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An MIP formulation for joint market-clearing of energy and reserves based on ramp scheduling

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Abstract— The day-ahead unit-commitment (UC)-based marketclearing (MC) is widely acknowledged to be the most economically efficient mechanism for scheduling resources in power systems. In conventional UC problems, power schedules are used to represent the staircase energy schedule. However, the realizability of this schedule cannot be guaranteed due to the violation of ramping limits, and hence conventional UC formulations do not manage the flexibility of generating units efficiently. This paper provides a UC-based MC formulation, drawing a clear distinction between power and energy. Demand and generation are modeled as hourly piecewise-linear functions representing their instantaneous power trajectories. The schedule of generating unit output is no longer a staircase function, but a smoother function that respects all ramp constraints. The formulation represents in detail the operating reserves (online and offline), their time deployment limits (e.g., 15 min), their potential substitution, and their limits according to the actual ramp schedule. Startup and shutdown power trajectories are also modeled, and thus a more efficient energy and reserves schedule is obtained. The model is formulated as a mixed-integer programming (MIP) problem, and was tested with a 10-unit and 100-unit system in which its computational performance was compared with a traditional UC formulation.

Index Terms— Mixed-integer programming, operating reserves, startup and shutdown ramps, UC-based market-clearing

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