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Ph.D. DISSERTATION DEFENSE

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Date:	Wednesday, April 16th, 2025
Time/Location:	3:00p.m. – 4:30p.m., Burchard Building 219
Title:	On Optimal Planning and Operation of Smart Grid Edge Devices: Electric Vehicles and Distributed Energy Resources
Chairperson:	Dr. Lei Wu, Department of Electrical and Computer Engineering, School of Engineering and Science
Committee Members:	Dr. Xiaojiang Du, Department of Electrical and Computer Engineering, School of Engineering and Science Dr. Philip Odonkor, Department of Systems and Enterprises, School of Engineering and Science Dr. Shirantha Welikala, Department of Electrical and Computer Engineering, School of Engineering and Science

ABSTRACT

The power system has undergone a remarkable transformation, evolving from traditional centralized paradigms to dispersed and dynamic characteristics marked by technological advancements and environmental considerations. As the demand for sustainable solutions continues to grow, electric vehicles and distributed energy resources have emerged as one of the most critical boosters towards decentralized, cleaner, and more adaptive energy systems. Associated with the rapid development of electric vehicles, electric vehicle charging facilities are increasingly crucial in supporting the electric vehicle charging needs and alleviating the range anxiety of electric vehicle users but are facing challenges in both planning and operation, especially considering the interaction with multiple entities and electric vehicle uncertainties. In terms of distributed energy resources, integrating the increasingly penetrated distributed energy resources into the efficient operation of power systems has become a challenge. To address this, distributed energy resource aggregation has been expected to be an effective solution, while a gap still exists in embedding them into the operation of the power system and mitigating their negative influences on the power system. To this end, the dissertation explores efficient schemes for electric vehicles and distributed energy resource aggregations:

(i). Chapter 2 introduces a bilevel electric vehicle charging facility planning model integrating traffic and distribution network operation models. The statistical charging time is modeled to address macro traffic patterns and micro charging behaviors. The model also incorporates social factors and driver behaviors and is transformed into a tractable formulation for practical computation.

(ii). Chapter 3 studies a semi-decentralized real-time charging scheme in which the central operator and individual chargers collaborate to achieve optimal electric vehicle charging schedules. The uncertainties of electric vehicles are captured by both the central operator and individual chargers over different time granularities.

(iii). Chapter 4 presents a chance-constrained unit commitment model to determine system optimal operation plans with multi-transmission-node distributed energy resource aggregation based on uncertain distribution factors. A novel bounded hetero-dimensional mixture model is also proposed to describe the complex distribution of distribution factors.

(iv). Chapter 5 explores an optimal node aggregation approach to establish the optimal multi-transmission-node distributed energy resource aggregation formation scheme. Moreover, a multi-parametric optimization-based approach is proposed to calculate accessible capacity expansion regions to assist multi-transmission-node distributed energy resource aggregations' complex expansion planning problems.