V2X USE-CASE COMBINATIONS: A COMPREHENSIVE BREAKDOWN

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Abstract

Smart charging use cases for bidirectional electric vehicles in vehicle-to-home or vehicle-to-grid can significantly accelerate sector coupling between the transport and energy sectors. Building on the tried and tested use case methodology and existing use case descriptions, we include additional tools from the unified modelling language to provide a deeper understanding of the underlying processes and interactions. With this paper, we try to structure a large variety of complex use case combinations into a few use case combinations (releases) that, in their entirety, cover the field of possible V2X applications. Applying these tools to the use cases of BDL Next, we discuss how different use cases complement each other and map their interaction, indicating synergies, constraints, conflicts, and transition conditions. To give end customers insight into the processes and benefits of the use cases, we also prepare the customer journey during the usage phase.

1. Introduction and Project Overview

1.1. Background and motivation

In 2024, the electric vehicles (EVs) in Germany experienced a significant drop in sales, presumably due to the cuts in government subsidies. In the first six months, EVs saw a decline of 16.4% compared to the same period last year [1]. At the same time, however, with a current share of over 20% of total greenhouse gas (GHG) emissions, the electrification of the transport sector remains an indispensable lever if Germany wants to meet the goals of the Paris Climate Agreement [2]. However, this positive effect of switching from internal combustion engine vehicles (ICEVs) to EVs can only be achieved if the electricity consumed is generated from renewable energy [3]. To ensure the security of supply, even at the required high levels of wind and photovoltaic (PV) integration, the energy system must be flexible to shift demand according to the variable generation or the current load on the power grid. These are also why smart charging strategies are being developed for EVs: to shift the charging process to periods of low demand or low prices, interrupt an ongoing charging process, or reduce the charging power.

With the introduction of bidirectional EVs, these intelligent smart charging strategies are gaining importance, as this technology can be used to control not only the charging but also the discharging process, thereby providing far greater flexibility potential for different use cases. Depending on whether the use case takes place mainly behind the meter or in front of the meter, in the bidirectional case, we speak of vehicle-to-home (V2H) and vehicle-to-business (V2B) or vehicle-to-grid (V2G). We refer to the entirety of these use cases as vehicle-to-everything (V2X). While explicit V2H and V2G capabilities are currently only technically possible in certain cases or pilot projects, at the end of 2024, it can be assumed that some vehicle models will be available on the market that are at least “bidi-ready” [4]. The availability of further models will increase considerably over the next five years.

1.2. State of research

With the increasing adoption of smart charging and bidirectional electric vehicles, the associated use cases have received significant attention in recent research projects. At the European level, for example, the Sciurus project should be mentioned in this context, which distinguishes between the use cases of PV self-consumption optimisation, optimisation against a time-of-use (ToU) tariff, and explicit flexibility marketing using aggregators [5]. The Danish Parker and ACES projects break V2G applications in their service catalogues (list of use cases) further down into different domains, like services for the region (Transmission System Operator – TSO) or the neighbourhood (Distribution System Operator – DSO) [6]. Within the project BDL, the researchers first differentiated the use cases based on the general flexibility application between market-oriented, system-oriented- and grid-oriented use cases. In addition, a further distinction was made regarding relevance for different customer groups, e.g., private vs. commercial [7].

To explicitly develop and describe use cases for EVs in collaboration with project partners, for example, unIT-e² and Trade-EVs II applied a structured use case methodology [8]. This methodology is based on norms, standards, and experience from other projects. Utilising this methodology,

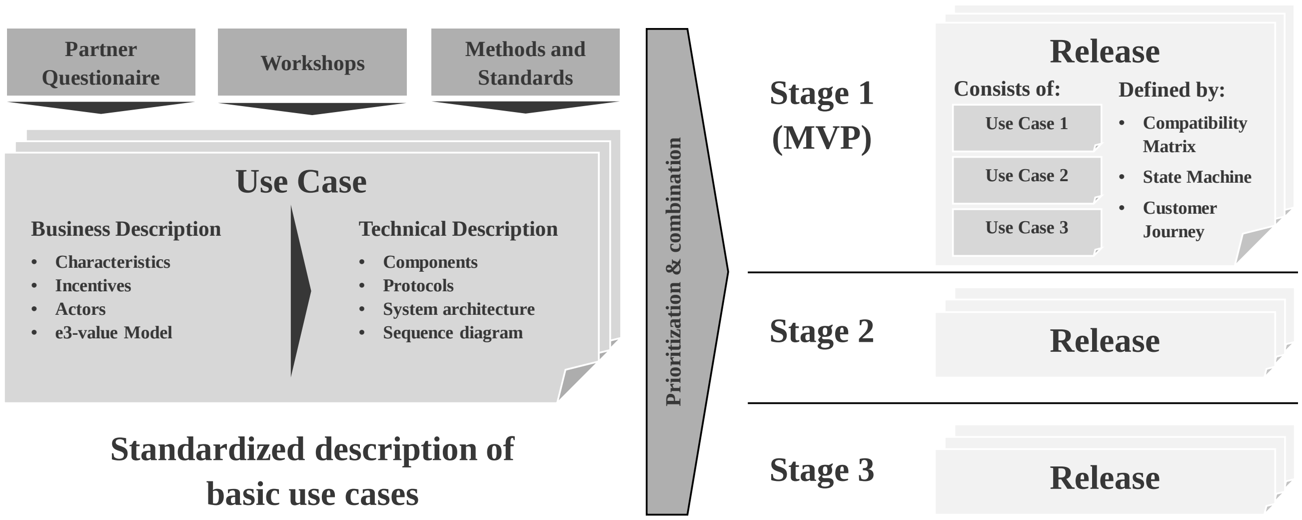

Fig. 1: Graphical outline of the BDL Next use case process

these research projects achieved a streamlined and standardised documentation of the individual use cases. The methodology supports a common understanding of the associated technical and regulatory challenges and constitutes a foundation for the following development phase [9].

1.3. The project BDL Next and the contribution of this paper

As the direct successor to the BDL project, BDL Next strives to develop technical solutions further to integrate the systems more closely with established processes in the energy industry for marketing energy volumes on the electricity exchange or system services. At the same time, work is also being carried out on the grid-oriented operation of bidirectional vehicles so that they can become an integral part of our robust and intelligent electricity grid in the future. A multi-stage field trial will use the experience gained from real-life operations to reveal weaknesses in the design and technical development, further increase the economic and ecological added value of bidirectional charging, and further simplify technology integration from the customer’s perspective. By the end of the project, the partners (original equipment manufacturers, energy service providers, connectivity experts, DSO, TSO, and research institutes) want to empower the mass operation of bidirectional electric vehicles and provide attractive, smart charging use cases that work together seamlessly.

As we have shown, the definition and description of use cases in electromobility is a tried and tested tool in the early stages of research projects. However, our experience from previous projects revealed that the existing tools reach their limitations when presenting several use cases in a multi-use network and preparing the added value for non-experts. Thus, this paper aims to address these deficits and expand the methodology in a targeted manner to meet the specific requirements of the BDL Next project. We thereby want to answer the following research questions:

- Which other tools help the partners to have efficient discussions about the system to prepare for the technical implementation?
- How can complex use cases be presented for potential end customers so that they comprehend the process and the associated added value?
- How can multi-use scenarios’ dependencies and transition conditions be specified unambiguously to avoid conflicts between the invoked systems?

Therefore, the remainder of this paper is structured as follows: In the *Methodology* section, we describe the tools used, their background and how they function as part of the BDL Next Use Case process. In the *Results* section, we illustrate the application of these tools using what we consider a promising use case combination as an example.

2. Methodology

As described in Section 1, BDL Next is not reinventing the use case methodology but instead expanding the existing toolset to cover multi-use applications and describe the transitions between use cases or their simultaneous operation. The entire process is shown in Fig. 1. While the left side of the figure mainly draws on familiar tools and methods from previous projects, the right side shows the specific further developments from BDL Next.

The use case methodology was first applied at FfE in the project C/sells as a three-stage process of 1. business use case description with a focus on a company’s internal processes and the business or operational benefit, 2. process- / system description focusing on the overall system and associated system components and 3. a detailed procedure specification including sequence diagrams. [10] Based on further applications of the methodology in the projects InDEED, Trade-EVs II, and BDL, potential simplifications in the use case documentation and visualisation were identified and the need for a more precise separation between business and technical discussions. Therefore, in the project unIT-e², the methodology was adapted, differentiating between two use case levels. The first level of business use cases (BUC) consisted of the use-case identification, a basic concept, and the desired implementation from conceptual to real operation. Selected business use cases were then specified in the more detailed second level of technical use cases (TUC). For the second level, the second and a reduced version of the third step of the C/sells use case methodology were also performed. [9], [10]

In BDL Next, as the focus lies less on identifying new but more on an in-depth elaboration of existing use cases and their combination, there is no broad collection of business use cases like in unIT-e². Yet each use case discussed has a business and a technical use case description to cover both aspects and streamline partner discussions. Additionally, in the technical use case description, we focused more on Unified Modelling Language (UML) toolbox than in unIT-e². The UML toolbox proved to be especially suitable for the representation of use case combinations with the utilisation of state machine diagrams.

BDL Next introduces an approach to combine use cases in releases. A release describes a product with several use cases showing synergies in a multi-use framework. To meet the tight schedule for the field test and still be able to test as many use cases as possible, we decided to launch these releases in various stages and thereby gradually increase complexity. Stage 1 comprises all releases in the V2H context and with flexibility marketing on the intraday market. Stage 2 will then also include grid-supporting services for TSOs and DSOs. Stage 3 will cover multi-use applications that require the interaction of different customer interfaces and aggregating platforms.

2.1. Business description of basic use cases

The development of the BUCs was based on questionnaires completed by each project partner and discussed in several workshops to further enhance the BUC descriptions. To structure the results and present them in a compact yet convenient-to-read style, we used the E3-value model again, which is used in the unIT-e² project [9]. The E³-value model represents a simplified graphic representation of value streams between actors of a use case, thus enabling a straightforward representation of business models. It, therefore, abstracts from process details, which are shown, for example, in the UML use case diagrams. As the primary goal of the business use case representation in BDL Next was the efficient and understandable representation of single and multi-use cases for project partners and end customers, the more detailed UML use case diagrams were not used in the project, but the focus lied on the more simplified representation of the E³-value model.

2.2. Technical description of basic use cases

For the development of the project team, we focussed on the UML toolchain, as it is a commonly used framework in software development and system design, concluding with the many publications that can be found about UML. [11], [12] Due to its popularity, many team members could work with it without or without much training. However, not all UML modelling tools are used. The tools used in this work are sequence diagrams and state machine diagrams, so-called state machines.

Sequence diagrams and state machines within the UML are used to describe and visualise the behaviour of a technical system. Sequence diagrams illustrate the time-ordered flow of actions and events within a use case, capturing the interactions between various system components over time. By visualising all the system's components and their interactions, sequence diagrams clearly depict which component is actively involved at each phase of the use case, thereby offering insights into the system's operational dynamics. This helps in understanding the sequence of operations but also aids in identifying potential bottlenecks, inefficiencies, or areas where system performance can be optimised. Furthermore, sequence diagrams are valuable in the design and validation process, enabling stakeholders to ensure that all components function cohesively and that the system's behaviour aligns with the intended design requirements.

2.3. Description of multi-use applications (releases)

In contrast to the preceding project, in BDL Next, use cases are tested one after the other and in combination. To evaluate which use case combinations work well together. What the transition conditions between the use cases should look like, we have added new tools to the use case methodology.

2.3.1. Compatibility Matrix: To illustrate the extent to which synergies or conflicts can arise in the simultaneous operation of use cases, following the approach of [13], we compare the use cases involved using a compatibility matrix. Within the matrix, we describe the respective relationship uniformly and non-directionally. Thus, only the upper diagonal of the matrix in Table 2 is utilised. We thereby use the following attributes:

- **Synergy:** The charging strategy within one use case also contributes to the objectives of the other use case or vice versa.
- **Conflict:** Elements from one use case hinder the objectives of the other or vice versa. The combination is nevertheless examined because it is required by regulation, for example.
- **Limitation:** The objectives of the use cases are not in direct conflict or synergy, but the limited charging capacity means that only a certain amount of the power can be reserved for individual activities.

2.3.2. State machine: State machine diagrams show all states of the system's use case (e.g., (Dis-)charging, Initialising, etc.) On a more abstract level, state machines could visualise all use cases and their relations to each other and the transitional boundaries to switch from one use case to another.

A state machine consists of several types of states. Simple states have no further nested states or transitions compared to composite states. The latter consists of more states and transitions that are activated as soon as the composite state is entered. The contained states might be running sequentially or simultaneously. A composite state is indicated by a dashed line that partitions the state into regions and terminates when all of its sub-machines reach a final state or if a predefined exit point is activated. Composite states might be visualised in a short way that does not show contained sub-machines. That is symbolised in the lower right corner, with a scheme that looks like two simple states with one connecting edge between them. [14]

In BDL Next, we use state machines to specify the complex interaction of different use cases within a release. In the state machines, use cases are represented mainly by composite states and states using sub-machines.

2.4. Customer Journey:

In line with this paper's objective, this research focuses on the innovative developments of several components and the overall system, their technical details processes, and application in use cases. However, integrating the user's perspective and conducting a thorough analysis of the customer journey [15] is crucial for successfully developing, rolling out, and adopting new technologies. The customer journey provides a comprehensive view of customers' interactions and experiences with a product or service and contains the pre-purchase, purchase and post-purchase phases [15].

By identifying key touchpoints and impactful moments - often referred to as "moments of truth" - companies can pinpoint pain points and opportunities for improvement. This customer-centric approach not only enhances service quality but also ensures that new technological developments are closely aligned with users' needs and expectations, increasing the likelihood of adoption and sustained satisfaction [15, 16], ultimately leading to successful market introduction and long-term user engagement [17].

In complex systems comprising multiple interconnected components, users interact with an increasing number of touchpoints across diverse channels [15, 18], resulting in non-linear and multifaceted customer journeys. In contrast to the linear paths typically observed in single-product purchases, these journeys are distinguished by many interactions that collectively influence the customer experience. This complexity is particularly relevant in scenarios such as bidirectional charging use cases. To enhance the customer experience and improve business outcomes, it is essential to analyse the customer journey with its many touchpoints in the context of these complex systems.

These touchpoints represent instances of interaction between the user and the system, and their analysis is essential for comprehending user acceptance and satisfaction. By evaluating these interactions within the context of the overall system, companies can derive practical insights to optimise the customer experience across all system components [15, 19]. This paper focuses on use cases relevant to bidirectional charging, with a specific focus on the post-purchase phase of the customer journey. In this phase, usage, engagement, consumption, and service requests are prevalent [15].

UML sequence diagrams were utilised as a foundation tool to develop a customer-focused understanding of the use cases generated in the project context. While these diagrams primarily shed light on the technical aspects of the use cases, user-relevant touchpoints were extracted systematically. Based on these touchpoints, a description of the user interactions involved in the use cases of increased PV self-consumption and Intraday Arbitrage (EV-only) was formulated.

3. Results

3.1. Resulting use cases in BDL Next

Multiple Workshops among the partners yielded nine basic use cases listed in Table 1. We categorised them based on three criteria: Control, Feed-In, and Aggregation. In the case of the control signal, we distinguish between local or on-site control and remote origin, e.g., via active external market participant (aEMP). In the 'Feed-in' column, we show whether the use case implies feeding back into the public grid. The 'Aggregation' column provides information on whether aggregation across several households is necessary for the use case – in contrast to the aggregation of several flexibilities behind a grid connection point via a Home Energy Management System (HEMS).

Table 1: List of use cases in BDL Next

#	Use Case	Control	Feed-In	Aggregation
1	Increased PV self-consumption	Local	No	No
2	Dynamic electricity tariff	Local	No	No
3	Intraday trading	Remote	Yes	Yes
4	Redispatch	Remote	Yes	Yes
5	Frequency Containment Reserve	Local	Yes	Yes
6	Grid-oriented curtailment	Remote	Yes	No
7	Dynamic grid tariff	Local	No	No
8	Reactive power provision	Remote	Yes	Yes
9	Coordinated DSO-control	Remote	Yes	Yes

3.2. Resulting system architecture

Based on the use cases that comprise the releases in stage 1 (MVP) and stage 2, Fig. 2 depicts the underlying system architecture of BDL Next. The system architecture describes the structure of the system and the relationships between the involved components and actors. Where communication resorts to established standards, they are indicated alongside the connecting lines. Within stage 1, the project takes two paths in the aggregation of flexibility to ensure a suitable solution regardless of existing equipment or customer preferences.

- **alt a.)** utilises an aggregation platform that connects via HEMS Backend and HEMS to the electric vehicle supply equipment (EVSE) and other flexibilities from different households.

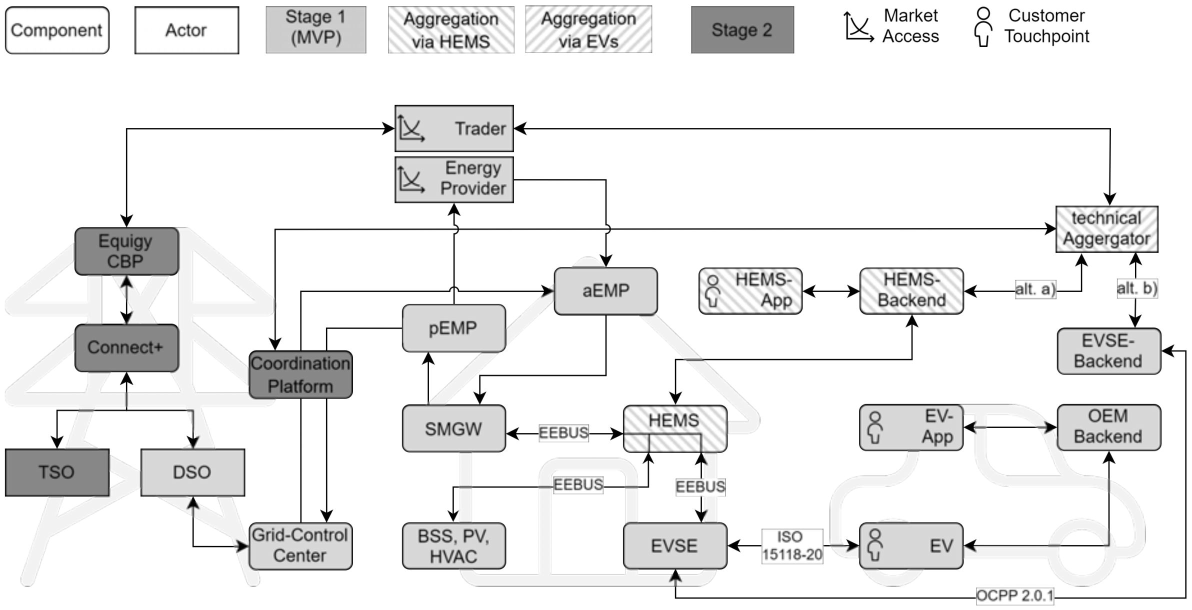

Fig. 2: BDL Next system architecture for stage 1 and stage 2 releases

- **alt b.)** utilises the car manufacturer's aggregation platform to connect to a pool of EVs from different households.

When no HEMS is available in the household, the EVSE and other flexibilities such as battery storage systems (BSS), PV, or heating ventilation and air conditionings (HVAC) connect directly to the Smart Meter Gateway (SMGW).

3.3. Description of V2H & V2G optimization via HEMS

As one of the first releases, we evaluate the combination of V2H &V2G optimisation via HEMS as part of our MVP. The release comprises **UC 6:** Grid-oriented curtailment (§ 14a EnWG), **UC 1:** Increased PV self-consumption, **UC 3:** Intraday trading.

3.3.1. Application of Compatibility Matrix: To better understand the interaction of these use cases, we apply the compatibility matrix from Section 2.3.1 in Table 2. We find a Synergy between UC 1 and UC 6, as the latest specifications for § 14a EnWG allow locally generated electricity to be deducted from the grid-effective consumption power of a controllable load [20]. By optimising PV self-consumption, the power peak at the grid connection point is reduced, and the grid operator must intervene less frequently. However, intraday trading relies on exchanging electrical energy with the public grid at high power levels [21]. In addition, the global price signal from the intraday market can lead to increased simultaneity in charging processes and thus increase the overall load on the distribution grids [22]. Therefore, UC 6 and UC 3 can conflict with each other.

With UC 1 and UC 3, it is less clear. It could be advantageous to sell the charged PV electricity at high prices later in the intraday market to avoid efficiency losses when feeding back to the household at low power levels. However, the charging capacity of most private EVSEs is limited to 11 kW, so only a certain proportion of the power can be used for the respective purpose (intraday trading vs PV optimisation) when operating the use cases simultaneously.

Table 2: Compatibility matrix of V2H & V2G optimisation via HEMS

Use Case	Grid-oriented curtailment	Increased PV self-consumption	Intraday trading
Grid-oriented curtailment		Synergy	Conflict
Increased PV self-consumption			Limitation
Intraday trading			

3.3.2. Application of State Machine Diagram: In Fig. 3, we show a UML state diagram for V2X-multi-use-case-operation with simultaneous optimisation of PV self-consumption and intraday trading with the possibility of grid-oriented curtailment by the DSO. The state machine shows a draft of how the operation of at least two use cases could be designed.

The operation starts with the EV connection to the EVSE and vice versa, ending with the EV disconnecting from the EVSE. After initialisation, where several sub-processes are concluded, the next step is to check the EV's state of charge (SOC), which is processed in sub-machines of the 'SOC Management'. Thus, it ensures that the EV is always charged to a default minimum SOC that offers the user basic mobility. The 'SOC Management' also watches when the DSO orders grid-oriented curtailment, which is found in the diagram as 'DSO signal'. After fulfilling the minimum SOC condition, the actual V2H and V2G operation starts. In the composite state 'Multi-Use Case', two sub-machines, 'PV-Optimisation' and 'Intraday Trading', are activated upon entering the composite state. Those sub-machines hold further control mechanisms to shift the EVSE's power to either one of the active states or distribute the power dynamically between them.

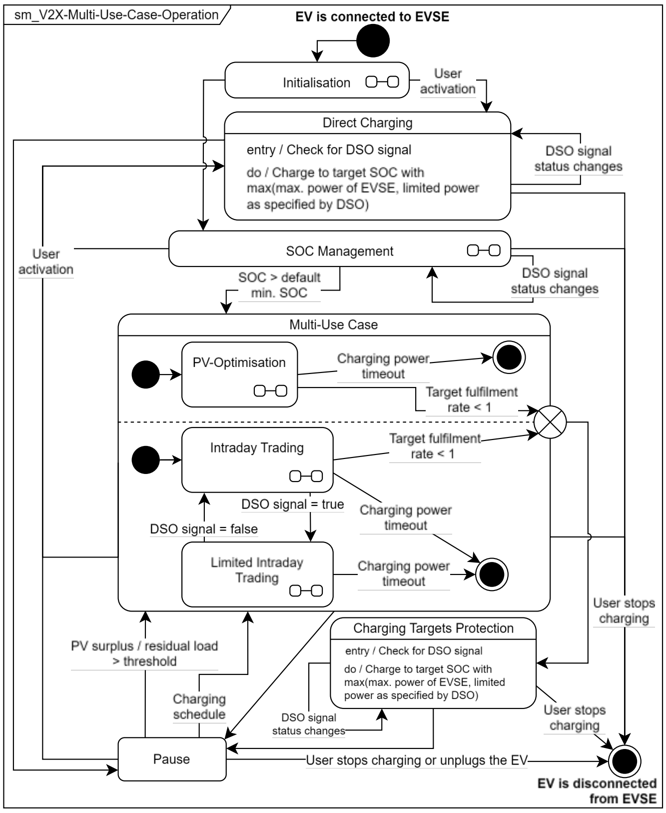

Fig. 3: State machine for V2X-multi-use-case-operation

This paper won't show the sub-machines, as their control mechanisms are not yet completely developed. However, the charging strategy will follow some basic guidelines: If sufficient PV power is available to compensate for internal system losses, the PV surplus is used to charge the vehicle. If the intraday price also drops below a certain threshold, the EVSE's power reserve above the PV power can charge cheap electricity from the grid. Suppose the electricity price falls further below the feed-in tariff. In that case, it is advantageous to charge the vehicle – and supply the household – exclusively with grid electricity while 100% of the PV power is fed into the grid. Similar price- and power thresholds also apply to the discharging of the EV. The 'Multi-Use Case' state also has a sub-machine for 'Limited Intraday Trading', activated by a DSO signal. This would change the system behaviour described above so that the trading potential of the aggregator is limited. In contrast, the full potential of the remaining EVSE power is still available to optimise the PV plant. In all cases of this example, the composite state 'Multi-Use Case' is paused after a specified timeout period, as described by the state 'Pause'. The 'Pause' state is activated after reaching the target SOC through the states described below.

These other system functions are 'Direct Charging' and 'Charging Targets Protection'. Users can activate the first one out of each state through one of the system touchpoints, and the system is ordered to use the maximum available power (limited power in case of grid-oriented curtailment) to charge the EV to the target SOC. The second one is automatically triggered by a control function that checks the current SOC and the remaining time until the departure and directly charges the EV to the target SOC if the departure time gets close. This function is found in the composite state 'Multi-Use Case' and leads to an exit point into the 'Charging Targets Protection' state. After reaching the target SOC, both states transition into the 'Pause' state. The 'Pause' state is left by any positive or negative power demand, as they occur through intraday trading schedules, PV surplus, residual load of the household or direct charging ordered by the user, as well as disconnecting the EV from the EVSE, which will end the current charging session.

3.3.3. Application of Sequence Diagram: The sequence diagram presented in Fig. 4 illustrates the interactions among various components involved in a V2X multi-use case operation. This diagram provides excerpts of how the components interact to achieve an optimised and balanced energy management that integrates electric vehicles into the grid.

The process begins with the initialisation and setup of the multi-use case scenario. During this phase, several critical operations are performed, including initialisation, parameterisation, and the assessment of system flexibilities. These steps are sequentially executed and start with the plug-in of the EV at the EVSE. This foundational setup ensures that the system is configured to respond appropriately to different demands and conditions. Following the setup phase, the system progresses to establish a charging schedule. The charging schedule is then communicated to the HEMS, which delegates the execution to the EVSE. After the charging schedule is set, the system engages in intraday trading. This trading is managed by the aggregators and backend systems, ensuring that the energy resources are utilised optimally throughout the day. Depending on the transition conditions described in 3.3.2, the system can also focus on PV optimisation, aiming to maximise the self-consumption of PV energy generated by the household's solar panels. As the system operates, critical grid conditions may arise, influencing the operational state of the system in the household, as detailed in Fig. 4. To manage this, measurements taken from the household's SMGW are sent to the grid control centre via the passive external market participant (pEMP) to assess the grid's current state. Based on these assessments, the DSO can determine whether load restrictions are needed to maintain grid stability. This information is transmitted from the grid control centre through the aEMP to the SMGW. The SMGW relays the load restrictions to the HEMS, which are implemented across household devices. The charging schedule can be modified to accommodate the new conditions if load restrictions are imposed. When the restrictions are lifted, the system adjusts to ensure that the EV owner's mobility needs are met under the updated circumstances.

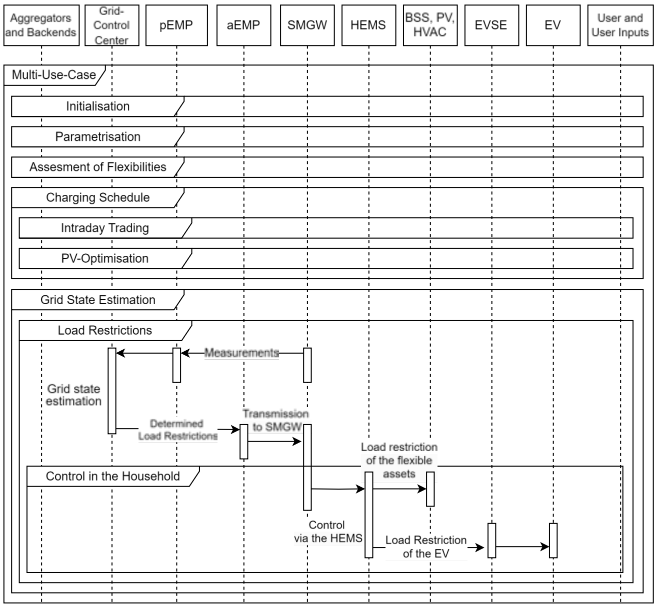

Fig. 4: Sequence diagram for V2X-multi-use-case-operation

3.5. *Application of Customer Journey Touchpoints during post-purchase-phase:*

To develop a more user-oriented description of the relevant use cases for bidirectional charging, existing diagrams were utilised to identify user-relevant components, particularly touchpoints within the overall system. This analysis of exemplary user touchpoints in the usage phase highlights the system's complexity, where users interact with numerous components across various touchpoints essential for its operation. A key finding is that users must navigate a complex customer journey, engaging with multiple touchpoints to effectively use the entire system.

Further, our analysis indicates that specific touchpoints are likely to be accessed in a defined sequence within the exemplary modelled customer journeys. For instance, the interaction between the EV and EVSE during the charging (dis-)connection process can be mentioned. Furthermore, some touchpoints can be classified as "overall touchpoints", which users interact with continuously for tasks such as monitoring processes or updating service settings. This includes using the EV app to adjust the EV's scheduled departure time.

Table 3: Touchpoint Analysis for Increased PV self-consumption

stage	Touch-Point	Description	Impact /Effect
Initialisation (V2H)	EV / EVSE	User connects EV to EVSE	EV connects to the EVSE
	EV / EV-App / HEMS App [alternative]	component reports 'Connected' status back to the user	User is informed that the EV is connected to the EVSE.
Parameterisation	HEMS App	User defines preferred destination SOC and departure time	Sending user preferences (SOC, departure time) to HEMS (and to HEMS Backend)
Optimised Charging	EV/ EV App / HEMS App [alternative]	User can continuously check current status (charging, SOC) during this phase	User is provided with information regarding the optimised charging and status of charging
Disconnect	EV / EVSE	User unplugs EV from EVSE	EV is disconnected from EVSE, and the charging process was terminated
Billing	Energy Supplier	Energy supplier sends monthly bill to user	User receives bill from the energy supplier

The extraction and analysis of user-relevant touchpoints in Table 3 constitute a crucial foundation for a deeper exploration of the user experience within the overall system. Future research is recommended to prioritise these touchpoints, particularly those that emerge as critical "moments of truth", to minimise or eliminate customer pain points. Focusing on key design parameters, such as transparent communication and usability at each touchpoint, can address user uncertainties, enhance system user-friendliness, and improve the overall user experience. Based on our results, it is further recommended that practitioners continually analyse and optimise the customer journey and its specific touchpoints within this complex system and its various use cases to ensure customer satisfaction and long-term user engagement.

4. Conclusion & Outlook

This paper provides an overview of use cases for bidirectional EVs that we evaluated in the BDL Next project in the context of V2X applications, focusing on V2H and V2G scenarios in the development process. We use established tools to provide a detailed framework for understanding the interactions and dependencies in multi-use case environments. In addition, to extend the existing use case methodology, we applied tools such as the compatibility matrix and state diagrams to map the synergies and conflicts between different use cases to enable smoother integration and transition conditions. This way, the paper provides stakeholders and end users with a transparent insight into the functioning and benefits of V2X technologies.

Besides the presented toolset, other methods were discussed to support the visualisation and modelling of multi-use applications. Although Petri nets offer a promising approach for modelling the complexity of V2X scenarios, providing a clear visualisation of concurrent events and state transitions.

Their use can facilitate early error detection and leverage established tools for system validation, which is why we consider them promising for future analyses. However, we found that Petri nets can also introduce high complexity and require specialised knowledge. For our purposes, we have therefore decided to use tools that have a lower entrance barrier. We also prioritised pragmatism over methodological completeness and often relied on the elements of a method that promise the most significant benefits for collaborative work.

The successful integration of V2X technologies hinges on managing complex interactions between different use cases and systems. This paper demonstrates that extending the established use case methodology with advanced modelling tools makes it possible to create a coherent and adaptable framework for implementing V2X solutions. The BDL Next project exemplifies how such an approach can guide the development of practical, scalable solutions that meet the technical requirements and deliver economic and systemic value. As the market for bidirectional EVs continues to grow, the methodologies and insights presented here will be crucial in addressing the challenges of multi-use scenarios, ensuring the seamless operation of V2X applications, and enhancing the overall resilience and flexibility of the power grid. Future work will involve refining these models and methodologies to accommodate emerging technologies and evolving market conditions, ultimately paving the way for a more integrated and sustainable energy ecosystem.

5. Acknowledgements

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