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Chance-constrained Scheduling of Variable Generation and Energy Storage in a Multi-Timescale Framework

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Abstract – This paper presents a hybrid stochastic deterministic multi-timescale scheduling (SDMS) approach for generation scheduling of a power grid. SDMS considers flexible resource options including conventional generation flexibility in a chance-constrained day-ahead scheduling optimization (DASO). The prime objective of the DASO is the minimization of the daily production cost in power systems with high penetration scenarios of variable generation. Furthermore, energy storage is scheduled in an hourly-ahead deterministic real-time scheduling optimization (RTSO). DASO simulation results are used as the base starting-point values in the hour-ahead online rolling RTSO with a 15-minute time interval. RTSO considers energy storage as another source of grid flexibility, to balance out the deviation between predicted and actual net load demand values. Numerical simulations, on the IEEE RTS test system with high wind penetration levels, indicate the effectiveness of the proposed SDMS framework for managing the grid flexibility to meet the net load demand, in both day-ahead and real-time timescales. Results also highlight the adequacy of the framework to adjust the scheduling, in real-time, to cope with large prediction errors of wind forecasting.

Keywords: Multi-timescale scheduling, Energy storage, Mixed-integer linear programming, Unit commitment, Wind generation

1. Introduction

The main disadvantage of variable renewable generation resources relative to conventional generation is their high intermittency, unpredictable fluctuations and limited output control capability. Consequently, these cause existing power system operation paradigms, especially generation scheduling, to face profound challenges [1]. A grid system with extra flexibility resources is needed to even out the intermittency and variability of wind generation in order to enable the high penetration of variable generation into the grid system.

Different approaches have been proposed in the literature to investigate the effect of adding various levels of variable renewable generation into the generation mix [2-5]. Chance-constrained programming is an alternate option to the modelling of uncertainties in power systems, in which constraints can be violated with a predefined level of probability [6]. The chance constraints are often converted into deterministic equivalents and a standard solution technique is applied to solve the stochastic power system problem, such as the optimal power flow [7] and transmission planning problem [8]. Throughout the literature, researchers have proposed chance-constrained optimization to solve the generation scheduling problem with only demand uncertainty [9, 10], only wind uncertainty [11, 12], or both simultaneously [13-15]. In [12], the authors proposed a generation scheduling problem, with uncertain wind power, formulated as a two-stage chance-constrained stochastic program; which ensures a large portion of the wind power output at each operating hour could be utilized. In [11], a chance constraint is proposed to restrict the probability of load imbalance. A Sample average approximation (SAA) algorithm, [16], was ubiquitously proposed in the above generation scheduling models, [10-13], to replace the chance constraint, by a pointwise constraint that must hold at a finite number of sample points drawn randomly from the chance constraint distribution. However, the SAA algorithm requires repetitive iterations and multiple validation scenarios to calculate the optimality gap for solution validation. These drawbacks make the SAA unsuitable for large scale generation scheduling problem formulation that requires long processing time.

The prospect for deployment of the emerging energy storage has become much more possible in recent years. Storage devices are expected to have the potential to become competitive under high penetration levels of renewable generation. This, in turn, will improve power system reliability, meet real-time power demand, and enhance economic efficiency [17]. Successful cases of bulk

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