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Operation of hydropower generation systems in the Alps under future climate and socio-economic drivers

Daniela Anghileri (1), Andrea Castelletti (2), and Paolo Burlando (1)

(1) Institute of Environmental Engineering, ETH Zürich, Zürich, Switzerland , (2) Department of Electronics, Information, and Bioengineering, Politecnico di Milano, Milano, Italy

Alpine hydropower systems are an important source of renewable energy for many countries in Europe. In Switzerland, for instance, they represent the most important domestic source of renewable energy (around 55%). However, future hydropower production may be threatened by unprecedented challenges, such as a decreasing water availability, due to climate change (CC) and associated glacier retreat, and uncertain operating conditions, such as future power needs and highly fluctuating demand on the energy market. This second aspect has gained increasingly relevance since the massive introduction of solar and wind generating systems in the portfolios of many European countries. Because hydropower systems have the potential to provide backup storage of energy to compensate for fluctuations that are typical, for instance, of solar and wind generation systems, it is important to investigate how the increased demand for flexible operation, together with climate change challenge and fluctuating markets, can impact their operating policies.

The Swiss Competence Center on Supply of Electricity (www.sccer-soe.ch) has been recently established to explore new potential paths for the development of future power generation systems. In this context, we develop modelling and optimization tools to design and assess new operation strategies for hydropower systems to increase their reliability, flexibility, and robustness to future operation conditions. In particular, we develop an advanced modelling framework for the integrated simulation of the operation of hydropower plants, which accounts for CC-altered streamflow regimes, new demand and market conditions, as well as new boundary conditions for operation (e.g., aquatic ecosystem conservation). The model construction consists of two primary components: a physically based and spatially distributed hydrological model, which describes the relevant hydrological processes at the basin scale, and an agent based decision model, which describes the behavior of hydropower operators. This integrated model allows to quantitatively explore possible trajectories of future evolution of the hydropower systems under the combined effect of climate and socio-economic drivers. In a multi-objective perspective, the model can test how different hydropower operation strategies perform in terms of power production, reliability and flexibility of supply, profitability of operation, and ecosystem conservation. This contribution presents the methodological framework designed to formulate the integrated model, its expected outcomes, and some preliminary results on a pilot study.