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A dilemma of small hydropower plants: Design with uncertainty or uncertainty within design?

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Small hydropower plants (SHPPs) are subject to multiple uncertainties and complexities, despite their limited scale. These uncertainties are often ignored in the typical engineering practice, which results in risky design. As this type of renewable energy rapidly penetrates the electricity mix, the impacts of their uncertainties, exogenous and endogenous, become critical. In this vein, we develop a stochastic simulation-optimization framework tailored for small hydropower plants. First, we investigate the underlying multicriteria design problem and its peculiarities, in order to determine a best-compromise performance metric that ensures efficient and effective optimizations. Next, we adjust to the optimal design problem a modular uncertainty assessment procedure. This combines statistical and stochastic approaches to quantify the uncertainty of the inflow process per se, the associated input data, the initial selection of efficiency curves for the turbine mixing in the design phase, as well as the drop of efficiency due to aging effects. Overall, we propose a holistic framework for the optimal design of SHPPs, highlighting the added value of considering the stochasticity of input processes and parameters. The novelty of this approach is the transition from the conventional to the uncertainty-aware design; from the unique value to Pareto-optimality, and finally to the reliability of the expected performance, in terms of investment costs, hydropower production, and associated revenues.