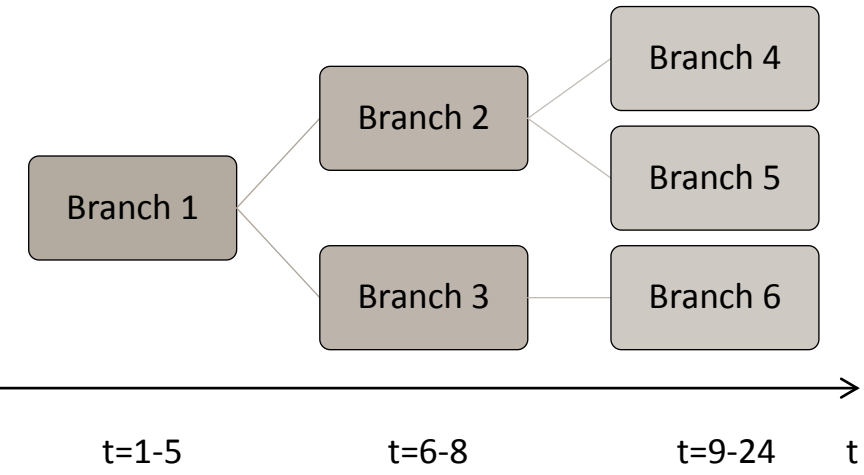
SHARM – Short-term Hydro Application with Risk Measure

- Developed since 2009
- Based on successive linear programming with several scenarios
- Higher calculation times
- Less extreme results from optimization
- Useful with new, improved end description with cuts

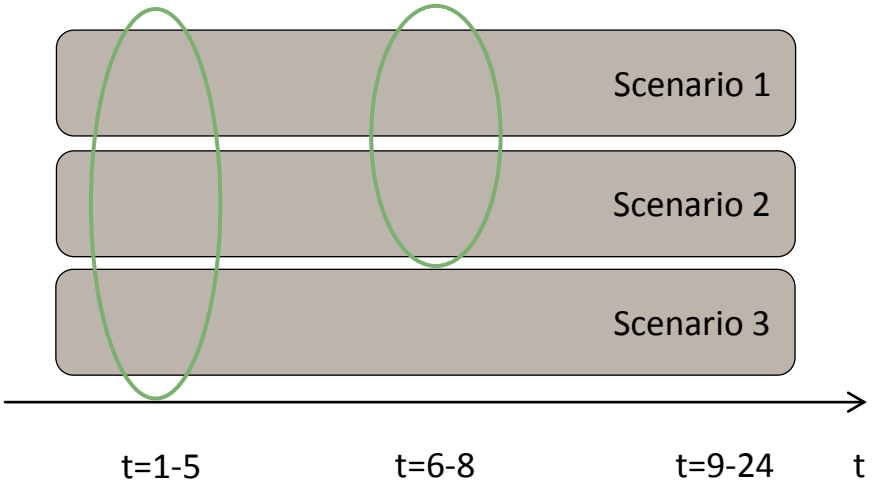


Experiences with description of uncertainty

Previous representation



Current representation



= common scenario

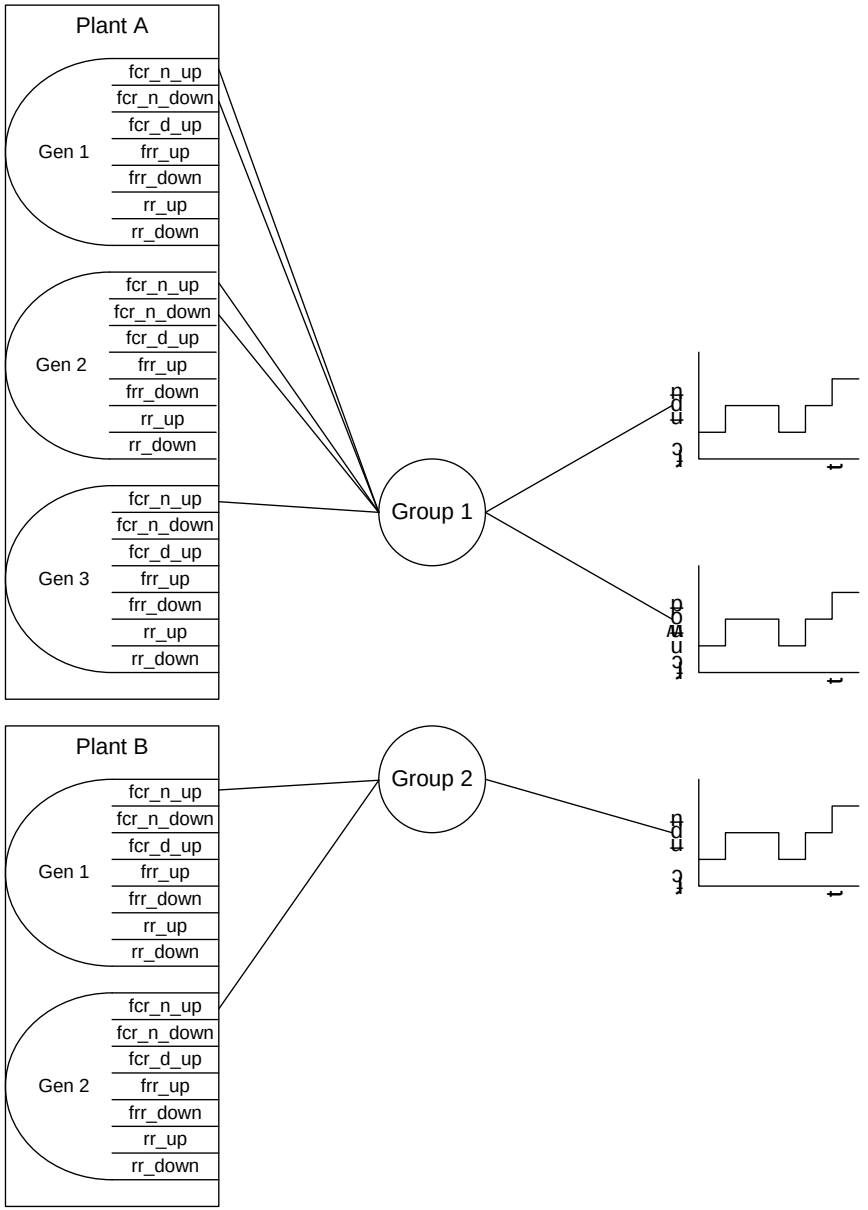
- Prepared for decomposition
- A large common share of code with deterministic model
- Any input data could in principle be given as stochastic

MultiSharm – Optimal bidding taking multiple markets into account

- Under development
- Optimal bidding in the day-ahead market
- Description of uncertainty and correlation between price and inflow
- Model balancing markets
- Time is the basis for stages in the stochastic decision tree

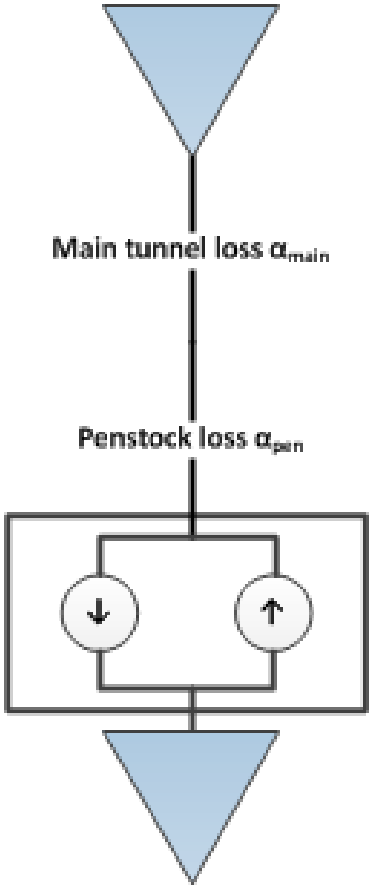
Optimal distribution of reserve obligations

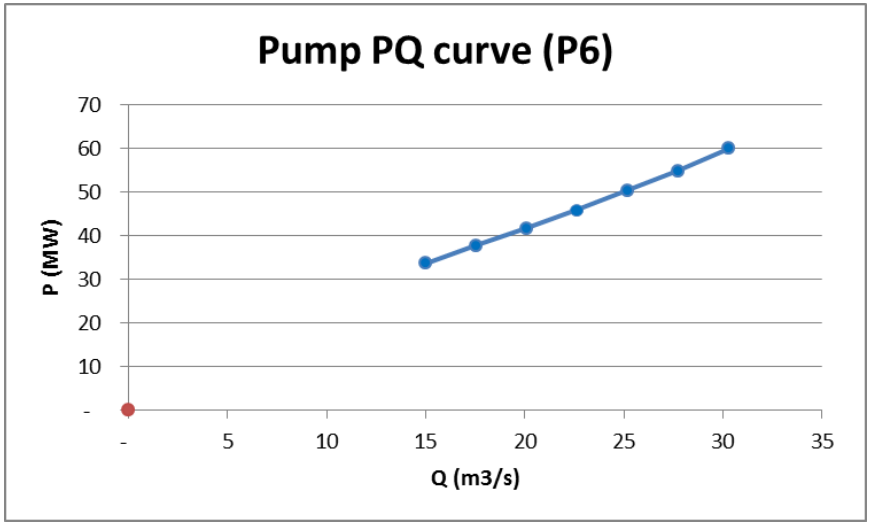
- Distribute reserve requirements optimally on a set of units
- Optimize droop on unit level
- Comply with several constraints
  - 2% available capacity
  - short-time min- and max-production limits
- Extra functionality
  - symmetry requirements
  - max / min plant restrictions
  - clustering of reserves
- New pump model allows pumps to contribute to reserve delivery



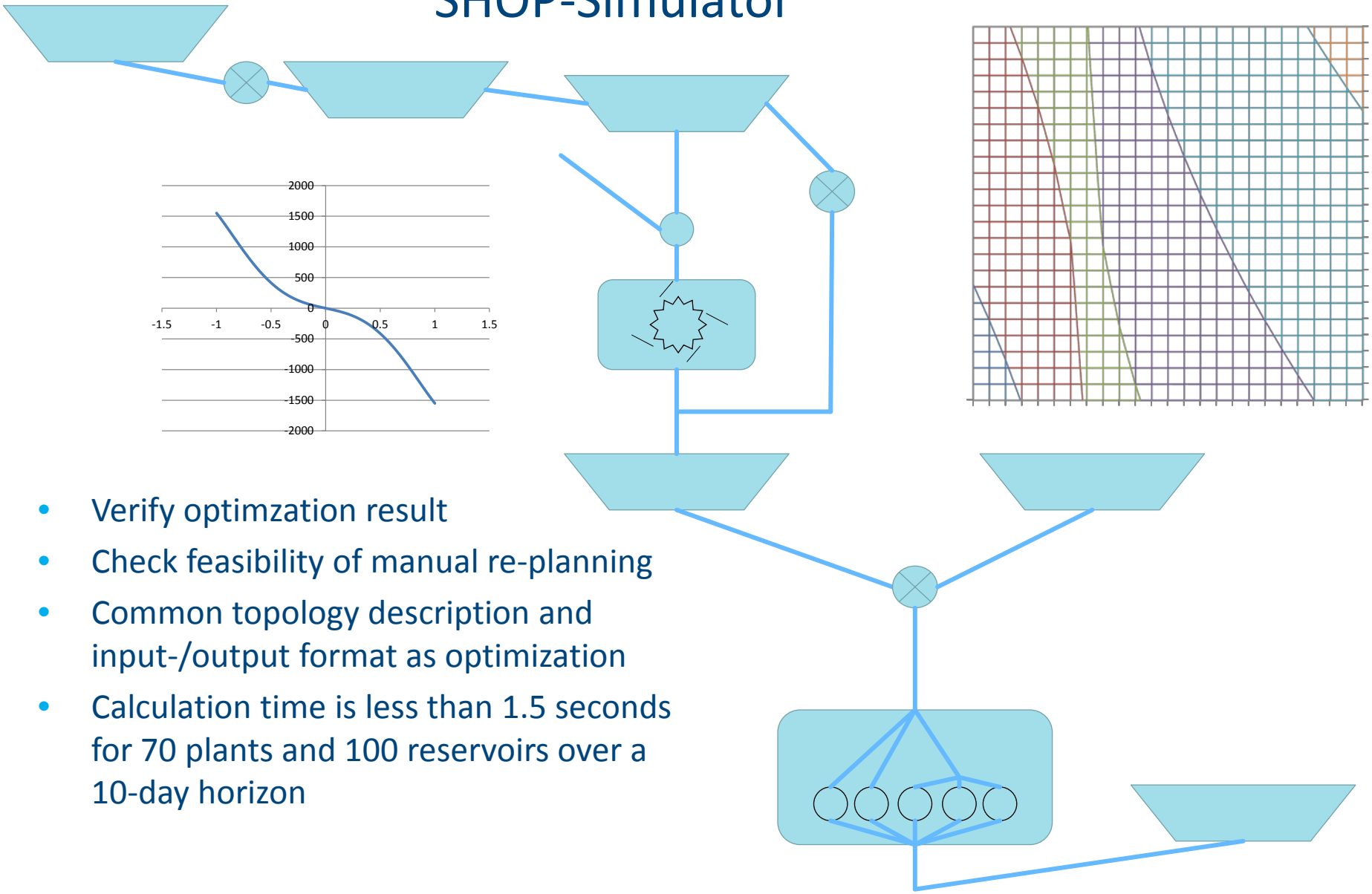
Variable speed pumps and hydraulic short circuit

- Operation of pumps no longer fixed to a single point
- Pumps can also contribute to primary and secondary reserve
- Incentive to reduce head loss by running a turbine and a pump simultaneously below a shared tunnel



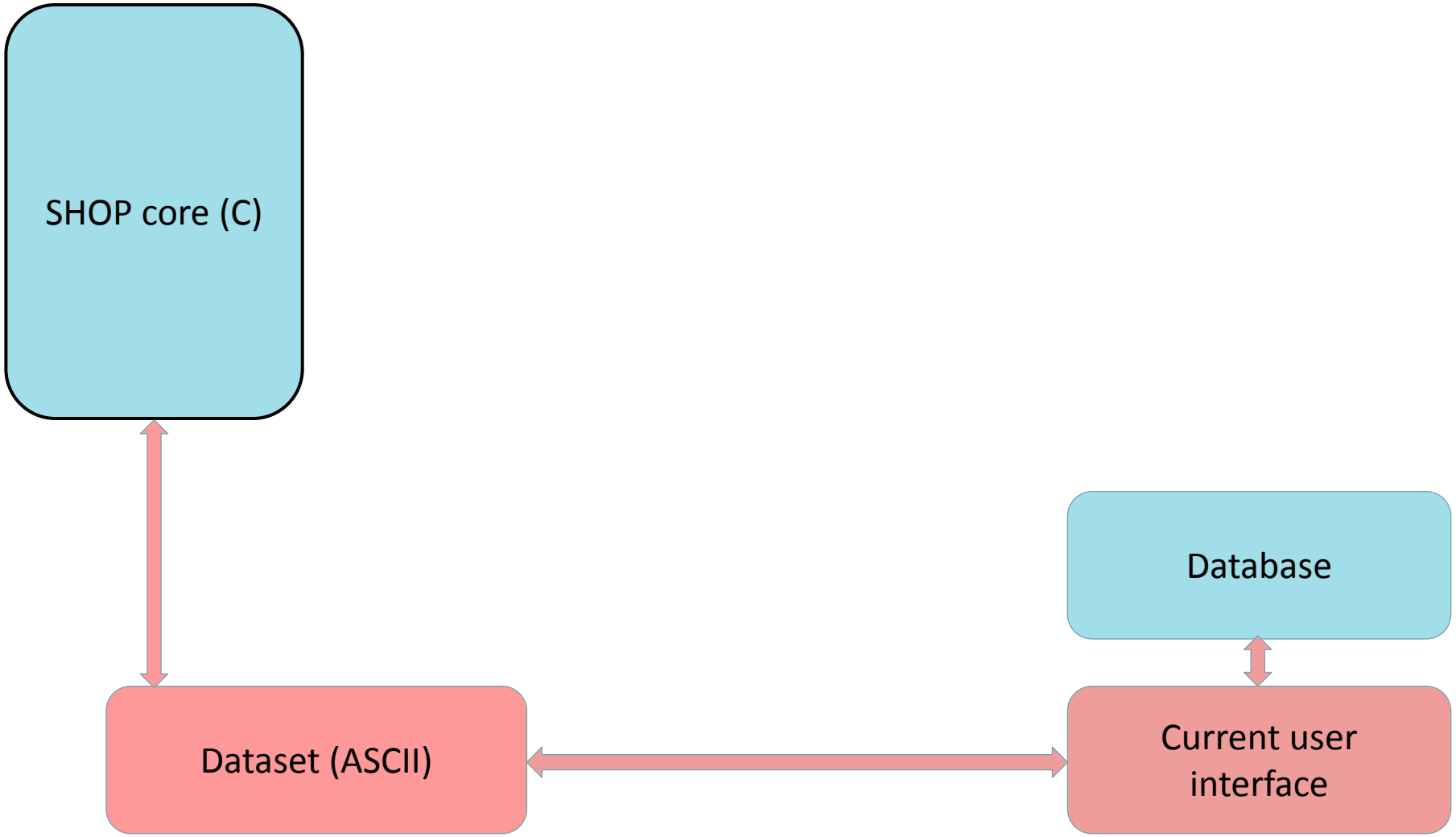


SHOP-Simulator

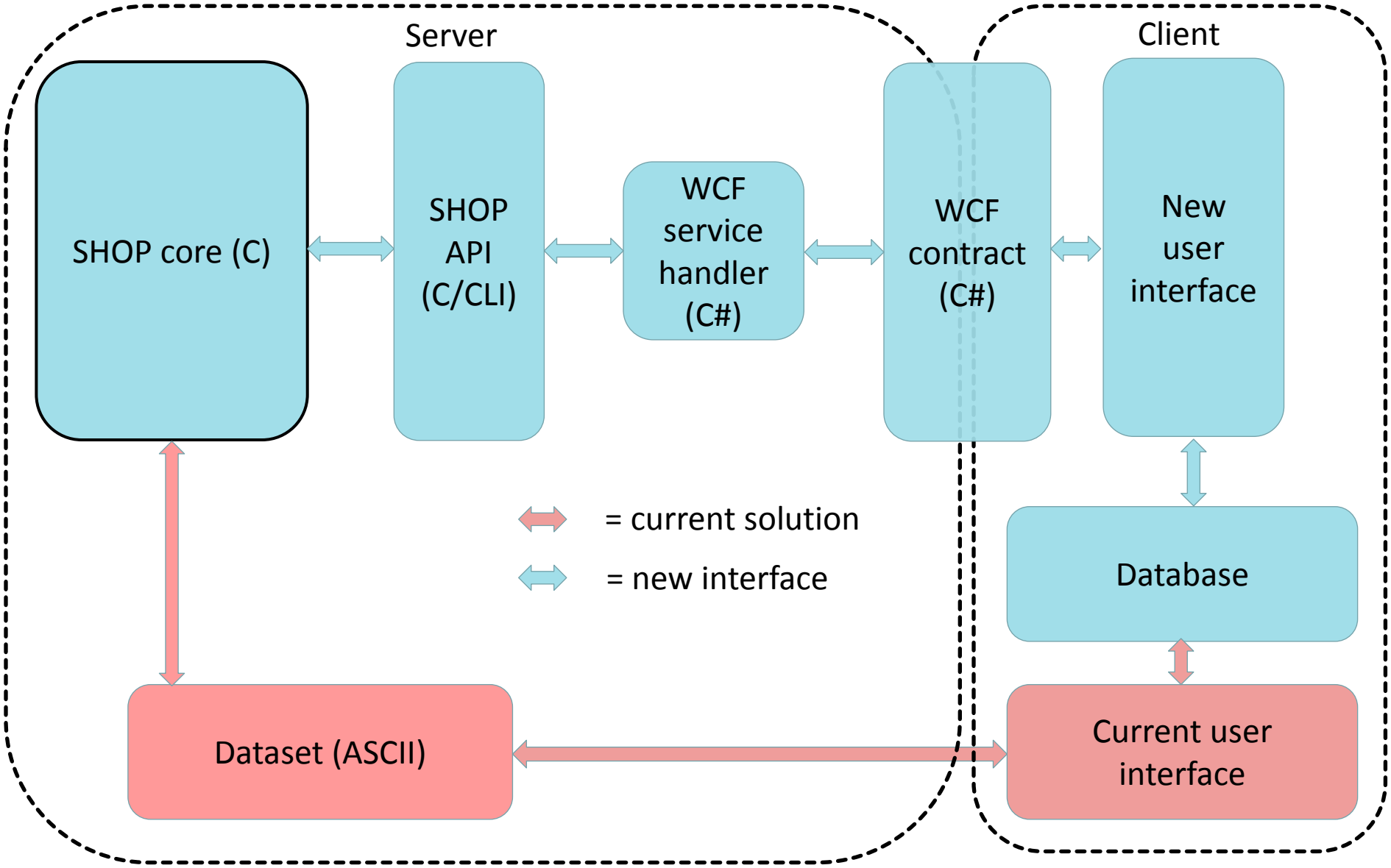


- Verify optimzation result
- Check feasibility of manual re-planning
- Common topology description and input-/output format as optimization
- Calculation time is less than 1.5 seconds for 70 plants and 100 reservoirs over a 10-day horizon

Current interface to SHOP core



New interface to SHOP core



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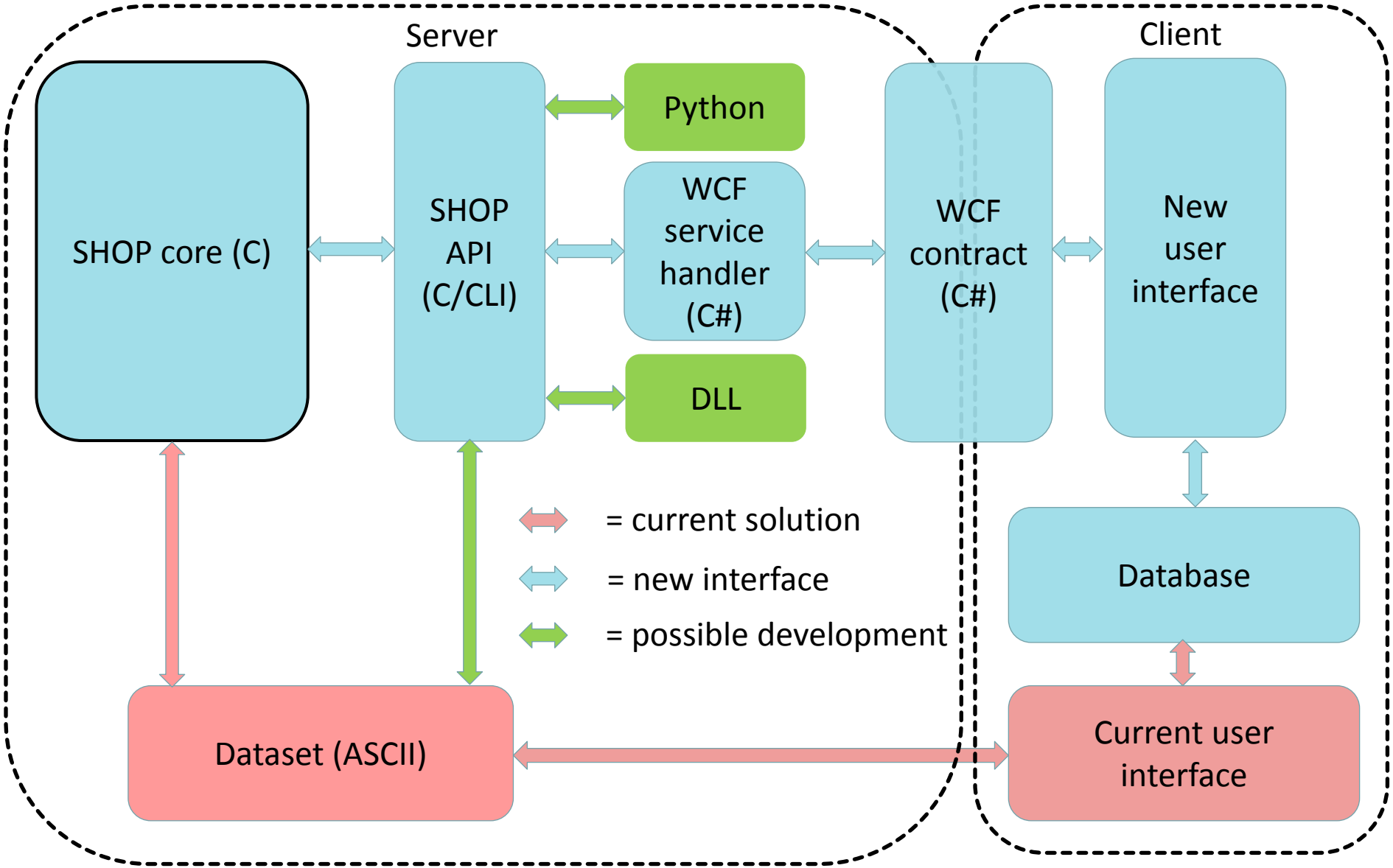
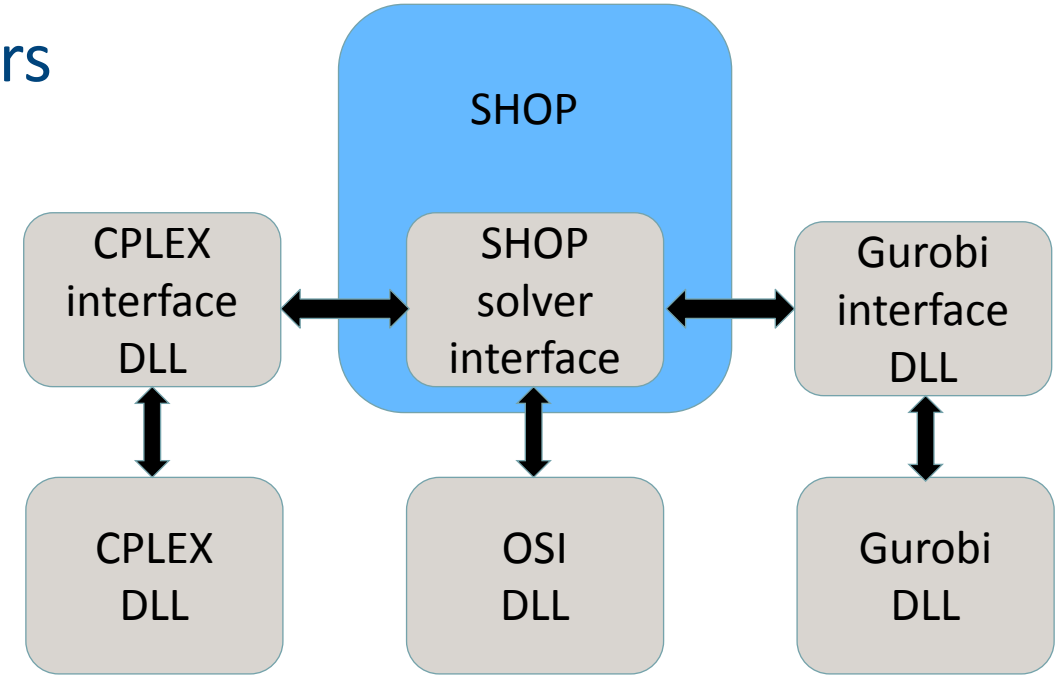


Alternative solvers



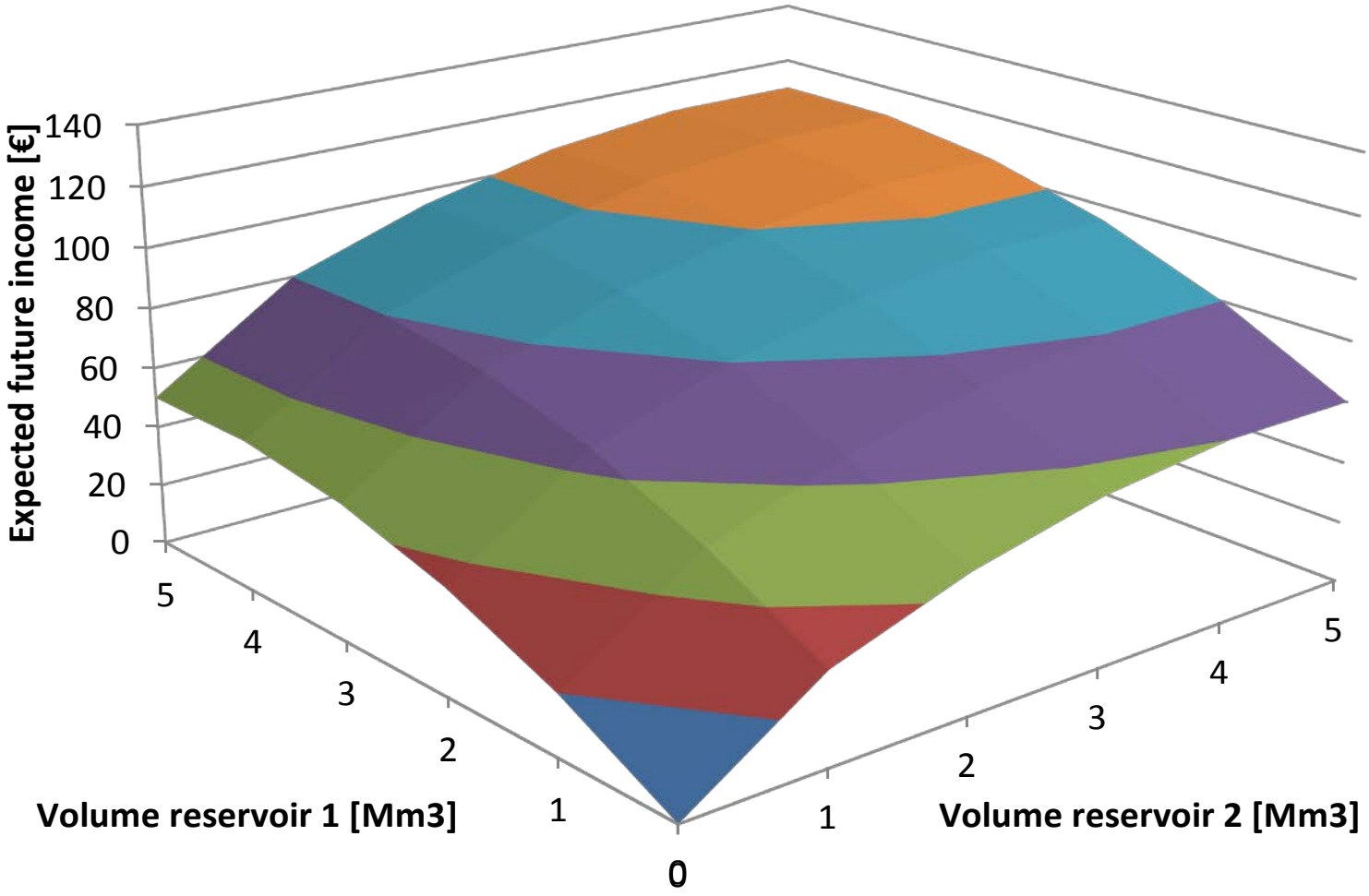
Solver	Relative LP time	Relative MIP time
CPLEX 12.2	1.0	1.0
Gurobi 5.6	0.3	3.0
OSI 2.8	5.6	9.0

MIP-tuning achieves 30% reduction of calculation time without significant reduction in objective

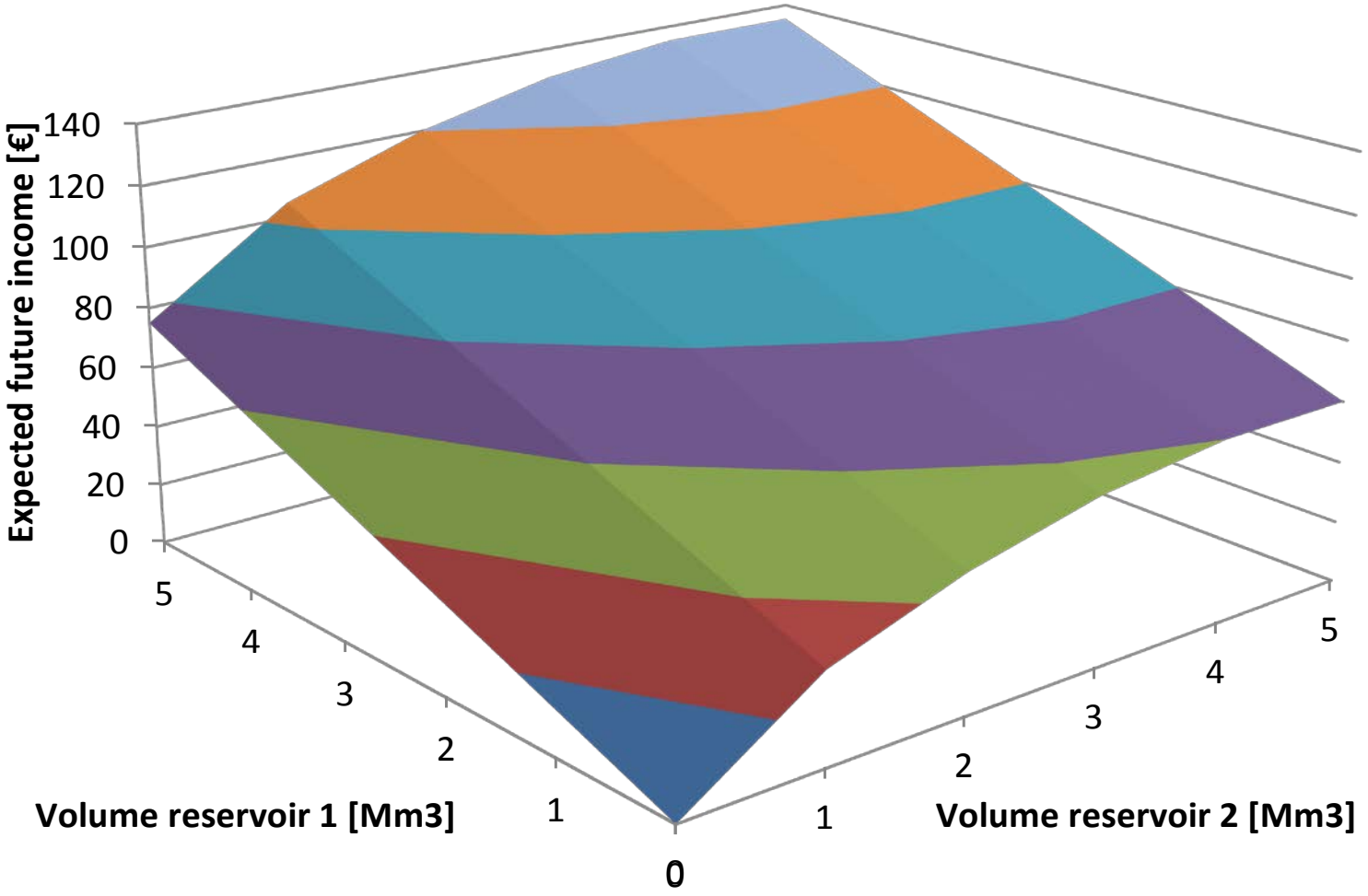
Remaining challenges

- Calculational time is significantly higher with uncertainty
- Several non-linear elements where non-linear optimization has not been tested
- Some noise may occur in the SLP/SSLP iterations, compared to formal optimization

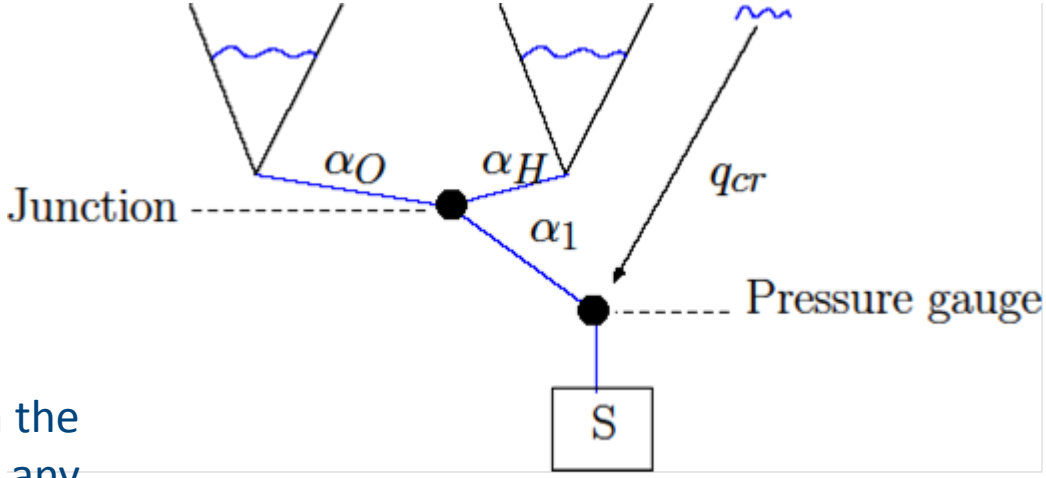
Mixing cuts and individual water values: pure cuts



Mixing cuts and individual water values: mixed



Pressure points



- New topology object:

  "Pressure point"
- Minimum pressure restriction in the main tunnel must be met to run any generators in the plant
- Single reservoir or junction above pressure point
- Extra MIP-variables to account for direction of flow in junction tunnels
- Possible with pre-processed inflow directly into the pressure point