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Effects of climate periodicity on hydropower production planning

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Hydropower accounts for almost half of all electricity production in Sweden 2016 according to the Swedish Energy Agency, while also being the most important energy balancing resource. Since nuclear power plants are gradually being decommissioned up to 2045 in Sweden, long-term and large-scale hydropower production become crucial to complement other intermittent renewable energy sources, such as wind and solar power. Hydro-climatic periodicity to some extent has impacts on the long-term hydropower production. Several studies have indicated significant variation in river discharge and runoff caused by periodical climatic factors. The variance in the power of runoff averaged all over Sweden is to certain extent periodic, and especially longer-term climate driven fluctuations have periodicities centered around 2 and 8 years. However, it is not exactly clear how periodical climate change impacts hydropower production in a large basin and how forecasting it affects the planning of hydropower production.

The aim of this study is to describe how the historic periodic change in hydro-climate and how the hydrologic response affects hydropower production planning in a long-term span. This problem is studied by using production planning models fed by runoff forecasts that a) systematically accounts for the periods of the climate system and b) neglects these periods by randomization of the runoff forecast. As a basis for a comparative study of the two forecast approaches, we utilized an extensive aggregation of historical hydro-climatological data and derived generalized hydrological time-series for half a century backwards in time, with the purpose of revealing the relationship between the selected forecast approach as well as climate periodicity on one hand and hydropower production on the other hand.

We use Dalälven River Basin as a study case, which is a watershed stretching from western Sweden to the Baltic in the east. A large-scale optimal hydropower production model was built in MATLAB, in order to simulate the multi-reservoir operation system, which includes 13 reservoirs and 36 hydropower plants in Dalälven River Basin. We apply sequential-quadratic-programming (SQP) in the nonlinear optimization model which satisfies constraints for reservoir levels, discharge and power production. The objective of the optimization can be formulated as the maximization of total economic profit of energy production and the potential economic profit of water kept stored in reservoirs. The results of the analysis show the relationship between the climate periodicity acknowledged in forecasts and the hydropower production. This acknowledgement is assured by using a new method where the randomized ensemble of forecasts is systematically lagged by a selected period.