EDITOR

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INSTITUT FÜR INNOVATION UND TECHNIK

MANAGEMENT OF CHARGING PROCESSES FOR ELECTRIC VEHICLES

Representation of the communication channels using a map for smart charging, extended Edition I

WHITEPAPER

IMPRINT

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DISCLAIMER EXTENDED EDITION I

Various projects and project partners were actively involved in the implementation of Edition I of the white paper. The contents of the extended Edition I were updated and supplemented by the accompanying research based on publications and project results. The accompanying research group Elektro-Mobil is responsible for the contents of this white paper and the editorial work. All persons and projects involved in the white paper Edition I and those who endorse the contents of the extended Edition I are listed below

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ABSTRACT

Intelligent control of electric vehicle charging – and other flexible installations – is necessary for efficient and economic grid operation and is becoming increasingly important due to the plans and goals for a sustainable transformation of the energy and transport sectors in Europe and Germany.

THE AIM OF the white paper is to structure the activities in the field of charging process management in electromobility for the reader.

THE CONTENT OF the white paper is the result of intensive consensus building within the Elektro-Mobil funding programme of the German Federal Ministry for Economic Affairs and Climate Action. Together with the accompanying research Elektro-Mobil, the research projects have developed a so-called "communication map for charging control", which depicts the relationships between all actors involved for the digital communication to control a charging process of an electric vehicle on a property with several installations. This representation provides an overview of the respective relationships, norms and standards – including application rules – depending on selected use cases. To simplify the classification of the use cases, the traffic light model for network status description was used as a basis.

The model allows a simple structuring of the selected use cases "emergency control" (red traffic light phase), "price-controlled procurement without restriction" (green traffic light phase) and "market-oriented provision of system services" (yellow traffic light phase).

The present communication channels have been classified as feasible solutions at the selected level of abstraction by the project consortia named in the imprint and funded by the German Federal Ministry for Economic Affairs and Climate Action. They are the basis for the ongoing real-world tests in the research projects and the input for further research activities.

AS A RESULT, possible communication paths and associated norms and standards are shown, which enable a consistency of the control of the charging processes. In addition, the connectivity to the existing technical, normative and regulatory framework is shown as well.

The present EXTENSION of Edition I (first edition 01/2022) contains an update of the currently discussed and partially stipulated framework conditions, an addition of proposals for prioritisation and orchestration of the control signals and control via a digital grid connection point.

The white paper thus provides a good insight into what is technically feasible today or will be feasible in the near future with intelligent control of charging processes.

TABLE OF CONTENTS

NOTE: CHAPTERS WHOSE HEADINGS ARE HIGHLIGHTED IN BLUE HAVE BEEN ADDED OR UPDATED TO A GREATER EXTENT IN THE EXTENDED EDITION I.

1 INTRODUCTION

The sustainable transformation of the (energy and) transport sector in Europe and Germany is one of the central building blocks for achieving the international, European and national climate targets. Global warming is to be limited to below 2 °C and, if possible, to below 1.5 °C compared to pre-industrial levels (main goal of the Paris Climate Agreement) (United Nations 2015). The goal formulated in the EU Green Deal is to reduce greenhouse gas emissions by at least 55 % by 2030 compared to 1990 levels. The reduction target in the German transport sector is to achieve a 40 to 42 % reduction in greenhouse gas emissions by 2030 compared to 1990 levels (European Commission 2019). In order to realise these ambitious goals, the new German government has set out to make Germany the lead market for electromobility by 2030, with a stock of at least 15 million fully electric passenger cars, and that these should be safely integrated into the electrical grid (Die Bundesregierung 2021). Furthermore, the coalition agreement states that bidirectional charging of electric vehicles should be made possible by 2025.

In addition, according to the European Commission's proposal, only CO_2-neutral vehicles will be allowed in Europe from 2035 onwards, which will have a correspondingly earlier impact on Germany. Likewise, the new federal government aims to significantly accelerate the expansion of renewable energies and thereby increase their share of electricity consumption to 80 % by 2030. The associated further increase in decentralised feed-in sources through volatile generation plants as well as the increasing electricity demand of flexible systems with higher power consumption than previously known at regular household connections pose major challenges for the electrical grid. These flexible systems include heat pumps as well as the high power demand caused by the charging of electric vehicles compared to usual household needs. The resulting challenge of securing grid stability is particularly acute at distribution grid level. It is precisely here that unidirectional control of charging processes has a direct positive effect. Contributions to grid stability through the provision of short-term storage capacities from the bidirectional control of charging processes are currently mainly considered at transmission grid level (aggregated provision of power).

There is a wide range of charging solutions for electric vehicles. In 2015, the National Platform for Electric Mobility (NPE)[1] structured use cases for charging solutions (NPE 2015). Consistently uncontrolled charging of electric vehicles does not make sense from an economic and grid operation point of view. It would mean immense investments in the expansion of the electrical grid in order to be able to guarantee security of supply. Unidirectional control of charging processes alone could potentially reduce the investment costs in grid expansion by up to 50 % (Agora Verkehrswende 2019).

[1] Successor body is the National Platform for the Future of Mobility (NPM). Follow-up structures are currently being established for the NPM.

The aim is to intelligently control the charging processes across all phases of the grid status so that, on the one hand, customers benefit from reduced prices and, on the other hand, experience as few restrictions as possible on their charging behaviour despite the control. At the same time, preventive action should be taken at an early stage and curative action should be taken in the event of an imminent bottleneck to counteract any threat to grid stability. The premise for action is to avoid the need for curtailment or power reduction as a direct intervention by the grid operator in emergency situations as much as possible. For this purpose, concrete ideas have to be developed in which cases a coordination of the control signals has to take place and how these are then orchestrated.

For use cases involving grid security and stability, the German Federal Ministry for Economic Affairs and Climate Action (BMWK) and the Federal Office for Information Security (BSI) have envisaged the use of an intelligent measurement system (iMSys). These form a secure anchor of trust within the property and are protected by extensive mechanisms against manipulation and attacks from outside.

Against this background, the accompanying research for the funding programme Elektro-Mobil of the BMWK together with the funded R&D projects have compared the control solutions of the charging processes implemented in the projects – both for uni- and bidirectional use cases – with the current standardisation activities as well as the ongoing regulatory activities with the use of iMSys in a series of workshops.

As a result of this series of workshops and the joint development of a "communication map for charging control" (hereinafter referred to as the map), the white paper Edition I was published in January 2022, which focused on the presentation of the contents of the map. For the development of the map, the systematics of the grid traffic light, which was introduced for the first time by the German Association of Energy and Water Industries (BDEW) for all grid areas and which has since been revised by the Forum Network Technology/Network Operation in the VDE (FNN) especially for the low-voltage grid, was used to structure the potential use cases, to show the complexity, and to reduce it to the essentials. The model enables the process structuring presented here for the selected use cases; starting from intervention to avoid grid bottlenecks to market-oriented price and power control.

The contents of the extended Edition I presented here have been updated and supplemented by the accompanying research team on the basis of publications such as those by the FNN in 2022 (FNN 2022) and project results presented in the meantime. All people and projects involved in the white paper Edition I and those who endorsed the contents of the extended Edition I are listed in the imprint.

The aim of the white paper in its extension is to show the reader the complex system of standardisation for the control of charging processes in electromobility, to structure it, and thus to simplify it. As a result, communication channels and the associated norms and standards or rules of application are presented, which enable the control of charging processes to be consistent and on whose usefulness the project participants in this process have agreed. Furthermore, this extension contains proposals for prioritising and orchestrating the standardised control signals.

2 THE PHASES OF THE „GRID TRAFFIC LIGHT“ AND THE USE CASES

BDEW has created a concept for grid operation and grid operation planning that includes a traffic light model with the help of which the different use cases can be sorted and grouped (BDEW 2017).

The so-called traffic light model is divided into three phases (green, yellow and red) and requires the cooperation of grid users and grid operators with the aim of reducing the grid load at peak times. In addition to the solutions of time-variable grid charges and plan-value-based power limitation, the target picture is the trading of flexibilities, which can relieve the grid in the event of a high load (e. g. a high feed-in of renewable energies or load peaks at the end of the day).

In the green traffic light phase - the market phase - the current and foreseeable grid status

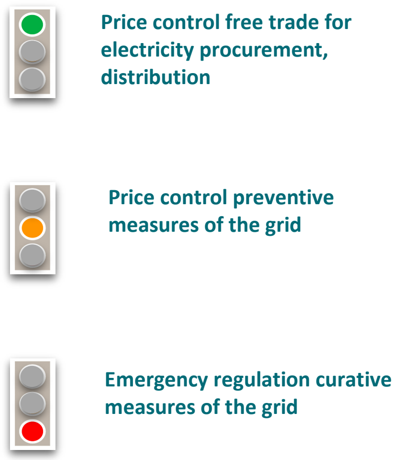

Figure 1: The traffic light phases

is not critical. There is no need for action on the part of the transmission system operator (TSO) and/or distribution system operator (DSO). The electricity can be traded freely.

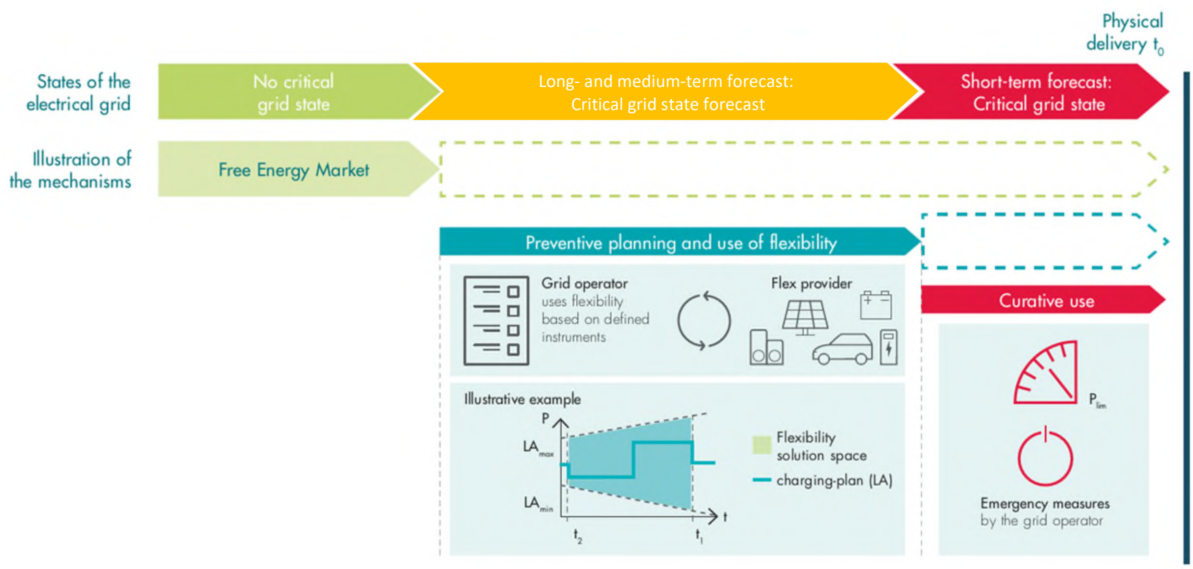

Figure 2: FNN traffic light phase concept (own illustration based on source FNN 2022)

In the yellow traffic light phase - the interaction phase - grid congestion would occur if no measures were taken. The grid operators therefore call up flexibilities according to the previously negotiated prices. In this case, the market participants increase their consumption, for example, so that more electricity is purchased or they shift the load.

During the red light phase - which is also referred to as the grid phase - there is an "immediate threat to grid stability in the distribution grid" (BDEW 2017). The DSO and/or TSO must therefore intervene in terms of market regulation and also act on the operating mode of consumers, generators and storage facilities so that grid stability can be restored. This can be done, for example, by limiting consumption or feed-in.

Based on the BDEW traffic light model, a large number of further designs of a grid traffic light have been developed, which also deal in particular with the allocation of measures to the traffic light phases. In its impulse "Eckpunkte zum zukünftigen Netzbetrieb mit Flexibilitäten in der Niederspannung (Cornerstones for future grid operation with flexibilities at low-voltage)" (FNN 2022), the FNN also uses the BDEW traffic light concept as a starting point and develops the FNN traffic light phase concept from it. However, the FNN traffic light phase concept (see Figure 2) differs by emphasising a "clear temporal demarcation between yellow (long-term and medium-term forecast) and red phase (short-term forecast and observation) (FNN, p. 3)". This white paper aims to use the division into traffic light phases to structure the different use cases with the associated norms and standards.

2.1 The six use cases

For better differentiation and structuring, the six use cases are assigned to the traffic light phases presented in chapter 2 below. The direction of the arrow to the right symbolises a current flow into the vehicle, the direction of the arrow to the left symbolises a current flow into the power grid. The use cases listed in Figure 3 are described below. The description of the use cases is based on the structure of the actors involved shown in Figure 4.

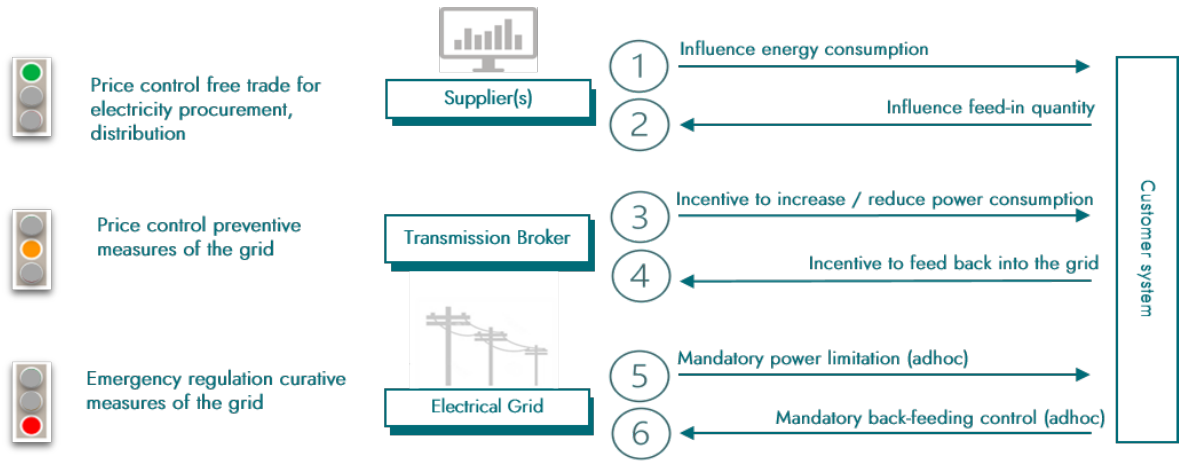

Figure 3: The six use cases (own illustration)

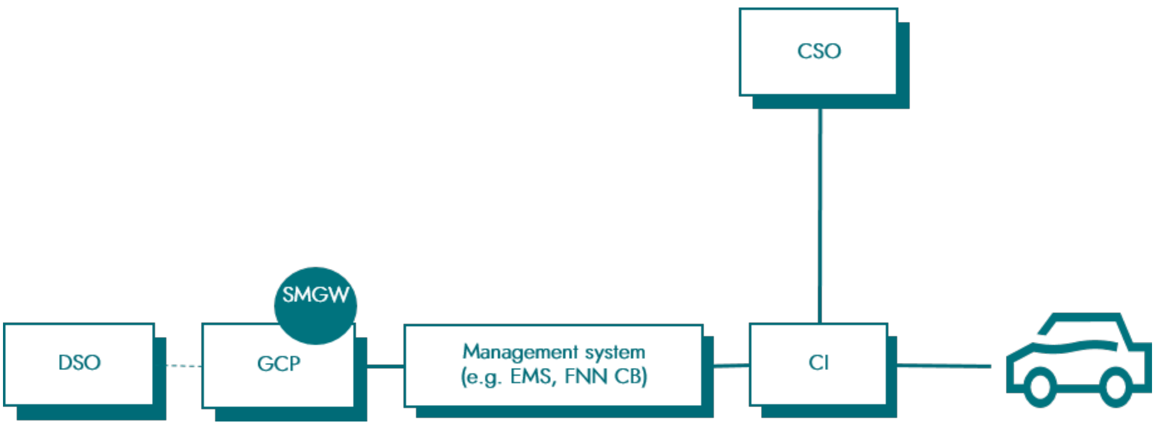

Figure 4: Actor structure - DSO: distribution grid operator, GCP: grid connection point, EMS: energy management system, FNN CB: FNN control box, CI: charging infrastructure, CSO: charge station operator (own representation)

Use case 1: Influencing energy consumption in free trade, charging – green traffic light phase:

In this case, the grid condition is not critical and there is no need for action on the grid side. Customers are free to decide which amount of energy they want to purchase and when, taking into account the technically available grid connection capacity, e. g. based on the exchange price.

The free trading of electricity, e. g. via EEX futures trading, the day-ahead or the intraday market, allows price advantages to be exploited and own costs to be reduced. The charging capacity (quantity, time) of the customer facilities can be variably controlled via agreed static tariffs and/or direct variable price in-formation from the energy sales.

Use case 1 is already technically feasible today.

Use case 2: Influencing feed-in quantity (feeding back) in free trade – green traffic light phase:

In this case, the grid condition is not critical and there is no need for action on the grid side. The customers can feed in energy quantities taking into account the technically available grid connection capacity and in accordance with the electricity supply contract.

This application can be used, for example, for energy balancing via vehicles capable of feeding energy back into the grid in neighbourhood solutions or via vehicle pools. In the area of photovoltaic systems, this application is already being used and technically implemented today (e. g. generation systems > 100 kW by means of direct marketing via exchange prices). This principle must now also be applied to pooled mobile storage systems under comparable grid access conditions. The R&D projects of the Elektro-Mobil funding programme are working out how this application can be implemented. The use case is already being demonstrated by other individual players.

Use case 3: Incentive to increase / reduce energy demand as a preventive measure of the grid – yellow traffic light phase:

In this case, the occurrence of a generally local grid bottleneck, e. g. in low–voltage grids, becomes apparent, which is why preventive measures are taken in grid operation. In order to avoid bottlenecks, contractual agreements lead to market-driven power in-creases or reductions at the relevant times or a complete postponement of the power purchase[2].

Instruments for this use case are, for example, variable grid charges, which shift the purchase of power through price incentives, or predictive power limitations, which, for example, take capacity planning into account (e. g. customer forecast, check-in mechanisms), optimally utilises grid capacities and only reduces them in case of "planned overbooking".

This use case has already been demonstrated in the R&D projects of the Elektro-Mobil funding programme (cf. TRC 2020).

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2 The possibility of offering unidirectional control of charging services on balancing energy markets for balancing measures at the level of the transmission grids via vehicle pools is possible in principle, but due to the high prequalification requirements, it should rather be seen in use case 4.

Use case 4: Incentive to feed back as a preventive measure of the grid – yellow traffic light phase:

In this case, the occurrence of e. g. a regional or even supra-regional grid bottleneck emerges predominantly at the medium or high-voltage level. As a fleet power plant, contractually agreed and digitally aggregated mobile storage systems from electric vehicles provide the same system services and back-feeding as pumped-storage or gas-fired power plants and pre-ventively stabilise the state of the grid. In order to avoid bottlenecks, use case 4 involves market-driven feedback through the organised call-up of flexibility.

Flexibilities from electromobility are called up, for example, via the balancing energy markets (primary control, secondary reserve, minute reserve) or redispatch via pooled electric vehicles as fleet power plants.

This use case is being tested and demonstrated in R&D projects of the Elektro-Mobil funding programme. For grid-supporting backfeeding, there is a particular lack of grid connections and automated prequalification conditions and registration processes – which should preferably be standardised throughout Germany. These are a prerequisite for the provision of these grid-supporting services, efficient registration for fleet power plants and participation in balancing energy markets.

Use case 5: Mandatory power limitation as a curative measure of the grid (emergency control), charging – red traffic light phase:

In this case, there is an immediate threat to grid stability, usually at the level of the distribution grid, e. g. because too much power is being consumed. In the grid, an immediate curative measure in the sense of a temporary power limitation must be taken to avert an imminent grid failure. For this purpose, a power limitation (P_{lim}) is carried out via the grid connection point (GCP) in the customer system.

The implementation of this use case is technically possible today and was demonstrated, among other things, as part of the promotion of Elektro-Mobil.

For the implementation in real operation, it is necessary to implement an automated partial short-term power limitation of short duration based on the cur-rent grid state to avert the critical grid state. For this purpose, the BNetzA (Federal Network Agency for Electricity, Gas, Telecommunications, Post and Railway) will define the regulations formulated in § 14a EnWG (Energy Industry Act).

Use case 6: Mandatory feed-in limitation as a curative measure of the grid (emergency control), regeneration – red traffic light phase:

In this case, there is an immediate threat to grid stability, usually at the level of the distribution grid, e. g. due to excessive feed-in or a lack of generator power. An immediate curative measure in the sense of temporary back-feed control must be taken to avert an imminent local grid failure.

Via this use case the required stability can be ensured by means of local and temporary feedback control at targeted grid connection points in the local grid.

This use case is also addressed in R&D projects of the Elektro-Mobil funding programme.

3 MAP OF COMMUNICATION FOR CHARGE CONTROL

The map serves as an abstract representation of the possible communication paths between all actors involved in an electric vehicle charging process or the corresponding components.

3.1 General assumptions and delimitation of the frame of reference

In order to be able to represent the complex system completely and correctly, assumptions must be made in advance and the framework within which the statements are made must be defined. These are reflected in the six use cases that the project partners have crystallised together with the Accompanying research Elektro-Mobil.

To reduce complexity, the map initially focuses on the red and green traffic light phases of the grid traffic light. Only charging infrastructure in private and public properties and their grid connection point on the distribution grid level are considered. Other controllable systems and buildings are located within the property. The actors can perform different functions depending on their role in the respective use case. In this context, the term "function" is understood to mean a communication activity and the influencing of communication and control signals. Several functions can be performed differently depending on the role assumed by the actors. The physical flow of energy is not shown in the map.

The map is based on the current legal requirements (GDEW, MSBG, EEG, etc.). The topology and the actor relationships for the iMSys are not addressed in this map, but a location of a potentially available smart meter gateway (SMGW) at the grid transfer point is assumed (cf. BMWK 2022).

For a complete representation of the relationships, the contractual relationships are informatively attached to the map.

A later extension to include the yellow traffic light phase is planned. The two simple use cases of the red and green traffic light phase of the total of six use cases and the actors involved thus form the framework of the current map.

3.2 Normative framework conditions

These considerations are based on the preliminary work of the German National Platform Future of Mobility (NPM) as well as the FNN and German Commission for Electrical, Electronic & Information Technologies (DKE) in the Association for Electrical, Electronic & Information Technologies (VDE DKE). Ensuring IT security in all stages of communication is considered a necessary and underlying requirement and is not the focus of this white paper.

3.2.1 NPM WG 6 – Focus Roadmap Intelligent Load Management

The NPM WG 6 Focus Roadmap Intelligent Load Management lists the need for standardisation in the charging infrastructure environment (NPM 2020).

The paper clearly separates the concepts of performance management (to be assigned to the red traffic light phase in the context of this white paper) and procurement- and tariff-optimised operation (to be assigned to the green and yellow traffic light phase here).

The power limitation (red traffic light phase) by the grid operator is drawn via local control at the grid transfer point analogously to the communication paths of the map presented in this white paper – starting from the digital grid connection point with a SMGW, via a control box and an energy management system (EMS) to the charging infrastructure. The need for standardisation identified for this purpose in the roadmap has now been solved via the application rules VDE-AR-E 2829-6 and the compatible VDE-AR-E 2122-1000. Both application rules are based on the safety requirements of technical rule TR 03109 and have found their way into international standardisation committees. The control and management of the charging infrastructure from the operator backend via the International Electrotechnical Commission's group of standards IEC 63110 is currently being worked on in the standardisation committee.

Whether the local EMS or the Charge System Opera-tor (CSO) controls the purchase- and tariff-optimised operation of the charging infrastructure depends on the chosen topology. The research projects listed in this white paper have each considered both topologies (see chapter 3.5 and appendix) and all the standards mentioned above are capable of doing so.

The NPM roadmap also identified the need for a continuous information chain across the standardisation strands, which should also include the route between the CSO and the electromobility service provider. This continuity has not yet been achieved.

3.2.2 FNN – Target image of the control-lability of charging infrastructure

In this listed FNN note, it is formulated how the topology for the control of the charging infrastructure with connection to the distribution grid level can look like.

Five different versions of the topology are given there. The distinctions lie in where the logical function of the control is positioned and at which point the processing steps are carried out via which infrastructure and by which actor or role.

In the notes, it is stated that currently only the control box version is standardised and published via IEC 61850 and VDE-AR-E 2829-6 (FNN 2021).

3.2.3 Normative triad

In contrast to other consumption units, three communication strands come together at the charging infrastructure. Firstly, the charging infrastructure must communicate with the digital grid connection point directly or via an EMS. Furthermore, the charging infrastructure is in direct connection with the CSO and the electric vehicle. The NPM roadmap and the FNN target image "Controllability of charging infrastructure for e-vehicles" set out norms and standards for this, which coincide with the communication technologies used in the projects. These form the "normative triad" listed in this white paper.

From previous explanations, it can be summarised that the use cases of traffic light phases can be well represented by the norms and standards mentioned here (Figure 5).

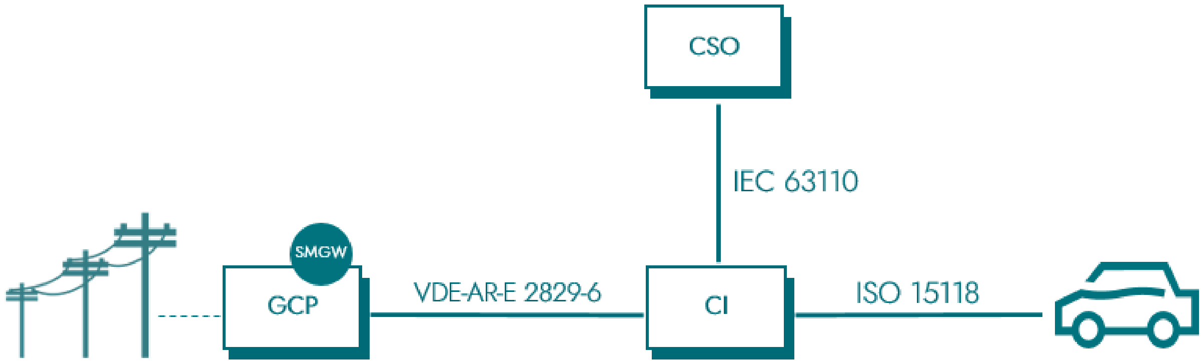

Figure 5: Normative triad behind the grid connection point from the perspective of the charging infrastructure - GCP: grid connection point, CI: charging infrastructure, CSO: charge station operator (own illustration)

3.2.4 VDE-AR-E 2829-6

VDE-AR-E 2829-6 has been adopted for the use case of the red traffic light phase and was published in spring 2021. For this purpose, it is congruent with VDE-AR-E 2122-1000, which ensures communication between the EMS and the charging infrastructure. The use cases of the green traffic light phase are about to be adopted in both application rules, those of the yellow traffic light phase are still being developed. The contents of VDE-AR-E 2122-1000 are currently being incorporated into IEC 63380, which means that the local power limitation as a limit value to be complied with is gaining international acceptance as price-based business models and price-controlled operation are potentially possible below this limit.

The application rules VDE-AR-E 2829-6 and VDE-AR-E 2122-1000 are based on the EEBUS

standards- and norms-based communication interface) specifications; for the use cases listed in chapter 1 of the application rules, they describe SPINE (Smart Premises Interoperable Neutral-Message Exchange) as the data model and SHIP (Smart Home IP) as the transport protocol in the further parts. This enables a technology-open approach: Compatibilities between communication standards or protocols are promoted on the basis of chapter 1.

The compatibility of VDE-AR-E 2829-6 with IEC 61850 has been established for the red traffic light phase and published via the FNN specification for the control box.

Compatibility with KNX (home and building control systems) is given via VDE-AR-E 2849-7; compatibility with openADR is in progress.

3.2.5 IEC 63110

The IEC 63110 series of standards defines an international overall solution that basically enables a standardised connection of a CSO backend with the charging infrastructure. It thus serves in particular solutions in which operators of charging parks or other energy service providers supply the installed charging stations with the necessary information and connect the various players with each other in terms of communication.

The series of standards is based on the Open Charge Point Protocol (OCPP), although parts of it have since been differentiated. Different versions of OCPP are used in the projects; consolidation work will be necessary in the future until a uniform solution is found.

3.2.6 ISO 15118

The ISO 15118 series of standards for road vehicles – communication interface between vehicle and charging station – is an international series of standards that contains, among other things, specifications for uni- and bidirectional communication between electric vehicles and charging stations. In particular, it also supports Vehicle-to-Grid (V2G) and the automatic authorisation and payment of the charging process using payment data stored in the vehicle (Plug & Charge). In addition to the Plug&Charge function, which is currently in the foreground, ISO 15118 primarily offers added value through energy management. This function makes it possible to receive tariff data in addition to a power limit and to negotiate a charging plan between the vehicle and the charging station.

3.3 SMGW roadmap process as a contribution in low-voltage

The "Step-by-step model for the further development of standards for the digitalisation of the energy transition" describes the development path for the iMSys for the coming years (BSI 2021).

The existence of an SMGW is currently not a pre-requisite for the controllability of a bidirectional charging and recovery process. Especially in the area of (semi-)public charging, at the employer's, supermarket or apartment building, many of the billing and business models are located "behind" the grid transfer point from a control and billing point of view and are also functional as such. Additional protection through the use of an SMGW, on the other hand, is considered desirable in the future.

Within the BSI level model, it is assumed that, for example, data relevant to the energy industry is also communicated to the property via the iMSys. This includes data that is necessary to ensure grid stability, such as control signals in the red traffic light phase. Data for optimising operations can be exchanged via a second WAN connection. This includes software updates, status data for system monitoring and remote maintenance data. In the current stage 3, the measurement and control data concerning the grid connection point are transmitted via the CLS proxy of the SMGW.

The BSI imposes interoperability and security requirements on the control devices, which are described in BSI-TG-03109-5 (technical guideline from the German Federal Office for Information Security). This TG regulates the connection to the SMGW system landscape at system level. The requirements described their concern, among other things, interoperability with the SMGW, network separation between the customer network and the CLS proxy and minimum requirements for the security of the interface to the customer facility. As the first concrete design of such a control device, the FNN control box has been specified, tested and validated in numerous projects (e. g. SINTEG [3]) (cf. Figure 6).

In the coming stage 4, it should also be possible to process and log the control signals as setpoint specifications (e. g. P_{lim}) in the SMGW, for example, and forward them from there to the downstream local systems such as an EMS or other controllable units. In addition to billing at the grid connection point, the SMGW is to be given further optional billing options for voluntary value-added services (BSI 2021), the use of which can be decided by the industry itself. In addition, the amendment to the EnWG was passed in the summer of 2022, in which, among other things, the definition of storage and the control of flexible consumers according to § 14a (this includes the charging infrastructure) is newly regulated (German Bundestag 2022). In this, the Federal Network Agency (BNetzA) has been given more extensive definition competence and is authorised, for example, to create uniform federal regulations for the grid integration of controllable consumption devices or grid connections. The controllable consumption devices themselves and controllable grid connections were defined as reference points. The use of the iMSys for a secure, uniform communication connection is specified there. Furthermore, market-organised flexibilities are to be used as a matter of priority and the grid-oriented control by the DSO is to take place in particular by means of the specification of maximum withdrawal capacities, which corresponds to the ideas on P_{lim} that have meanwhile become established. The present legislative amendments already correspond to the ideas drawn in the map.

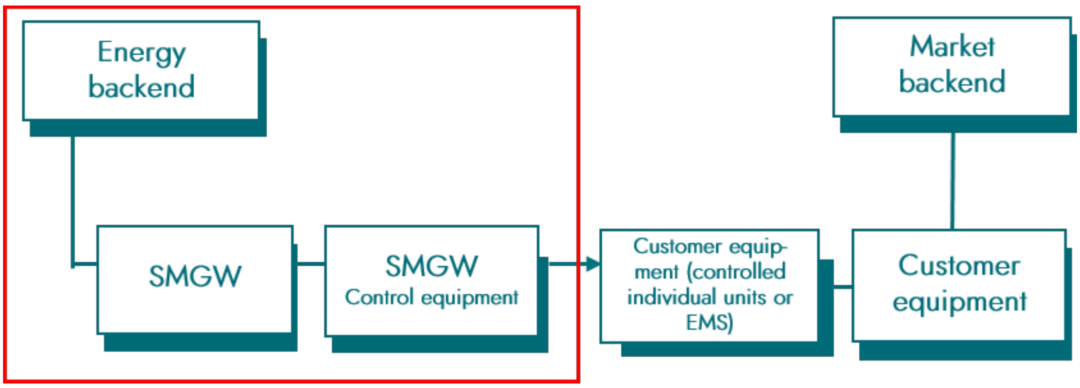

Figure 6: Network separation between customer network and CLS proxy according to BSI requirements

[3] https://www.sinteg.de/

3.4 Control via digital grid connection

The term "digital grid connection" describes first of all the functionality: a concept to transmit the information relevant for the network connection into and out of the property via a digital path. This information can be processed and implemented within the property with the support of a customer device (e. g. EMS). At a minimum, the information transmission of measurement and operating data (performance data) and the transmission of the power limit value (P_{lim}) from the grid connection point must be ensured. This enables the continuous comparison of target and actual values. The digital grid connection first appeared in the SINTEG (German research programme "Smart Energy Showcase - Digital Agenda for the Energy Transition") projects and its development is being continued in the projects in the Elektro-Mobil funding programme.

The digital grid connection is necessary for limiting the current throughput at the grid connection point for the implementation of use cases 5 and 6.

Other functionalities already envisaged in the projects of the ElektroMobil funding programme are conceivable and useful for the implementation of the business models within use cases 3 and 4 (e. g. meter readings for customers, tariff information, planning information from the customer system). However, not all functionalities would be considered by the minimum requirements.

Many measurements control and billing functionalities of the bidirectional charging infrastructure are technically located behind the digital grid connection point and are only limited at the grid connection point. What happens on the customer side "behind" the grid connection point can be freely controlled by the digital control and billing systems of the bidirectional charging service provider or fleet power plant operator in such a way that the respective targets are met.

The functionality of the digital grid connection can be realised by means of one or a group of devices. The concrete design and the regulatory provisions that apply to it vary from country to country. While the connection to the IT system of the network operator depends regionally on the respective grid operator, the interface to the customer system (EMS or controlled individual device) must be standardised at least on a European level.

The following figure 7 improves the understanding where the digital grid connection point is to be located in the context of the iMSys. Even though the digital grid connection is basically a concept, it is to be located at the transition between the grid operator and the customer installation. In addition to its functional task described above, the digital grid connection also enables an assignment of responsibilities, be it for operation or e. g. for possible regulatory requirements for the design[4].

[4] E. g. BSI TR-03105, FNN specification sheet

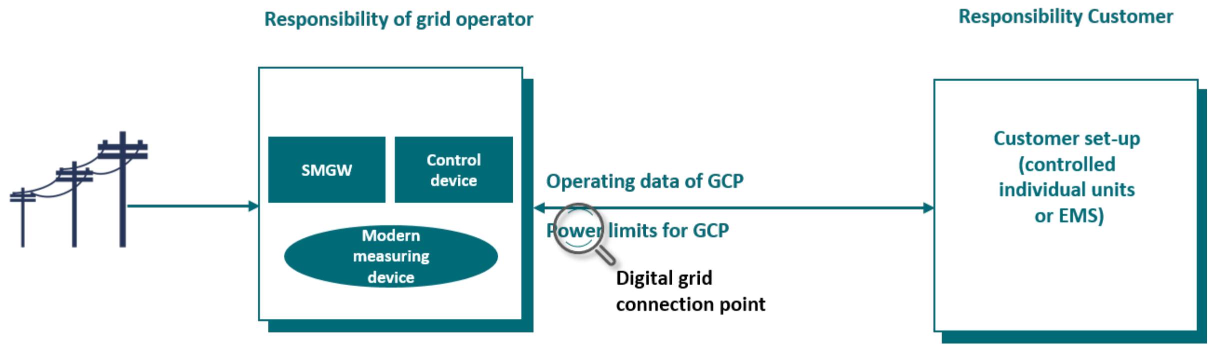

Figure 7: Control via a digital network connection (own representation)

3.5 Presentation of the map

The map shows relationships and communication paths for the two use cases "market-based control" (use case 1) and "emergency control" (use case 5). It presents the currently available norms and standards that are possible for the control of charging processes behind a grid connection point, for charging infrastructure with its own grid connection point and in combination with other consumers and buildings, and that are used in the projects (see Figure 8).

When looking at the map, it is important that it is to be understood in consideration of the legal requirements for iMSys, the BMWK/BSI step-by-step plan and consideration at the level of the distribution network.

The map shows that a large number of different actors are involved in the control of the charging infrastructure and other consumers. The map shows the respective relationships and communication channels.

The respective norms and standards or application rules of the communication paths must be checked and defined for each application and each connection situation to the power grid.

The map graphically shows the different variants of use cases 1 and 5 resulting from two possible connection situations:

- Charging infrastructure usually does not have its own grid connection point and is connected to the grid connection point of the building together with other consumers.
- Charging infrastructure usually has its own grid connection point.

In chapter 3.5.1, the two use cases 1 and 5 (UC 1 and UC 5) are described in more detail in different variants. In the appendix, the descriptions of the detailed statements on the different variants can be found in tabular form.

Map for the control of charging processes behind the GCP for charging infrastructure without and with own GCP (private, partly public, public)

- Merging scenarios: Emergency control (red) and market-based control (green)-.

Note: The map is to be understood in consideration of the legal requirements for SMGW and consideration at the level of the distribution grid. Ensuring IT security at all levels of communication is considered a given requirement.

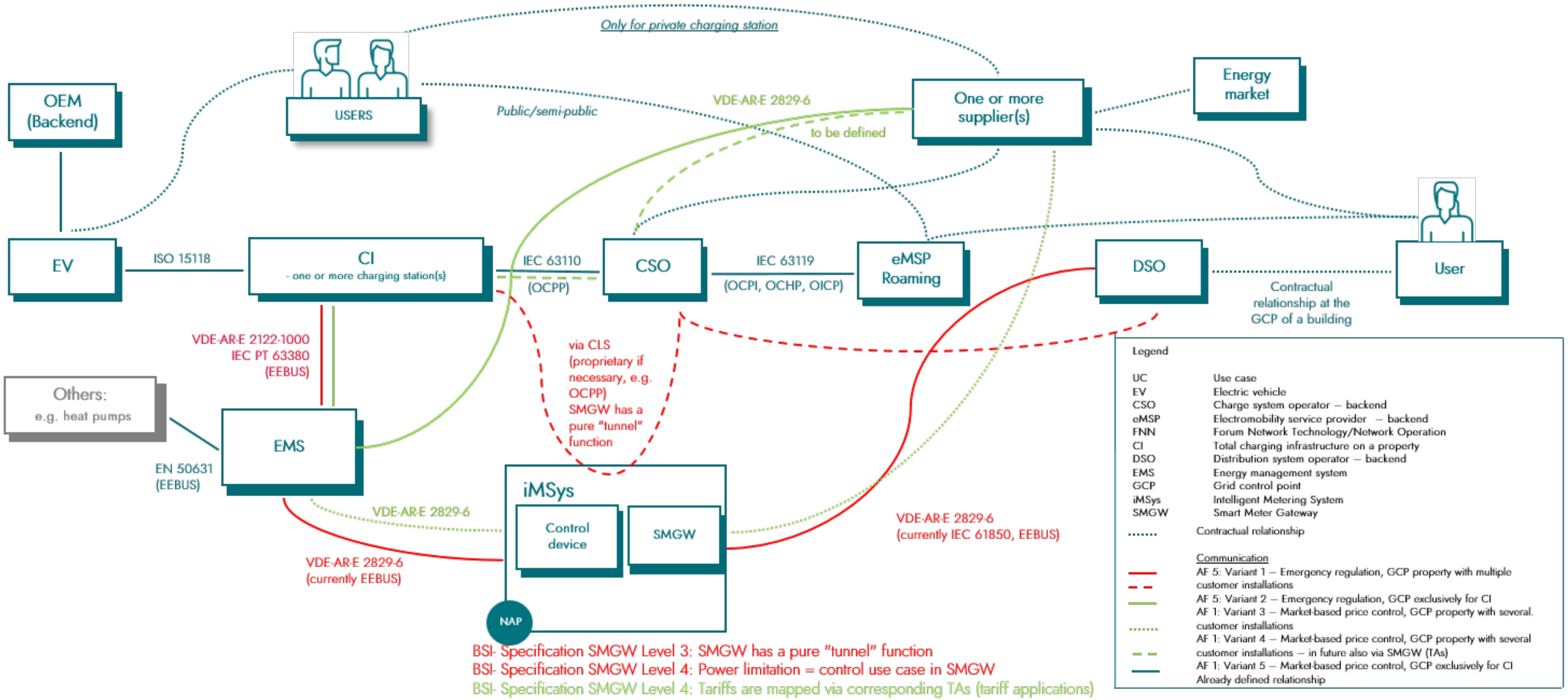

Figure 8: Communication map for charging control (own representation)

3.5.1 Description of use cases 1 and 5

Use case 1: Market-based price control (green traffic light phase)

In use case 1 (UC 1), the electricity purchase is decided based on the respective exchange price/tariff for the amount of energy used.

An energy supplier communicates the electricity price in UC 1 variant 3 within the framework of VDE-AR-E 2829-6 directly without the involvement of the iMSys to the EMS, which processes the tariff information and can route it to the charging infrastructure in accordance with VDE-AR-E 2122-1000 (IEC PT 63380). The tariffs are not assumed to be relevant for the infrastructure here; they are purely for operational optimisation and proper billing of the delivered amount of energy.

UC 1 variant 4 describes the same communication path with the EMS via the iMSys. The necessary tariff information is imported into the SMGW via the metering point operator (MSB) and transmitted from there to the EMS at the HAN interface, e. g. via VDE-AR-E 2829-6. The EMS and the charging infrastructure communicate via VDE-AR-E 2122-1000 (IEC PT 63380) as in UC 1 variant 3. This means that the EMS always has the current billingrelevant value available. This is particularly important against the background of the locally valid variable grid charges in the yellow traffic light phase. This case of variable grid charges in the yellow traffic light phase is being worked on normatively, but is not yet in the project planning stage of any research project. It is also envisaged in the BSI roadmap process from stage 4 at the earliest.

In contrast to UC 1 variants 3 and 4, the energy supplier provides the tariff information in UC 1 variant 5 directly to the CSO, which transmits this information to the charging infrastructure ("systemspecific") in accordance with IEC 63110.

The standard according to which this communication path is designed has not yet been defined. It is currently being examined whether openADR can be used in this connection.

Use case 5: Emergency control (red traffic light phase)

Use case 5 (UC 5) considers the case involving an immediate threat to grid stability at distribution grid level and the curative measure of power limitation. This value is assumed by the BSI to be relevant for the secure energy infrastructure and must therefore be transmitted to the grid connection point via the iMSys.

For UC 5 variant 1, the SMGW can be used in perspective as a transmitting technical component ("tunnel function"/CLS proxy) in stage 3 of the BMWK/BSI roadmap process, which provides a transparent, protocolindependent communication channel. The transferred power limitation at this point is unknown to the SMGW. The actual executing component is the FNN control box or a comparable control device connected to the SMGW. From there, the signal is routed to the EMS using the same VDE application rule before being sent from there to the charging infrastructure according to the VDE application rule VDE-AR-E 2122-1000.

The standardisation of this use case has been largely completed; together with the security requirements TR 03109-5 of the BSI, a rollout-ready solution is available.

The continuous communication for the grid emergency from the grid control, via the grid connection point to the vehicle, has already been successfully demonstrated by the ARNi project. This was realised by the norms and standards formulated in chapter 3, VDE-AR-E 2829-6, the derived VDE-AR-E 2122-1000 and IEC 61850 as well as ISO 15118 for the reduction of the purchased electricity through a power limitation at the grid connection point. The BDL project is concerned with relocating the function of the control box (provision of a signal for power limitation via VDE-AR-E 2829-6) to the SMGW, logging the limitation and integrating verification under calibration law into the SMGW (outlook on stage 4 of the BMWK/BSI roadmap process).

In UC 5 variant 2, in which the grid connection point is usually only responsible for the charging infrastructure, the DSO sends the control signal for power limitation directly to the CSO. At the moment, there is no standard defining this communication relationship. In the R&D projects of the Elektro-Mobil funding programme, for example, openADR or the IEC 60870-5-104 standard are used. The communication relationship between the CSO and the charging infrastructure is a pure CLS route. The SMGW establishes a transparent channel between the DSO and the charging infrastructure. The transferred power limitation at this point is unknown to the SMGW. The main difference to UC 5 variant 1 is that here only one device class (charging infrastructure) is controlled on a systemspecific basis, whereas UC 5 variant 1 refers to the grid connection point of the property or building. The ELBE project has successfully implemented this approach on the basis of OCPP, which is based on IEC 63110.

4 PRIORITISATION AND ORCHESTRATION OF CONTROL SIGNALS

Reduction of complexity

The previous chapters listing use cases and the map show the complexity of the system, but also concrete solution spaces for norms and standards as well as for communication paths for use cases 1 and 5. And it shows the necessity of clarifying the processing and prioritisation of the control signals in this system, which arise when use cases 3 and 4 in particular are added. In this white paper, the term "prioritisation order" is used for this. This is because the term "coordination function", which is often used in this context, is already used in a wide variety of subject contexts and already has specific definitions there.

Before the prioritisation order is specified, the following chapter deals with the concept of the variable power limit at the grid connection point.

4.1 The concept of the variable power limit at the grid connection point

In low-voltage, all "control measures" by the DSO should primarily act on the grid connection point via specifications for power limitation. This requirement is also formulated by the FNN in its impulse paper on "Key points for future grid operation with flexibilities in low-voltage" (FNN 2022) and strengthened by the amendment to § 14a EnWG passed in the summer of 2022. Requirements for the reduction of electricity consumption in use case 5"Emergency control" should be carried into the system by means of a power limit at the digital grid connection point. The power limit is defined by the P_{lim} signal. This defines the maximum power purchased from the electricity grid for a defined period of time (see figure 9). Below this power limit, the customer system can act freely. If there is more than one controllable consumer, an EMS takes over the orchestration behind the grid connection point and ensures that the defined P_{lim} is maintained.

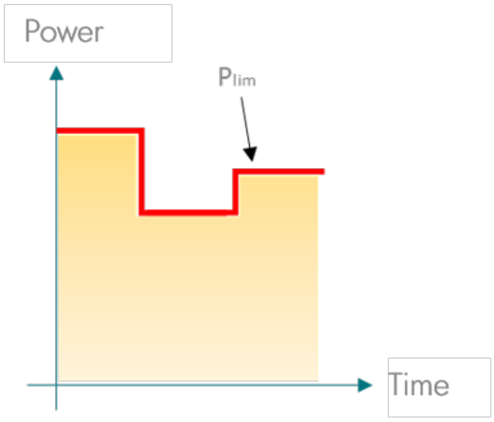

Figure 9: Concept of variable power limitation (own representation) [Below the red limit (P_{lim}) the customer system can act freely]

This ensures that the grid's requirements are implemented. How this requirement is implemented on the property downstream of the grid connection point is left up to the connected party. Thus, for the implementation of the grid's requirements in use case 5 "Emergency control", no individual systems are directly controlled by the grid, but a transfer of responsibility to the end customer is carried out via setpoint specifications.

This approach enables the industry to develop business models that are located behind the grid connection point without endangering grid stability. In this way, different requirements for the grid connection point in the European countries would not affect the further development of the business models for uni- and bidirectional charging, which are usually driven by companies that operate at least on a European level.

4.2 Prioritisation levels

Under the premise that in a critical grid situation the emergency control ensures grid stability by reducing the P_{lim}, a variety of business models can be implemented to control charging processes outside of such an emergency intervention. I. e. emergency control as local power limitation has priority over all three levels described below.

Behind each use case already described are different possible business models, which in turn trigger tax requirements. The first step in implementing a prioritisation order is to reduce these business models to the origin of the incentive signals.

For this purpose, the business models with the resulting incentive signals are assigned to the following three levels:

1. Loading target according to user preference
2. Monetarily remunerated grid support and system services
3. Participation in the electricity market

These three areas are the basis for the prioritisation order of the control signals. Figure 10 shows the prioritisation levels. Prioritisation levels 2 and 3 and the "network intervention" act analogously to the FNN traffic light phases. Only the preferences of the users act outside of this traffic light system as an individual framework of action for the users of the electric vehicles.

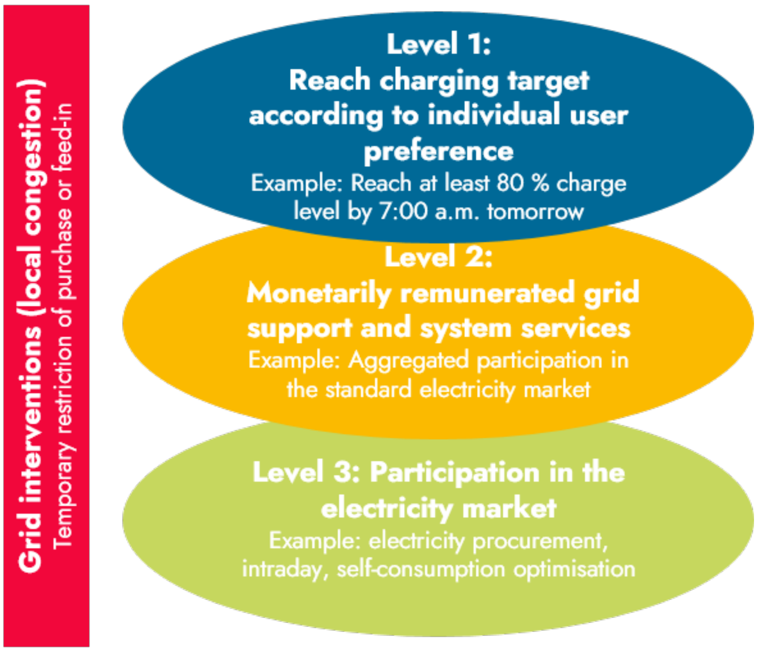

Figure 10: Prioritisation levels of control signals (own representation)

The preferences of the users are on the highest of the three levels in the hierarchy (Figure 10, blue). At all times, the goal must be to fulfil the user's wishes and thus to ensure the acceptance of electromobility. Level 1 control signals always have priority.

Within the limits defined by the user experience according to level 1 (e. g. "car 80 % charged the next day at 7:00 a.m."), the control signals of level 2 (figure 10 yellow) can now be used by the aggregator and operator of a fleet power plant for monetarily remunerated grid support (within the framework of the remaining battery capacity). The user is granted corresponding advantages within the framework of his chosen tariff (e. g. provision of the same grid and system services as is currently still reserved for pumped storage or peak load power plants). For example, parts of the battery capacity of the electric vehicles pooled in this way can be marketed via aggregators/pooling providers to remedy regional or even supra-regional generation or grid bottlenecks. Finally, the third prioritisation level follows, the electricity market (Figure 10 green). On this level, the control signals serve e. g. the purchase or sale of energy at attractive prices, the sale of e. g. CO_2-neutrally generated charging power for electric vehicles, or the optimisation of self-consumption.

In summary, it can be said that in the green and yellow traffic light phase, the control signals to fulfil the preferences of the users have priority over those of grid support and the electricity market, while grid support signals are prioritised compared to those of the electricity market. In the red traffic light phase, all three levels of prioritisation are overridden by the local grid intervention at the grid transfer point.

The framework parameters and desired implementation of this prioritisation are the responsibility of the customer system. The owner of the system will, for example, use an appropriately programmed and parameterised EMS in which the preferences are stored.

The prioritisation order thus helps to break down the multitude of use cases and the associated control signals to the four levels described. The complexity of the overall system is thus reduced. This can be accompanied by simple coordination, which makes it possible to prioritise and process the control signals and their sometimes contradictory natures.

4.3 Orchestration

Simple start-up model

In the simplified representation for the implementation of the prioritisation order, it is assumed for the time being that the left-hand side (localised network intervention at the grid connection point) and the right-hand side (market intervention on the customer installations) do not influence each other significantly (Figure 11).

The project results – especially of the BDL project – show that the congestion intervention of the DSO is on the one hand locally limited and minimal in its frequency and duration, so that the aggregated contribution to grid support against grid problems is not disturbed (Müller 2022). The local power limitation via a P_{lim} always serves as a "last backup measure" that reliably supports the local distribution grid.

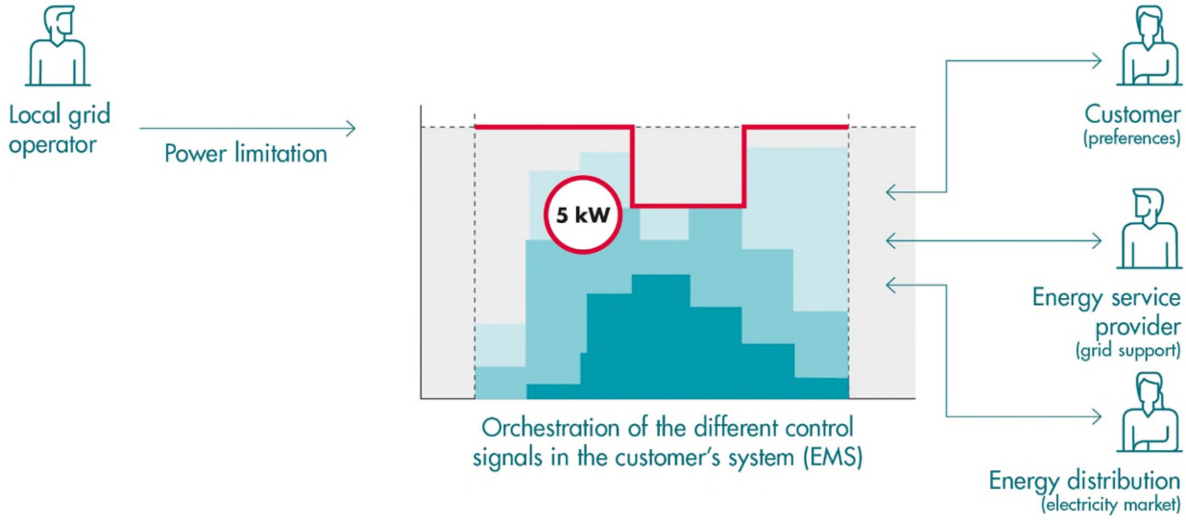

Figure 11: Variable power limitation (own representation)

FUTURE NEED FOR COORDINATION

With increasing expansion and advancing digitalisation of the distribution grids, more and more flexibility instruments will also become established in the yellow traffic light phase for optimising local and supraregional grid utilisation.

Variable grid charges can preventively avoid grid bottlenecks. The unIT-e² project is addressing this issue, among others. Forecast data from the customer systems can then be used to use adaptive power limitation preventively.

In the temporal development steps, new necessities of the communication links and the resulting control information to be orchestrated can thus arise. Further research is being conducted in the funded projects to determine whether a central coordination function in the sense of the ongoing FNN project work is necessary in the yellow and red traffic light phases and, if so, from what possible degree of implementation of the use cases it must be correspondingly pronounced. The RESIGENT project, for example, is dealing with this question. Detached from the question of a central coordination function, the different use cases and traffic light phases at the grid connection point must act in a coordinated manner. This requires holistic standardisation approaches such as the VDE-AR-E 2829 series, which place the various control specifications in an overall context. They must be able to exchange the necessary information consistently and across device typologies up to the charging point with the ISO 15118 series and IEC 63110 (OCPP). According to current knowledge, the adaptations to the above-mentioned norms and standards are being processed in the committees in order to ensure the continuity of communication.

5 CONCLUSION AND OUTLOOK

Conclusion

The consideration and structuring of the control forms of the charging processes on the basis of use cases oriented to the traffic light models is a useful structuring element. It serves to simplify the framework of observation and to better approximate the simpler to the more complex control processes.

The white paper in Edition I is a consensus paper resulting from a participation process with the projects and project partners of the Elektro-Mobil funding programme of the BMWK named in the imprint. It shows solutions for standardised communication paths of exemplary control processes, which are classified as feasible solutions by the projects involved and are used in real-world tests. These solutions enable the use of market prices for tariff-optimised electricity procurement as well as power limitation in the event of an impending bottleneck. ISO 15118-20, IEC 63110 (OCPP) as well as VDE-AR-E 2829-6 (EEBUS) today provide a basic framework or functionality, by which continuity of the control of charging processes can be achieved.

The created map was linked to the explanations published in the FNN note "Zielbild Steuerbarkeit von E-Fahrzeugen", the "Schwerpunkt-Roadmap Intelligentes Lastmanagement" of the NPM WG 6 as well as activities for gateway standardisation of the BMWK/BSI. The present elaboration and the work of the projects have thus created a large, communal consensus.

The contents of the extended Edition I presented here were updated and supplemented by the accompanying research on the basis of publications by the FNN (FNN 2022) and project results presented in the meantime.

Digital grid connection, the market-based use of flexibilities to avoid supraregional grid bottlenecks, e. g. through the use of fleet power plants, as well as variable electricity tariffs are instruments that have already been tested today and can soon be used on a mass scale in further activities. In this way, they can contribute to accelerating the energy transition in the near future.

The considerations in chapter 4 of the extended Edition I show that during and after the ramp-up phase of electromobility, the simplified representation of prioritisation and orchestration is well suited to describe the conditions in the next few years and to roll out market-ready systems. The first preventive use cases in the yellow traffic light phase have been successfully tested and demonstrated in pilots in the BDL project, among others.

Market mechanisms for grid-compatible or grid-serving charging can initially be solved by a simple prioritisation order. The concept of variable power limits at the grid connection point and the simplified prioritisation levels show how, with the appropriate regulatory framework for grid intervention, the customer's point of view and requirements for mobility are taken into account just as much as the security of the electricity grids.

Outlook

Through the work of the accompanying research and the participating projects, the white paper Edition I shows possibilities and ways for the design of the control forms of charging processes, for the future use of which the foundation stone has been laid here with a broad consensus. Building on this fundamental basis, the following aspects are to be further developed, defined and regulated.

Permeability of control information: For all use cases it must be successively analysed in detail which concrete adaptations must be made in the norms and standards in order to ensure the continuity of communication in the entire control process. This should be done in particular taking into account the work of DKE/AK 353.0.401.

Expansion of the map: In the further process, the information on the communication flow of the present map is to be supplemented by further aspects. These include elements such as the distribution of roles of the actors, the view and scope of action of the users, interactions between users, charging infrastructure, eMSP and CSO. In the future, other actors may be involved in the individual use cases. In this case, the map must be expanded to include these new actors and components and their functions.

Yellow traffic light phase: Preventive use cases in the yellow traffic light phase should be further developed. Here, for example, it must be taken into account that system services, which are provided e. g. by bidirectionally charging electric vehicles, act on different voltage levels of the electricity grid. Therefore, correspondingly flexible solutions are needed in which requirements are optimally linked with each other.

Challenges include the establishment of a nationwide control capability in the low-voltage grid and the coordination between the flexible plants and consumers and the different grid levels.

Need for standardisation and sub-legislative regulation: There is a need for action, among other things, in the standardisation work for the connection of fleet power plants to the grids. The grid connection conditions required for this and common, cross-manufacturer control signals for implementing the prioritisation order in the electricity markets of Germany and Europe must be coordinated. The regulatory framework within which the standardisation takes place must now be designed in such a way that an economic implementation of the use cases is made possible. In this interaction, the intelligent control of charging processes (unidirectional and bidirectional) can make a meaningful contribution to the energy transition through the grid integration of electromobility.

Regulatory: A clear legal framework is necessary for the design of governance processes.

In order for the industry to be able to implement the control option via the grid connection point quickly and with legal certainty, the BNetzA must publish clear statements on the concrete design of § 14a.

Feed-in as pooled flexibility into the distribution grid has not yet been defined by regulation. Electric vehicles capable of feeding electricity back into the grid need to be classified in the systematics of generation and storage facilities. Furthermore, a discourse on dynamic tariffs must be conducted. A legal framework is needed that allows relevant business models to be developed via performance specifications and/or price signals and that these can represent a sufficient price incentive. Proposals have already been developed in this regard in the funded projects.

IMSYS: The design of the integration of the iMSys and the associated communication interfaces as a complete digital network connection is to be further specified in connection with the SMGW roadmap process. The recommendations that were brought into the roadmap process from the projects are to be taken into account for stage 4. The billing of individual charging processes (e. g. in the case of employer charging) has not yet been considered. The BDL and LamA-Connect projects, for example, deal with event-triggered billing options for customer systems behind the grid connection point.

RESILIENT DESIGN OF THE CHARGING INFRASTRUCTURE SYSTEM: The multitude of use cases and business models and the need for a prioritisation order automatically make the connection and information exchange between charging points and the energy system more complex. There are starting points for unpredictable disruptions and problems in sub-areas that affect the entire system, the more complex the system is. In order to build a resilient system for electric vehicle charging, all components of the energy system must be covered, also with regard to their future design. The information level and the technical resources themselves must be considered. Here, the resources for energy production, transport or consumption must be considered. The potentials and also risks for making the energy system resilient can be found at all these levels (Fraunhofer IEE 2022).

In order to be able to guarantee a resilient system, it must be clarified what happens if signals do not arrive at the charging points for several hours or even several days due to e. g. disruptions in the infrastructure or if iMSys are not fully functional. Causes can include environmental disasters, extreme weather conditions, criminal attacks, defects, etc. Charging infrastructures must be designed in such a way that they can also cope with higher frequency fluctuations or even provide support in the event of a black start. Further clarification is needed on the question of how strong the influence of the iMSys failure is on the entire national energy system and on the charging infrastructure. In addition, the question must be answered as to whether reactive power, phase shift, voltage and frequency must be measured in micro-units in the EU network and stabilised in an automated and decentralised manner by each micro-unit within its capabilities.

For a sustainable transformation of the energy and transport sector in Europe and Germany, a system with high complexity is emerging. In order to make the system stable and safe, resilient systems in autonomous, system-supporting mode are necessary. These must also be able to continue running automatically in isolated operation and be capable of black-starting. Such systems allow automated systemserving control as soon as a local deviation from the set values is measured. Safety in the overall system is ensured by the fact that each element of the system automatically strives to stabilise itself and its (grid) environment. This system architecture is sometimes described under the terms "smart micro-grids" or "cellular grid" and can make the all-important difference as a further line of defence. The topic of resilient systems will be further discussed and consulted in the following activities of the accompanying research.

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ANNEX

Overview of the variants due to different connection situations

In chapter 3.5.1, the use case 1 "market-based price control" and use case 5 "emergency control" with the different variants were described in detail. In addition to the description, the two use cases for two different connection situations are combined in the following table for a better overview

Connection situation	Charging infrastructure does not have its own grid connection point and is connected to the grid connection point of a property			Charging infrastructure usually has its own grid connection point	
Use case (UC)	Emergency regulation - UC 5 -	Market-based price control - UC 1 -	Market-based price control - UC 1 -	Emergency regulation - UC 5 -	Market-based price control - UC 1 -
Variant	1 Access at the grid connection point	3 Access at the grid connection point; currently	4 Access at the grid connection point; in future	2 Access at the charging point via CPO	5 Access at the charging point via CPO
Description	**Power limitation** The DSO carries out a power limitation. This runs via the iMSys into the EMS and from there into the charging infrastructure. From there, a signal goes to the EV. Line type: Solid red	**Flexible price control** This is an electricity tariff concluded by the connectee for the entire property. The tariff applies to all consumers of the property. The tariff is routed directly to the property's EMS. There are no specific legal requirements to be observed in this regard. The EMS can work in a tariff-optimised manner. Line type: Green solid	**Flexible price control** This is an electricity tariff concluded by the connectee for the entire property. The tariff applies to all consumers of the property. The tariff information is stored in the SMGW and forwarded from there to the EMS of the property. The SMGW records the billing-relevant data. Line type: Green dotted	**Power limitation** This is a pure CLS route between the CSO and the charging infrastructure. The DSO carries out power limitation. The SMGW establishes the secure channel between the CPO and the charging infrastructure, and the transferred power limitation remains unknown to the SMGW ("tunnel function"). Line type: Red dashed	**Flexible price control** The CSO receives the prices directly from the energy supplier and passes them on directly to the charging infrastructure. Currently, there is no standard for communication between the energy supplier and the CSO. It is being examined whether openADR can be used in this connection. Line type: Green dashed

Table 1: Communication paths taking into account the connection situation and application case

List of abbreviations

ABBREVIATION	NOTION
Connector	Owner and user of a connection object that is connected to the electricity grid of a grid operator.
BDEW	Federal Association of the Energy and Water Industry e. V.
BMWK	Federal Ministry for Economic Affairs and Climate Protection
BNetzA	Federal Network Agency
BSI	Federal Office for Information Security
Control system	Term describing various components that serve to control the energy flows, e. g. EMS
CSO	Charge Station Operator - operator of the charging station/charging infrastructure
DKE	German Commission for Electrical, Electronic & Information Technologies
EEG	Renewable Energy Sources Act
EMS	Energy management system
eMSP	Electromobility service provider - Backend
EnWG	Energy Industry Act
EV	Electric vehicle
FNN	Forum Network Technology/Network Operation
GDEW	Act on the digitalisation of the energy transition
iMSys	Intelligent measuring system
KNX	KNX is a bus system for electrical installation. It enables the networking of all components of home and building system technology.
KOF	Coordination function according to FNN
LIS	Charging infrastructure - one or more charging stations
MSB	Metering point operator
NAP	Grid connection point
NPM AG 6	National Platform Future of Mobility, Working Group 6 Standardisation, Normation, Certification and Type Approval. In this working group, the focus roadmap Intelligent Load Management was developed.
OEM Backend	Vehicle-side backend for a charging process
OpenADR	OpenADR is an open and bidirectional information exchange model and a smart grid standard
P_{lim}	Power limit

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