Modeling and Energy-Optimal Control Policies for Electromobility Networks

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Application type: PhD. Gross salary: 2 135 Euros/M (CNRS PhD official salaries).
Start: any time. **Duration**: 36 months.
Employer: CNRS. **Location**: Grenoble, France (GIPSA-Lab and INRIA-RA)
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Request Background. Control Systems, Applied mathematics

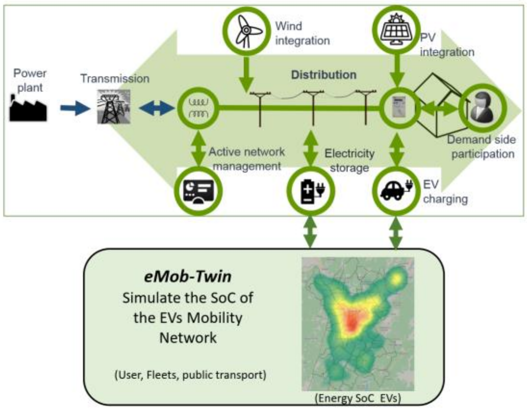

Figure **Electromobility scheme**

Context. As efforts for environmental protection become a major priority, Electric Vehicles (EVs) have started to emerge as one of the main components of sustainable traffic systems in cities worldwide**.** By 2030, however, EVs will account for 70% of all the vehicles sold, according to the EU roadmap (the Fit for 55 plan), which envisions a ban on the sale of new petrol and diesel cars as early as 2035. Integration of the electrical vehicles (EV) with the city infrastructure (charging stations), and the electrical power supply network (power grid) possess unsolved critical problems that will become critical with the massive adoption of EV by the population. Contrary to what is generally thought to be the case, electromobility (e-mobility), i.e., the electrification of the transport system, will not necessarily be a hurdle to the development of future electric power systems, where most synchronous generators will be replaced by utility-scale and behind-the-meter renewable energy sources (RES). Massive amounts of daily and seasonal storage capacity will be required in the medium-term future in order to properly compensate for the lack of RES dispatchability. On the daily horizon, a large portion of this storage capacity could be provided by EVs (here named e-flexibility), if the future vehicle-to-grid (V2G) technology is duly developed and managed to meet the needs of the moment. The electrification of transport could therefore help to integrate much larger amounts of renewables at a lower cost, which is crucial to achieving Europe's long-awaited energy independence [Ref.5]. One of the main potential barriers to fully exploit the e-flexibility potential available (by optimizing the infrastructure, and developing new EV services and business strategies), is the lack of tools and methods for forecasting EV fleets' e-flexibility in both time and space. This means being able to forecast when and where EVs are going to move, how their State of Charge (SoC) is evolving, and how they going to interact with the infrastructure and the power grid. Besides, combining EVs mobility models with grid power models will allow to use the EVs e-flexibility potential to minimize the energy curtailment of renewables and the better use of the existing power transmission network.

Work program. The PhD will include two main topics on modeling and control design.

Electromobility Modeling. The starting point, is the model obtained in the ERC AdG Scale-FreeBack [Ref.6], which recently developed a large-scale mobility model describing the daily movements of people in an urban network between their place of residence and destinations of five kinds (work, schools, etc.) This model generates a dynamic graph with nodes (origins and destinations) and their interconnections via an origin/destination matrix specifying the directions, arc weights and temporal profiles of the connections between nodes [Ref.1].. A set of nonlinear ordinary differential equations (ODEs) describes the movements of people at an aggregated anonymized level. This model has been recently extended to include EV mobility with battery charging/discharging dynamics, i.e. its State-of-Charge (SoC) [Ref. 2]. It will be completed with charging station models of several kinds (with low, medium, and high-power levels). This large-scale ODEs model [Ref. 3] can be transform by applying the continuation method developed in the context of the ERC AdG Scale-FreeBack [Ref. 4] into a partial differential equation (PDE) to obtain an aggregated and distributed representations of the energy and traffic density evolution in time and space. In work program we wish to study extensions of the previously described model to include the possibility of separate flows of EVs with different classed of SoC. This will provide the model with the capability to differentiate different levels of e-flexibility (i.e. low, medium and high charges). Finally, the model will be coupled with a grid network using available open-source existing software, in the spirit of the Fig.1.

Control strategies for optimally exploiting the distributed EVS flexibility. A first direct use of the model will be in solving problems of evaluating, locating, and dimensioning charging stations to support the VE power demand in favor of the car owners, and charge station operators. In addition, electrical vehicles can also be seen as a storage energy element sending energy back and forward to the power network (V2G) in order to: improve the grid operation, to balance the grid power demand/supply, and to maximize the energy use from renewables by minimizing the amount of energy curtailment [Ref. 6]. For that we will investigate several optimizations and learning policies. Aspect related to energy markets will be also investigated in connection to the use and exploration of the e-flexibility. Simulations will be conducted using our digital twin under development.

Collaborations. It is envisioned a collaboration in this topic with Prof. Marta Gonzalez at the department of civil & Environmental Eng. UC-Berkeley, USA, to extend these models using real-time mobility data.

References

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