Reliable Dispatch of Active Distribution Networks via a Two-layer Grid-Aware Model Predictive Control: Theory and Experimental Validation

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Dispatching active distribution networks (ADNs) is an energy-intensive application that, if implemented via battery-energy storage systems (BESSs), can require a large capacity of these assets in order to fully balance the uncertainties caused by the stochastic demand and generation. The insufficient capacity of the BESSs often leads to their state-of-charge (SOC) saturation; this results in unreliable dispatch tracking. In this work, we propose and experimentally validate a real-time control scheme that achieves a highly-reliable dispatching of ADNs and ensures that the BESSs’ SOC is not saturated during the daily operation. Our proposed scheme uses a two-layer model predictive control (MPC). The upper-layer MPC, running every 5 minutes, optimizes the BESSs’ SOC trajectories while minimizing the tracking error, considering the prosumption forecast of the whole day. Then, the lower layer MPC, running every 30 seconds, takes the BESSs’ SOC trajectories as constraints while achieving a high-resolution tracking of the dispatch plan over the current 5-minute time horizon. Both layers account for the grid constraints by using the augmented relaxed optimal power-flow (AR-OPF) model; an exact convex relaxation of the original AC-OPF and used in this paper (for the first time in the literature) to solve a real-time constrained control problem for ADNs. Our proposed framework was experimentally validated using a 1.5 MVA/2.5 MWh BESS connected to an actual 24-node medium-voltage (MV) ADN that, in Aigle, Switzerland, hosted an uncontrollable 3.2 MWp distributed photovoltaic generation, 3.4 MVA hydro-power generations, and a 2.8 MW base demand.