MODEL BASED ANALYSIS OF THE DEPLOYMENT OF ELECTRIC VEHICLE IN THE PARIS ILE DE FRANCE REGION

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Overview

The European Union's energy and environmental strategy simultaneously pursues several operational objectives such as efficiency increase, renewable sources, greenhouse gases mitigation, and internal market expansion. They are declined for the transport sector in specific initiatives such as the 61 to 74% GHG mitigation target compared to 1990 proposed in the EU 2050 energy roadmap. To meet these ambitions electric vehicles have hence been increasingly promoted because they provide an appropriate technological answer to oil dependency, flexibility since many energy carriers can be converted to electricity, end-use energy efficiency, and transport related greenhouse gases and air pollutants.
Yet evaluating concrete transitions of transport system towards sustainability is a more complex task due to the fundamentally transversal nature of mobility both as a core societal aspiration, a major energy consumer, and a field where efforts to mitigate environmental impacts need to be increased. For electric vehicle their integration in both local electricity network constraints and local mobility patterns is hence an important research question.
The work proposed here was performed within the EV-STEP project funded under the Electromobility plus research program. It focuses on the impacts of electric vehicle on regional mobility and electric systems. The Paris Ile de France region which is our case study has an ambitious objective of 400 000 electric vehicles by 2020 in line with the target of 2 million for France as whole. The impact of this deployment on demand for power (15mn time step), charging behaviors, the availability of fast charging or standard charging stations and their interaction with changing car usage patterns are discussed using a modeling platform.

Methods

Based on a transport survey, a 2013 report the JRC proposed an analysis of load implication at national scale for few European countries and pointed out the insufficient number of studies addressing such issues. The aim of this paper it to propose a model based analysis of the impact of electrified mobility in the mobility and electric systems for the Paris Ile de France Region. This implies a better association of differentiated mobility needs to vehicles usage (distribution of hours for individual trips, mileage, load factor, ownership) and performances. It also means a better association of vehicles, infrastructures and electric system, since fast or standard recharging solutions have different impacts on maximum power and charging time. The platform connects four modules. The first one is a mobility module that computes the hourly trip schedule for a large electric vehicle fleet. It is based on a statistical analysis of the most recent French transport survey. From this analysis of current cars usage patterns the possibility to design alternative patterns is included as synthetic surveys where key statistical data (distribution, mean) can be modified. The second one is a charging optimization module that derives a charging plan that respects the mobility plan while allowing the optimization of complementary electric system's constraints. Non-optimized charging, forbidden charging time, caped maximum power, standard, fast or ultrafast charging are possible options. The third module then adds charging behaviors to the problem. Indeed several studies work with the ideal assumption of several charging event per days for all cars. Distributed behaviors are hence induced by this module. Finally the cost signal module, gives the evolution over time of the electric system's cost and maximum available power.

Results

The statistical analysis was based on the 2008 national transport survey that provides data for 16000 local trips for the Paris Ile de France region. The results cover the mean, standard deviation and distribution of several parameters: number of trips per persons, trip durations and distance, sub-areas of origin and destination. It can for instance be noted that while in average each car perform 3.31 trip per day the standard deviation equals 56% of this value. Using a single average car is hence not appropriate. For trip distance this ratio even reaches 90%. As electric vehicle can also be developed in niche markets for drivers with specific patterns the case of the 20% more mobile drivers and 20% less mobile drivers are considered. In terms of number of trips for instance the discrepancies range from 1.8 trips to 6.23 trips in average for both categories. As a consequence the planning of car charging does not obey the same constraints. The optimal charging module then allows the computation of a charging program with a time step of 15mn for each vehicle while respecting the admissible current intensity (depends on the charging infrastructure). Figure 1 below illustrates this process for two alternative charging programs (in red) satisfying the same mobility program (in blue) but for different allowed charging time. An interest of a formal model is hence to determine maximum peak power and their timing while respecting electric system and mobility constraints.

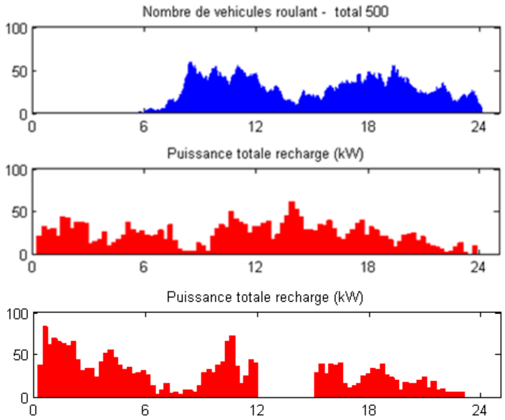

Figure 1. Alternative charging patterns for a given mobility plan

Finally results for sub regional zones are discussed. Île-de-France can be divided in three successive areas centered on paris: Paris, “ the Petite Couronne” area which is the inner suburb and the “Grande Couronne” area which is outer suburb. This is important to further capture the very different driving patterns in each area.

Conclusions

While electric vehicles are being increasingly promoted for their advantages against fossil fuels in the transport sector, the evaluation of their impact at more local scale poses interesting scientific challenges as they link two complex systems: mobility patterns and electric systems. We propose here a model based analysis for the Paris Ile de France Region. This region has a target of 400000 electric vehicles by 2020. The methodology developed combines statistical analysis of mobility survey with a charging optimization framework and consider a variable context characterized by charging behaviors and costs. The distinction in 3 sub-regional areas and niche markets restricted to the 20% more or less mobile car users are also included in the modeling work.

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