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Hydropower Aggregation by Spatial Decomposition – An SDDP Approach

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Technology for a better society

Background

- Long-term scheduling (LTS) models are used for many tasks:

  price forecasting, system analyses, expansion and maintenance planning,..

- Modest computation times are important
  - Energy equivalent representations (EER) of the hydropower

- We seek to increase the accuracy of hydropower representation in LTS models while maintaining modest computation times
  - Spatial decomposition by feasibility cuts
  - Embedded in SDDP applied to EER hydropower representation

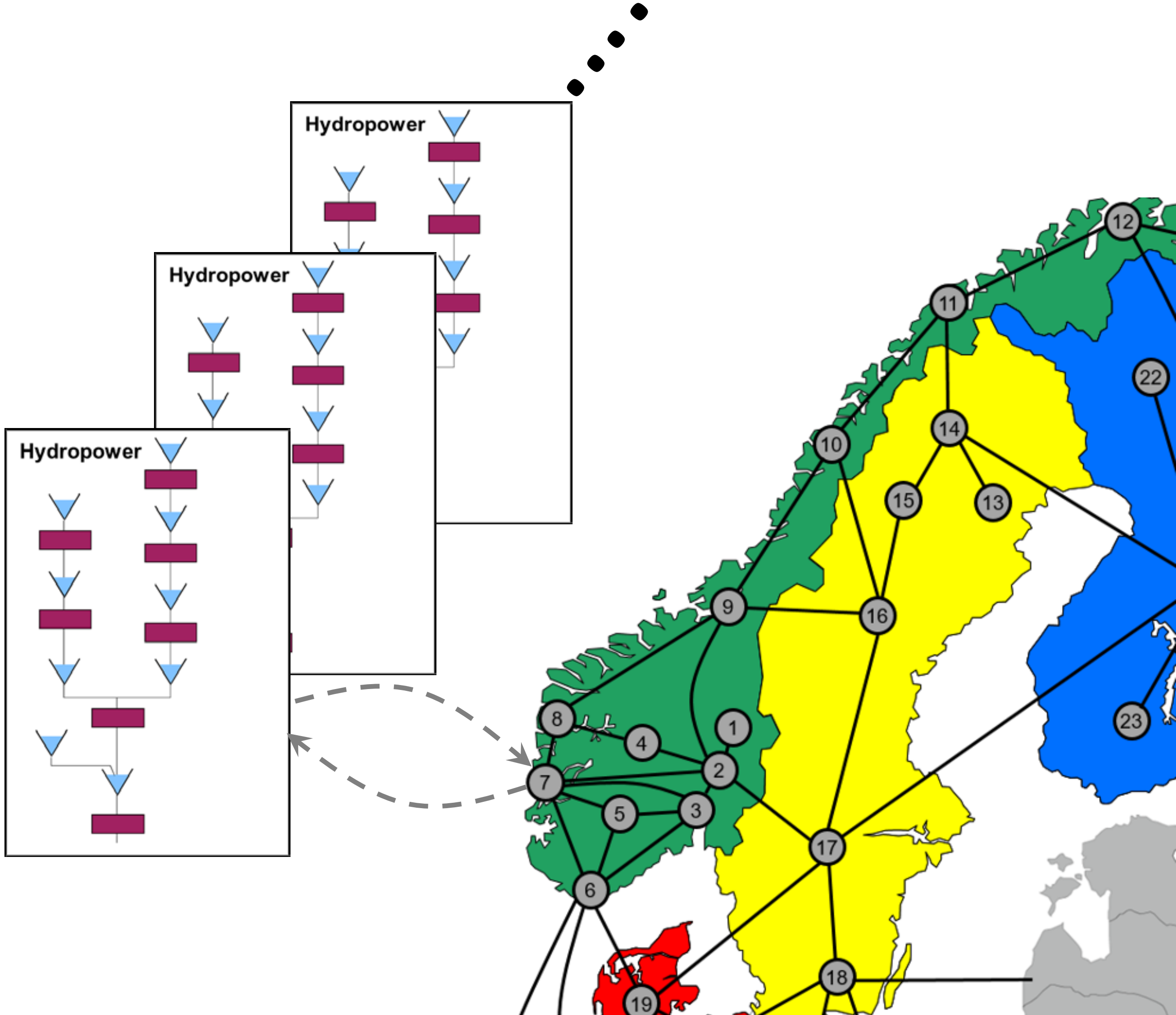
Decomposition Principle

Spatial decomposition

- Lagrangian Relaxation often used
- Benders decomposition also possible

- Feasibility cuts
  - Hydropower = (hard) constraints

- Embedded within SDDP model applied to aggregated hydro



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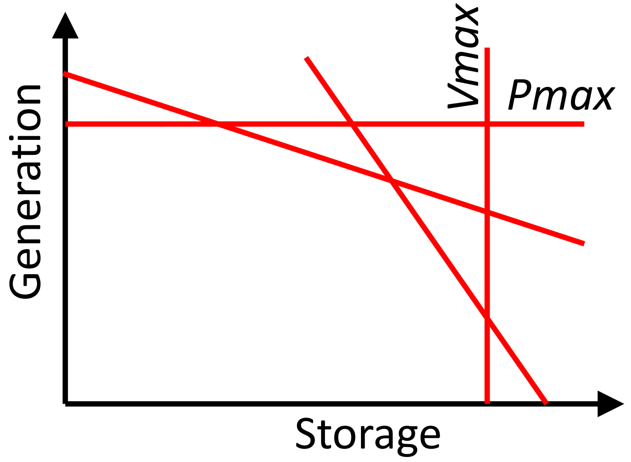
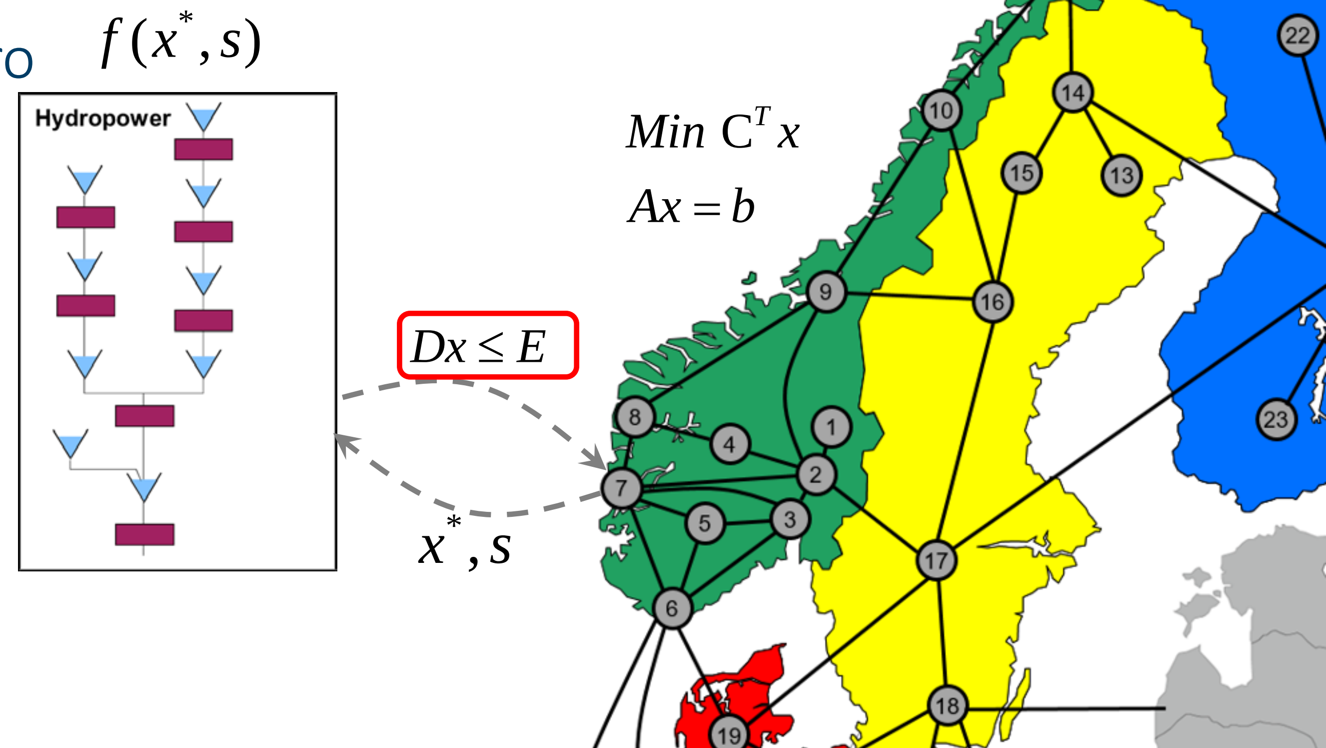
Feasibility Cuts

1) Optimize LTS problem with EER hydro
2) Send trial schedule (generation and storage) and state (storage and inflow) to detailed hydro
3) Test if schedule is feasible on detailed hydro
4) If not: return feasibility cut





SDDP + Feasibility Cuts

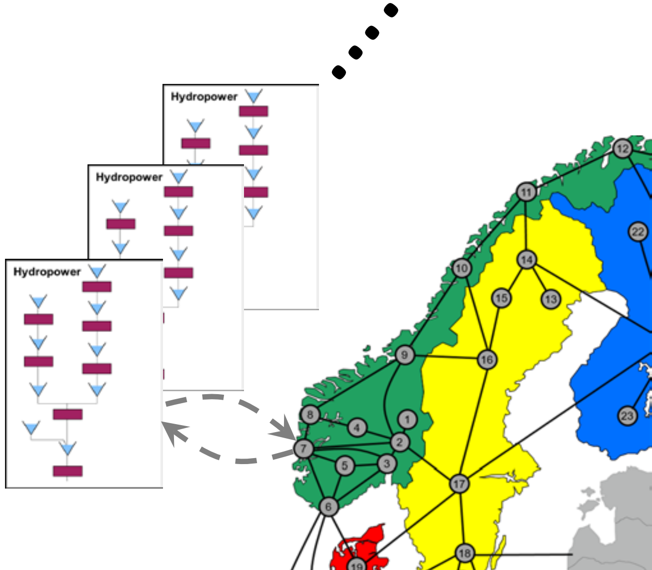
SDDP on system with aggregated hydro. States: storage and inflow

Feasibility check is on a convex problem and state-dependencies can be accounted for

- Embedded in SDDP with sharing of feasibility cuts
- Distribution keys coupling aggregated ←→detailed hydro

Two strategies tested:

1) *Dynamic* – Compute feasibility cuts in forward iteration
2) *Static* – Prepare feasibility cuts in advance



Details explained in:
A. Helseth and B. Mo, *Hydropower Aggregation by Spatial Decomposition – An SDDP Approach*

https://www.techrxiv.org/articles/preprint/Hydropower_Aggregation_by_Spatial_Decomposition_An_SDDP_Approach/19738165

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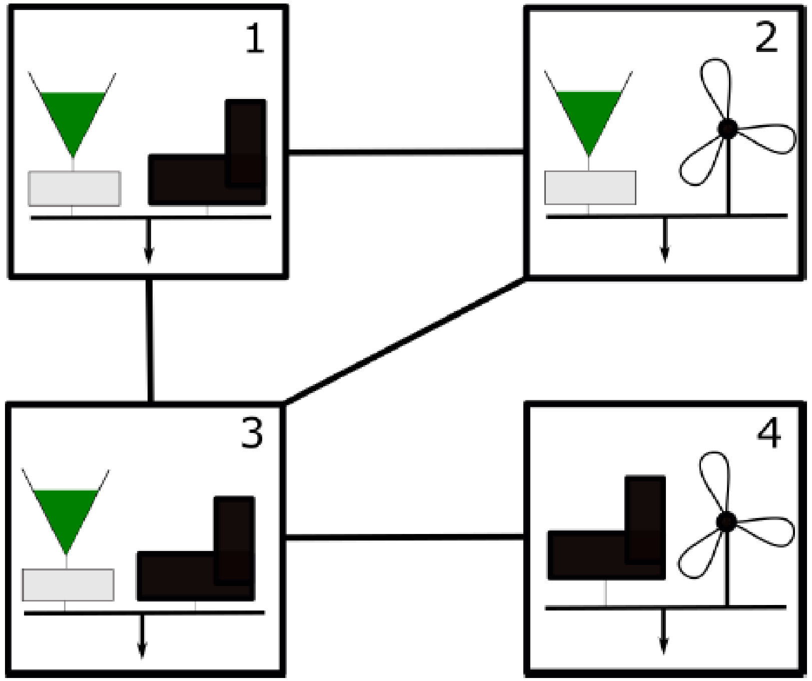
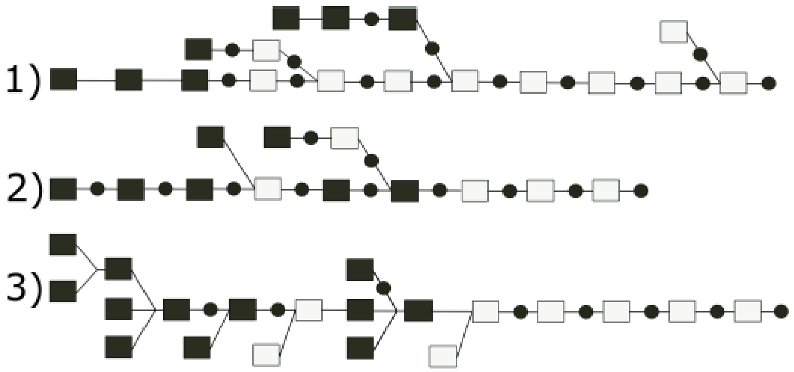
Computational Experiments

- Test system:
  - 4 price areas with hydro, thermal and wind supplying demand
  - 50 hydropower modules (70% of generation capacity)
  - 3 year horizon, weekly stages, 56 time steps within week
- We are concerned about LTS results
  - Feasibility cuts serve to make the hydro operation more realistic
- Cases
  - *REF*: reference, SDDP without feasibility cuts
  - *DYN*: SDDP with dynamically computed feasibility cuts
  - *STAT*: SDDP with pre-defined feasibility cuts



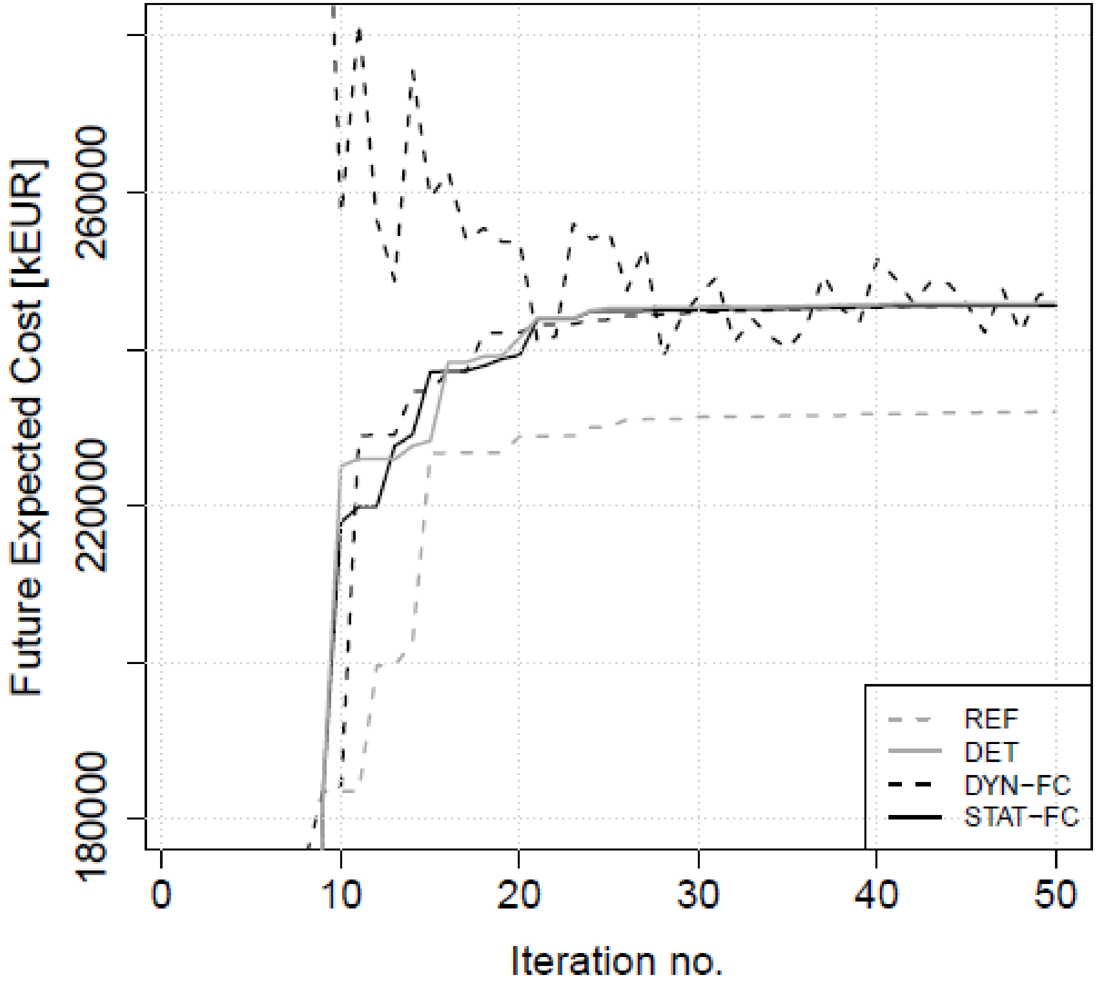


Computational Performance

TABLE I: Computation times, in seconds.

Case	Iter no. 1	Iter no. 50	Iter no. 100	Total
REF	3.2	5.1	11.4	370
DYN-FC	4.1	294.0	736.5	14347
STAT-FC	39.9	52.8	77.5	3204

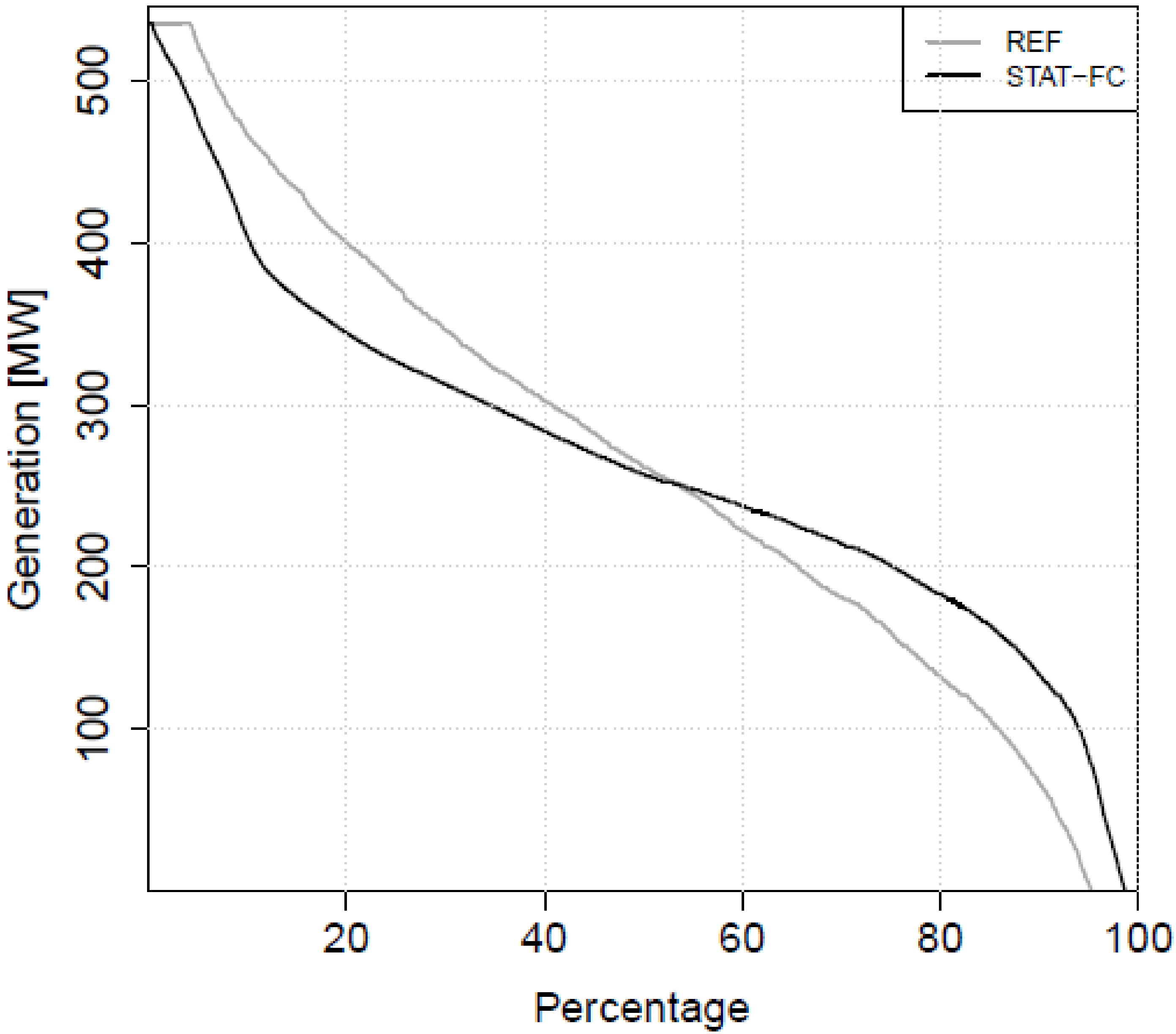
DYN-FC takes less than 10% of time for fully detailed treatment hydro



Results

EER generation for Area 2

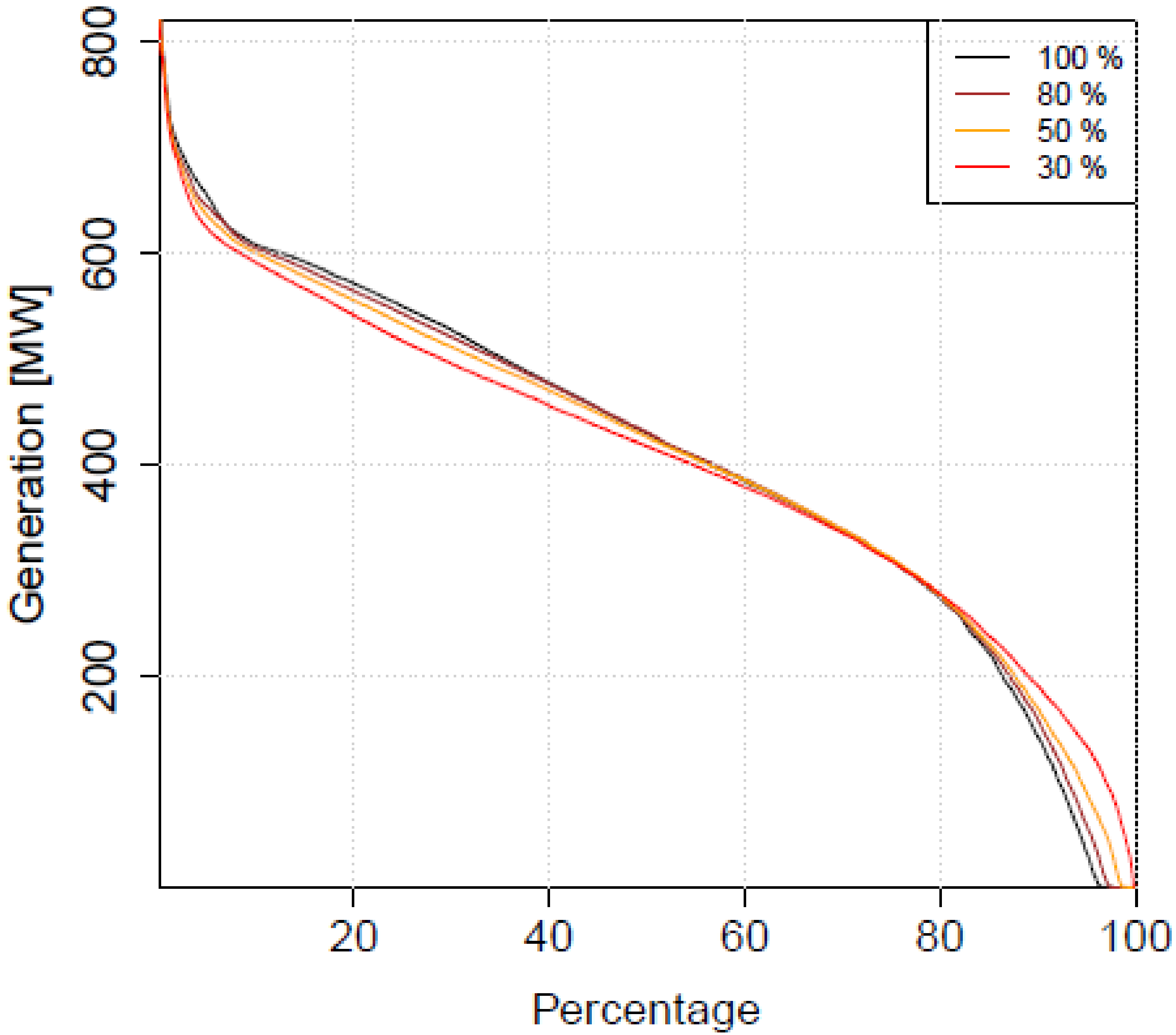
- Total generation is similar
- Generation capability overestimated without feasibility cuts



Results

EER generation for Area 3 for case STAT

- Different levels of ramping on discharge in detailed hydropower system
- Feasibility cuts capture stricter operational regime



Conclusions

Models based on hydro equivalents are still relevant and needed!

SDDP on aggregated hydropower + Feasibility cuts

- Method demonstrated on a test system with realistic hydropower
- Satisfactory convergence properties
- Computation time increases with feasibility cuts

Possibilities for further work

- Pre-processed feasibility cuts with proper cut management
- Testing on larger systems