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

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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

![Reservoir volume chart](chart.png)
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
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 m³/s and 48 MW
- Analysis of generation and spilled outflows

<table>
<thead>
<tr>
<th>Case</th>
<th>Maximum output flow [m³/s]</th>
<th>Generation flow [hm³/year]</th>
<th>Spilled flow [hm³/year]</th>
</tr>
</thead>
<tbody>
<tr>
<td>1a</td>
<td>200</td>
<td>2007</td>
<td>1079</td>
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<tr>
<td>2a</td>
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<td>2446</td>
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<td>4a</td>
<td>800</td>
<td>2725</td>
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</table>
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

<table>
<thead>
<tr>
<th>Case</th>
<th>Generation energy</th>
<th>Spilled energy</th>
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<td></td>
<td>Total</td>
<td>Peak [GWh/year]</td>
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<td>107</td>
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<tr>
<td>2a</td>
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<td>3a</td>
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<td>178</td>
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<tr>
<td>4a</td>
<td>210</td>
<td>190</td>
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</tbody>
</table>
Application to hydroelectric scheme design (III)

- Assessment of the number of units (1 to 4):
  - For a fixed outflow of 600 m³/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

<table>
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<th>Case</th>
<th>No. of units</th>
<th>Generated flow [m³/year]</th>
<th>Spilled flow</th>
<th>Generation energy Total [GWh/year]</th>
<th>Peak [GWh/year]</th>
<th>Off-peak [GWh/year]</th>
<th>Spilled energy</th>
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</tbody>
</table>
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