COUPLING BETWEEN DISTRIBUTED BATTERY SYSTEMS AND PHOTOVOLTAIC GENERATION: A TECHNO-SOCIO-ECONOMIC REVIEW

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Overview

In the energy transition scenario, the need to decarbonize the power and mobility sectors are the two main goals established during important international environmental meetings such as COP21 in Paris. Those two sectors contribute together half of all the greenhouse gases emissions on the planet due to the use of fossil fuels to produce electricity in power plants and to set internal combustion vehicles in motion [1]. The coordination between agents in both sectors is necessary to accelerate the development and integration of recent technologies which substitute fossil fuel applications in the market [2]. The increase of electric vehicle (EV) units sold as well as the great augmentation of photovoltaic battery systems deployed around the world are clear consequences of policies established to drive the deployment of these technologies to reach climate agreement targets [3,4]. Distributed battery storage, notably the electric vehicle batteries and the stationary ones, and photovoltaic (PV) systems are disruptive technologies not only because they can individually contribute to CO_2 emissions reduction but also due to the positive synergies between them. Batteries can store electricity surplus produced by PV during the day, avoiding curtailment, and restore it to shave load peak or when external grid constraints are identified [5,6]. Several services behind and in front of the meter can be provided by battery systems and electrical vehicle fleet, such as: frequency regulation, voltage regulation, demand response support and congestion management [7]. The technical and economic issues are well studied separately in the literature [8]; nevertheless, a general panorama including social and joint aspects between these three fields is lacking.

Methods

This article provides up-to-date techno-socio-economic information on the coupling between electric vehicles equipped with bidirectional chargers, stationary batteries and PV. We provide a framework to academics, stakeholders and policymakers involved in an energy transition scenario willing to gain further knowledge of the under-explored relationship between these three entities. Aiming to provide a complete analysis, we split the coupling in three aspects (technological, economic and social) with intersections (techno-economic, socio-economic and socio-technical). The most important information in each area is highlighted with the support of literature on each aspect studied as well as the relations between them which allow the identification of the impacts and feedbacks that one field has over the other.

Results

The viability of the coupling is impacted by the techno-economic scenario and its future perspectives, i.e., the massive adoption of distributed battery storage charged by solar PV, are economics-driven [9], but as the technology tends to become more affordable this barrier will not be impossible to overcome. The emerging social aspects are found to be decisive variables in whether people are receptive and willing to change their behavior or invest in distributed energy systems [10]. Regarding participation in V2G (vehicle-to-grid) markets, people are becoming less worried about remuneration and mainly seeing it as a service provided to the community via the electricity power grid [11]. This last find could be applied to the whole coupling viability; information campaigns and commitment to achieve energy transition towards renewable energies (e.g. solar PV) could work very well in many countries around the world. However, inappropriate regulation of the electricity sector and outdated strategies formulated by the automotive one in respect to these new technologies could jeopardize all the potential benefits brought by electric vehicles as an electricity source. Electricity tariff design is still an open issue in the presence of distributed battery systems and solar PV due to the spillovers induced, i.e., cost-shifting and equity issues may arise if the regulator misunderstands the situation and sets an inappropriate tariff to costumers. Finally, community energy systems and community energy storage are found to be a promising socio-technical trend in the field of distributed energy resources. The objective of these communities is to group different households to invest together in renewable generation, storage and electric vehicles to supply their own needs for electricity as a heterogenous community and to be an example to be followed [12]. It can be a very good platform for regulators and policymakers to test, on a small-scale, new policies for local electricity markets and to analyse different social behaviors among communities.

Conclusions

The synergies of the coupling between distributed battery resources and photovoltaic power generation will help to decarbonize the electric power and mobility sectors while being profitable, if well managed, to all the agents involved: systems operators, regulators, ordinary consumers, etc. In the energy transition context, the urgency to change outdated electricity production methods that contribute to greenhouse emissions is driving the development of "cleaner" new technologies and new synergies; however, important policies and regulations are still struggling to follow this evolution and provide a perfect framework for them to be integrated without major inconveniences.

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