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Simulation Application to Hydropower Systems Management and Design in a Market Environment

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  - Hydro scheduling
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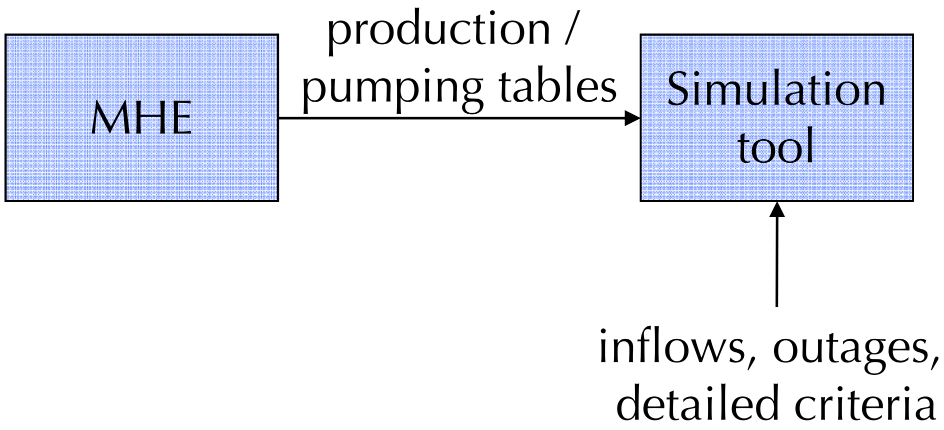
Introduction

- Relevance of hydroelectric power
  - Reduced production cost
  - High flexibility
  - Important role in the generation mix
- Simulation allows full detail modeling of operation:
  - Nonlinearities in the production function
  - Specific behavior of river basin elements
- Simulation can produce scheduling plans
  - Closer to real operation
  - With lower computational requirements

Simulation model (I)

- Medium term simulation model
  - Coupled with a long term model stochastic hydrothermal (MHE)



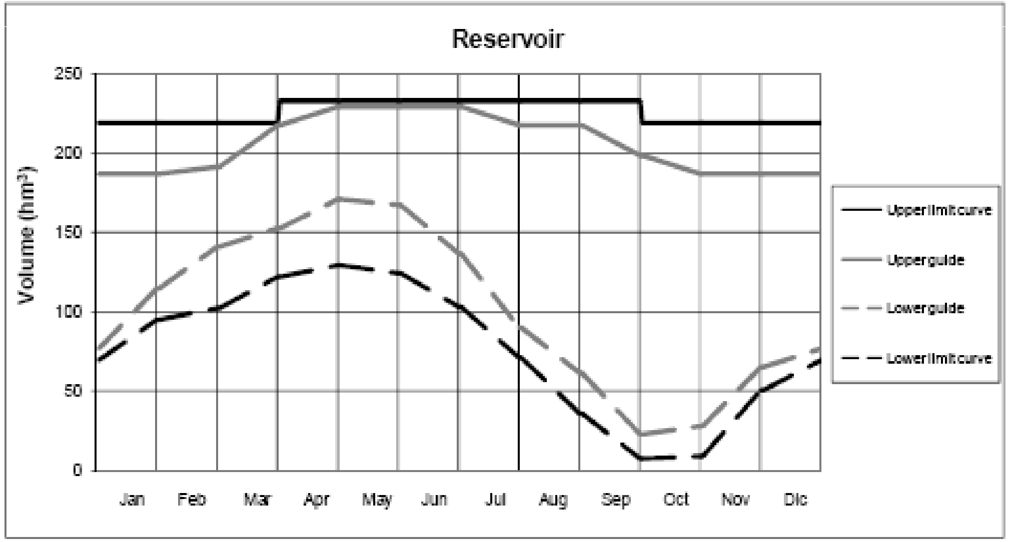
- Possible applications:
  - Hydro scheduling
  - Hydroelectric scheme design support
  - Scheduling of planned outages
  - Specific studies like reliability analysis

Simulation model (II)

- Sequential simulation model:
  - Discrete time, with daily step
  - Yearly time scope
  - Stochastic hydro inflows and unexpected outages
  - Considers different elements: reservoirs, power plants and channels
- Simulation method divided into several phases:
  - First, individual management of each element
  - Computes possible actions of each element to avoid problems (spills and lack of water for release agreements)
  - Applies corrective actions where they are needed

Simulation model (III)

- Initial reservoir scheduling:
  - Initially water released from production / pumping lookup tables
  - Checked against:
    - Technical limits (i.e. partial outages)
    - Water agreements (ecological or entertainment needs)
    - Operation areas delimited by volume guiding curves



Simulation model (IV)

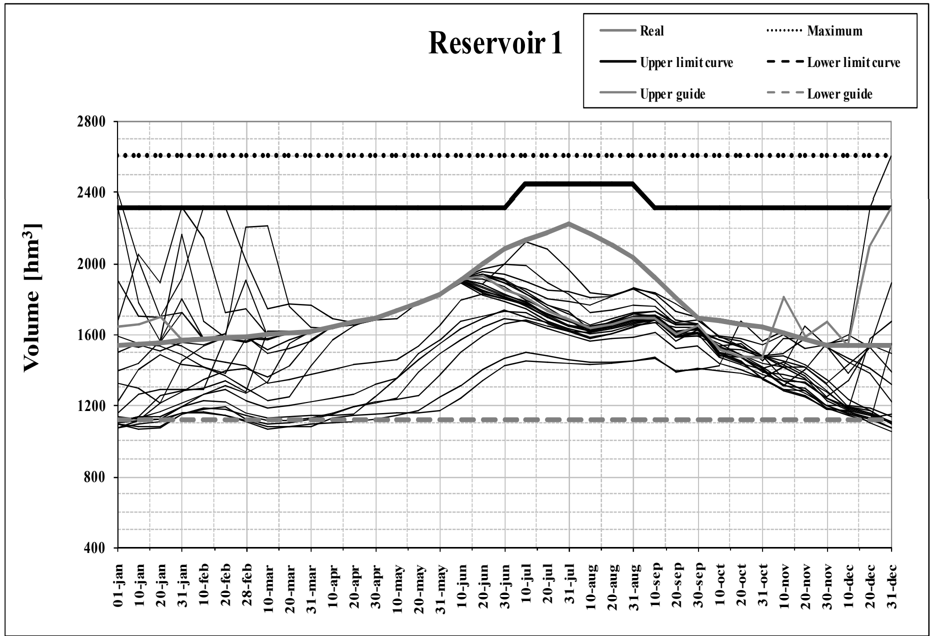
- Power plant initial management:
  - Forced outages during scheduled dates
  - Unplanned outages sampled independently for each day
  - Recent development: bathtub curve

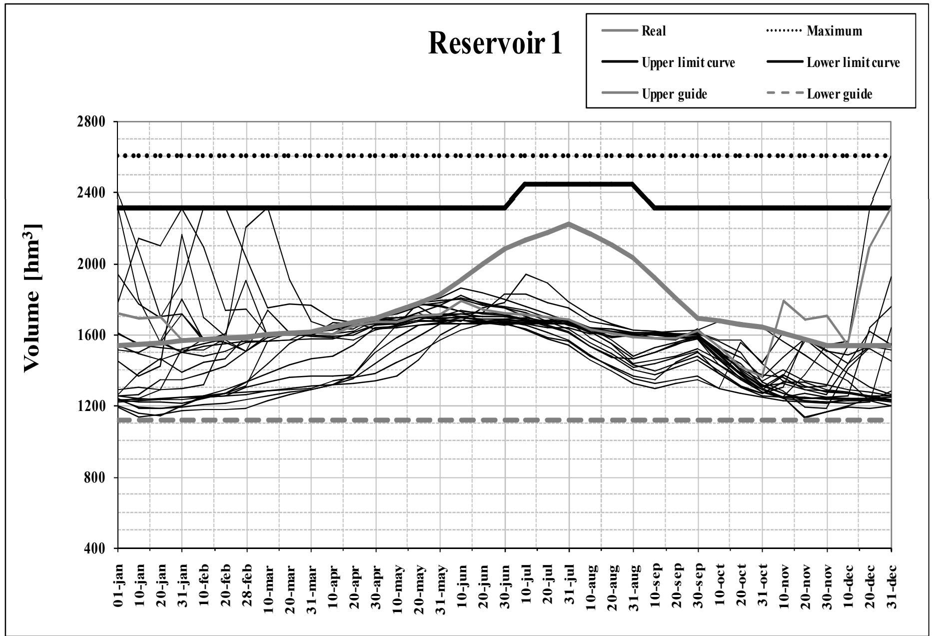
Application to hydro scheduling (I)

- Realistic case of 9 reservoirs
- Two effects studied:
  - Variation of peak and off-peak hourly prices spread
  - Variation of installed thermal capacity
- Simulation for 24 yearly series
  - Previous generation of production / pumping lookup tables for each case
- Results for yearly operation reservoir

Application to hydro scheduling (II)

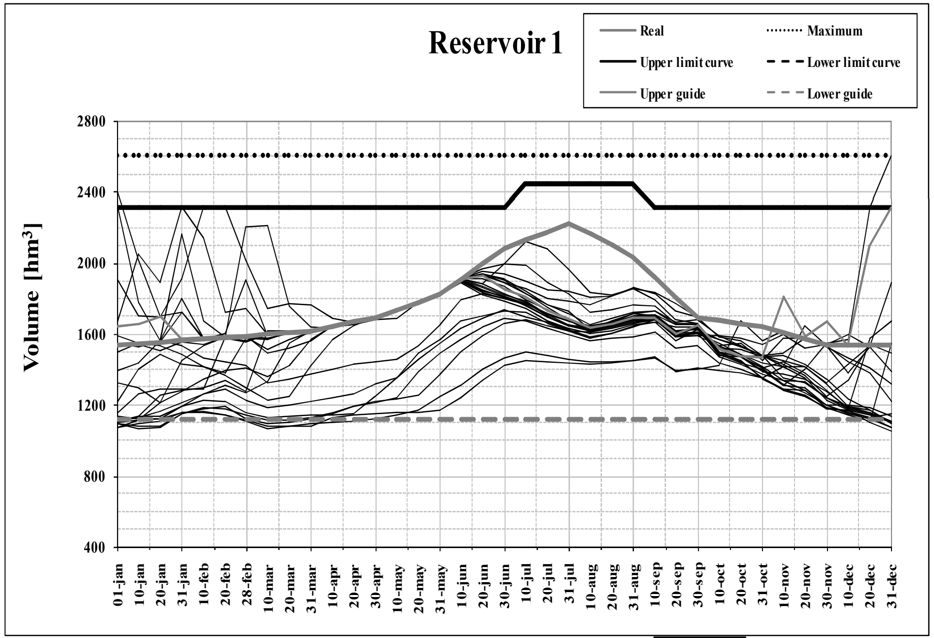
- Effect of the increased price spread among peak and off-peak hours:
  - Narrower reservoir volume evolutions

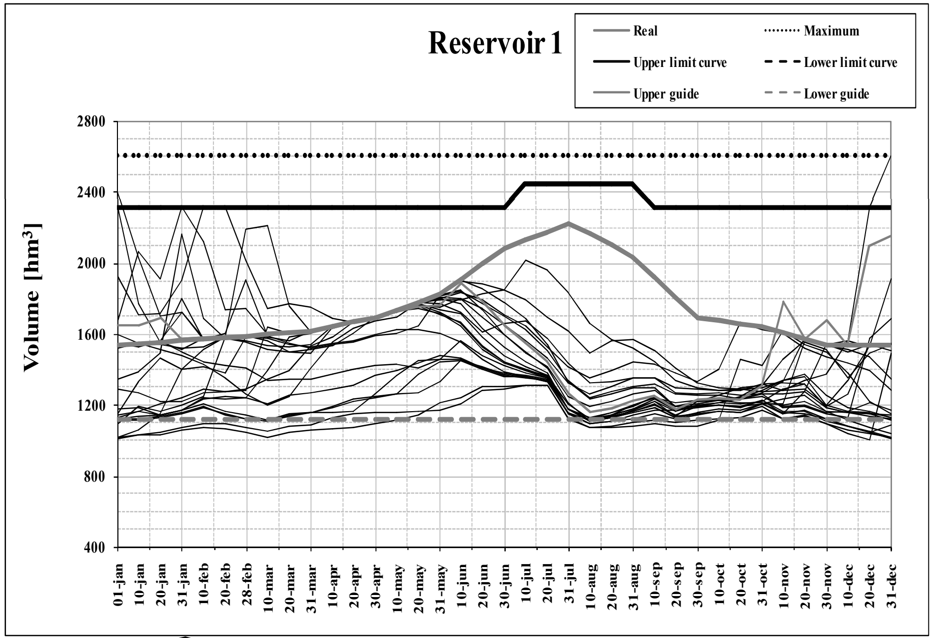




Application to hydro scheduling (III)

- Effect of the increased installed thermal capacity:
  - Allows free allocation of hydro production
  - Does not need to keep a reservoir volume during summer





Application to hydroelectric scheme design (I)

- Example case:
  - Simulation of 24 historical series
  - Unplanned outage rate of 5%

- Assessment of the maximum outflow:
  - Power plant with up to 4 units of 200 m^3/s and 48 MW
  - Analysis of generation and spilled outflows

Case	Maximum output flow [m^3/s]	Generation flow [$hm^3/year$]	Spilled flow [$hm^3/year$]
1a	200	2007	1079
2a	400	2446	641
3a	600	2623	464
4a	800	2725	363

Application to hydroelectric scheme design (II)

- Assessment of the maximum outflow:
  - Power plant with up to four units of 200 m^3/s and 48 MW
  - Analysis of results:
    - Generation increase and spillage reduction
    - Allocation of more energy in peak hours

Case	Generation energy Total	Peak	Off-peak	Spilled energy [GWh/year]
	[GWh/year]			
1a	155	107	48	83
2a	189	153	35	49
3a	202	178	24	36
4a	210	190	20	28

Application to hydroelectric scheme design (III)

- Assessment of the number of units (1 to 4):
  - For a fixed outflow of 600 m^3/s
  - Should be combined with the economic valuation of investment costs
  - The increase from 1 to 2 units is more significant than the rest of new units installation

Case	No. of units	Generated flow [hm3/year]	Spilled flow [hm3/year]	Generation energy Total [GWh/year]	Generation energy Peak [GWh/year]	Generation energy Off-peak [GWh/year]	Spilled energy [GWh/year]
1b	1	2454	632	189	158	31	49
2b	2	2610	478	201	177	24	37
3b	3	2615	473	202	178	24	36
4b	4	2659	428	205	180	25	33

Conclusions

- Medium term simulation model
  - Considers detailed operation
  - Connected to longer term stochastic hydrothermal model
  - Stochastic inflows and outages
- Application to hydro scheduling
  - Provides feasible operation
  - Different operation criteria
- Application to hydro scheme design
  - Considering several options about installed units
  - Unplanned outage sampling

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