Towards Digitalisation of the Charging Value Chain

Alois Steiner, Anna Eisner, Sandra Trösterer, Rainer Schruth, and Annika Hämmerle

Abstract The number of battery-powered electric vehicles in the EU is expected to increase to 30–40 million by 2030. This strong increase of electric vehicles is a major challenge for the energy system in Europe, but at the same time an opportunity to use new technologies such as smart charging or vehicle-to-grid. The EU project "XL-Connect" is investigating these new technologies, as the overall project goal is to optimise the entire charging chain—from energy provision to the end user—in order to create clear benefits for all stakeholders. This is to be achieved through the implementation of demonstration actions in combination with a digital twin of the charging chain. With the help of the digital twin, the so-called "upscaling" can be carried out to simulate the impact of large fleets of electric vehicles and their impact on the grid.

Keywords Digital twin · Smart charging · Vehicle-to-grid · User behaviour

1 Introduction

The expected strong increase in electric vehicles—30–40 million are expected in the EU by 2030—poses a major challenge for the energy system in Europe. Especially the local distribution grids may be pushed to their limits if the future owners of electric cars will charge their vehicles at the same time (e.g. mainly in the evening). Expensive reinforcements and extensions of the grid would be necessary to avoid partial shutdowns. An alternative to these reinforcement measures is the use of advanced charging solutions that can bring benefits to all stakeholders.

Within the EU-project "XL-Connect", the following advanced charging concepts will be investigated in detail:

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- V1G: Smart charging, also called V1G, refers to the ability to modify the charging power and the charging time. This can help to reduce the grid load during peak hours and to decrease the cost of charging.
- V2B/V2H: Vehicle-to-building (V2B) refers to the transfer of energy from an electric vehicle to a non-residential building and vehicle-to-home (V2H) to a residential building.
- V2G: Vehicle-to-grid (V2G) refers to bidirectional energy flow between an electric vehicle and the grid. Thus, the owner of an electric vehicle becomes a "Prosumer" (consumer who also produces) of energy and can help to stabilize the grid during peak hours.

To enable the usage of these technologies on a large scale, all involved stakeholders including the EV owners need to see a clear benefit. Thus, the overall objective of the XL-Connect project is to optimize the entire charging chain—from energy provision to the end user—and to create a convincing benefit for all stakeholders.

2 Investigation of the User Behaviour

One key element to successfully apply advanced charging technologies is to understand the user behaviour related to these technologies. Figure 1 shows an overview how the models for the user behaviour shall be set up, divided in charging (Grid-to-Vehicle (G2V)) and discharging (Vehicle-to-Grid (V2G)). For both elements the users will have different interests to consider. E.g. for charging the procedures factors like time/duration, costs or related CO_2-emissions might be interesting for the users. For discharging also the time/duration will be important, but probably also factors related to battery ageing (state of health (SoH)), the remaining battery state of charge (SoC) and some incentive (remuneration, free parking etc.) to attract EV owners to allow V2G will be important.

In order to investigate these aspects a questionnaire has been set up and will be distributed through the project partners of XL-Connect. The structure of the questionnaire is depicted in Fig. 2. Starting with a collection of demographic data the survey splits into persons who already drive an electric vehicle and those who plan to buy or lease one. For the first group questions regarding details of the electric car, their usage in daily life and their charging behaviour are stated. The second group gets questions regarding the time frame, reasons for an electric car as well as the planned charging behaviour. If they are unsure if they want to buy or lease an electric vehicle, the reasons for that will be asked. Finally, all persons are questioned regarding their attitude towards advanced charging technologies as smart charging, vehicle-to-home and vehicle-to-grid.

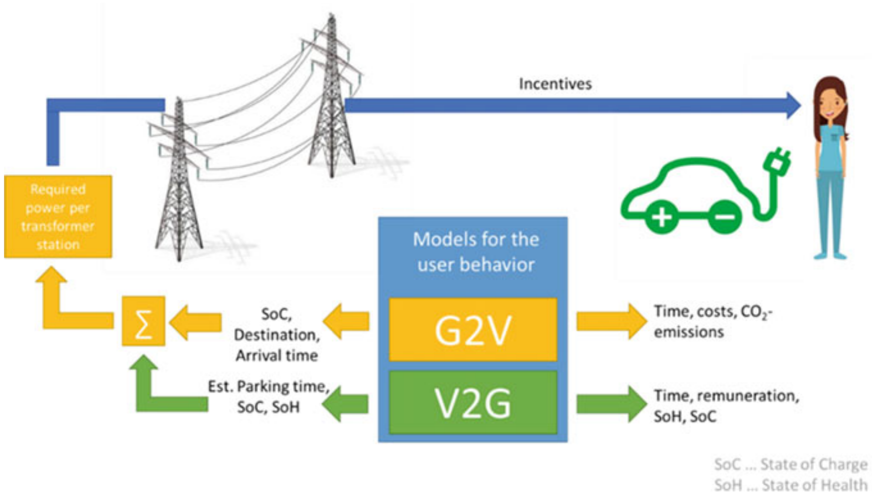

Fig. 1 Investigation of the user behavior

3 Digital Twins and Virtual Demonstration Actions

With the help of digital twins of the whole charging chain from the grid to the electric vehicles, different use cases using different advanced charging technologies can be investigated. Figure 3 shows an overview of different actors that will be represented in the digital twin and how the relations in terms of information and energy flow are expected to be.

With the digital twin the so-called "upscaling" can be carried out—i.e. the number of electric vehicles can be easily changed/increased—to simulate the impact of large fleets of electric vehicles and their impact on the grid.

Virtual demonstration action—Neuman Aluminium use case:

In XL-Connect real-word demonstration actions are complemented by virtual demonstration actions, which allow the investigation of different parameters (e.g. number of electric vehicles, control strategies etc.). One of the virtual demonstration actions is the so-called "Neuman Aluminium use case", which deals with a production site for aluminium parts and a possible use of vehicle-to-building to optimize the on-site energy management.

In general, the company Neuman Aluminium, located in Lower Austria, produces aluminium parts and has an overall yearly energy demand of ~111,000 MWh according to their energy intensive production processes. Overall, the total energy demand in 2022/23 of this use case can be divided in ~36% electricity demand and ~64% natural gas demand. According to this high energy demand, Neuman has employed three small hydroelectric power plants with an overall size of 0.95 MWp and a photovoltaic system of size 1.1 MWp. Currently, these power plants produce

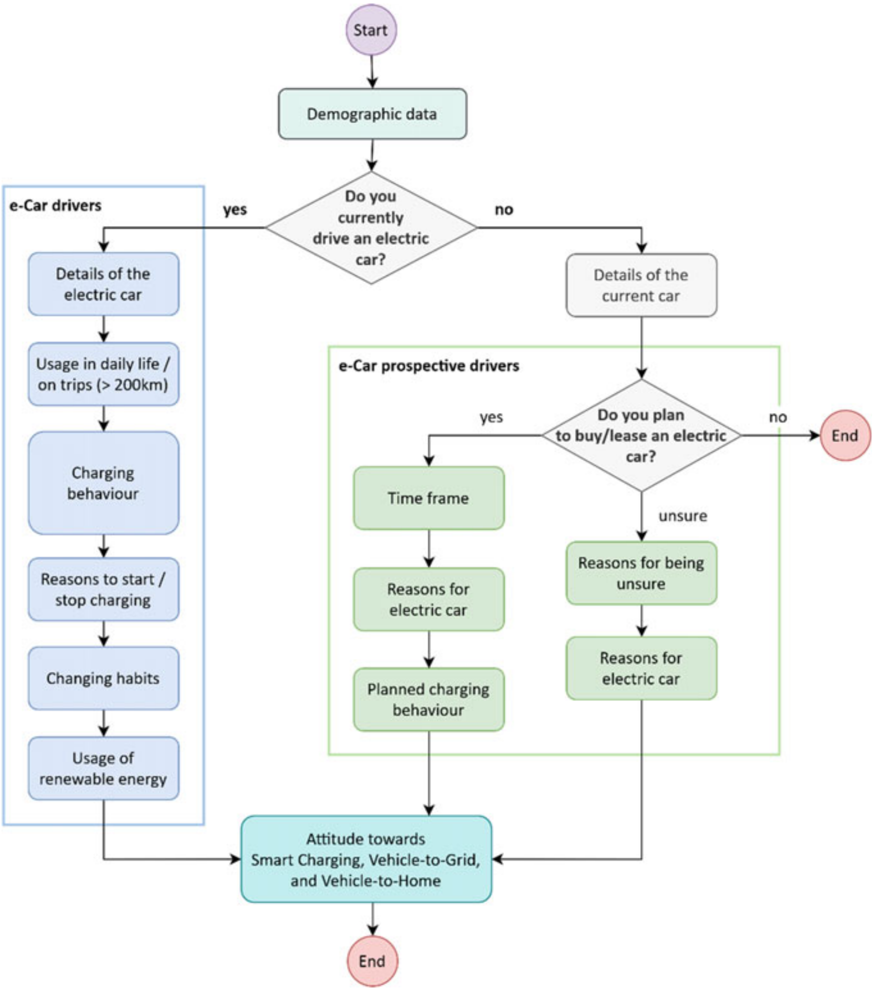

Fig. 2 Questionnaire for the investigation of the user behavior

~4,100 MWh/year. As the production could cover only ~10% of the needed electricity, Neuman wants to increase their renewable energy production by employing additional PV systems (up to 4 MWp) and two wind turbines (overall 10 MWp).

In XL-Connect the target is to analyse how the expansion of renewable energy power plants in combination with different storage possibilities impacts the overall energy consumption and the resulting financial benefits of Neuman Aluminium. Therefore, three future scenarios will be investigated (Table 1).

To analyse these scenarios, a three-step approach is applied. In the first step, the energy production and consumption data of Neuman Aluminium will be analysed in detail in order to determine the periods and amount of surplus of energy

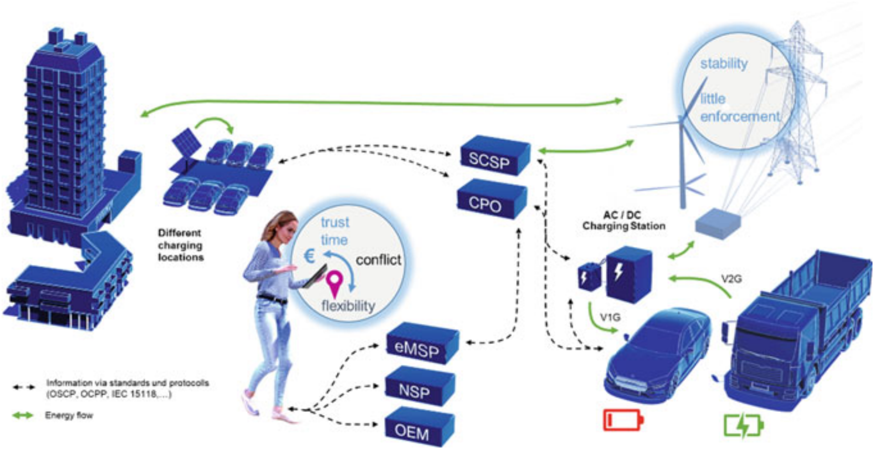

Fig. 3 Overview of different actors in the charging chain

Table 1 Overview scenario setups

	Status Quo (MWp)	Scenario 1 (MWp)	Scenario 2 (MWp)	Scenario 3 (MWp)
Hydroelectric power plant	0.95	0.95	0.95	0.95
Photovoltaic power system	1.1	1.3	4.0	4.0
Wind power station	–	–	–	10

production for the different scenarios. With these findings the impact of different sizes of battery storages can be investigated in a second step in order to achieve a self-consumption optimization or peak shaving. These results will also contain the possible economic benefit for Neuman Aluminium. In the third and last step, a vehicle-to-building solution for a parking area with 300 vehicles is investigated as an alternative storage solution to the battery storage by means of a simulation model. Therefore, the parking situation at Neuman Aluminium will be simulated considering the behavior of the EV owners in order to determine the available energy storage capacity during the day considering the different work shifts. When analysing this alternative solution, it is also important to find out under which conditions the employees would agree to (temporarily) discharge their vehicles. A schematic overview of the Neuman Aluminium use case can be seen in Fig. 4.

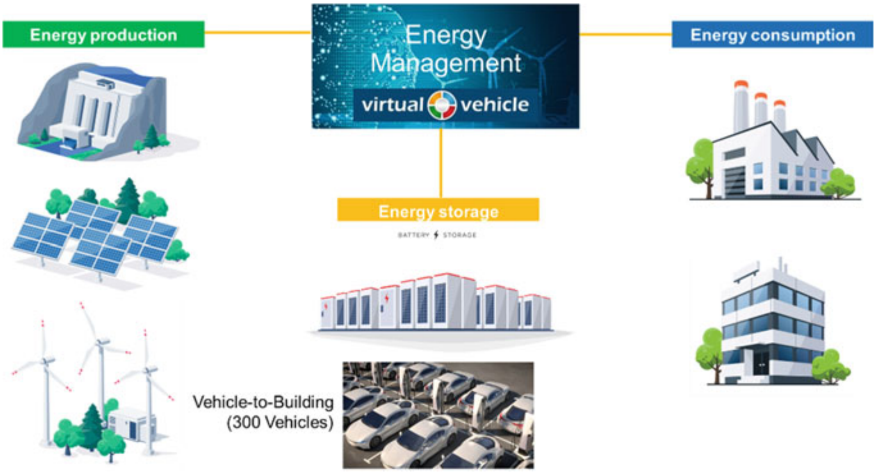

Fig. 4 Schematic overview of the "Neuman Aluminium" use case

4 Conclusion and Outlook

The EU project "XL-Connect" is investigating advanced charging technologies as smart charging, vehicle-to-building or vehicle-to-home and vehicle-to-grid. Therefore, demonstration actions are carried out to collect the necessary data to build up a digital twin of the "charging chain"—containing all elements and actors from the vehicles to the grid. One important element related to charging technologies is the investigation of the user behaviour. So, in order to calculate the possible benefits of technologies as vehicle-to-building or vehicle-to-grid, knowing when the vehicles are connected to the charging station as well as the willingness of the users to use these technologies (i.e. allowing to discharge their vehicles) is crucial. In order to investigate the charging behaviour of the EV users as well as their attitude towards advanced charging technologies a questionnaire has been set up. The results will be assessed also related to the differences between European countries. Complementary to real-word demonstration action virtual demonstration actions are performed to analyse the possible benefits of advanced charging technologies. A virtual demonstration action assesses the benefits of a battery storage or a parking area with 300 vehicles and vehicle-to-building as alternative solution are assessed. Therefore, the production and consumption data are analysed to determine the periods and amount of surplus of energy production. With these findings the impact of different sizes of battery storages can be investigated in order to achieve a self-consumption optimization or peak shaving for three future scenarios. Finally, a vehicle-to-building solution for a parking area with 300 vehicles is investigated by means of a simulation model as an alternative storage solution to the battery storage.

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