Hydropeaking Mitigation with Re-Regulation Reservoirs

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The role of hydropower as a renewable and balancing power source is expected to significantly increase in a scenario of Net Zero Emissions by 2050. As a common phenomenon in hydropower plants, hydropeaking will become more prominent, resulting in additional stresses on the ecological status of rivers. Here we propose a novel engineering approach to operate auxiliary reservoirs, termed re-regulation reservoirs to address the challenges posed by hydropeaking on river flow regimes. A re-regulation reservoir aims at smoothing flow fluctuations caused by hydropeaking by diverting and retaining parts of high flows and returning them back to river corridors during low flows. The regulatory performance of re-regulation reservoirs is a function of its geometry and volume availability, and it is defined and optimized by restricting the thresholds of various flow components.

In this study we developed a methodology and an open-access algorithm to operate re-regulation reservoirs using data from Kemijoki River, one of the most regulated rivers in Finland. The theoretical foundation of the algorithm was based on two main objectives, with the first aiming to reduce the hourly peak flow and increase the minimum hourly flow induced by hydropeaking. While the second objective aims to reduce the up- and down-ramping rates to increase the timespan of water level changes in the river’s corridor. Thus, the algorithm establishes a hierarchy of conditions to restrict peak flow, minimum flow, up-ramping rates, and down-ramping rates. However, as the ideal flow conditions for various ecosystem services may be different, a range of thresholds was utilized in each of the algorithm’s conditions resulting in thirty-five possible hydropeaking mitigation scenarios.

In all of the thirty-five tested scenarios, the re-regulation reservoir limits peak and minimum hourly flows and ramp rates according to thresholds defined by the algorithm. The results demonstrated that in most cases the required volume of the re-regulation reservoir increased as the thresholds for flow components became more stringent. However, for some scenarios this trend was not observed, indicating that matching the peak and minimum hourly flow with the ramping rates thresholds is required to achieve optimal re-regulation reservoir design. Nonetheless, our calculations show clear theoretical possibilities for regulating hydropeaking with re-regulation reservoirs.

Compared to other mitigation measures, such as the installation of downstream flow control devices or modifying the operation of hydropower facilities, re-regulation reservoirs offer greater flexibility and adaptability to changing environmental conditions, power, and water demand.
without increasing the operational cost of power systems.