A REVIEW OF INTERACTIONS BETWEEN ELECTRIC MOBILITY AND PHOTOVOLTAIC ENERGY

Quentin Hoarau, Université Paris-Sud & Climate Economics Chair, +33676322896, hoarauquentin@gmail.com
Yannick Perez, Université Paris-Sud & CentraleSupelec, yannick.perez@gmail.com

Overview

Photovoltaic generation (PV) and electric vehicules (EV) are two disruptive technologies in the power and transport sectors that are raising several issues regarding power grids. In 2017 for instance, world EV fleet has reached two million units, while solar energy has got the largest growth of all energy sources. Numerous studies have been indicating that a synergistic potential exists between these two technologies. This special interaction would alleviate their burden on power grids and at the same time, would empower one technology with the others specificities. Indeed, electric vehicles could use photovoltaic energy to benefit of a low-cost and carbon-free electricity to charge. In return, photovoltaic systems would use the bi-directional exibility of electric vehicles battery to maximize their self-consumption. With such synergy, business cases of both technologies improve and therefore their joint development could be stimulated.

The objective of this paper is to develop a framework in order to analyze technical and economic aspects of this synergy. We tackle these issues with a literature review on systems including electric vehicles and photovoltaic energy. This literature mostly describes technical aspects of these interactions. There is a lack of knowledge on the economic conditions of the implementation of such synergy. We identified several open issues about these conditions that should be worth further investigation.

Methods

Our selected literature gathers all the studies on systems including electric vehicules and photovoltaic generation we were aware. From this selection, we analyse the properties these systems through the following framework. One the one hand, these systems exist in a specific spatial level (house, building, charging station or territory) and in a technological environment (storage, heating, energy sources…). This system is then organized by a control strategy, which exploits the complementarities between EV and PV and their environment in order to reach a specific objective. These three elements form the technical part of the framework.

On the other hand, the coupling organization and performance are dependent on economic interactions inside the system, between technology owners (between EV drivers and a charging station manager or between a EV fleet manager and a PV energy producer), and outside, with the power networks (distribution and transmission). These economic interactions are then shaped by policies and regulations (princing, subsidies, entry conditions).

As the literature used broadly techno-economics methods, economic aspects are mostly taken as fixed parameters (pricing, forecasting errors, drivers' behaviors...). Therefore, we interpreted the studies with an economic perspective through a prism of economic interactions and conditions.

Results

Our literature review enlightened the main following results. Technical studies showed that there exists a synergy between EV and PV that leads to better economic and technical efficiency and reduced ecological footprint of the EV/PV system. This synergy is determined by a smart control strategy aiming at optimizing the energy flow in the system, mostly by adapting the EV recharge to photovoltaic generation variations. Spatial configuration of the EV/PV system is a major aspect of the synergy. We saw that EV/PV coupling were particularly efficient in intermediate scales (large workplace buildings and charging station). During the day, these configurations host a medium number of EV (10-200), which facilitates the predictability of charging demand. In addition, this demand is adapted to the PV generation profile and therefore, smart control is very efficient. On the other hand, the specificity of EV/PV couplings is less obvious on other scales (households, territories) and technology diversified system.

As for the economic aspects, an interpretation using concepts of game theory showed that cooperation and the sharing of the added value between technology owners was a determining condition for synergy. Then, systems efficiently managing EV and PV could provide several services to facilitate power networks operations. We linked these issues with novel regulatory frameworks proposed in the literature. Finally, the efficiency of the EV/PV synergy is enhanced by policies and regulations that give incentives to onsite self-consumption (as appropriate dynamic pricings, low feed-in tariffs…).

Conclusions

The forthcoming energy transition should bring complex technological systems in which each technology development will be closely linked together. The nature of these interactions and the understanding of their technical and economic determinants shall influence the pace of the transition towards more sustainable industrial systems. This paper focused on one of these links between two apparently independent technologies: the potential synergy between electric mobility and photovoltaic energy. Based on a thorough literature review, we presented a precise description of EV/PV systems.

We showed how one technology could benefit from the other. This synergy was analyzed in a framework distinguishing EV/PV systems in three components: its smart control strategy, its spatial configuration and its technological environment. From our point of view, it is difficult to determine on general effect of EV/PV synergy on both technologies lifetime costs due to the variety of the different influencing parameters. A specific study should then be conducted. Then, we investigated the economic conditions of such synergy. Although our selected literature was mainly technical, we exhibited some elements on how EV/PV synergy was reinforced by cooperation between technology owners inside EV/PV systems, mutually beneficial interactions between EV/PV systems and power networks (transmission and distribution) and appropriate regulations and policy.

This review work led us to enlighten unanswered questions worth, according to us, further investigations. In the end, what would be a realistic typical decrease for EV on its lifetime costs in a territory covered by EV/PV systems? How would cooperation between stakeholders take place in EV/PV systems? Which participants behaviors would enable EV/PV synergy (transaction costs, reaction to pricing incentives...)? How can the added value of this synergy be shared between participants of the system? Practically, which business model would be best suited for car sellers to incite car owners ? An efficient EV/PV synergy requires certain proportions of EV and PV in the system. Therefore, what would be an efficient EV fleets and PV capacities development in order to benefit from EV/PV synergies? What is the combined effect of EV and PV integration in distribution network on the operator's revenue? And thereafter, which tariff design would be appropriate for a distribution system with joint EV and PV systems? As both electric mobility and photovoltaic energy are subsidized separately, would a public policy taking into account the synergy be more efficient? Then, what would look like a practical regulation that would target specifically the synergy?