energies

Editorial

Recent Developments on the Incentives for Users' to Participate in Vehicle-to-Grid Services

Davide Astolfi [1,*], Antony Vasile [1], Silvia Iuliano [2] and Marco Pasetti [1]

[1] Department of Information Engineering, University of Brescia, Via Branze 38, 25123 Brescia, Italy; antony.vasile@unibs.it (A.V.); marco.pasetti@unibs.it (M.P.)
[2] Department of Engineering, University of Sannio, Piazza Roma 21, 82100 Benevento, Italy; s.iuliano@studenti.unisannio.it
* Correspondence: davide.astolfi@unibs.it

1. Perspectives of Electrical Mobility

The transportation is the sector of human activities which contributes the most to greenhouse gas emissions by far. For example, in [1], it was reported that, in the year 2022, upon the restrictions related to the Coronavirus having been lifted, the proportion of greenhouse gas emissions associated with the transportation peaked to 37% of the total.

Electric Vehicles (EVs) represent the most promising solution to de-carbonize the transportation sector, provided that the electricity employed for charging them is mainly produced from renewable sources [2,3].

The market share of electric vehicles reached the 10% in the year 2021, which is four times higher than in 2019. The total number of electric vehicles worldwide in the year 2021 was estimated to be 18.5 million, which is thrice the number in 2018. The growth of the EVs market share has been accelerating in various areas of the world, especially in Europe, where it is estimated to further accelerate in the upcoming years due to the diesel ban [4].

2. Negative Impacts of Electric Vehicles on the Power Systems

The growing share of EVs worldwide might lead to disrupting consequences on the power grid [5], such as the following:

- *Increase in peak demand*: for example, in [6], it was estimated that the peak demand increased by 53% when uncontrolled EVs charging was assumed with a 30% penetration level.
- *Voltage instability*: in [7], it was argued that uncoordinated charging at the peak period might lead to voltage deviations beyond the acceptable limits.
- *Phase unbalance*: an excessive use of single-phase charging might lead to phase unbalances, as argued, for example, in [8], where it was estimated that deviations beyond the limit can be reached, even with only 25% EV penetration level, provided that 80% of the recharges are connected to the same phase.
- *Harmonics distortion*: Due to the power electronics devices employed in the EV chargers, the harmonics injected into the power grid by the EV chargers cause remarkable total harmonics distortion. Most of the studies in the literature conclude that such an effect is meaningful, e.g., [9].
- *Overloading of the distribution system components*: The high EV power demands require large transmissions from the generation stations to the distribution networks. In various studies, such as [10], it was shown that the uncontrolled charging of EVs accelerates the aging of 25 kVA distribution transformers.
- *Increase in power system losses*: The extra power demand represented by the EVs causes higher currents flowing and, if the charging requests are concentrated at peak hours, the losses might be remarkable. For example, in [11], the distribution network of a

check for updates

Citation: Astolfi, D.; Vasile, A.; Iuliano, S.; Pasetti, M. Recent Developments on the Incentives for Users' to Participate in Vehicle-to-Grid Services. *Energies* **2024**, *17*, 5484. https://doi.org/10.3390/en17215484

Received: 24 October 2024
Accepted: 31 October 2024
Published: 1 November 2024

Korean island was analyzed, and it was argued that the power system losses increased by 66% for a 40% EV penetration level.

3. The Opportunity of Vehicle-to-Grid Services

The negative impacts of EVs on the power system outlined above are related to the additional load constituted by the charging request. Nevertheless, viewing EV solely as a load would be unmotivatedly limiting. In [12], it was estimated that EVs are employed for transportation for no more than the 5% of the time, and are stationary for the remaining 95%.

Hence, the framework, based on which electric vehicles can act as power sources for electric utilities [13], is well established. The possibility of furnishing Vehicle-to-Grid (V2G) services [14,15] is thus technically sound, and might be decisive for power systems' resilience in future scenarios [16,17], but is still embryonic due to the lack of large-scale applications [18]. In terms of principles, the use of EVs as power sources in the grid can contribute to peak shaving, frequency and voltage regulation, reactive power compensation, and electricity cost management [19,20].

The critical aspect from a social point of view is that such a practice is noticeably appealing to the Distribution System Operator and the energy market [21], but might sound unappealing to the user, because of concerns related to the lifetime of the EV battery [22], and due to the fear of running out of range (so-called range anxiety [23,24]). It is then fundamental to devote attention to the attitude of EV users [25,26].

4. Users' Attitude Towards V2G Services

A recent work [27] classifies through ad hoc surveys the users of electric vehicles in five categories, according to their attitude towards the hypothesis of participating in V2G services. Namely, the categories are the following:

- Reluctant;
- Careful;
- Self-sufficient;
- Idealistic;
- Tech-savvy.

The first two categories are overly concerned about running out of battery charge. Hence, these categories of users are the most affected by so-called range anxiety [23]. Reluctant and careful users have an over-protective attitude towards their batteries, since they do not have technical awareness of the fact that the impact of sporadic V2G participation on the battery's State of Charge (SoC) and State of Health (SoH) is very modest [28,29].

Self-sufficient users tend to prefer to employ the excess charge of their electric vehicles as a power source for their homes [30,31]. They are not characterized by a clear reluctance towards V2G services but, on the other hand, have no strong motivations which might stimulate them.

Idealistic users are the most interested in sustainability and civic engagement. Typically, they are the share of users more experienced with EVs and their concerns, also in relation to participation in V2G services, and mainly deal with the explicit sustainability and climate-neutrality.

Finally, tech-savvy users are very experienced and interested in the latest technology developments. Their attitude towards V2G is favorable, and their degree of skepticism might be related to the effective functionality of V2G schemes.

5. Advances in Incentives to User Participation

The above outlined classification of the users leads to identification of several possible types of incentives for participating in V2G services. Each type of incentive brings non-trivial scientific and technological challenges related to the charging stations [32], their grid connection, and the Information and Communication Technology (ICT) aspects, on which the research should focus in the near future.

- The participation of idealistic users might be stimulated by making explicit the sustainability of the charging station infrastructure. This entails exploiting as many renewable energy technologies as possible, in particular photovoltaics [33–35]. However, this poses technical challenges, in that the grid connection of the charging station should comply with the utility restrictions with respect to power oscillations at the point of common coupling. Hence, there is a need for flexible, reliable, and highly scalable computing architectures that can coordinate the charging and discharging process of EVs while identifying the best trade-offs between the vehicle charging expectations and grid requirements [36].
- In [27], it was argued that the share of users which are most conservative towards their batteries (namely the reluctant and careful groups) might be encouraged to participate in V2G if the proposed schemes have some fundamental features: customization and simplicity. Such features might be implemented, for example, through modular V2G schemes, where the level of commitment (hence the share of battery power used in the grid) can be selected by the user from among various pre-implemented options.
- The participation of tech-savvy users might be stimulated by developing Smart Charging algorithms which, for example, provide real-time information about the SoC of the battery [37], and on the efficiency of the charging procedure which, especially for wireless charging [38], might be particularly affected by alignment issues [39,40]. This entails developing non-trivial algorithms, which estimate the SoC when the EV is connected to the charging station. The communication and privacy-preserving requirements and, possibly, real-time estimation of remuneration require adequate informatics and ICT infrastructures, such as the blockchain, for example [41–43].

On the grounds of the above discussion, there are several multi-faceted research directions which should be pursued in the immediate future in order to encourage the participation of the users in V2G services.

Funding: This study was carried out within the MOST—Sustainable Mobility National Research Center and received funding from the European Union Next-GenerationEU (PIANO NAZIONALE DI RIPRESA E RESILIENZA (PNRR)—MISSIONE 4 COMPONENTE 2, INVESTIMENTO 1.4—D.D. 1033 17/06/2022, CN00000023), Spoke 5 "Light Vehicle and Active Mobility". This manuscript reflects only the authors' views and opinions, neither the European Union nor the European Commission can be considered responsible for them.

Conflicts of Interest: The authors declare no conflicts of interest.

References

1. Pamidimukkala, A.; Kermanshachi, S.; Rosenberger, J.M.; Hladik, G. Barriers and motivators to the adoption of electric vehicles: A global review. *Green Energy Intell. Transp.* **2024**, *3*, 100153. 100153. [CrossRef]
2. Chen, L.; Ma, R. Clean energy synergy with electric vehicles: Insights into carbon footprint. *Energy Strategy Rev.* **2024**, *53*, 101394. [CrossRef]
3. Shamshirband, M.; Salehi, J.; Gazijahani, F.S. Decentralized trading of plug-in electric vehicle aggregation agents for optimal energy management of smart renewable penetrated microgrids with the aim of CO_2 emission reduction. *J. Clean. Prod.* **2018**, *200*, 622–640. [CrossRef]
4. Dey, S.; Caulfield, B.; Ghosh, B. Potential health and economic benefits of banning diesel traffic in Dublin, Ireland. *J. Transp. Health* **2018**, *10*, 156–166. [CrossRef]
5. Nour, M.; Chaves-Ávila, J.P.; Magdy, G.; Sánchez-Miralles, Á. Review of positive and negative impacts of electric vehicles charging on electric power systems. *Energies* **2020**, *13*, 4675. [CrossRef]
6. Wang, Z.; Paranjape, R. An evaluation of electric vehicle penetration under demand response in a multi-agent based simulation. In Proceedings of the 2014 IEEE Electrical Power and Energy Conference, Calgary, AB, Canada, 12–14 November 2014; pp. 220–225.
7. Clement-Nyns, K.; Haesen, E.; Driesen, J. The impact of charging plug-in hybrid electric vehicles on a residential distribution grid. *IEEE Trans. Power Syst.* **2009**, *25*, 371–380. [CrossRef]
8. Ul-Haq, A.; Cecati, C.; Strunz, K.; Abbasi, E. Impact of electric vehicle charging on voltage unbalance in an urban distribution network. *Intell. Ind. Syst.* **2015**, *1*, 51–60. [CrossRef]
9. Miraftabzadeh, S.M.; Pejovski, D.; Longo, M.; Brenna, M.; Pasetti, M. Impact of Electric Vehicle Charging on Voltage and Current Harmonics at the Point of Common Coupling. In Proceedings of the 2023 IEEE International Conference on Environment and

Electrical Engineering and 2023 IEEE Industrial and Commercial Power Systems Europe (EEEIC/I&CPS Europe), Madrid, Spain, 6–9 June 2023; pp. 1–6.

10. Hilshey, A.D.; Hines, P.D.; Rezaei, P.; Dowds, J.R. Estimating the impact of electric vehicle smart charging on distribution transformer aging. *IEEE Trans. Smart Grid* **2012**, *4*, 905–913. [CrossRef]
11. Chang, M.; Bae, S.; Yoon, G.g.; Park, S.h.; Choy, Y. Impact of electric vehicle charging demand on a Jeju island radial distribution network. In Proceedings of the 2019 IEEE Power & Energy Society Innovative Smart Grid Technologies Conference (ISGT), Washington, DC, USA, 18–21 February 2019; pp. 1–5.
12. Mancini, E.; Longo, M.; Yaici, W.; Zaninelli, D. Assessment of the impact of electric vehicles on the design and effectiveness of electric distribution grid with distributed generation. *Appl. Sci.* **2020**, *10*, 5125. [CrossRef]
13. Kempton, W.; Letendre, S.E. Electric vehicles as a new power source for electric utilities. *Transp. Res. Part Transp. Environ.* **1997**, *2*, 157–175. [CrossRef]
14. Noel, L.; De Rubens, G.Z.; Kester, J.; Sovacool, B.K. *Vehicle-to-Grid*; Springer: Cham, Switzerland, 2019.
15. Ravi, S.S.; Aziz, M. Utilization of electric vehicles for vehicle-to-grid services: Progress and perspectives. *Energies* **2022**, *15*, 589. [CrossRef]
16. Loni, A.; Asadi, S. Power System Resilience: The Role of Electric Vehicles and Social Disparities in Mitigating the US Power Outages. *Smart Grids Sustain. Energy* **2024**, *9*, 23. [CrossRef]
17. Saldarini, A.; Longo, M.; Zaninelli, D.; Consolo, V.; Crisostomi, E.; Ceraolo, M.; Dudkina, E.; Miraftabzadeh, S.M. Literature Review on Electric Grid Resilience: Electric Vehicles as a Possible Support? In Proceedings of the 2023 AEIT International Conference on Electrical and Electronic Technologies for Automotive (AEIT AUTOMOTIVE), Modena, Italy, 17–19 July 2023; pp. 1–6.
18. Heilmann, C.; Friedl, G. Factors influencing the economic success of grid-to-vehicle and vehicle-to-grid applications—A review and meta-analysis. *Renew. Sustain. Energy Rev.* **2021**, *145*, 111115. [CrossRef]
19. Patil, H.; Kalkhambkar, V.N. Grid integration of electric vehicles for economic benefits: A review. *J. Mod. Power Syst. Clean Energy* **2020**, *9*, 13–26. [CrossRef]
20. Ali, Q.; Di Silvestre, M.L.; Restifo, G.L.; Sanseverino, E.R.; Sciumé, G.; Vasile, A.; Zizzo, G. A Simulation Study for Assessing the Minimum Number of V2G Recharge Points in Favignana. In Proceedings of the 2022 IEEE International Conference on Environment and Electrical Engineering and 2022 IEEE Industrial and Commercial Power Systems Europe (EEEIC/I&CPS Europe), Prague, Czech Republic, 28 June–1 July 2022; pp. 1–6.
21. De Caro, F.; Graber, G.; Calderaro, V.; Ippolito, L.; Vaccaro, A.; Galdi, V. Economic Challenges in V2G Implementation: An Italian Market Analysis. In Proceedings of the 2024 IEEE PES Innovative Smart Grid Technologies Europe (ISGT EUROPE), Dubrovnik, Croatia, 14–17 October 2024; pp. 1–5.
22. Secchi, M.; Barchi, G.; Macii, D.; Petri, D. Smart electric vehicles charging with centralised vehicle-to-grid capability for net-load variance minimisation under increasing EV and PV penetration levels. *Sustain. Energy, Grids Netw.* **2023**, *35*, 101120. [CrossRef]
23. Rainieri, G.; Buizza, C.; Ghilardi, A. The psychological, human factors and socio-technical contribution: A systematic review towards range anxiety of battery electric vehicles' drivers. *Transp. Res. Part Traffic Psychol. Behav.* **2023**, *99*, 52–70. [CrossRef]
24. Pevec, D.; Babic, J.; Carvalho, A.; Ghiassi-Farrokhfal, Y.; Ketter, W.; Podobnik, V. A survey-based assessment of how existing and potential electric vehicle owners perceive range anxiety. *J. Clean. Prod.* **2020**, *276*, 122779. [CrossRef]
25. Solja, L.; Liimatainen, H.; Simolin, T. Attitudes Towards and Conditions to Use V2G Among Electric Vehicle Owners. In Proceedings of the 2024 International Conference on Electrical, Computer and Energy Technologies (ICECET), Sydney, Australia, 25–27 July 2024; pp. 1–5.
26. van Heuveln, K.; Ghotge, R.; Annema, J.A.; van Bergen, E.; van Wee, B.; Pesch, U. Factors influencing consumer acceptance of vehicle-to-grid by electric vehicle drivers in the Netherlands. *Travel Behav. Soc.* **2021**, *24*, 34–45. [CrossRef]
27. Evertsson, A.; Nylander, A. Investigating Vehicle-to-Grid from a User-Centric Perspective. Master's Thesis, Chalmers University of Technology, Goteborg, Sweden, 2024. Available online: https://odr.chalmers.se/items/014e6125-c139-493c-9e69-0b18c14f10ed (accessed on 22 October 2024).
28. Sagaria, S.; van der Kam, M.; Boström, T. Vehicle-to-grid impact on battery degradation and estimation of V2G economic compensation. *Appl. Energy* **2025**, *377*, 124546. [CrossRef]
29. Wen, S.; Lin, N.; Huang, S.; Wang, Z.; Zhang, Z. Lithium battery health state assessment based on vehicle-to-grid (V2G) real-world data and natural gradient boosting model. *Energy* **2023**, *284*, 129246. [CrossRef]
30. Alilou, M.; Tousi, B.; Shayeghi, H. Home energy management in a residential smart micro grid under stochastic penetration of solar panels and electric vehicles. *Sol. Energy* **2020**, *212*, 6–18. [CrossRef]
31. Fahrner, V.M.; Bergfeld, M.; Eisenmann, C. Electric vehicles and their charging–in or out? User acceptance of bidirectional charging in Germany. *Transp. Res. Procedia* **2023**, *70*, 196–203. [CrossRef]
32. Corti, F.; Iacono, S.D.; Astolfi, D.; Pasetti, M.; Vasile, A.; Reatti, A.; Flammini, A. A comprehensive review of charging infrastructure for Electric Micromobility Vehicles: Technologies and challenges. *Energy Rep.* **2024**, *12*, 545–567. [CrossRef]
33. Eldeeb, H.H.; Faddel, S.; Mohammed, O.A. Multi-objective optimization technique for the operation of grid tied PV powered EV charging station. *Electr. Power Syst. Res.* **2018**, *164*, 201–211. [CrossRef]
34. Cheikh-Mohamad, S.; Sechilariu, M.; Locment, F.; Krim, Y. Pv-powered electric vehicle charging stations: Preliminary requirements and feasibility conditions. *Appl. Sci.* **2021**, *11*, 1770. [CrossRef]

35. Astolfi, D.; Bellagente, P.; Brandão, D.; Iacono, S.D.; Depari, A.; Ferrari, P.; Flammini, A.; Gaffurini, M.; Pasetti, M.; Rinaldi, S.; et al. ICT-Equipped Portable E-Bike Charging Station Powered by Renewables for Mass Cycling Events. In Proceedings of the 2024 IEEE International Workshop on Metrology for Automotive (MetroAutomotive), Bologna, Italy, 26–28 June 2024; pp. 141–146.
36. Vaccaro, A.; Iuliano, S.; Galdi, V.; Calderaro, V.; Graber, G. Achieving Consensus in Self-Organizing Electric Vehicles for Implementing V2G-based Ancillary Services. *IEEE Access* **2024**, *12*, 137222–137236. [CrossRef]
37. Pasetti, M.; Dello Iacono, S.; Zaninelli, D. Real-Time State of Charge Estimation of Light Electric Vehicles Based on Active Power Consumption. *IEEE Access* **2023**, *11*, 110995–111010. [CrossRef]
38. Palani, G.; Sengamalai, U.; Vishnuram, P.; Nastasi, B. Challenges and barriers of wireless charging technologies for electric vehicles. *Energies* **2023**, *16*, 2138. [CrossRef]
39. Ghazizadeh, S.; Ahmed, K.; Seyedmahmoudian, M.; Mekhilef, S.; Chandran, J.; Stojcevski, A. Critical Analysis of Simulation of Misalignment in Wireless Charging of Electric Vehicles Batteries. *Batteries* **2023**, *9*, 106. [CrossRef]
40. Carratù, M.; Iacono, S.D.; Pietrosanto, A.; Paciello, V. Self-alignment procedure for IMU in automotive context. In Proceedings of the 2019 IEEE 17th International Conference on Industrial Informatics (INDIN), Helsinki, Finland, 22–25 July 2019; Volume 1, pp. 1815–1820.
41. Kakkar, R.; Gupta, R.; Agrawal, S.; Tanwar, S.; Altameem, A.; Altameem, T.; Sharma, R.; Turcanu, F.E.; Raboaca, M.S. Blockchain and iot-driven optimized consensus mechanism for electric vehicle scheduling at charging stations. *Sustainability* **2022**, *14*, 12800. [CrossRef]
42. Dorokhova, M.; Vianin, J.; Alder, J.M.; Ballif, C.; Wyrsch, N.; Wannier, D. A blockchain-supported framework for charging management of electric vehicles. *Energies* **2021**, *14*, 7144. [CrossRef]
43. Pasetti, M.; Iacono, S.D.; Astolfi, D.; Vasile, A. On the Use of Blockchain for the Operation and Management of EV Charging Infrastructures. In Proceedings of the 2023 Asia Meeting on Environment and Electrical Engineering (EEE-AM), Hanoi, Vietnam, 13–15 November 2023; pp. 1–8.