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Increased information flow between hydropower scheduling models through extended cut sharing

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Abstract

We present initial results and description of a method for coupling long term hydro scheduling models to short term hydro scheduling models. The method is based on an established approach but extends on the principle to increase the available information of the future estimates provided by the long term model.

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1. Introduction

In hydropower scheduling, numerical models are used for various tasks depending on by planning horizon and user needs. In a research setting, use cases could be long-term analyses investigating grid structure/expansions or future scenario analyses, while in an operational scheduling setting the use case could be an immediate scheduling problem for bidding in power markets.

This span has led to a hierarchy of models starting with very long term models at one end where the scheduling horizon can be several years , the geographical span can be extensive and the level of detail usually coarse. The scope of the models then decrease in scheduling horizon and geographical span and increase in level of detail to models covering a year or several months or weeks . At the other end of the hierarchy the models tend to cover only a small geographical region with a scheduling horizon of only days or a few weeks. However, the level of detail is much greater than for the long term models .

This hierarchy is coupled through information shared between the different models so that results from one model is input to the next model. One example is that a long-term market model produce power price forecasts that one inputs to long-term or seasonal models. These models again provide estimates on, e.g., the value of stored water at a certain time, which again can be used as input to more detailed short-term models.

In this paper, we present details of a method which uses the hydropower scheduling optimisation problem structure to provide more information in the link between long-term and short-term models. The method has been developed

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using and applied to two models developed by SINTEF Energy Research, both of which are in operational use by several of the market actors in the Nordic power markets. The method should be readily applicable to any set of models using a similar solution approach; this will become apparent in the following section.

Nomenclature

All sizes are vectors unless explicitly noted otherwise.

J_t	object function of the optimisation problem at time t, scalar
α_t	future cost estimate at time t, scalar
$\mathbf{x}_t$	vector containing all variables at time t except the reservoir volumes
$\mathbf{v}_t$	reservoir volumes at time t
$\mathbf{c}_t$	vector containing all direct costs associated with x_t
$\mathbf{q}_t$	physical inflow
$\mathbf{z}_t$	normalised inflow
$\mathbf{m}_t$	mean of q_t
$\mathbf{Q}_t$	estimated standard deviation of q_t, diagonal matrix representation
ϕ	transition matrix in the inflow model
ξ_t	noise term in the inflow model
$\mathbf{A}_V$	matrix containing the hydrosystem topology
$\mathbf{d}_t$	firm power demand at time t
$\mathbf{S}_t$	power balances at time t required to meet the firm power demand, matrix
λ_t^r	hydro storage cut coefficient for cut r at time t
ν_t^r	inflow cut coefficient for cut r at time t
b_t^r	right-hand side of cut description r at time t, scalar

2. Problem definition and information sharing

The two models used in this study are the long-term optimisation tool ProdRisk [1–5] and the short-term optimisation tool SHOP [6–8] . Both solve in essence the same optimisation problem, consisting of the optimisation problem for $t \in T$ periods defined by equations (1)-(6). We focus here on the equalities of the models, leaving most details to their respective cited papers. The long-term model has a typical scheduling horizon of one to five years with $t = 1$ week and a geographical extension of one to a few river systems. The short term model has a typical scheduling horizon of one to two weeks and is typically applied to one production area with a common price. The short-term model has a more detailed and physically accurate description of the river system and the hydropower generation.

The objective of both models is to optimise the utilisation of the hydro resources through minimisation of the future cost of operation,

$$J_t = \min(\alpha_t + \mathbf{c}_t^\mathsf{T}\mathbf{x}_t) \;, \tag{1}$$

subject to global and local constraints

$$\mathbf{v}_t = \mathbf{v}_{t-1} + \mathbf{q}_t + \mathbf{A}_V\mathbf{x}_t \tag{2}$$

$$\mathbf{S}_t\mathbf{x}_t = \mathbf{d}_t \tag{3}$$

$$\alpha_t + (\lambda_t^r)^\mathsf{T}\mathbf{v}_t + (\nu_t^r)^\mathsf{T}\mathbf{z}_t \geq b_t^r \;, \quad r = 1, \ldots, R \;, \tag{4}$$

$$\mathbf{x}_t^{\min} \leq \mathbf{x}_t \leq \mathbf{x}_t^{\max} \tag{5}$$

$$\mathbf{v}_t^{\min} \leq \mathbf{v}_t \leq \mathbf{v}_t^{\max} \;. \tag{6}$$