E-mobility: Smart Charging

An IEEE European Public Policy Committee Position Statement

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Large-scale deployment of electric vehicles (EVs) is considered a major step towards more sustainable mobility[1]. In addition to the technological advances which are needed in the field of the EVs, there are three concerns strongly related to such a large-scale deployment:

i) energy balance between generation and load due to simultaneous charging;
ii) local congestions of the distribution grid;
iii) *range anxiety* due to insufficient charging infrastructure.

These challenges can be successfully tackled through the adoption of a smarter and more widely distributed EV charging infrastructure, together with proper economic incentives in tariffs to stimulate efficient charging.

This position statement aims to complement the recommendations provided in the IEEE EPPC statement entitled "Electrification of Transportation in the European Union"[2]. European policy makers are therefore encouraged to take measures for the establishment of a smart and harmonised pan-European network of electric charging facilities for EVs. The deployment of easy-to-access and convenient smart charging facilities for EVs throughout Europe removes the hurdles of access to the charging infrastructure which refrain most European citizens from moving freely and without concerns across Europe. In addition, a smarter charging infrastructure enables a more efficient and reliable use of renewable energies and of the distribution grid. Appropriate policies related to the deployment of a pan-European network of smart charging facilities, based on innovative technologies, can:

- position Europe as a potential hub for research and development in smart charging technologies;
- promote the widespread creation of highly skilled employment opportunities;
- stimulate the deployment of e-mobility in Europe;
- provide incentives for building up the needed charging infrastructure;
- provide effective means to help overcome electric grid congestion problems, commonly correlated to the large-scale deployment of EVs;
- curtail the lifecycle CO2 emissions related to EVs;
- provide a framework for interoperable charging solutions throughout Europe;
- ensure technology leadership in developing and deploying dynamic charging[3] technologies;
- enable intelligent transportation energy systems[4] by providing fora and frameworks upon which power grid and transportation system stakeholders can create collaborative synergies;
- take a major and important step towards the Energy Union, the harmonisation, and the interconnection of EV charging facilities inside the European Union (EU).

[1] European Environment Agency: "Electric vehicles and the energy sector - impacts on Europe's future emissions", DOI: 10.2800/139182

[2] IEEE EPPC, "Electrification of Transportation in the European Union", https://www.ieee.org/about/ieee-europe/publications.html

[3] Dynamic charging is defined as any charging procedure performed while the vehicles are moving.

[4] A. M. Farid, "Electrified transportation system performance: conventional vs. online electric vehicles," in *The On-line Electric Vehicle: Wireless Electric Ground Transportation Systems* (N. P. Suh and D. H. Cho, eds.), ch. 20, pp. 279–313, Berlin, Heidelberg: Springer, 2017.

IEEE EPPC Recommendations

1. Foster the large-scale development of a unified network of electric charging facilities, featuring the possibility for users to either charge their vehicles - grid to vehicle (G2V) - or provide energy to the electric grid - vehicle to grid (V2G) - in order to provide comprehensive and cost-attractive charging solutions. In this regard, incentives to stimulate the integration of intermittent renewable energy sources in the smart charging infrastructure could be introduced in order to support the decarbonisation of the transportation sector.
2. Provide funding to the main involved parties, such as:
    (a) research entities and manufacturers: to develop innovative power conversion and power transfer technologies, with improved efficiency and higher power densities, as well as novel strategies for charging coordination and optimal G2V/V2G power flow management;
    (b) private and public right entities (e.g., facility owners): to implement charging infrastructures featuring improved smartness;
    (c) Distribution System Operators (DSOs): to manage the energy distribution network constraints in a cost-effective way, to cooperate and invest on the implementation of the charging infrastructures, and to establish the required coordination efforts with foreign DSOs, critical while ensuring interoperability and easy access to the pan-European network of smart charging facilities.
3. Develop regulations requiring new public or commercial buildings to include fast and ultra-fast chargers with smart charging capabilities. This measure intends, on the one hand, to broaden the coverage of smart charging facilities and, on the other hand, to provide EV users with charging points in locations where they typically keep their EVs standstill for relatively long periods of time. Incentives can also be provided to commercial / retail operators to deploy charging stations in their facilities. Also, power management tools should be developed to assist all these entities incorporating multiple charging stations, while minimising investment and operation costs.
4. Assign top priority to technical standardisation initiatives dealing with interoperable smart charging solutions to complement and improve existing standardisation efforts relevant to this matter, as for instance IEEE 2030.5-2018[5] or IEEE PC62.230 - Guide for Surge Protection of Electric Vehicle Infrastructure[6]. Emphasis should be placed on standardisation of communication protocols, surge protection mechanisms, charger plugs, power levels, or other items considered critical for the interoperability of the charging systems.
5. Create a European framework for interoperability and data exchange for energy management from and to electric vehicle charging. In particular, the promotion of a common communication infrastructure between vehicles, chargers and utilities would enable new services related to charging systems (V2G, aggregators). In order to promote new business models based on the intelligent and automatic exchange of energy between infrastructures and vehicles, it is necessary to promote a common infrastructure with a European standard for both the interface part (connectors) and the communication protocols. On this common infrastructure it will be possible to define new business models, including electrical aggregators.
6. Support new research initiatives aimed at improving cutting-edge technologies required for the successful deployment of the smart charging concept, providing funding opportunities to develop novel technologies and to speed up large-scale technology implementation.
7. Encourage relevant stakeholders, namely DSOs and carmakers, to take a proactive stance on this mobility revolution, notably by providing beneficial taxation plans to those stakeholders willing

[5] 2030.5-2018 - IEEE Standard for Smart Energy Profile Application Protocol
[6] PC62.230 - Guide for Surge Protection of Electric Vehicle Infrastructure

to pioneer the integration of solutions targeted at smart charging systems in their portfolios. In the long term, a more proactive involvement of private stakeholders should be promoted.

8. Introduce programmes aimed at reducing the cost of fast charging devices. Accelerating the introduction of cheaper fast chargers is essential to network build-out and to providing the public with more fast charging capabilities.
9. Develop regulations concerning demand chargers and interconnection build-out to allow fleet operators to incorporate electrification without being penalised due to demand chargers or interconnection build-out. Power management software needs to focus as much as possible on helping facilities reduce cost so as to become a mechanism for smart charging and seek revenues from the charging assets.

The adoption of these recommendations opens up a plethora of new opportunities, paving the way to strengthen the distribution grid of the future, assuring easy and convenient access to the charging infrastructure and leveraging the potential of renewable energy sources.

The following sections further elaborate on the expected benefits arising from the adoption of these recommendations, providing additional details on how the proposed recommendations can be put in practice.

Strengthening the Future Power Systems

Currently, smart charging is defined as the ability to charge EVs during periods with higher availability of the distribution grids and at the lowest cost for consumers[7]. In the future, the concept of smart charging should be broader, aiming to provide EV users with comprehensive utilisation solutions.

The implementation of smart charging should encompass multiple services. EV users are not the only players that benefit from a harmonised network of smart charging facilities. DSOs, for instance, may also attain major gains from this evolution. The proactive stance that EVs can play within electric energy systems offers a cornerstone for leveraging e-mobility. Indeed, the role of EVs within the electric grid does not necessarily need to be limited to an energy consuming element. With the appropriate coordination strategy, EVs are also able to act as demand peak shavers, thus contributing to banish some of the major concerns frequently related to the large-scale deployment of EVs, such as local congestions on the distribution grid or energy balance between generation and load.

The electric grid balancing problem, considered one of the bottlenecks of EV expansion within Europe, can be cushioned, although not entirely, through the adoption of smart charging techniques supported by a thorough management of the power flows taking place between either the electric grid and the vehicle (G2V) or between the vehicle and the electric grid (V2G). Moreover, a pan-European network of charging facilities employing smart charging techniques would also provide a solid framework for the large-scale integration of renewable energies and distributed energy storage across Europe, since the resulting peaks in the energy generation can be handled in a far more effective manner. The significant energy storage capability of EV powertrains can be fully exploited even when not in use to absorb the energy excess available in the grid (G2V) during periods of excessive energy generation. Meanwhile, the energy stored in EVs can be released into the electric grid (V2G) during periods of energy generation shortage, allowing to partially fulfil the energy demand requirements.

The implementation of a pan-European charging infrastructure employing smart charging techniques is one of the most effective solutions for limiting the overburden on the currently existing energy transportation and

[7] European Parliamentary Research Service: "Electric road vehicles in the European Union - Trends, impacts and policies", p. 9

energy distribution grids[8], which means that the investment on such a charging infrastructure would be advantageous.

For this solution to happen, it will be fundamental to take actions on multiple domains. Firstly, it is important to stimulate the joint involvement of DSOs, carmakers, regulatory bodies, private right entities, and research institutions, assuring that coordinated actions lead to the desired results. The coordinated involvement of these stakeholders is of paramount importance for the development and implementation of the charging infrastructure, as well as for the broader integration of intermittent renewable energy sources. Moreover, it will be important to ensure that the economic incentives are properly passed along to electricity tariffs with a time and spatial granularity that stimulates consumers to do efficient charging, thus meeting the power system needs. This objective is part of a major and global effort to adapt power systems regulations to enable the increasing penetration of distributed energy sources in an effective way.

Ensuring Convenient and Easy-to-Access Charging Solutions Everywhere

The uptake of environmental-friendly mobility solutions, especially EVs, is conditioned by a set of forces. From the viewpoint of carmakers, the expansion of the EV fleet throughout Europe is limited by the lack of a dense and widespread network of charging facilities[9]. Promoting the expansion of a pan-European and easy-to-access network of charging facilities is the best way to effectively tackle this hurdle. Charging facilities with smart charging capabilities, which do not necessarily require further land occupancy, may consist of a simple plug installed at a public lighting pole or parking meter, for instance.

Further, one of the major concerns raised during the ongoing energy policy discussions regards the complex billing procedures that would need to be established as a consequence of the growing offer of EV charging services. In a scenario of implementation of a unified smart charging infrastructure, the billing procedures should also be standardised at the pan-European scale. This solution favours, first of all, EV users. On the other hand, DSOs take advantage of the energy storage capabilities of EV batteries to stabilise and balance power grids in periods of generation shortage. Easy access to the charging infrastructure is indeed the best stimulus for citizens to shift towards environment-friendly solutions.

Easy access to the charging infrastructure can also be assured through the implementation of initiatives suitable to broaden and speed up the coverage of the charging infrastructure. These include, amongst the other, the development of regulations requiring new public or commercial buildings to include fast chargers with smart charging capabilities and the reduction of the cost of fast charging devices.

Along with the broad coverage, the standardization and interoperability of equipment and procedures are keys to facilitating access to the charging infrastructure. Support from European authorities to technical standardisation initiatives would prove beneficial in this regard as well. The uptake of smart charging is not only a matter of new technologies, but also of a new regulatory framework, in which all stakeholders should collaborate to support new innovations.

Foster the Development of Cutting-Edge Technologies

The development of a harmonised pan-European network of electric charging facilities for EVs poses complex technical challenges. The charging technology development will need to address the emerging trends on the use pattern of EVs, without compromising the important goal of reducing the costs of chargers. With the increase in the use of car-sharing and car-pooling, the use pattern will change towards increased utilisation and

[8] European Environment Agency: "Electric vehicles and the energy sector - impacts on Europe's future emissions", DOI: 10.2800/139182

[9] ACEA Position Paper: The European Commission's proposal on post-2021 CO2 targets for cars and vans

reduced parking time, thus offering less opportunity for smart slow-charging solutions. This will call for stationary fast-charging and ultra-fast charging solutions that can still apply smart charging, as well as for smart dynamic charging technologies. One option to fast charging can be battery swapping, which works best for fleets of cars with identical battery specifications and frequently passed swapping hubs. Battery swapping may suit buses, taxi fleets, truck fleets and two-wheelers. Another alternative consists of onboard integrated fast charging, which enables the fast charging capability through integration of charging with the already available onboard power electronics. Fast-charging stations with buffer storage and co-location with local renewable energy sources provide an additional viable solution. Local energy storage can be used to level out the load from the EV charging and avoid demand peaks.

Despite its early stage of development, dynamic charging has already demonstrated tremendous potential to overcome a plethora of technical issues related to the presently-established charging infrastructure. Along with the well-known user-friendliness of dynamic charging technologies, one of the most noticeable advantages of dynamic charging is the fact that EV users would be able to charge their vehicles while driving. The effectiveness of the dynamic charging concept is already demonstrated in pilot plants, such as the Online Electric Vehicle (OLEV) Project[10]. Dynamic charging technologies, in combination with smart charging techniques, have the potential to overcome the concerns related to the whole lifecycle emissions of EVs. Analyses made on the EV fleet currently available in the market show that the batteries incorporated into the EV powertrain represents one of the major contributors to the overall lifecycle CO2 emissions of EVs[11]. Through the adoption of smart charging technologies, it becomes possible to optimise the charging and discharging procedures, resorting to advanced energy management strategies capable of limiting the stress conditions imposed on the batteries, thus extending their lifetime. Longer-lasting batteries enable the adoption of improved e-waste management strategies. On the other hand, the adoption of dynamic wireless power transfer technologies allows charging while driving. Hence, it becomes possible to reduce the size of the battery packs required to cover the same mileage in comparison to state-of-the-art batteries employed in existing EV powertrains. In practice, the previous two achievements translate into EV powertrains equipped with longer-lasting batteries, capable of attaining higher driving ranges.

The combined adoption of cutting-edge technologies provides answers to some of the technical concerns arising from the uptake of EVs:

- level the energy consumption related to EVs over the day, reducing the concentrated load pressure during specific periods of the day[12];
- decentralise energy consumption assigned to charging procedures;
- downsize the energy storage systems employed in the powertrains of EVs, while maintaining or even improving the driving range of EVs[11];
- facilitate the interoperability of charging procedures at both the power and communication tiers, enabling the connection between charging infrastructure and vehicles even when the technical specifications of the power transmitter and receiver devices do not match completely[13,14];
- optimise land occupancy through the reduction of the number of physical charging stations;
- foster the adoption of electric powertrains in heavy-duty vehicles, such as buses. The integration of battery packs capable of meeting a reasonable balance between energy storage capability and weight

[10] Online Electric Vehicle (OLEV): Concept
[11] Electric vehicles from life cycle and circular economy perspectives
[12] H. Humfrey, H. Sun, and J. Jiang, "Dynamic charging of electric vehicles integrating renewable energy: a multi-objective optimisation problem," in *IET Smart Grid*, vol. 2, no. 2, pp. 250-259, June 2019
[13] Industry Statement of Charging Interface Initiative e.V.: Interoperable wireless power transfer (WPT)
[14] SAE Recommended Practice J2954: Wireless Power Transfer for Light-Duty Plug-In/Electric Vehicles and Alignment Methodology

is a critical hurdle to the electrification of heavy-duty vehicles, which can only be dealt with by resorting to dynamic smart charging technologies.

A number of technical aspects still present some hurdles to the deployment of smart charging solutions and, consequently, should be carefully addressed, since they deserve further technical improvements:

- improvement of the efficiency of dynamic charging technologies, through the adoption of state-of-the-art technologies like wide-bandgap semiconductors and high-performance magnetics;
- communication and coordination between the EV, the charging infrastructure, and the transactional entities, in order to optimise power flows (G2V and V2G) in a manner that is suitable for concurrently attaining the objectives of optimisation of the lifespan of the vehicle energy storage system and harmonisation of the energy consumption related to EVs along the day.

The technological hurdles that remain can be effectively overcome through the promotion of innovation efforts. The assignment of funding to new research initiatives aimed at improving cutting-edge technologies, along with the promotion of collaborative programmes amongst research entities and OEMs, reveal fundamental to speeding up the broad implementation of a charging infrastructure relying on novel technologies.

Conclusion

Additional stimuli should be implemented to promote the uptake of EVs in Europe. The establishment of a European-scale fleet of EVs, operated with the support of a wide and easy-to-access network of charging facilities employing smart charging techniques, provides key answers to the ambitious targets of reducing lifecycle CO2 emissions related to transportation technologies. Furthermore, the successful deployment of smart charging facilities should be closely tackled through the development of interdisciplinary efforts. Due to the pan-European dimension of such charging facilities, it is critical to ensure technical coordination actions between charging facilities, supported via proper Information and Communication Technologies (ICT).

This statement was developed by the IEEE European Public Policy Committee (EPPC) Working Group on Energy and represents the considered judgment of a broad group of European IEEE members with expertise in the subject field. IEEE has nearly 60,000 members in Europe. The positions taken in this statement do not necessarily reflect the views of IEEE or its other organizational units.

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