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Effects of hydro-climate periodicity on hydropower production operation

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Hydropower accounts for almost half of all electricity production in Sweden, while also being the most important energy balancing resource. Nuclear power plants are gradually being decommissioned up to 2045 in Sweden according to the government's plans. It means there is a need for a dramatic expansion of renewable energy production, especially for hydropower as a balancing resource. The availability of renewable energy fluctuates with the weather, seasons, and between years, which is an important factor for the coordination of renewable energy production.

The aim of this research is to investigate how runoff forecasts affect hydropower production planning when the account is taken to hydro-climatic variations. This problem is studied by using production planning models fed by runoff forecasts that exhibit climate-driven periodicity. Statistical ensemble predictions and receding horizon control are implemented to reveal the effect on the production. Further, we utilize half-a-century long daily hydro-climatological data to runoff forecasts that are aggregated in ensembles particularly reflecting the bi-annual climate periodicity apparent from spectral analysis of the data.

Dalälven River Basin is used as a study case, which is a watershed stretching from western Sweden to the Baltic in the east and which has more than 30 hydropower stations. Four forecast ensemble scenarios have been analyzed out by studying the periodicity of discharge data in Dalälven River Basin. According to the seasonal and two-year periodicity, the four scenario ensembles are defined as: a) Odd year, wet month; b) Even year, dry month; c) Odd year, dry month; d) Even year, wet month. [A1] A large-scale optimal hydropower production model was built in MATLAB, in order to simulate hydropower production in Dalälven River Basin. It includes 13 reservoirs and 36 hydropower plants, and applies the sequential-quadratic-programming (SQP) as the optimization method. Receding horizon control is embedded into the optimal production programming, which can correct the systematic error. The historical data shows that the one-year-long sampling has a consistent biannual periodicity, with wet and dry years of different strength depending on the start month of the data selection in the year. It indicates the discharge data selection start from November and December gives the most dramatic effect on periodicity, while starting from May and July have a lower impact. Dynamic programming of hydropower production shows for both dry and wet runoff conditions that matching the forecast ensemble with the right phase of the actual climate conditions has a significant effect on the production profit.