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An interval-based nested optimization framework for deriving flexibility from smart buildings and electric vehicle fleets in the TSO-DSO coordination

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Abstract-

Emerging renewable-based transmission and distribution systems, despite many environmental and economic benefits, due to the intermittent nature of their production resources, compared to traditional systems, need more flexibility capacities, which necessitates the need for more suppliers of flexibility. To deal with these challenges, a nested framework is presented to derive the required flexibility of the transmission system operator (TSO) from distributed energy resources (DERs) and active end-users such as smart buildings (SBs) and electric vehicle (EV) fleets at the distribution level. To this end, a novel mechanism to design the demand response program (DRP) is introduced in which tariffs with time-varying rewards are built based on flexibility requirements. The coordination between TSO and distribution system operator (DSO) is initially modeled as a bi-level non-linear programming (NLP) problem, in which the upper-level is day-ahead (DA) operational planning of DS considering the schedules received from SBs, while the lower-level is DA operational planning of the TS. The bi-level NIL problem is transformed into a single-level linear programming (LP) problem by Krush Kuhn Tucker (KKT) conditions, Big-M method and Strong Duality Theory (SDT), which makes it computationally tractable. Finally, a two-stage interval-based algorithm solves the obtained single-level problem to secure the planning against uncertainties where battery energy storage systems (BESSs) are responsible for dealing with extreme conditions. The simulation results testify that the proposed interval-based nested framework has improved the economic, technical and security aspects of the TSO-DSO coordination since it has reduced the daily costs of the energy and flexibility markets, relieved lines congestion and improved voltage characteristics.

Index Terms- TSO-DSO coordination; Energy and flexibility markets; Smart buildings; Electric vehicles; Strong duality theory; Demand response programs

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