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Opportunity cost including short-term energy storage in hydrothermal dispatch models using a linked representative periods approach

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Abstract— Short-term energy storage systems, e.g., batteries, are becoming one promising option to deal with flexibility requirements in power systems due to the accommodation of renewable energy sources. Previous works using medium- and long-term planning tools have modeled the interaction between short-term energy storage systems and seasonal storage (e.g., hydro reservoirs) but despite these developments, opportunity costs considering the impact of short-term energy storage systems in stochastic hydrothermal dispatch models have not been analyzed. This paper proposes a novel formulation to include short-term energy storage systems operational decisions in a stochastic hydrothermal dispatch model, which is based on a Linked Representative Periods approach. The Linked Representative Periods approach disposes of both intra- and inter-period storage constraints, which in turn allow to adequately represent both short- and long-term storage at the same time. Apart from the novelty of the model formulation itself, one of the main contributions of this research stems from the underlying economic information that can be extracted from the dual variables of the intra- and inter-period constraints, which allows to derive an hourly opportunity cost of storage. Such a detailed hourly economic value of storage has not been proposed before in the literature and is not possible in a classic Load Duration Curve model that does not adequately capture short-term operation. This advantage is reflected in the case study results. For instance, the model proposed in this paper and based on Linked Representative Periods obtains operating decisions of short-term energy storage systems with errors between 5% and 10%, while the classic Load Duration Curve approach fails by an error greater than 100%. Moreover, the Load Duration Curve model cannot determine opportunity costs on an hourly basis and underestimates these opportunity costs of hydro (also known as water value) by 6%-24% for seasonal hydro reservoirs. The proposed Linked Representative Periods model produces an error on the opportunity cost of hydro units lower than 3%. Hourly opportunity costs for short-term battery energy storage systems using dual variables from both intra- and inter-period storage balance equations in the proposed model are also presented and analyzed. The case study shows that the proposed approach successfully internalizes both short- and long-term opportunity costs of energy storage systems. These results are useful for planning and policy analysis, as well as for bidding strategies of ESS owners in day-ahead markets and not taking them into account may lead to infeasible operation or to suboptimal planning.

Index Terms— energy storage systems, power system planning, hydrothermal dispatch, representative days, water value, oppor-tunity cost.

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