Topic: **Electrical Vehicles optimization under uncertainty**

Electric vehicles (EVs) are a rapidly emerging transportation technology that holds great promise for addressing the challenges of fossil fuel dependence and reducing greenhouse gas emissions. These vehicles are powered by electricity stored in rechargeable batteries, offering a clean and sustainable alternative to traditional internal combustion engine vehicles. EVs have gained significant attention in recent years due to advancements in battery technology, which have led to improved driving ranges and reduced charging times. In addition to their environmental benefits, EVs offer lower operating costs and potential grid integration for energy storage and demand response. With supportive government policies, expanding charging infrastructure, and increasing consumer acceptance, electric vehicles are poised to revolutionize the transportation sector and play a crucial role in achieving a sustainable and low-carbon future. Uncertainty arising from factors such as weather conditions, demand fluctuations, international geo-politics, and supply variability poses a considerable obstacle to efficient energy utilization. This PhD proposal aims to address these challenges by developing a data-driven optimization framework for EVs under uncertainty.

## Research Objectives

The primary objectives of this research are threefold:

a) To investigate the application of stochastic game theory, stochastic geometric programming, and related optimization methods to understand, model, and enhance network effects within the context of electric vehicle (EV) distributed storage systems.

b) To design optimization algorithms that utilize the uncertain data to optimize incentives for EV owners to participate in the distributed storage system while ensuring the overall efficiency and resilience of the grid.

c) To evaluate the performance of the proposed framework in realistic EVs platforms, considering various uncertainty sources.

## Methodology

In this research, we will focus on developing robust and flexible models to represent the uncertain parameters in the energy generation and EV integration (charging and/or discharging). This will involve statistical techniques, machine learning algorithms, and stochastic optimization approaches to capture the uncertainty associated with energy generation, demand, and storage, where the goal is to be able to provide a framework for vehicule-to-grid integration. We will explore methods such as chance constraints, two-stage stochastic optimization, multistage optimization, Markov decision processes, and scenario generation to quantify and represent uncertainty accurately.

We will develop optimization algorithms that can effectively handle the uncertainty in EVs. The algorithms will integrate the uncertain data into mathematical programming models, allowing for the determination of optimal EV storage strategies, and demand response actions.

The following topics will be employed to balance the trade-off between cost, reliability, and environmental sustainability.

- Game Theory: Explore how game theory can be applied to model the behavior of EV owners in the context of a distributed storage system under uncertainty. Investigate strategic interactions among the EV owners and how these interactions influence their decision to participate in the system.
- Geometric Programming and Optimization Techniques: Develop geometric programming models and optimization algorithms to design and optimize random incentive structures for EV owners. Evaluate how these incentives can maximize system-wide benefits while ensuring fairness among participants.
- Machine Learning Techniques: Implement machine learning algorithms to analyze and predict EV owner behavior, simulate network growth, and analyze the emergence and impact of network effects. Use these insights to refine the incentive structures dynamically.
- Network Effects: Study the dynamics of network effects in the context of EV distributed storage systems. Understand how network effects can be harnessed to boost system performance and accelerate the adoption of the storage system.
- Integration of Approaches: Combine stochastic game theory, stochastic geometric programming, optimization techniques under uncertainty, and machine learning in a unified framework. Investigate how these techniques can complement each other in the design and optimization of a distributed storage system.
- Practical Implementation and Validation: Test the proposed models, algorithms, and techniques in real-world settings. Validate their performance using data from actual EV distributed storage systems. Reflect on the practical implications and potential limitations of the proposed research.

To assess the effectiveness of the proposed framework, we will evaluate its performance using real-world EV systems. Case studies will be conducted on representative power grids or microgrids, considering different uncertainty scenarios and system configurations. Performance metrics such as cost minimization, reliability improvement, and carbon footprint reduction will be analyzed to demonstrate the advantages of the proposed approach compared to existing methods.

**Expected Contributions**

The anticipated contributions of this research include:

a) A comprehensive understanding of uncertainty sources in EV systems and their impact on energy management.

b) Advanced modeling techniques to accurately represent uncertainty in EV together with energy generation, demand, and storage.

c) Development of optimization algorithms that integrate uncertain data into decision-making processes for optimal EV.

d) Practical insights and guidelines for policymakers and energy managers to enhance EV system performance under uncertainty.

**Timeline**

The proposed research is a part of collaboration between Youree, FrenchTech labeled startup dedicated for vehicule to grid integration technologies, and Laboratoire des Signaux et

Systemes – CentraleSupelec. It will be conducted over a period of three years, divided into the following phases:

Year 1: Literature review, data collection, and uncertainty analysis. Write an article survey on EVs and the related state-of-the-art of optimization approaches to submit to international journal.

Year 2: Model development, optimization algorithm design, and implementation. Write articles on different approaches and results to submit to international journals and conferences.

Year 3: Performance evaluation, case studies, and thesis writing.

**Profiles and skills**

The candidate should have a solid background in game theory and optimization, and holds a master degree in applied mathematics with experience in probability theory. A good knowledge of Machine Learning and Python are expected. Fluency in English and good communication skills in general are highly required.

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