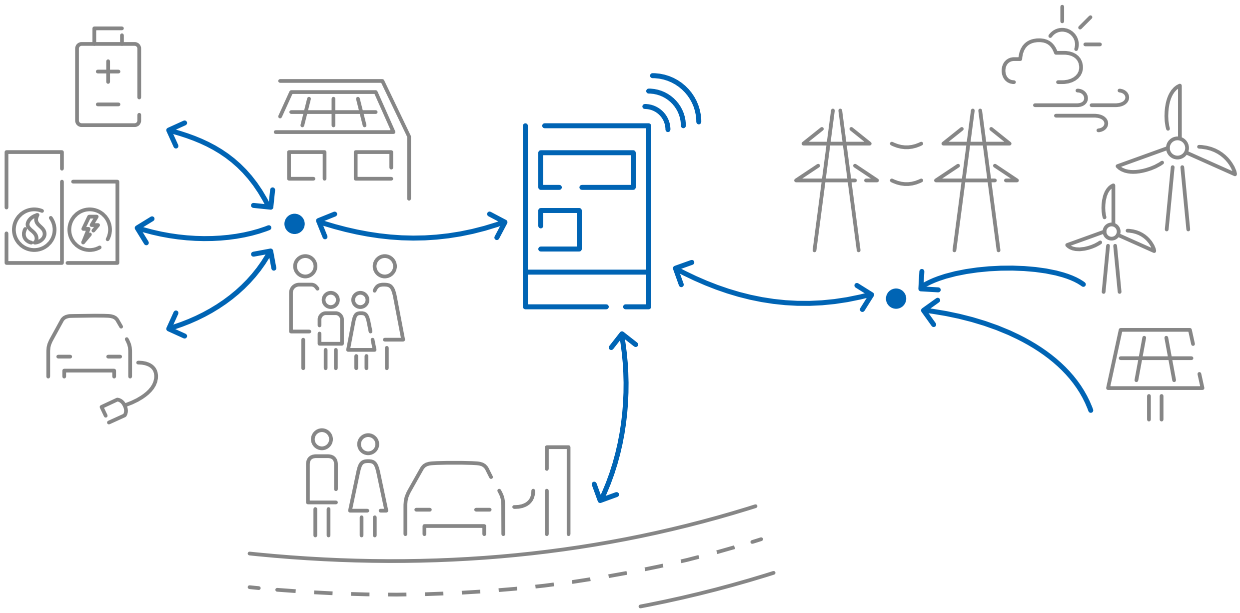


Requirements for the technical design of the physical and logical interfaces of the control device for connecting and transmitting the control command to a controllable load device or an energy management system

Nationwide recommendation from VDE FNN based on the state of the art regarding clause 2a according to the Federal Network Agency's ruling BK6-22-300

English version, August 2026

Original version in German first published in October 2024

VDE FNN

Content

Image list

BNetzA..Federal Network Agency
BSI ....Federal Office for Information Security
DSO ....Distribution sytem operator
EEG ....Renewable Energy Sources Act
EGP ....Generation system
EMS ....Energy Management System
EnWG ....Energy Industry Act
MPO..Metering point operator
SMGW ....Smart meter gateway
SteuVE..Controllable consumer device
VDE FNN ....Network technology forum/network operation within VDE

Terms and definitions

Operator

In this document, 'operator' refers to operators of controllable devices. This includes both operators of generation systems (EZA) and operators of controllable load devices (SteuVE) as defined by the Federal Network Agency (BNetzA) in BK6-22-300 Annex 1, section 2.5. [1]

Digital interface

The term 'digital interface' refers to the IP-based communication interface of a control device for connecting a controllable device.

Energy Management System (EMS)

An 'energy management system' (EMS) allows multiple controllable devices to be bundled to achieve local optimisation in the customer's installation.

Generation system (EGP)

'Generation system' (EGP) is defined, according to VDE-AR-N 4105, as a system 'containing one or more electrical energy generation units and all electrical equipment required for its operation'. Electrical energy storage systems and electric vehicles that can feed electrical energy back into the grid are also considered generation systems in this document.

FNN control box

The term 'FNN control box' refers to VDE FNN-specified configuration of a device-integrated control unit. [2] In the context of this document, 'control box' always refers to the FNN Control Box. The control box includes a communication adapter according to BSI TR-03109-5 [3].

Coupling relay

A 'coupling relay' is used to separate the potentials between the control unit and the customer installation.

Customer installation

The definition of a 'customer installation' in this document corresponds to the definition according to VDE-AR-N 4100: 'The total of all electrical equipment downstream of the point of transfer with the exception of the metering equipment for supplying the connection holders and the connection users'. In smart metering systems, metering equipment also includes control equipment.

Charging unit

In this document, 'charging unit' refers to non-public charging units for electric vehicles that comply with SteuVE [1].

Requirements specification

The term 'requirements specification' always refers to VDE FNN 'Specification for control box' version 1.4. [2]

Grid-effective power consumption

The definition of 'grid-effective power consumption' in this document corresponds to the definition of the Federal Network Agency according to BK6-22-300 Annex 1, section 2.3: 'that portion of the electrical power withdrawn from a public electricity distribution network via the grid connection that is simultaneously caused by one or more controllable loads'. [1]

Specification

In this document, 'specification' refers to the precise description of features and characteristics for a technical design and implementation in the device technology. The specification provides the content for testing and conformity assessment of the device technology.

Controllable loads

'Controllable devices' include controllable consumption devices (SteuVE) as defined in Section 14a of the German Energy Industry Act (EnWG) and controllable generation systems (EZA) as defined in Section 9 of the German Renewable Energy Sources Act (EEG). From the perspective of a control device, an EMS is to be treated like a controllable device, which is why the term 'controllable device' in this document is to be understood as a generic term for individual controllable devices and EMS.

Controllable Consumption Device (CCD)

The definition of a 'controllable consumption device' in this document corresponds to the definition of the Federal Network Agency according to BK6-22-300 Annex 1, Section 2.4: A CCD is 'a charging point for electric vehicles that is not a publicly accessible charging point within the meaning of Section 2 No. 5 of the Charging Station Ordinance (LSV), a heat pump heating system including auxiliary or emergency heating devices (e.g. heating elements), a system for space cooling, and a system for storing electrical energy (electricity storage) with regard to electricity withdrawal (storage)'. [1]

Control task

The 'control task' is determined by the technical characteristics of the controllable device, which must be specified by the system operator or their electrical installer during registration. Each controllable device (charging station for electric vehicles, heat pump, renewable energy system, energy management system, etc.) is assigned a control task by the distribution network operator when directly controlled. Multiple control tasks can exist within a building or property.

Control device

A 'control device' refers to a technical device of the metering point operator (MPO) that transmits control specifications as active power limitations to controllable devices. This document considers the implementation both as a separate physical device (e.g. a control box) and as a function integrated into the smart meter gateway.

Control function

The term 'control function' refers to the capabilities of a control device for implementing a control command. A control unit in the form of the FNN control box provides the user with, for example, self-contained control functions in the form of switching programs, wiper commands, direct commands, and derived internal device events.

Control concept

The 'control concept' is developed by the responsible MPO. This is defined by the number of control tasks reported to the MPO by the DSO. Thus, the control concept represents the connection or wiring of the FNN control box to the controllable devices, resulting from the assigned control tasks.

Heat pump

In this document, 'heat pump' refers to heat pump heating systems that include auxiliary or emergency heating devices (e.g. heating elements). This is based on the definition of the Federal Network Agency according to BK6-22-300 Annex 1 Section 2.4.b. [1]

Active power limitation

'Active power limitation' refers to the transmission and specification of a limit value to a controllable device, which it must adhere to. It is essential to ensure compliance with permissible value ranges. Using a controllable load device as an example, this means considering the minimum power for grid-relevant power consumption according to BK6-22-300.

Foreword

The Federal Network Agency's ruling BK6-22-300 of 27 November 2023 [1]regarding the implementation of Section 14a of the German Energy Industry Act (EnWG), stipulates that controllable load devices (SteuVE) and energy management systems (EMS) must reduce their grid-relevant power consumption in accordance with the specifications of the distribution network operator (DSO) in the event of a critical load situation in the upstream low-voltage network.

In the BNetzA's decision, 'Section 2' stipulates that network operators must develop recommendations based on the state of the art. These recommendations are intended to contribute to 'achieving the best possible standardisation and thus enabling efficient and scalable implementation of grid-oriented control' [1, p. 83]. All relevant market participants must be appropriately involved. These recommendations must be submitted to the Federal Network Agency by 1 October 2024, at the latest.

In consultation with the BNetzA, VDE FNN has assumed responsibility for coordinating and developing the recommendations for clauses 2 a, b, c, e, f, and g.

The Network technology/network operation forum within VDE (VDE FNN) is proactively developing electricity grids. The goal is to ensure the safe operation of the system at all times using 100 percent renewable energy. VDE FNN makes innovative technologies suitable for practical application and provides answers to the grid-related challenges of tomorrow. Various expert groups with diverse interests work together here to develop solutions. Members include over 500 manufacturers, grid operators, utilities, system operators, authorities, and research institutions.

With this document, VDE FNN submits its recommendation to the Federal Network Agency regarding clause 2a, based on the state of the art.

The recommendation was developed within VDE FNN committees.

Clause 2a defines the requirements for the technical design of the physical and logical interfaces of the control device for connecting to and transmitting the control command to a control device or an energy management system.

The recommendation for clause 2a is based primarily on the specifications for control boxes, version 1.4, with regard to the interfaces described [2]. To provide manufacturers of control devices and users with early guidance on how controllable devices can be connected to a control device via the digital interface, VDE FNN published VDE FNN Impulse 'Design of the digital interface on a controllable consumer device or an energy management system' in January 2024 [4]. This document summarises previously published work results from VDE FNN, primarily from the specifications for the control box, version 1.3 [5], and aims to make them accessible to a wider audience due to the interface's relevance. For the control of controllable devices where connection via a digital interface is not yet possible, VDE FNN Impulse 'Development of a standardised interface on a controllable device or an energy management system for connection to an FNN control box' [6] was also published in January 2024. This initiative therefore focuses on the use of conventional relays and proposed a harmonised design for a relay interface. Feedback on this VDE FNN initiative was possible until the end of March 2024. The feedback received was taken into account in the further development of the recommendation for clause 2a.

Furthermore, as part of the development process for clause 2a, workshops with participating market stakeholders were held on 15 February 2024, and 28 May 2024, under the direction of the Federal Network Agency. At these workshops, VDE FNN provided information on the current work, and participants had the opportunity to comment.

This document represents a combination of the two VDE FNN initiatives from January 2024, with more additions for the overall context and the incorporation of feedback from the commentary process.

The statements in this VDE FNN guidance are based primarily on the decision of Chamber 6 of the Federal Network Agency on the 'Determination procedure for the integration of controllable consumption devices and controllable grid connections pursuant to Section 14a of the German Energy Industry Act (BK6-22-300)' [1] and Annex 1 contained therein. Unless explicitly stated otherwise in this document when citing a passage or number from the BNetzA determination, this always refers to BK6-22-300.

By submitting this document to the BNetzA, the network operators fulfil their obligation under clause 2a of the operative part to develop state-of-the-art recommendations. The recommendation submitted to the BNetzA will subsequently be published on the BNetzA website and made available for public consultation. Following the consultation, the BNetzA will issue a notification regarding the final documents.

1 Introduction

The integration of numerous consumption devices, such as heat pumps or charging stations for electric vehicles, is a current challenge for distribution system operators and market participants. In this context, control via smart metering systems is a key component. For a functioning end-to-end control process via smart metering systems, the design of an interoperable interface between the control device and the operator's system is of paramount importance.

This document describes the requirements for the interface of controllable devices in order to be connected to a control device.

Controllable devices include controllable energy storage systems (CESs), such as charging stations for electric vehicles or heat pumps, as well as a controllable energy storage system (ESS) or an energy management system (EMS). An EMS can be used to bundle multiple controllable devices to achieve local optimisation within the operator's system. For participation in grid-oriented control in accordance with the 'Definition for the integration of controllable consumption devices and controllable grid connections pursuant to Section 14a of the German Energy Industry Act (EnWG)' issued by the Federal Network Agency (BK6-22-300), [1] the focus is on SteuVE and EMS.

According to VDE FNN Specification for controllable devices, Version 1.4, [2]the FNN control box offers various interface options for connecting controllable devices. The interfaces between the control box and controllable devices are represented by the grey lines in Image 1. A system can be controlled conventionally via relays or via a digital interface. The goal is to predominantly use standardised digital interfaces in the future, as described and explained further in this document. The decision as to which interface(s) are implemented in a controllable device is made by the respective manufacturer.

This document begins by describing the target image of the digital interface in Chapter 2, before introducing the terms 'control task' and 'control concept' in Chapter 3. These terms are crucial for harmonisation and implementation. Chapter 4 outlines the fundamental requirements for a standardised digital interface, followed by a description of the specific implementation of the digital interface in Chapter 5. Chapter 6 addresses the connection via relays. The recommendation in clause 2a is summarised in Chapter 7, and an outlook on further procedures is provided in Chapter 8.

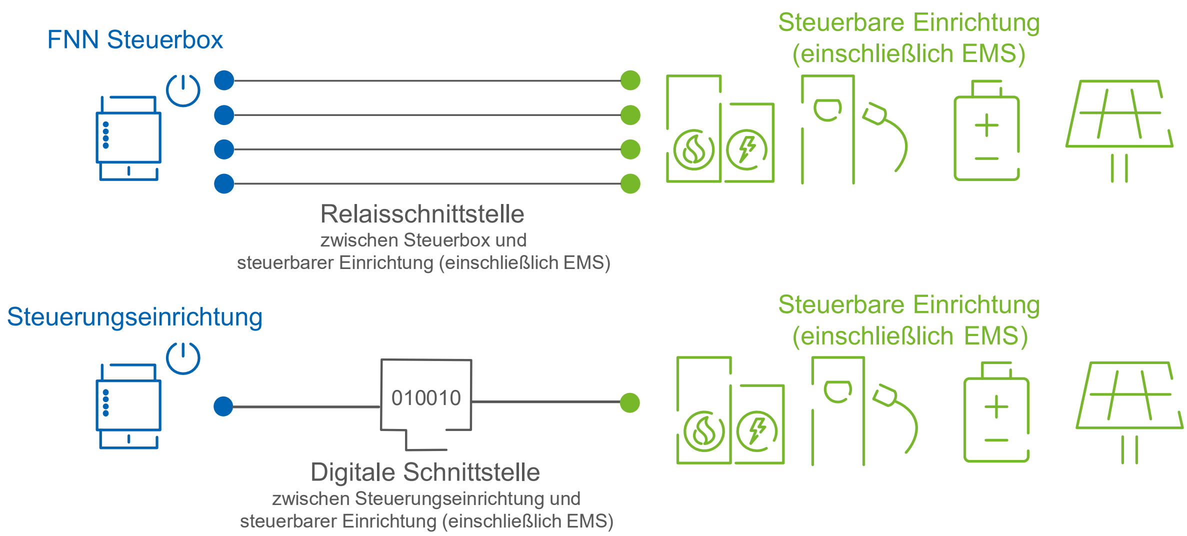


Image 1 Representation of the relay-based and digital interface between outputs of the control device and inputs of the controllable device (including EMS)

2 Target image of the digital interface

Previously, control via relays was widespread, particularly within the context of ripple control technology. Control information can be transmitted to a system via one or more relays, which can be configured as normally open or normally closed contacts. However, data exchange via relays is severely limited, as only two states – on or off – can be transmitted per relay. Furthermore, communication is unidirectional, from sender to receiver. This means that the sender receives no feedback on successful reception or processing of the information.

In contrast, modern digital interfaces offer advantages that are of great importance for both current and future requirements in the energy sector and technology. They allow for the continuous, fine-grained transmission of information and can transmit virtually any number of states. This enables precise control to any desired value, allowing customer demand and available grid capacity to be optimally aligned.

A crucial advantage is bidirectional communication. While relays only transmit a single state and the sender receives no feedback on reception or processing by the receiver, a digital interface allows the receiver to confirm both the receipt and the correct processing of the information. This bidirectional communication increases the reliability of information transmission, opens up additional application possibilities, and therefore offers long-term usability of these interfaces. Feedback and acknowledgements contribute significantly to ensuring that digital interfaces can also be used in future systems and applications.

The digital interface can be used to implement not only network-oriented but also market-related requirements. For example, dynamic tariff information can be transmitted to the customer's system in the future, enabling operators to react to price signals and adjust their energy consumption accordingly. Using the interface, for example for direct marketing, opens up further market-related applications. Virtually unlimited expansion, for example for exchanging data from the connected system, is also conceivable. This enables comprehensive integration and networking of various systems and components. Thanks to the ability to expand the scope of information via updates, digital interfaces are future-proof and also suitable for upcoming requirements, such as power curves, forecast data, time-variable grid tariffs, or activation recommendations in accordance with Section 13k of the German Energy Industry Act (EnWG).

Given that devices with relays are still in use and available, this document also describes control via relays. However, managing different relay configurations for each system presents significant challenges for metering point operators and their CLS backend systems, generates additional process overhead, and increases the effort required to comply with the documentation obligations for a control system. Therefore, this description is intended solely to enable the regulated use of existing systems and a structured transition to the digital interface.

Due to the advantages outlined, VDE FNN strongly recommends the immediate use of the digital interface. The digital interface represents the clear target model that can accommodate all current and, above all, future requirements. The long-term use of relays for control is not a future-proof option and leads to limitations and a loss of flexibility for future adjustments. To avoid stranded investments, the digital interface should be used exclusively as soon as possible, as it offers the flexibility and adaptability required in a constantly evolving energy industry.

3 Control task and control concept

A control unit is assigned the complex task of controlling controllable devices in a wide variety of configurations, either directly or via an EMS using relays or a digital interface.

The VDE FNN control box specification defines the independent control of up to four controllable devices per control box. It is currently being examined whether the number of controllable devices that can be digitally connected to the control box can be increased as part of the next revision of the control box specification.

In this context, VDE FNN has already introduced the terms 'control task' and 'control concept' in its position papers on relay assignment and the digital interface to make the described complexity of the control implementation more comprehensible. These terms are explained below.

The following options are available for system control:

- one controllable device
- multiple controllable devices with EMS
- multiple controllable devices without EMS

If a property has only one controllable device, it can be directly connected to and controlled via the digital interface or a relay of the control unit.

If possible, controlling multiple systems of an operator via an EMS is preferable. Connecting via an EMS simplifies grid-friendly integration for the distribution network operator and simultaneously enables local optimisation on the operator's property. Furthermore, additional controllable devices in the operator's system can be easily connected via an EMS, simplifying market-based control. An EMS also allows the operator to integrate systems that do not have interfaces according to VDE-AR-E 2829-6-1. In this way, the operator can generally optimise all controllable devices and renewable energy systems for their specific use case (self-consumption optimisation, direct marketing, etc.) while still ensuring the controllability of systems that fall under Section 14a of the German Energy Industry Act (EnWG).

If no EMS (Energy Management System) is present on the property, several controllable devices can be connected and controlled separately via a control box or, in the future, via a smart meter gateway. The MPO provides only one network connection at the control box or, in the future, at the SMGW. If several controllable devices with a digital interface are to be used, the operator must ensure suitable network redundancy and its operation.

The control task, which is transmitted by the DSO to the responsible MPO, and the control concept resulting from these control tasks, create a defined separation between the market roles of DSO and MPO.

3.1 Control task

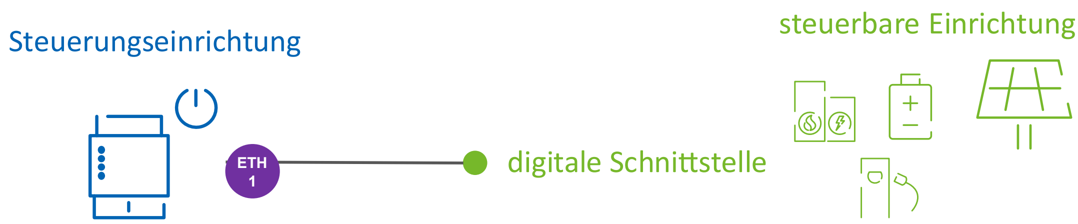
The control task is determined by the technical characteristics of the controllable device, which must be specified by the system operator or their electrical installer during registration. The DSO informs the responsible MPO of the control tasks. The MPO translates these control tasks into a control concept, selects the necessary control technology, and installs it at the operator's premises.

In individual control, the controllable device is assigned a control task by the distribution system operator. Multiple control tasks for individual controllable devices can exist within a building.

The energy management system (EMS) represents a separate control task. The connected individual controllable devices are controlled exclusively by the EMS itself.

The following control tasks can be performed using the digital interface:

I. Control of one or more controllable devices (direct control)

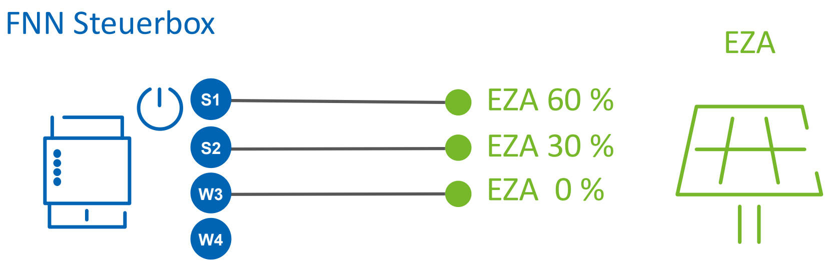


II. Control via EMS

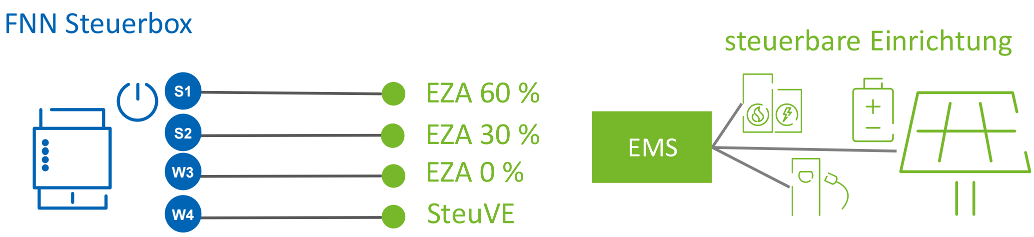
The following control tasks can be performed using relays:

III. Control of a control unit via a single contact [dimming]

IV. Step-by-step control of a power supply unit [0%, 30%, 60%, 100%]



V. Control of an EMS via relays



3.2 Control concept

The control concept is developed by the responsible MPO. This is defined by the number of control tasks reported to the MPO by the DSO. Thus, the control concept represents the connection or wiring of the control device resulting from the control tasks.

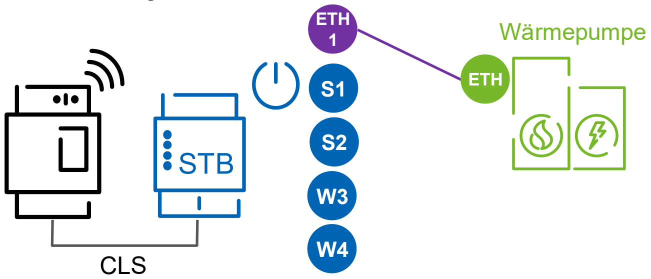
The following rules generally apply to the creation of control concepts:

- If only one control unit with a digital interface is available, it is connected directly or via a suitable network extension provided by the operator to the control device.
- If several control units with a digital interface are available, they are connected to the control device via a suitable network extension provided by the operator.
- Control concepts for the use of relays are described in detail in chapter 6. The following applies in principle:
  - All control devices according to Section 14a of the German Energy Industry Act (EnWG) (charging equipment, air conditioning, heat pump, storage) must be connected to relay W4 of the control box.
  - All energy storage units (ESAs) must be connected to relays S1 = 60%, S2 = 30%, and W3 = 0%.
- If more than four controllable devices are present, an additional control box is currently required. From the control box's perspective, the following definition applies:
  - Each digitally controlled control device = counts as one controllable device
  - All control devices according to Section 14a of the German Energy Industry Act (EnWG) with relays = count as one controllable device
  - All energy storage units (ESAs) with relays = count as one controllable device
  - Each energy management system (EMS) with a digital interface = counts as one controllable device
  - Each EMS with relays = counts as two controllable devices

Below are some **examples** of control concepts according to the rules mentioned above:[1]

Steuerungskonzept 1

1 SteuVE digital

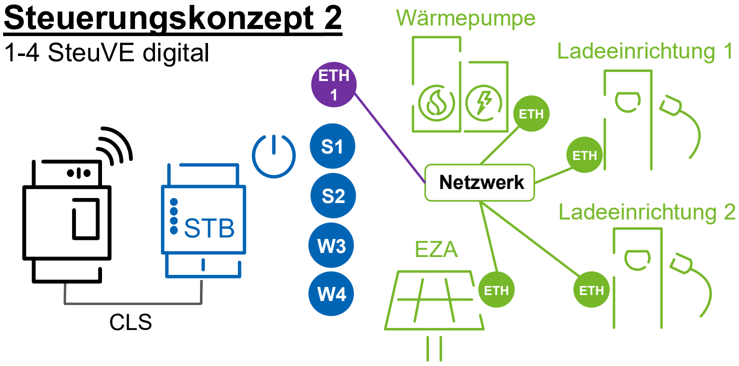


The operator has a control unit: a heat pump with a digital interface.

This is connected to the ETH1 digital interface of the control box.

Steuerungskonzept 2

1-4 SteuVE digital

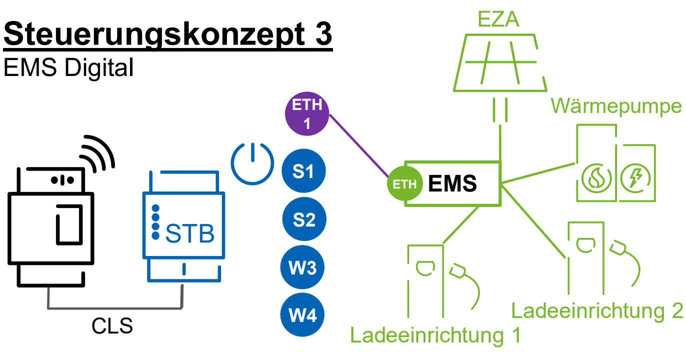


The operator has several control units with digital interfaces: one heat pump, two charging devices, and one EZA (electrical generation unit).

The operator's appropriate network is connected to the ETH1 digital interface of the control box.

Steuerungskonzept 3

EMS Digital

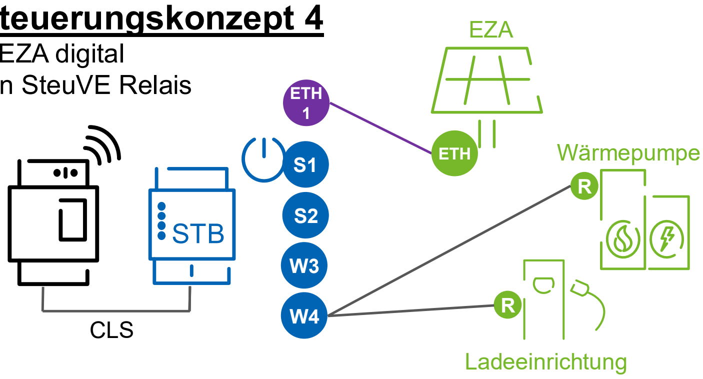


The operator has an EMS with several controllable devices: a heat pump, two charging units, and a generation system.

The operator's EMS is connected to the ETH1 digital interface of the control box.

Steuerungskonzept 4

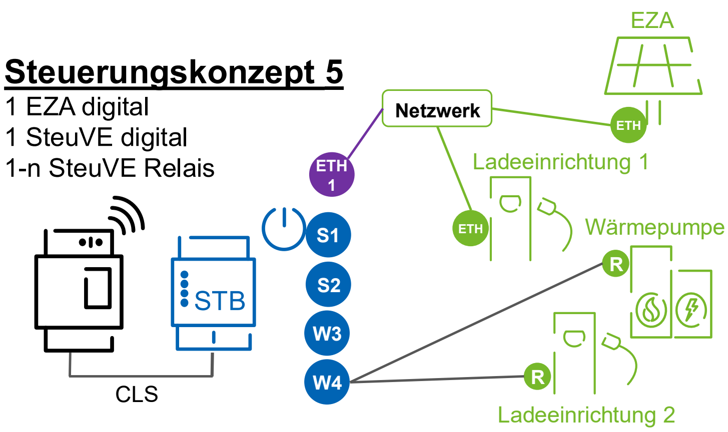
1 EZA digital
1-n SteuVE Relais



The operator has several control units: a heat pump with a relay, a charging unit with a relay, and a generation system with a digital interface.

The generation system is connected to the digital interface of the control box, and the two control units are connected to relay W4.

[1] It should be noted that, according to the definitions in this document, an EMS also counts as a controllable device.



The operator has several control units: a heat pump and a charging unit with a relay, as well as a generation system and a charging unit with a digital interface. The digital interface of the control box is connected to the operator's network. The two control units with relays are connected to relay W4 of the control box.

4 Requirements for a standardised digital interface

This chapter describes the criteria and requirements for a digital interface between the control device and the controllable device. This enables simple, standardised applications and interoperability when using a control unit in conjunction with the controllable devices of a property, both at the device level on-site and in downstream IT systems.

4.1 Basic requirements

With the control box specification, [2] VDE FNN offers a comprehensive requirements specification for a control unit, developed through several years of collaboration between users and manufacturers. This specification enables the standardised connection of controllable consumption and feed-in devices via smart metering systems, thus fulfilling applicable legal requirements.

Communication between a control box and its backend system, the control box administrator, is designed in accordance with the internationally recognised communication standard IEC 61850. The IEC 61850 series of standards not only contains syntactic and semantic rules for modelling exchangeable information, such as measurement data or status information, and addressable control elements in a data model, but also defines the actions applicable to such a data model in the form of communication services. In other words, the IEC 61850 communication standard describes both the '*what*' and the '*how*' of data transmission, thus enabling the complete definition of a communication interface at the application level.

Towards the controllable device, the control box can output received power values either via relays or use bidirectional communication via a digital interface. As also explained in VDE FNN Impulse 'Implementation of the digital interface on controllable device or on an energy management system', [4] the communication interface must be supported by both the control device and the operator's controllable device in a mirrored manner to achieve interoperability.

Since version 1.3, the control box specifications include two specifications for the implementation of a digital interface: one using the EEBUS communication standard and the other using KNX. The control box converts the relevant data into the appropriate format for transmission via the digital interface.

The digital interface specification uniformly defines both the data structures and the communication services. A pure transmission protocol such as MQTT, or even a pure data description language such as XML or JSON, cannot, on its own, provide a sufficient definition of a communication interface, as, among other things, the semantic description of the data structures is lacking.

The specific features of the digital interface were developed by the respective stakeholder group, taking into account the fundamental requirements described here, as a specification for the control box requirements specifications. The integration in the form of an appendix to the requirements specification was carried out in close cooperation with VDE's Control Box FNN project group.

The following principles, summarised below and described in more detail in the subsequent chapters, are considered requirements for a digital interface of a control device.

Criteria for the design of the digital interface:

- Normative standardisation of defined communication protocols, data structures, and a uniform application layer
- Availability, accessibility, and currency of the protocol specifications
- Active participation of experts in the detailed specification within the context of the intended use

- Feasibility of the use cases from sections 4.1.1 and 4.1.2
- Inherent security standards or compatibility with recognised security standards (see section 4.1.3)
- Interoperability and the possibility of conformity testing (see section 4.2)

4.1.1 Connectivity

The physical communication connection between the control box and the controllable device is established via a dedicated Ethernet interface. Additional network components (WiFi bridge/router) also enable the connection of controllable devices with wireless communication interfaces (e.g. WiFi) within the customer's installation.

To establish a logical communication connection, the controllable device MUST support IP-based communication using IPv4 or IPv6.

This can be achieved through a combination of various existing methods for dynamic address configuration (DHCP or Zero/AutoConf), automatic discoverability of the controllable device (e.g. mDNS), and a description of the services offered (e.g. mDNS-SD). This allows for the largely automatic establishment of a communication connection between the control device and the controllable device.

VDE FNN recommends clearly displaying the identification mark used (e.g. serial number or name) on the controllable device. Commissioning is significantly simplified because necessary information can be collected directly on-site. The VDE FNN specifications for the basic meter, the smart meter gateway, and the control box stipulate the use of a Data Matrix code (2D barcode) that provides the manufacturer-independent serial number as an identification feature.

Static configuration of IP addresses for devices is only conditionally applicable in this scenario, as this method incurs additional manual effort for connecting the controllable device to the control unit during installation and commissioning.

For data exchange between the control unit and the controllable device, connection-oriented transport protocols (e.g. TCP) should primarily be used, as these do not require additional mechanisms such as order integrity or reliability. When using modern communication protocols, the controllable device should assume the 'server' communication role, and the control unit the 'client' communication role. Care should be taken to ensure that these support the establishment of a direct communication connection, as dependence on additional communication infrastructure (e.g. message brokers) may reduce availability.

4.1.2 Functions

The following functions must be supported by the controllable device when using the digital interface for control.

4.1.2.1 Transmission of active power limitation to the system

Active power limitation allows a power limit to be set for the controllable device. The active power limitation is transmitted from the control device to the controllable device when a communication connection is established.

4.1.2.2 Confirmation and acceptance of active power limitation by the system

The successful acceptance and timely physical implementation of the active power limitation request by the controllable device must be confirmed and is logged by the control device in the operating log. Failure to confirm the active power limitation is also logged.

4.1.2.3 Feedback on the current power value of the system

The feedback on the current power value of the controllable device includes the ability to read the current active power limits (consumption and generation) as well as the current active power value. In addition, the reading of the power value for the grid connection point is also provided.

4.1.2.4 Cyclic connection monitoring

Cyclic connection monitoring ensures the reliable controllability of the controllable device. Furthermore, connection monitoring in the controllable device can be used to detect a communication failure with the control unit and subsequently assume a defined, safe state (failsafe state).

4.1.2.5 Failsafe function

The failsafe function ensures a deterministic operating state in the event of a communication failure between the control unit and the controllable device. For this purpose, the failsafe power limits (consumption and feed-in) and their duration are transmitted to the controllable device while a communication connection exists. In the failsafe state, these power limits are used by the controllable device for the specified duration.

4.1.2.6 Standardised (typed) data model or self-description

To ensure high interoperability between the control unit and various controllable devices, the use of a standardised communication protocol with a typified data model is essential and facilitates easy commissioning. Proprietary protocol solutions unnecessarily increase the effort required for establishing connectivity and commissioning, thus hindering mass adoption. Optional self-descriptive capability enables simple fault diagnosis in case of problems.

4.1.2.7 System information and status

System information and status refer to data used for the operation, monitoring, and description of a system. The following information should be provided by the controllable device:

- System malfunction
- System identification
- Manufacturer name
- Product designation
- Serial number
- Hardware revision
- Software revision

4.1.3 Security

Given the ever-increasing threat of attacks on critical infrastructure, the use of a secure and trusted communication connection is essential for the communicative link between the control box and a controllable device.

When using TCP as the transport protocol, the existing TLS standard (RFC 5246) is suitable for establishing secure and trusted communication connections. It is important to ensure that TLS is used and that the requirements of the German Federal Office for Information Security's (BSI) Technical Guideline TR-03116-

3 regarding cryptographic methods, permissible key lengths, and recommended certificate validity periods are observed. Therefore, the use of TLS in accordance with the BSI's specifications is the security option preferred by VDE FNN for digital interfaces. For alternative security options, proof of equivalence must be provided.

To establish a secure and trustworthy communication connection, authentication of the communication participants is also necessary, as otherwise neither the control device nor the controllable device can guarantee communication with the intended participant.

When using TLS, the use of communication certificates according to the X.509 standard is a common method for establishing the necessary trust relationship between the communication partners. Since no suitable methods for automatically establishing this trust relationship between the control unit and the controllable device are currently available, manual support is necessary during the initial trust establishment process.

One way to manually establish this trust relationship is to introduce unique identifiers of each communication partner. These identifiers can then be used for semi-automatic or automatic identification and authentication of the communication partners.

If a trust relationship is to be established between the control box and the controllable device, the manufacturer-independent identification number (HUID) is a suitable option, as it is used as a barcode on the control box's housing and in the communication certificate. Since the HUID is not cryptographically linked to the control box's communication certificates, the establishment of the trust relationship requires a one-time manual verification of the HUID.

Establishing the trust relationship is yet simpler if the identifier of the controllable device corresponds to the communication certificate used or is linked to the communication certificate via cryptography.

To ensure that the trust relationship established during commissioning between the control device and the controllable device is maintained beyond the validity period of the initial communication certificates, a (semi-) automatic exchange of communication certificates is essential. Otherwise, each certificate change necessitates a manual re-establishment of the trust relationship, incurring associated personnel costs.

For this purpose, the controllable device should support the temporary parallel operation of multiple communication certificates during the exchange process. This allows the controllable device to generate a new certificate (with the corresponding key pair) in addition to the existing certificate and then initiate the exchange process with the control device. Once the control device has confirmed the exchange of the controllable device's communication certificate, the controllable device can discard the previous certificate and use the new, confirmed certificate going forward. The control device can also exchange its communication certificate with the controllable device in the same way.

4.2 Conformity

VDE FNN develops and provides corresponding test case specifications for the components of smart metering systems described in VDE FNN specifications for the basic meter, smart meter gateway, and control box. Based on the test results, a VDE FNN EN MeKo conformity certificate can be issued.

The VDE FNN test case specification for the control box enables standardised testing of conformity to the requirements specification in the control box specification. Each requirement is covered by at least one test case. The VDE FNN test case specification for the control box thus contains test cases for the design, functions, and their implementation and mapping using the IEC 61850 communication standard. Corresponding test cases must also be available for the described implementation(s) of a digital interface for communication with a controllable device. These test cases are developed with the participation of experts from the respective stakeholder groups in collaboration with VDE's 'control box test cases' FNN project group.

Demonstrating conformity with the requirements specification in the specifications fosters confidence in product quality and contributes to the overarching goal of achieving interoperability and interchangeability in the device and system technology environment. However, a positive conformity test result alone – especially at the digital interface – is not a sufficient condition for interoperability. Firstly, VDE's FNN 'control box test cases' expected to be published in the fourth quarter of 2024, refer only to the control box, which is the responsibility of the building management system (BMS), and not to a controllable device. Secondly, the requirements, and consequently the test cases, are largely at the functional level. Although implicitly included in some functional test cases, the testing of the structure and content data of communication messages is not an explicit objective of VDE's FNN test case specification.

It is the responsibility of the experts of the stakeholder group that maintains the communication standard used at the digital interface to close these two gaps. Protocol-specific test cases can be performed for all communication partners, regardless of the application. Additionally, it is recommended to create a way to test and confirm the functional behaviour of a controllable device, insofar as it involves the processing of messages at the digital interface.

4.3 Further aspects for processes, installation, and setup

In addition to standardising the communication interface and the functions it represents, a simple and standardised commissioning and operating process is also necessary. Only in this way can sufficient mass-market suitability be achieved, which should ensure a low error rate during commissioning and operation. This increases the acceptance of all parties involved and enables rapid commissioning and troubleshooting. Furthermore, this also simplifies the training of technicians, service providers, and electrical contractors and accelerates the rollout.

Important process-related aspects, not only from the perspective of the distribution network operator or the responsible metering point operator, are listed below.

First, the commissioning process of the controllable device or the energy management system (EMS) should be mentioned. This must be 'plug and play' and accessible to any technician without special tools, e.g. via a browser, control panel, or commissioning button. All device parameters necessary for setup must be readable locally on the devices by the MPO technician and recordable for configuration in the MPO's backend systems, e.g. via a QR code.

Furthermore, process identity in the backend systems is of fundamental importance. This can only be guaranteed through consistent identification technology during commissioning and operational processes. It should also be possible to electronically capture the authorisation for login (e.g. QR code).

To avoid costly troubleshooting processes, the operator must not be able to change the authorisation credentials during operation. A certificate-based approach is preferable.

Another important aspect is that for troubleshooting management, the following applies: For example, when replacing identical customer systems, the necessary device parameters must be readable locally on the devices and recordable for setup in the backend systems, e.g. via a QR code.

In principle, any support for additional standards can be implemented by the operator in the form of an EMS or protocol converters.

The interoperability of the digital interface must be guaranteed when the MPO's control unit is changed.

Finally, versioning and update processes, as well as the backward compatibility of the digital interface, must be ensured and guaranteed.

5 Design of the digital interface on controllable devices or on an energy management system

The interoperable design of the digital interface for control (IF_CLS_CTRL, see Image 2 and Image 3) is of central importance.

The interoperable design of the interface offers several advantages:

- The behaviour and response of a controllable device are defined and known. This defines the interaction between the control device and the controllable device, thereby significantly simplifying the implementation of the control system.
- The effort required for installation and commissioning can be reduced through harmonisation.
- Changes in device technology are also facilitated during troubleshooting.
- Planning reliability is created because the energy service provider, operator, and manufacturer can rely on a defined interface.

Since the operator's controllable device is typically connected to the control unit of the metering point operator at this interface, the interface represents a transfer of responsibility between the two parties. For the components to interact smoothly, the interface must conform to uniform specifications. This chapter describes the mirror-image, compatible interface of the controllable device, building upon the digital interface of the control unit.

Accordingly, this chapter refers to cases where a clear transfer of responsibility occurs and defines how information on performance limitations is transmitted via the interface. The interface is thus described up to the application layer. The direct connection of a controllable device to the CLS interface of the smart meter gateway using only the SMGW's TLS proxy functionality without specifying the application protocol used is not described.

5.1 Overview of components and interfaces

The control unit can either be implemented as a separate device in the form of an FNN control box or, in the future, integrated into an SMGW. The following diagrams illustrate the options for connecting a control unit (SteuVE) or an energy management system (EMS). This document and VDE FNN requirements specifications focus on the IF_CLS_CTRL interface. However, all components and interfaces involved are described below for both diagrams. In Image 2 and Image 3, the two locally involved areas of responsibility are indicated, and it becomes clear that the IF_CLS_CTRL interface marks the transfer of responsibility between the energy supply operator and the operator of the controllable device. Image 2 and Image 3 (especially the arrows) illustrate the logical connection between the control unit and the controllable device (including the EMS) and do not make any statements regarding the ownership of the connection technology.

Image 2 shows the control unit as an FNN control box, i.e. as a separate physical device. Either one or more control units (SteuVE) can be connected, or an EMS that controls the power output in the operator's system accordingly.

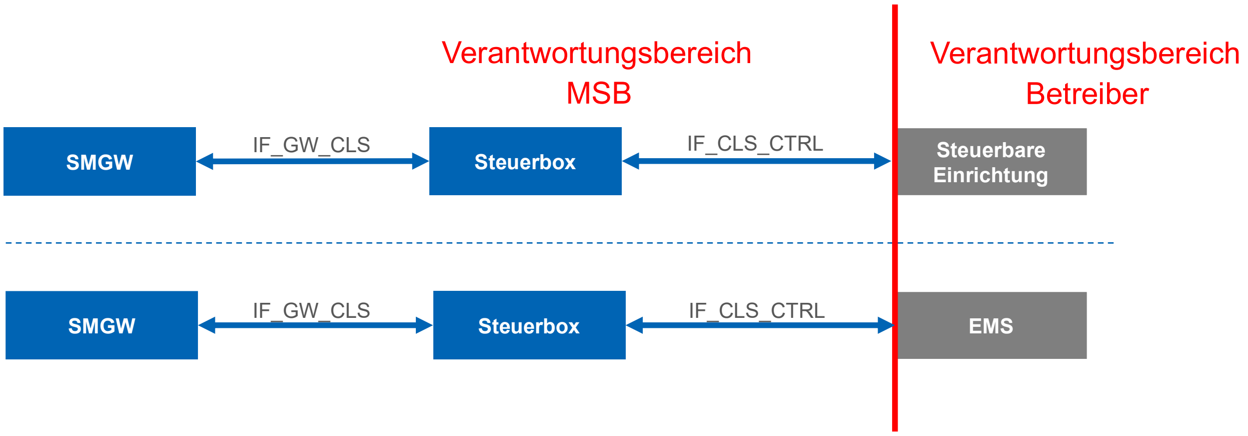


Image 2 Logical connection of the controllable device/EMS to the FNN control box

The following is an overview of the individual components and interfaces from Image 2:

SMGW: SMGW compliant with BSI protection profile PP0073 and BSI Technical Guideline TR-03109-1, which provides the CLS channel. For this purpose, the SMGW establishes a TLS channel to the backend system and the control box, via which the information is forwarded transparently.

IF_GW_CLS: CLS interface via which the SMGW enables the connection of CLS components. The CLS interface is defined by the specifications of BSI Technical Guideline TR-03109-5.

Control box: Control box compliant with VDE FNN specifications for control boxes and BSI Technical Guideline TR-03109-5. The CLS channel originating from the SMGW is terminated in the control box, and the control box transmits the control commands for the operator's systems via IF_CLS_CTRL.

IF_CLS_CTRL is a digital interface through which control specifications are exchanged with the operator's system. IF_CLS_CTRL is the subject of this brief and is described in more detail below.

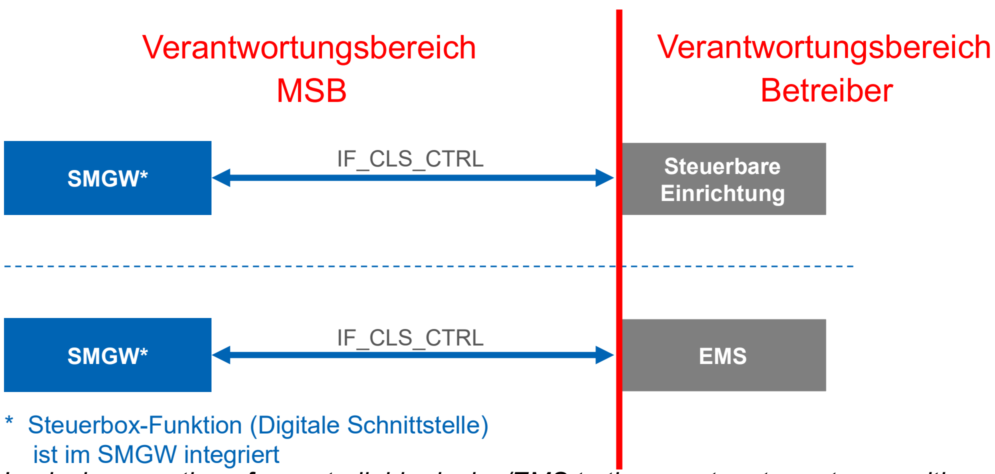


Image 3 Logical connection of a controllable device/EMS to the smart meter gateway with an integrated control interface

Image 3 shows the implementation of the control device as an integrated function in the SMGW. This implementation is anticipated by the Federal Network Agency's determination regarding Section 14a of the German Energy Industry Act (EnWG) and should be considered when developing the recommendations for clause 2a.

SMGW: The SMGW complies with BSI protection profile PP-0073 and BSI Technical Guideline TR-03109-1, which provides the digital control interface. This future development is anticipated in this document in accordance with the Federal Network Agency's guidelines.

IF_CLS_CTRL: As described in Image 2, but via the existing physical CLS interface of the SMGW. In the future, the SMGW will thus provide both the CLS proxy functionality and the digital control interface at this physical interface.

The following section discusses the IF_CLS_CTRL interface, the illustrated use cases, and the protocols to be used in detail.

5.2 Use cases for control actions

The current VDE FNN (Association of German Energy Companies) specification for control boxes defines the following use cases for controlling the controllable device via the digital interface of the control device:

- Active power limitation (supply)
- Active power limitation (generation)
- Provision of system data

The use cases for active power limitation (supply) and generation enable separate limitation of the supply and feed-in power of the controllable device. The specification for control boxes defines a series of control functions separately for supply and feed-in limitation.

Each control function has one or more control commands and can be executed at fixed or recurring times. This enables the distribution system operator to persistently store multiple control commands in advance on the control unit. The control unit then executes the stored control commands autonomously, independent of a communication connection to the DSO. This approach also allows for the control of a large number of systems via a limited communication infrastructure.

The current specifications for the control box already include additional control functions that enable the integration of other authorised controllers (e.g. aggregators). These control functions have a lower priority and are only executed when no DSO control function is active.

In addition to limiting the active power consumption and feed-in of the controllable device, the specifications for the control box also define the use cases for recording the current active power consumption or feed-in power of the controllable device or the grid connection point. In addition to the use cases, the control box specifications define the following technical functions:

- Connection monitoring
- Failsafe behaviour

For connection monitoring, the control unit must cyclically monitor an existing communication connection to the system. If a communication fault is detected, the control unit must log it and initiate a timely re-establishment of the communication connection. Control commands must be rejected during a communication fault, and the failure to execute them must be logged for later verification purposes.

The system behaviour during a communication fault is determined by the failsafe behaviour. When a communication connection is active, the control unit transmits the limit values for the use cases 'active power limitation consumption' and 'active power limitation feed-in' and the maximum duration of these limit values to the system.

In the event of a communication fault, the previously transmitted limit values must be adhered to by the system for the specified duration to ensure defined system behaviour. If the communication link is not restored within the specified time period, the system is no longer obligated to comply with the limit values after this period has expired. If the fault lies within the operator's area of responsibility, it must be rectified immediately, or the system must otherwise be permanently limited to the minimum power consumption.

5.3 Basic information on the IF_CLS_CTRL interface

The use cases of the IF_CLS_CTRL digital interface are defined in the application rule VDE-AR-E 2829-6-1. The technical information exchange via IF_CLS_CTRL is described in the form of generic, technology-agnostic use case functions. The application rule does not define a device or system architecture model, device properties, or a location relative to a device.

The following technical use cases from VDE-AR-E 2829-6-1 are implemented in IF_CLS_CTRL:

1. Limitation of active Power Consumption (LPC)
2. Limitation of active Power Production (LPP)
3. Monitoring of Power Consumption (MPC)
4. Monitoring of Grid Connection Point (MGCP)

The terms LPC, LPP, MPC, and MGCP are use case designations from VDE-AR-E 2829-6-1, used for limiting grid-relevant power consumption in accordance with the BNetzA decision BK6-22-300.

For the implementation of use cases 1 and 2 – limitation – IF_CLS_CTRL provides support for the following scenarios:

- Transmission of a limit for the reference value
- Transmission of a limit for the generation value
- Transmission of a heartbeat
- Transmission of the failsafe parameters

In the event of a fault during the heartbeat exchange, the controllable device reverts to the behaviour that was previously transmitted as the failsafe behaviour.

Measured values from a controllable device can be transmitted via use cases 3 and 4 – monitoring.

Image 4 This summarises the use cases from VDE-AR-E 2829-6-1 at the IF_CLS_CTRL interface:

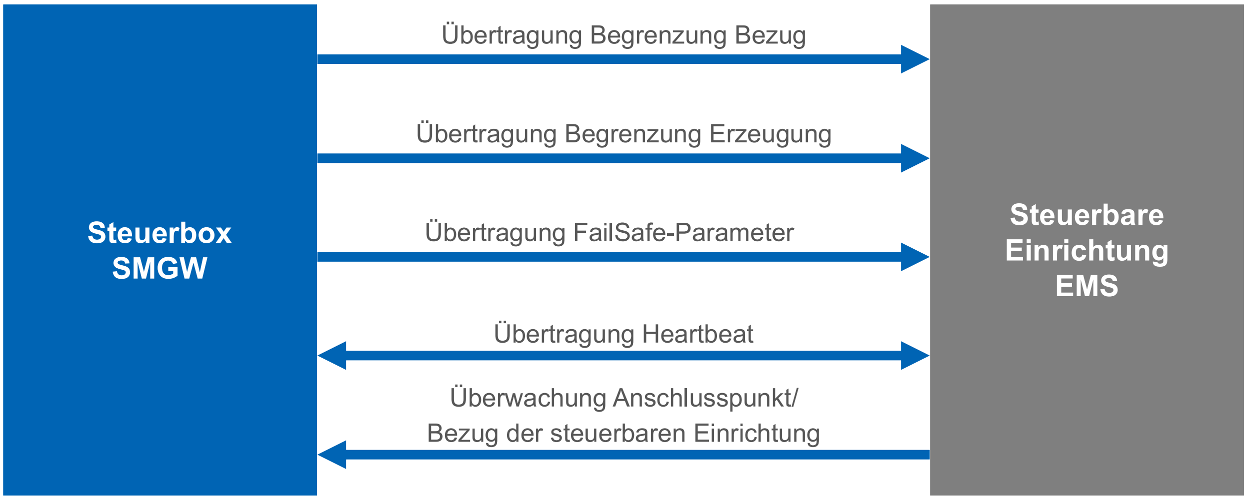


Image 4 VDE-AR-E 2829-6-1 at the IF_CLS_CTRL interface

To cover future requirements, the list of use cases and scenarios to be implemented in IF_CLS_CTRL can be expanded.

5.3.1 Protocol characteristics of the IF_CLS_CTRL interface in EEBUS

The VDE FNN specification for control boxes defines system control via the digital interface of the control device using the EEBUS communication protocol, which is specified in parts 2, 3, and 4 of VDE application rules VDE-AR-E 2829-6.

The protocol stack is shown and explained in Image 5.

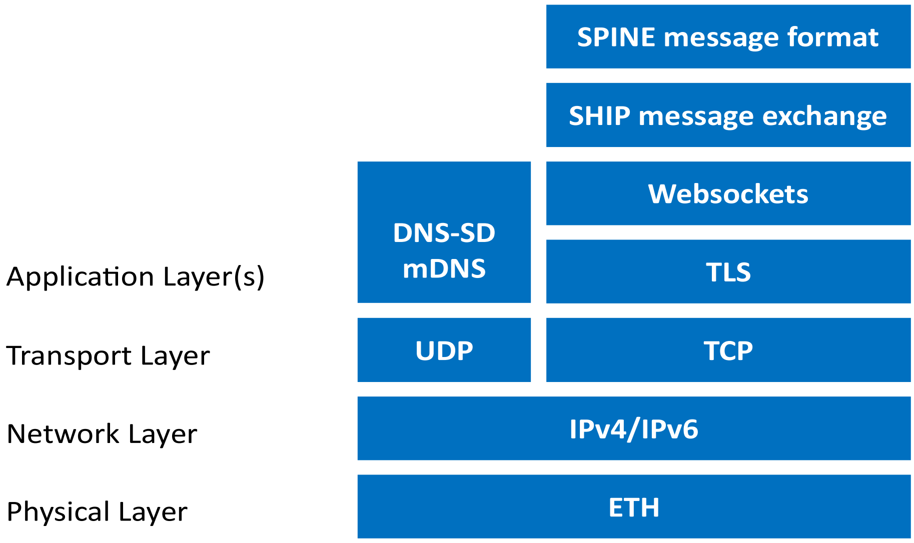


Image 5 EEBUS protocol stack

At the lowest communication level, the connection between the control device and the controllable device is exclusively via Ethernet. For communication between components, EEBUS supports both Internet Protocol version 4 (IPv4) and Internet Protocol version 6 (IPv6) at the network level, supporting both static and dynamic IP addresses. For communication scenarios without additional infrastructure, EEBUS also supports the automatic configuration of IPv4 or IPv6 addresses.

For mutual discovery between EEBUS components, mDNS (RFC 6762) and DNS-SD (RFC 6763) are used. Each EEBUS component publishes a description of the SHIP service described below using DNS-SD.

For data exchange between EEBUS components, TCP is used as the transport protocol with TLS in the version specified by the SHIP specification according to VDE-AR-E 2829-6 (currently version 1.2) as the security layer, and WebSockets (RFC 6455) as the application protocol. The Websockets connection is used to exchange user data in JSON format (according to Smart Home IP, aka ‚SHIP' specification), which is described in part 4 of VDE-AR-E 2829-6. Part 4 additionally defines the requirements for the TLS certificates used and the automatic process for updating the X.509 certificates during operation.

The implementation of the use cases 'LPC/LPP' and 'providing performance data' is carried out in EEBUS via use cases. The protocol messages associated with a use case are represented in the SPINE data model (Smart Premises Interoperable Neutral-Message Exchange), which is described in Part 3 of VDE-AR-E 2829-6.

The use case 'PLC' (1.) is represented by the EEBUS use case LPC, while 'LPP' (2.) is implemented by the EEBUS use case LPP. These EEBUS use cases also include the necessary functions for connection monitoring (heartbeat), failsafe behaviour, and confirmation of a successfully executed control command. The additional EEBUS use cases MPC and MGCP provide the performance data of a controllable device (3.) or the network connection point (4.).

5.3.2 Protocol characteristics of the IF_CLS_CTRL interface in KNX

The VDE FNN specification for control boxes defines system control via the digital interface of the control device using the KNX communication protocol, which is specified in VDE application rule VDE-AR-E 2849-7.

The protocol stack is shown and explained in Image 6.

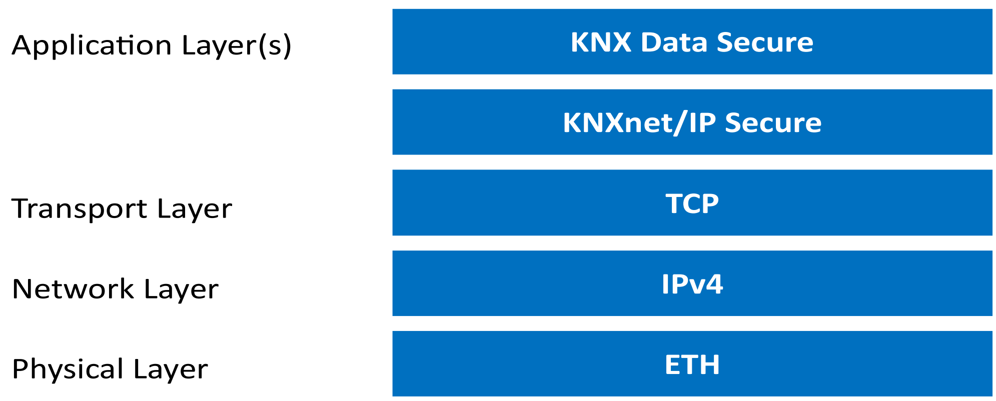


Image 6 KNX protocol stack

At the lowest communication level, the connection between the control device and the controllable device is exclusively via Ethernet, even though KNX specifies other wired and wireless communication technologies. For communication between components, KNX supports IPv4 with automatic IP address configuration at the network level.

[Image: KNX protocol stack] For secure data exchange between KNX components, TCP is used as the transport protocol with KNXnet/IP Secure according to DIN EN ISO 22510 as the security layer and KNX Data Secure as the application protocol. Authorised communication partners are identified via the device identification code or tool key, or the assigned password (Diffie-Hellman). Encrypted user data is exchanged via KNX Data Secure, as described in DIN EN 50090-3-4.

The implementation of the use cases active power limitation, consumption/generation, and provision of system data is carried out in KNX via so-called function blocks with associated group objects. The protocol messages are displayed according to standardised data point types, which are described in DIN EN50090-3-3.

The use case 'LPC' (1.) is implemented using the 'Limitation of Power Consumption' (LPC) function block, while 'LPP' (2.) is implemented using the 'Limitation of Power Production' (LPP) function block. These function blocks also include the necessary functions for connection monitoring (heartbeat) and failsafe behaviour. The additional function blocks 'Monitoring of Power Consumption' (MPC) and 'Monitoring of Grid Connection Point' (MGCP) provide the power data of a controllable device (3.) or the grid connection point (4.).

6 Design of a standardised interface when using relays in an FNN control box

The VDE FNN impulse 'Design of a standardised interface on a controllable device or an energy management system for connection to an FNN control box' [6] proposed a standardised interface using two relays for controllable devices (FNN-2bit). The comments and feedback received regarding this VDE FNN Impulse indicated a desire for simplicity and adherence to established solutions. Therefore, the FNN-2bit solution will not be considered.

Relay control will be implemented uniformly as follows:

Control unit: one relay with the status 'dimmed' when activated and 'enabled' (unrestricted operation) when deactivated

Relay W4	Control unit according to Section 14a of the German Energy Industry Act (EnWG)
0	Enabled (unrestricted operation)
1	Dimming (guaranteed minimum power supply, Section 14a)

Electricity Supply Unit (ESU): three relays for the power levels 60%, 30%, and 0%

Relay S1	Relay S2	Relay W3	Generation
0	0	0	100%
1	0	0	60%
0	1	0	30%
0	0	1	0%

This use of relays allows existing systems to be integrated and controlled without extensive modifications.

A control box with four relays can thus be used to control an ESW and a control unit.

6.1 Basic control concept when using relays

The following control concept (Image 7) is recommended as the basic control concept for standardised use with a control box:

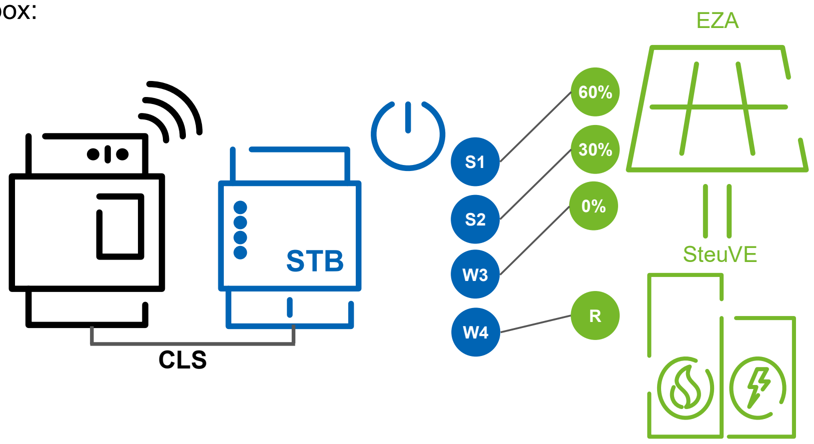


Image 7 Basic control concept for connecting controllable devices to an FNN control box using relays

With this basic control concept when using relays, all controllable devices controlled via relays can be connected to a control unit.

- All control units with 'single contact' are connected to relay W4 of the control box
- All energy storage units with 'step control' [100%, 60%, 30%, 0%] are connected to the control box via relays S1=60%, S2=30%, and W3=0%. If no relay S1, S2, or W3 is activated, the energy storage unit is enabled at 100%.
- All EZAs with 'single contact' [0%, 100%] are connected to the control box via relay W3. When relay W3 is closed, the EZA is reduced to 0%, and when W3 is open, the EZA is enabled at '100%'.

Controllable devices should be connected to the control box via coupling relays. This means that a separate coupling relay must be provided for each control unit (SteuVE), or three coupling relays for EZAs. This ensures safe galvanic isolation and more flexible connection of existing systems, for example, through the use of coupling relays with changeover contacts.

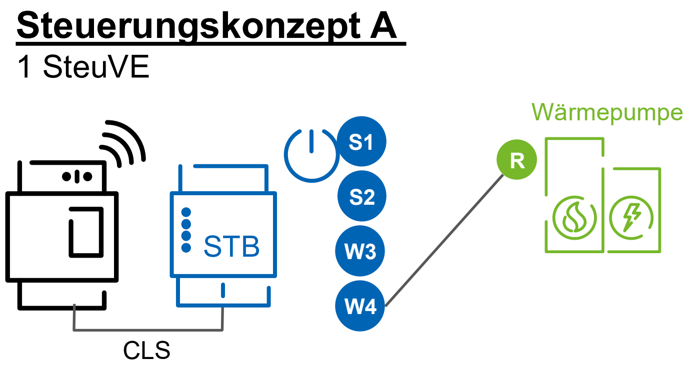
The basic control concept has the following advantages:

- Simple wiring of the customer's system to the control box of the metering point operator through a uniform relay assignment: W4 for SteuVE and S1, S2, W3 for EZAs
- Avoidance of errors when wiring the customer's system to the control box because only one basic control concept is used.
- Existing systems can be easily connected to the new control box. Only the coupling relays need to be retrofitted.
- Electrical installers only need to use one control concept. This reduces training requirements and ensures consistency across all distribution networks.
- This forms the basis for a nationwide standardised control concept for all distribution network operators and metering point operators
- Less space is required in the customer's installation, as only one control box with the associated coupling relays needs to be installed. This can lead to savings for the operator, as less space may be required in the meter cabinet, thus eliminating the need for costly retrofits.

6.2 Application examples

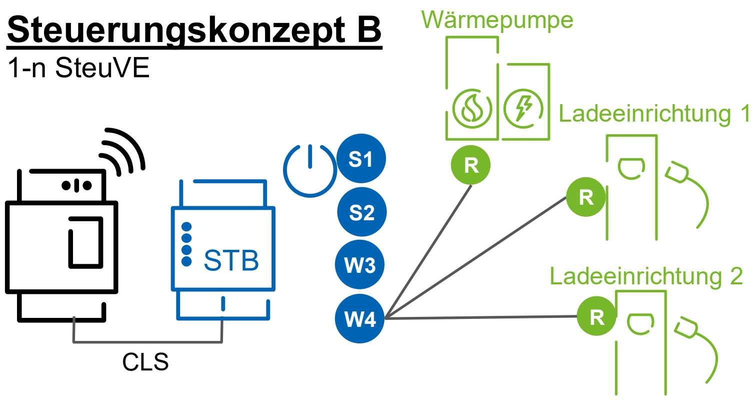
This section shows examples of how controllable devices are connected to the control box.[2]

It can be seen that no changes are made to the wiring during an expansion, and the assignment is always the same: control unit (SteuVE) on W4 and energy supply unit (EZA) with step control on S1, S2, W3, or, for energy supply units with a single contact, only W3.



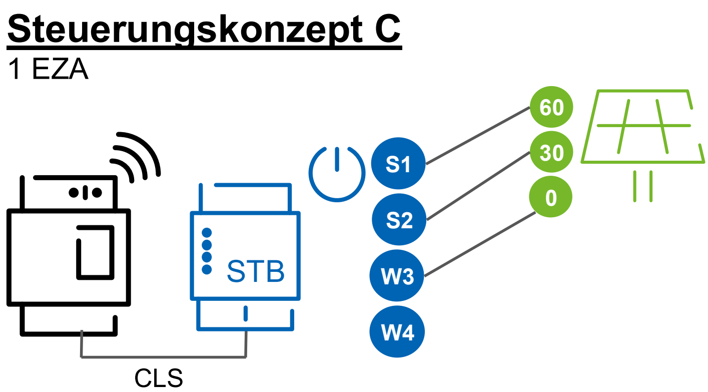
The operator has a control unit (SteuVE): a heat pump

This is connected to relay W4 of the control box.



The operator has several control units: a heat pump and two charging stations.

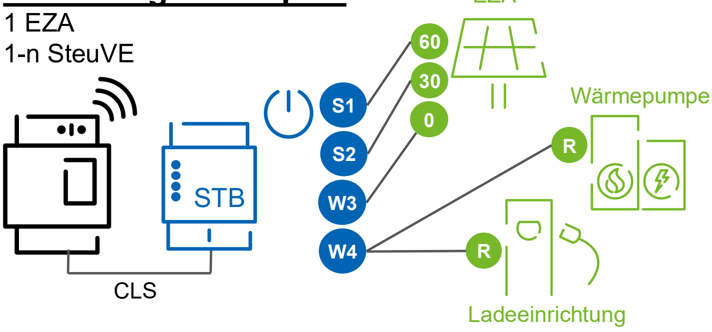
All control units are connected to relay W4 of the control box.



The operator has a single-use generator (SEG) that can be controlled in steps of 0%, 30%, 60%, and 100%. This is connected to relays S1 (60%), S2 (30%), and W3 (0%).

[2] It should be noted that, according to the definitions in this document, an EMS also counts as a controllable device.

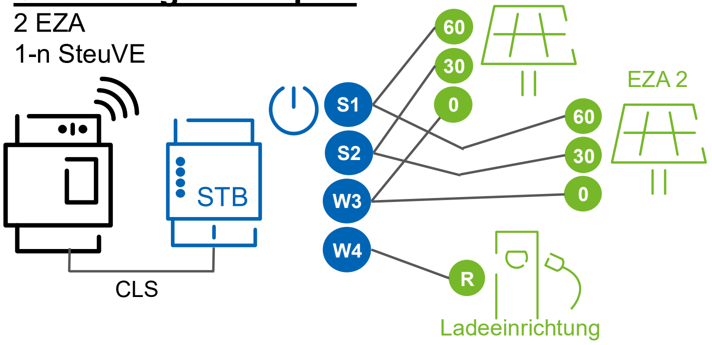
Steuerungskonzept D



The operator has two control units: a heat pump and a charging device. These are connected to relay W4 of the control box.

Furthermore, the operator has one EZA (Energy Transfer Unit), which can be controlled in steps of 0%, 30%, 60%, and 100%. This is connected to relays S1 (60%), S2 (30%), and W3 (0%).

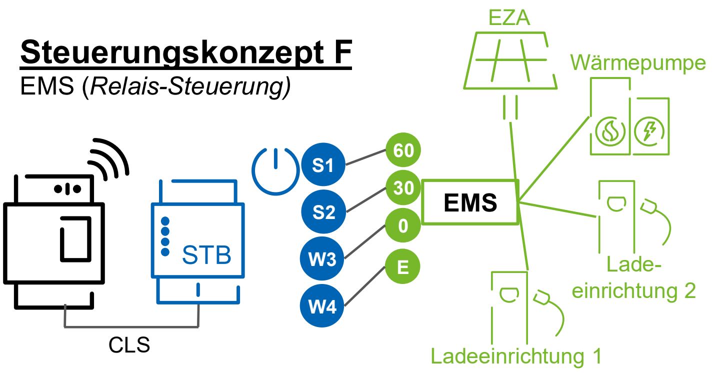
Steuerungskonzept E



The operator has one SteuVE (Control Unit): a charging device. This is connected to relay W4.

Furthermore, the operator has two EZAs, which can be controlled in steps of 0%, 30%, 60%, and 100%. These are connected to relays S1=60%, S2=30%, and W3=0%

Steuerungskonzept F



The operator has an EMS (Energy Management System), which is controlled via relays. The EMS controls three SteuVEs and one EZA.

Relay W4 is connected to the EMS for dimming the SteuVEs and is used for the step-by-step control of the EZAs (S1=60%, S2=30%, and W3=0%).

Note: For all control units (SteuVE) controlled by an EMS, the minimum power requirement must be determined taking into account an appropriate simultaneity factor. This minimum power requirement must be parametrised in the EMS by the system operator. The calculation of the minimum power requirement is explained in detail in VDE FNN guideline 'Grid operation with flexibilities'. [7]

In summary, the application examples are intended to illustrate that, using the basic control concept, any combination of control units (SteuVE) and energy storage systems (EZA) controlled via relays can be connected to a control box.

7 VDE FNN recommendation

For clause 2a of BK6-22-300, VDE FNN, representing grid operators and with appropriate participation from all relevant market participants, will submit the developed state-of-the-art recommendations on 1 October 2024. The basis for the state of the art is the currently valid VDE FNN Specification for control boxes, from Version 1.4 dated August 2024.

According to VDE FNN Specification for control boxes, the connection of controllable devices to a control unit is possible either via relays or via the digital interface. Due to the advantages and perspectives outlined, the connection via a digital interface is considered the target model (see Chapter 2).

If the use of relays is also necessary during a transition period, it is recommended to use the basic control concept (see Chapter 6).

For the design of the digital interface between the control unit and the controllable device, standardised protocols must be used in the energy sector context, as described in this document and in VDE FNN Specification for control boxes. In Version 1.4, the implementations using EEBUS and KNX are described in the appendices, based on elements of VDE-AR-E 2829-6-1. The characteristics of a digital interface cannot be reduced solely to a protocol or standard designation. The criteria and features mentioned in this document serve as a reference and benchmark and represent the requirements and effects necessary in the energy sector context.

When developing the recommendation for clause 2a, a balance was struck between the multitude of protocols available on the market and their manageability in practical application. This consideration was addressed by the two protocols defined in the control box specifications. The use of EEBUS for the interface between the control device and the controllable device is already available and has been successfully tested in funding projects and real-world laboratories, among other things.

Long-term development depends on demand, supply, and market acceptance.

8 Subsequent procedure

With this document, the network operators, with the participation of all relevant market partners and coordinated by VDE FNN, submitted their recommendation on the state of the art to the Federal Network Agency by the deadline of 1 October 2024. The recommendation submitted to the BNetzA will subsequently be published on the BNetzA website and made available for public consultation. Following the consultation, the BNetzA will issue a notification regarding the final documents.

As practical experience grows, the recommendations mentioned in this document must be reviewed. This is also taken into account in the BNetzA's decision BK6-22-300, specifically in clause 2, which states that the recommendations must be 'reviewed by the network operators at least every 3 years in accordance with the state of the art, updated if necessary, and submitted to the Federal Network Agency'.

9 Bibliography

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