COMPARING SSDP WITH STANDARD WATER VALUE CALCULATION ON TYPICAL NORDIC HYDRO SYSTEMS

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Stavanger, 13.09.2018
Outline

• Introduction
• Sampling Stochastic Dynamic Programming
• Implementation and Cases
• Results
• Conclusion and Discussion
Based on previous work


Introduction

**Objective:** To apply the SSDP method to typical Norwegian hydropower optimization problems and compare the results with a similar implementation of the water value method (i.e. stochastic dynamic programming).

**Hypothesis:** Improved representation of extreme weather years should give a better evaluation of severity of such years and improved operation of the hydro power reservoirs, lower operational costs and less curtailment.
Sampling Stochastic Dynamic Programming

Based on SDP, the main differences are that we in SSDP:

1) use historical weather years (inflow) directly as scenarios
2) calculates deterministic cost function for each scenario (year), which are used to estimate the future cost
Stage

Scenario specific cost functions

End-value setting for each scenario

T

T-1

T-2

T-3

Historical inflow years

Calculated transition probabilities for moving between scenarios!

Scenario specific cost functions

End-value setting for each scenario

Stage
(1) \[ f_t(S_t) = \min_{R_t} \{ C_t(S_t, Q_t^i, R_t) + E_{j|i}[f_{t+1}(S_{t+1}, j)] \} \]

(2) \[ f_t(S_t, i) = C_t(S_t, Q_t^i, R_t) + f_{t+1}(S_{t+1}, i) \]

(3) \[ E_{j|i}[f_{t+1}(S_{t+1}, j)] = \sum_{j \in M} P_t(j|i) [f_{t+1}(S_{t+1}, j)] \]
Implementation: model

Similar model for SDP and SSDP

- Equal formulation of the decision problem
- Water value calculation (optimisation) and simulation
- Optimisation and simulation on same scenarios
- SSDP method based on (Kelman, 1990) and (Faber, 2001)
- SDP model based on (Helseth, 2017)
Implementation: the decision problem

Objective function: Minimise total socioeconomic cost

Such that:
- Supply meets demand (marked balance: dual = power price)
- The reservoir balance is maintained (dual = water value)
- Max exchange capacity is honoured
- Max production capacity of the generators are honoured

Includes: one hydro power generator with reservoir, one thermal generator, one "ration generator" and exchange/trade to a market with exogenously given price. Inflow is stochastic.

Linear problem, no head effects, no start/stop costs or ramping.
Equal probabilities for moving between scenarios in the SDP model (No Markov model or correlation)
Calculated transition probabilities for moving between the scenarios in the SSDP model
Differences in probabilities

**Transition probabilities in SSDP:** Probability of moving between scenarios based on inflow calculation uses Bayes theorem
Cases

- Tested on three separate hydro system cases from Norway
- 1 year time horizon (52 weeks), 83 years of stochastic inflow
- Slack, base and tight cases

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Results

Only minor differences in operational cost in the SSDP and SDP solutions for the slack and base cases for all regions.
Results Reg 1 tight case

- Higher reservoir filling in SSDP solution
  - Reduced curtailment
  - Increased spillage
  - Overall higher cost

- Different evaluation of the severity of wet versus dry years
Conclusion and discussion

• Hard to conclude that one method is better than the other.
• Considering socioeconomic cost the SSDP model performed worse than the SDP model in the tight case.

Possible improvement: use different/additional hydrological state variable than inflow (i.e. snow storage)
References


Teknologi for et bedre samfunn
(4) \[ z_t^i = \frac{(Q_t^i - \bar{Q}_t)}{\sigma_t} \]

(5) \[ p[z_t|z_{t+1}^j] \sim N(\hat{z}_t(z_{t+1}^j), \sigma_e)) \]

(6) \[ P_t(j|i) = P_t[z_{t+1}^j | z_t^i] = \frac{p[z_t^i|z_{t+1}^j]p^j}{\sum_{k \in M} p[z_t^i|z_{t+1}^k]p^k} \]