Optimal sizing of energy storage systems based on two-stage stochastic programming

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The ever growing penetration of low carbon technologies, such as distributed generation (e.g. wind and photovoltaic), electric vehicles and heat pumps, is creating more and more critical issues to distribution systems operators (DSOs), which have to guarantee a predefined level of quality for electrical supply. In particular, modifications of typical power flows in distribution networks may cause abnormal fluctuations of the voltage magnitude, which are not tolerated beyond specified bounds around the nominal value. In this respect, thanks to their flexibility, energy storage systems (ESSs) have been recently recognized as an effective solution for DSOs to tackle voltage problems in distribution feeders [1]. Indeed, ESSs may act as loads in case of overvoltages, and generators in case of undervoltages.

To fully exploit the benefits of ESSs, their optimal allocation in the network is a key problem to be addressed at the planning stage. It consists of defining the number of devices to be deployed, their locations (siting) and sizes (sizing) [2]. Since future realizations of demand and generation are unknown at the planning stage, this uncertainty has to be taken into account in the formulation of the optimal allocation problem.

This work considers the aforementioned ESS sizing problem for voltage support in distribution networks. In order to accommodate uncertainty on demand and generation, the problem is formulated in a two-stage stochastic framework, assuming the ESS number and locations as known. The first stage decision is made with respect to ESS sizes, whereas the second stage problem computes the optimal ESS control policy for given demand and generation profiles. By taking a scenario-based approach, the two-stage problem is approximated in the form of a multi-scenario, multi-period optimal power flow (OPF). Since the size of the latter problem rapidly becomes computationally prohibitive as the number of scenarios grows, a suitable scenario reduction technique is proposed. Different from standard approaches based on probability measures [3], our procedure consists of a sequence of OPF problems with scenario sets of increasing size. The solutions of the downsized problems are lower bounds to the original problem, which converge to the exact solution from below typically after few iterations. The whole procedure is tested on the topology of a real Italian distribution network, whose historical data of demand and generation (used to define the scenarios) feature over- and undervoltages in the absence of ESSs.

References

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