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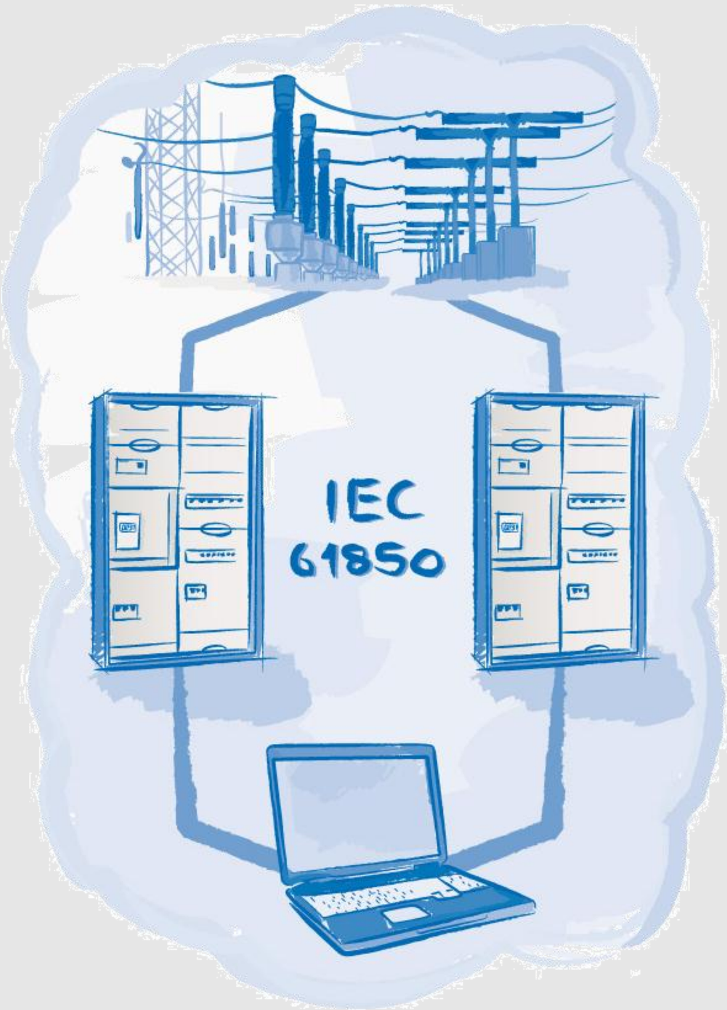

IEC 61850 from the user perspective

User Recommendation

December 2012

VDE

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1. Goal

In 2004, IEC 61850 was published, a communication standard for substations, which offers various advantages over the protocols of the IEC 60870 series if the concepts, services, and procedures laid out in the standard are utilized consistently. This paper highlights the aspects that may assist in the decision to utilize IEC 61850 in a company's substation in the future. It elaborates on the factors to consider for profiling, design of solutions, tendering and operation.

To further show that closer consideration may indeed be necessary, please see the following two quotes:

First quote (PAC.SUMMER.2009, S.20, Christoph Brunner (Brunner, 2009))

"…though a device can be compliant to the definitions of the standard, it may not be able to communicate with devices from other suppliers."

Second quote (PAC.SUMMER.2009, S.20, Christoph Brunner (Brunner, 2009))

"…, it is very important to perform interoperability testing between all devices intended for use in a project."

2. Boundary conditions for technical information

The observations and statements in this recommendation shall apply within the boundary conditions listed below.

2.1. Target group

Based on the experiences gathered in initial IEC 61850 projects with "Edition 1" of the series of standards, manufacturers and users began to wish for more concrete requirements in subsequent projects.
However, these first projects also made it clear that detailed knowledge of the standard as well as implementation of the user matters as described in VDN Recommendation IEC 61850 - Requirements from the user perspective (July 2004), for example, are essential for a more substantiated approach.
Since this paper will elaborate further on the implementation of individual functionalities, an in-depth understanding of the current series of standards "Edition 2" as well as knowledge of the existing VDEW Recommendation "Integrated control technology in stations" (1988) and Digital Station Control Technology (1994) are a prerequisite for understanding the functionalities described.
Furthermore, this user recommendation is based on the information provided in VDN Recommendation "IEC 61850 – Requirements from a user perspective - (Accompanying recommendations for the implementation of first-time projects)" (VDN IEC 61850 – Anforderungen aus Anwendersicht, 2004), which also provides a good overview over initial experiences/expectations with the IEC 61850 series of standards.

2.2. Basis Edition 2

The recommendation is based on Edition 2, which has been available as an international standard (IS) with its core parts since 2011.
This edition cleared up several of the inconsistencies found in Edition 1 and adds new or expanded functionalities (e.g. for testing).
New options were created for modeling (more characters for the sum of prefix and instance (12 now instead of 7), use of the structuring elements Function and Subfunction in the function structure rather than only on substation level, etc. In addition, the modeling was expanded (e.g. by adding the elements Function, Subfunction), and new nodes were added (e.g. for monitoring tasks).
Overall this version is better suited for the tasks that arise in substation environments.

2.3. Limitation to substations

While Edition 1 was limited to usage in substations, Edition 2 is generally intended for the power utility automation of electrical power supply.
Thus IEC 61850 was also selected as the core standard for smart grid applications.
This paper focuses on usage in substations.

2.4. Distribution of functions over several devices

Standard IEC 61850 does not contain any information on how the functions that are represented by the logical nodes will be distributed to real devices. This part of the standard will remain open for solutions. Theoretically, a concentration in one device would also be possible (though this would make communication superfluous).

This recommendation implies a distribution of functions over devices as it is generally found in station implementations (independent from IEC 61850) today and which was also published in a preceding paper published by the VDN under the title "IEC 61850 – Requirements from the user perspective" (VDN IEC 61850 – Anforderungen aus Anwendersicht, 2004) (at least one device per field).

2.5. Process bus

This paper only considers the classic process connection of primary technological devices such as disconnectors, circuit breakers as well as current and voltage transformers via copper wire connections to control and protection components.
It does not consider solutions, in which the primary components are connected via ethernet, for example in order to transmit measured values digitally with so-called sampled values or protection release signals, e.g. to circuit breakers via GOOSE.
The applicability of the process bus is currently being tested in individual pilot projects.
Due to a lack of extensive experience, the authors are currently unable to provide qualified answers or even recommendations on how the use of these systems affects factors such as reliability, availability, redundancy, testing, and processes.

3. Basic approaches of IEC 60870-5 and IEC 61850

3.1. IEC 60870-5 series of standards

The IEC 60870-5 series of standards essentially regulates the following:

- There is a clear correlation of the respective protocols with communication technology.
- IEC 60870-5-101/102/103 are serial, while -104 is based on IP

The mechanisms for communication will be explained in detail.
They are not object-oriented. Instead, a few simple data types are defined (e.g. message / command / measured value with and without time stamp, e.g. type info number 30 is single point message with time stamp).
The structure and addresses of the information objects are either operator-specific (-101 and -104) or exactly defined (numeric for -103, standardized part e.g. function type 128 and info number 68 "Trip" in a distance protection device").
Information on the engineering process or documentation will not be provided. The number of services applied is very limited.
Limited to very few services (e.g. generic functions are provided for failure transmission).
Fast Multicast and realtime communication is not intended for this series of standards.
The standards include compatibility lists, which are used to communicate information regarding compatibility via corresponding entries for communication between devices.

3.2. IEC 61850 series of standards

IEC 61850 goes far beyond these definitions and addresses the topic of communication extensively.
Functionally related information objects (such as the distance protection function PDIS) are structured and combined under the term logical nodes.
Standardized data classes (CDC - Common Data Classes) are provided for data creation.
The series describes significantly more services, such as services that allow a client to read data structures from devices (server).
Communication and its elements are described using a description language on XML basis. The contents are exchanged between the tools via defined files (*ICD*, *IID*, *SCD*, etc.).
Two models are described for the data structure:

- The functional model, which structures the system from the user perspective:
  station/voltage level/bay/function/subfunction/…logical node/…for functions and station/voltage level/bay/equipment/subequipment/…logical node/…for devices
- The product model, which reflects the station control technology solution from a device (supplier) perspective:
  ied/logical device/…logical node…/…

Note: The standard specifies that the product model must be used in communication on the bus.
Example for the possible presentation of the position feedback of a circuit breaker with the label QA1 according to IGEVU Recommendation for the use of IEC 81346 (IGEVU Kennzeichnung und

Dokumentation – Teil 1: Strukturierungsprinzipien und Referenzkennzeichnung nach IEC 81346 - 3. Ausgabe, 2011) in the 110-KV Field 3 of the station UW_Muster:

Functional view:
UW_Muster/110kV/Feld3/QA1/XCBR1.pos.stVal

with	station	corresponds to UW_Muster
	voltage level	corresponds to 110 kV
	bay	corresponds to Field3
	equipment/subequipment	corresponds to circuit breaker QA1

Product view:
Feldeinheit_3/Steuern/QA1XCBR1.pos.stVal

with	ied	corresponds to Field unit_3
	logical device	corresponds to Control
	prefix	corresponds to QA1 Note regarding switch name
	suffix	corresponds to 1, instance number must be available

Additional and more detailed information is provided in chapter 2 of the DKE paper (DKE AK 952.0.1 TG1 Modellierung, 2011), which discusses, for example, how the elements of the functional structure can be used for elements of the product structure in communication.
Section 10 of IEC 61850 describes conformity tests, which can be used to test implementations for nonconformity . In accordance with IEC 61850, **conformity** is defined as the syntactically and semantically unambiguous communication according to the definitions in the series of standards, meaning only the "general agreement" of a device's behavior according to the standard and meeting the requirements stipulated there.
The term **interoperability**, on the other hand, describes the ability of two or more devices (IEDs) - even if made by different manufacturers - to exchange information and utilize this information for proper cooperation without having to establish additional specifications (outside of the standard as well) as per the authors' interpretation.
It is clear that conformity is an essential prerequisite for interoperability. Although it is a necessary condition, it is not sufficient. Thus, the mere conformity of all devices in a system with the series of standards does not automatically mean that an interoperable system results. This is further confirmed by the results of the "InterOP" test report [InterOP Test Report, FGH e.V. Mannheim, (Krings, Schröder, & Wittlinger, 2010)].
Regarding **interchangeability**, it must be noted that this requirement always entails a check and adjustment of the configuration for the devices to be exchanged as well as - at the very least - an adjustment of communication parameters.
Interoperability is a compulsory prerequisite for achieving interchangeability.

4. Comparison of typical elements of IEC 61850 and IEC 60870-5

4.1. Report

In terms of the IEC 60870-5 standards series, the Report is the equivalent to classic message transmission with server client (analog master station - substation) communication, meaning field device to control center, to HMI, ... (details in Appendix B)

4.1.1. Buffered option

In the case of a communication failure, for example if the station bus fails, changes in information are saved on the server (up to a maximum number, depending on memory depth). When communication is reestablished, this information is submitted in a logical order (i.e. oldest first) so that no information loss occurs.
This procedure corresponds to the familiar solutions with IEC 60870-5 and is recommended as a classic form of communication for the classic clients control center, HMI, etc.

4.1.2. Unbuffered option

In this case, information is not saved in the event of a communication failure, which means, for example, that status changes, such as a warning message from off to on and back to off, will be lost.
This option is suitable for measured values, for example, where archiving is not necessary.

4.2. DataSet

While in conventional implementations, the elements of a report cannot be described with standardized methods, this is possible with IEC 61850 with services related to the term DataSet.
A DataSet is a group of information objects based on references to the data model, which can be transmitted via communication services.
There are two different types of DataSets:

4.2.1. DataSet generated statically per SCL

This means that the DataSet is created in the device during the engineering stage and then remains saved there permanently (non-deletable).
These DataSets can be described and documented in the IED section in the SCD and utilized in engineering.
This documentation option in the standard (via the *SCL* file), the static character of these DataSets, and the resulting reproducibility of the reports make the verifiability of a system significantly easier or may even be what makes it possible (for example by allowing the test tool with the engineering data to be loaded).
One of the disadvantages of this option is that changes after initial parameterization, e.g. post-parameterization of a message, result in a reconfiguration of the devices via the tools with all subsequent processes.

4.2.2. DataSet dynamically generated

There is no equivalent for this in IEC 60870-5.
We distinguish between persistent and non-persistent DataSets.
Dynamic means that the DataSet is only created during an existing communication connection between client and server, while unlike persistent DataSets, the non-persistent DataSets are deleted again automatically when the connection in the server is disconnected or broken.
When the connection is reestablished, it must therefore be generated by the client again. Dynamically created, persistent DataSets remain intact in the event of a communication failure, they may be deleted if no longer needed.
This option makes changes to the DataSet significantly easier than in the static solution because "only" the client has an active role here. Controlled by the client, the modified DataSet is generated in the participating servers.
One of the disadvantages of this approach is that the DataSet is not documented within the SCL and changes might therefore not be evident when repeat checks are performed.
Yet another limitation of non-persistent DataSets:
According to the standard, they are only transmitted with unbuffered services.
This conflicts with the above mentioned recommendation to use buffered reports in order to prevent information loss.
In the authors' opinion, this option should therefore only be used for temporary applications, for example to transmit information during protection testing.

4.3. GOOSE

There is no equivalent for this in IEC 60870-5.
This service can be considered a wiring substitute for information technology connections that rely on very fast transmission speeds between devices where failures need to be detected quickly and reliably on the application level. The implementation of additional functionalities for the detection of communication loss is not necessary.
The service is based on a prioritized Layer-2 Multicast communication, in which a server acts as a publisher at the bus and provides information which the other servers can subscribe to., Each server can take on the roles as publisher/subscriber at the same time.
The failure detection is based on the ability to send cyclic information even without an information change of the data objects received. A failure is detected whenever the signal is not received within the expected time.
This services is recommended for cross communication, for example between field units when realizing system functions (e.g. interlocking), which are realized with wire today. (see also recommendation (DKE AK 952.0.1 TG2 Applikationen mit Diensten der IEC61850, 2008), chapter 4)

4.4. Setting Group (SG)

Corresponding term: Parameter set switching in IEC 60870-5-103
With its SG service, IEC 61850 offers a variety of ways to generate, edit, and activate parameter sets.
In the current device implementations, these options are not being fully used yet. Just like in the previous devices with IEC 60870-5-103, for example, they only offer the option to activate parameter sets, which were parameterized in the devices outside of IEC 61850. This also allows parameters to be switched which are not part of the standard according to IEC 61850.
This approach is recommended because especially the protection applications use parameters outside the standard.
While in IEC 60870-5-103, the feedback of the active parameter set is practically available as part of the command for choosing the parameter set, it has to be generated through an indirect approach in IEC 61850.

The number of the active Setting Group, respectively the active parameter set, for example, can be reported via the LTRK node.

4.5. Logging

Corresponding term: Archive
There is no equivalent for this in IEC 60870-5.
IEC 61850 offers the option within the devices to create and access archives with a variety of contents, which are defined via DataSets in a similar manner as the reports.
Possible contents could include process data, information about the device condition, or security information, e.g. LPHD.PhyHealth, WacTrg, ..., which is then read and analyzed.
The implementation of this service is recommended, as saving information in the device is seen as useful.

4.6. File Transfer

Corresponding term: File transfer (IEC 104)
This service is used for file transfer.
Files (e.g. *ICD* files) can generally be transmitted using this service.
Its main use today lies in transmitting disturbance records coming fromprotection devices in Comtrade format.
This generally applies to both compressed and non-compressed formats. Using non-compressed formats is recommended because the compression can cause compatibility issues.

4.7. Controlling switching devices (Control)

As described in the standards, the logical node CSWI is recommended for switching device control.
The IEC 61850 offers the following control options.

4.7.1. Different models for controlling switching devices

Direct control:

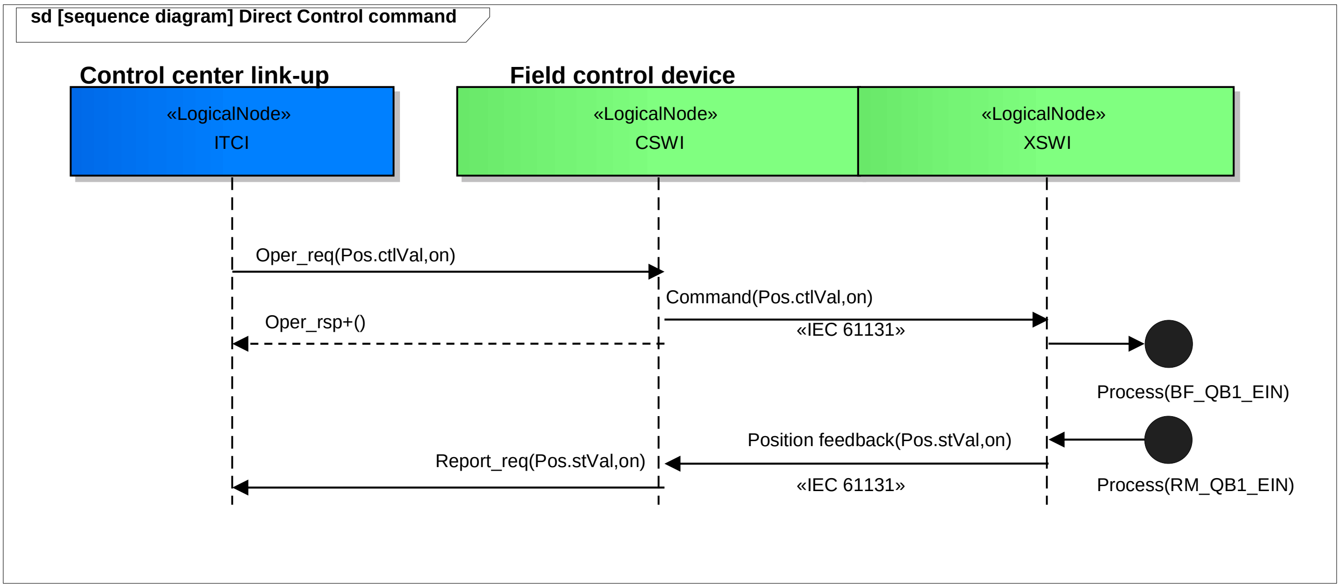

Fig. 1: Direct control - command switching device on

Select before operate:

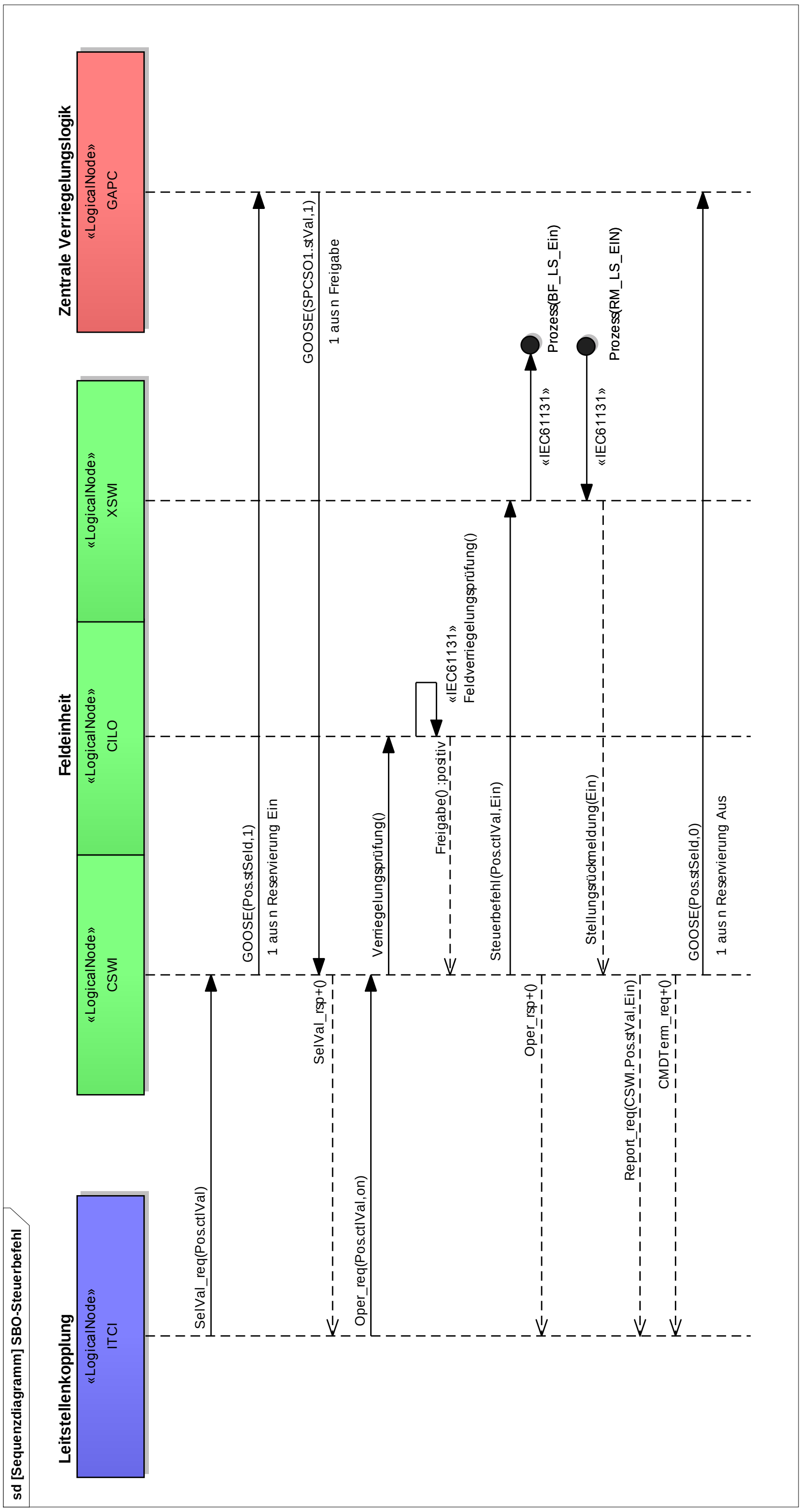

Fig. 2: Select before operate - command switching device on

The IEC 61131 indicated in the diagrams is representative of an internal logic for processing the information objects represented by the LN.

The analog IEC 60870-5-101/104 term for "operate" is "execute", while "select" is the same.
Both control models of the IEC 61850 are available with or without enhanced security, i.e. confirmation that the command was received and completed.
In IEC 60870-5-101/104, this functionality is available under the terms "confirmation – termination".

For use, the standard recommends the SBOw option in 61850-7-2 (select before operate with enhanced security), and the details are described there.

4.7.2. Control hierarchy

When controlling switchgears, the following control hierarchies must generally be taken into consideration:
Location or **local** for control panel operation in the field or near field
dataobject .**Loc**.stVal (TRUE)
Near or **station** for a central operation location in the station
dataobject .**LocSta**.stVal (TRUE)
Far or **remote** for operation from a control center
Loc.stVal and LocSta.stVal both FALSE
(see also chapter 8 in (DKE AK 952.0.1 TG2 Applikationen mit Diensten der IEC 61850, 2008))
The status of the control hierarchy is intended to affect the control of primary switching devices.
For automatic, the status is relevant for the MANUAL/AUTOMATIC switch as well as operation in MANUAL mode (it is not intended to affect operation in automatic mode).
There are two options:
Option 1: Only one control hierarchy is authorized for the orderlocal before near before remote at one time (author recommendation).
Option 2: Several control locations are authorized at the same time.
Both options can be implemented with IEC 61850, which is controlled by the attribute
LDx.LLN0.MltLev (CDC SPG)
Status FALSE (default) corresponds to option 1
Status TRUE corresponds to option 2
This value is to be predetermined via fixed parameterization (IED tool or SCD).
The following options allow for hierarchies to be activated or switched:

Data element Loc

For all devices in a LD:
Via physical switch on the device (author recommendation), which is presented via the data object
LDx.LLN0.LocKey.stVal (TRUE) (CDC SPS)
and transmits the status to all existing nodes in the LD.

Data element LocSta

For individual devices (e.g. disconnectors):
CSWI.LocSta.ctlVal (TRUE) (CDC SPC)
For all devices in a LD:
LDx.LLN0.LocSta.ctlVal (TRUE) (CDC SPC)
Since the data object LDx.LLN0.LocKey for the entire LD is only available in the LLN0 node, it is recommended not to make the switch on node level but rather centrally in the LD via a physical switch with the information being passed on to the nodes inside it (see above for automatic).

For analysis in the device and feedback as to which control hierarchy initiated a command, one can utilize the data object "origin" in CDC of the type "controllable", which consists of the attributes orCat and orIdent, which is also passed on for commands.
The values for the attribute orCat are:

not-supported	to be used when the function is not available, i.e. when it is not relevant according to the supplied recommendation
bay-control	control from location
station-control	control from near
remote-control	control from remote
automatic-bay	control by automatic on location level
automatic-station	control by automatic on near level
automatic-remote	control by automatic on remote level (e.g. central voltage control in the switch line)
maintenance	control initiated by maintenance and/or test tools
process	control not initiated by client or automatic

4.7.3. Control permission

Within substations, there may be different authorities for the control and monitoring of switching devices. When considering effective solutions, this creates new requirements for the devices.
Thus operating equipment (typically switching devices), which are subject to different control permissions and/or feedback concepts, are increasingly connected to **one** device (IED, device):

one IED with several switching devices

Control permission for the individual switching devices

green: Network operator 1
red: Network operator 2

	NCC 1	NCC 2	NCC 3	HMI 1	HMI 2	LOC
Switchgear 1	x			x		x
Switchgear 2	x	x	x	x	x	x
Switchgear 3		x	x		x	x
Switchgear 4		x	x		x	x
…						

Feedback allocation of the individual switching devices

green: Network operator 1
red: Network operator 2

	NCC 1	NCC 2	NCC 3	HMI 1	HMI 2	LOC
Switchgear 1	x			x		x
Switchgear 2	x	x	x	x	x	x
Switchgear 3	x	x	x	x	x	x
Switchgear 4		x	x		x	x
…						

no control permission but feedback

Fig. 3: Example of different control permissions and/or feedback concepts (NCC net control center, HMI human machine interface, LOC local)

More specifically, this means that it has to be configurable for each individual switching device which clients will be granted control permission.
One solution for this problem would be to utilize the above mentioned data object "origin" in CDC of the type "controllable", which consists of the attributes orCat and orIdent, which is also addressed for commands. With the orIdent attribute, the source of the command will be clearly identifiable.
The formation of identifiers follows the possibilities of the base64 alphabet (numbers, +, \, upper/lower case letters without special characters).
The decision regarding the permission must then be realized within the application by analyzing the orIdent (see image above for matrix per switching device).
OrIdent must be analyzed when a client controls. OrIdent is not necessary for station system internal function sequences (e.g. interlocking) since the participating devices know the communication relationships so that the value orIdent =ZERO.
Note: The feedback distribution is performed by client-specific reports with corresponding DataSets.

4.7.4. Using AddCauses during command execution

AddCauses are issued in relation to commands whenever a command is not being carried out.
The AddCause then delivers the relevant cause.
This application is recommended. It is recommended that the IEDs have implemented the AddCauses associated with the relevant function.
An analysis and further processing of this information in the client must always be possible.
The user should be able to determine whether a check that would cause a command to be aborted is netherthelessperformed or not (example: abort if position reached).

Table 54 – AddCause semantic

Value	Explanation
Blocked-by-switching-hierarchy	Not successful since one of the downstream **Loc** switches like in **CSWI** has the value TRUE
Select-failed	Canceled due to an unsuccessful selection (**select service**)
Invalid-position	Control action is aborted due to invalid switch position (**Pos** in **XCBR** or **XSWI**)
Position-reached	Switch is already in the intended position (**Pos** in **XCBR** or **XSWI**)
Parameter-change-in-execution	Control action is blocked due to running **parameter change**.
Step-limit	Control action is blocked, because tap changer has reached the limit (**EndPosR** or **EndPosL** in **YLTC**).
Blocked-by-Mode	Control action is blocked, because the LN (**CSWI** or **XCBR**/**XSWI**)is in a mode (**Mod**) which doesn't allow any switching.
Blocked-by-process	Control action is blocked due to some external event at process level that prevents a successful operation, for example blocking indication (**EEHealth** in **XCBR** or **XSWI**).
Blocked-by-interlocking	Control action is blocked due to interlocking of switching devices (in **CILO** attribute **EnaOpn.stVal="FALSE"** or **EnaCls.stVal="FALSE"**.
Blocked-by-synchrocheck	Control action with synchrocheck is aborted due to exceed of **time limit** and missing synchronism condition.
Command-already-in-execution	Control, select or cancel service is rejected, because **control action** is already running.
Blocked-by-health	Control action is blocked due to some internal event that prevents a successful operation (**Health**).
1-of-n-control	Control action is blocked, because another **control action** in a domain (for example substation) is already **running** (in any **XCBR** or **XSWI** of that domain, the **DPC.stSeld**="**TRUE**").
Abortion-by-cancel	Control action is aborted due to **cancel service**.
Time-limit-over	Control action is terminated due to exceed of some **time limit**.
Abortion-by-trip	Control action is aborted due to a trip (**PTRC** with **ACT.general="TRUE"**).
Object-not-selected	Control action is rejected, because control object was not selected
Object-already-selected	Select action is not executed, because the addressed object is already selected.
No-access-authority	Control action is blocked due to lack of access authority
Ended-with-overshoot	Control action executed but the end position has overshoot
Abortion-due-to-deviation	Control action is aborted due to deviation between the command value and the measured value.
Abortion-by-communication-loss	Control action is aborted due to the loss of connection with the client that issued the control.
Unknown	Command not successful due to Unknown causes
Blocked-by-command	Control action is blocked due to the data attribute CmdBlk.stVal is TRUE.
None	Control action successfully executed
Object-already-selected	Select action is not executed, because the addressed object is already selected.
Inconsistent-parameters	The parameters between successive control services are not consistent, for example the ctlNum of Select and Operate service are different.
Locked-by-other-client	Another client has already reserved the object.

Fig. 4: Table 54 "AddCause semantic" from IEC 61850-7-2

Example for using an AddCause: Interlocking violation

Scenario: An “on” command is sent to a disconnector even though the corresponding earthing switch is still in positionon. The devices are mutually interlocked.

An internal interlock check is performed upon receipt of the selection (select) when executing commands (when using SBOw as recommended). The example shows a negative result, the selection receives a negative response, command execution is aborted, the AddCause "blocked-by-interlocking" is added (parameter of the control service "oper" with negative response (Oper-resp -)).

5. Engineering approaches

Part 6 of the IEC 61850 standard discusses elements, files, and processes for the engineering of devices and overall systems.
To put it simply, it allows for the implementation of two basic engineering approaches:

5.1. Approach: Top-down

In the station configurator, the entire station is modeled (including IEDs) in a multisupplier manner via so-called templates (system types, field types, data objects, device structres, ...). Then the resulting file is submitted to the IED configuration tools, thus loading the individual devices, which can be configured via SCL for the most part.
The top-down engineering process specifies the multisupplier requirements of an IEC 61850 communication system of a station automation system for the speedy implementation in the tendering stage based on a model-driven engineering approach in an .SSD file.

5.1.1. Specification of system data model

The hierarchy of the primary technology in substations is described in the *substation* area of the .*SSD* file consisting of system, voltage level, fields, and the logical node as a representative of the primary technical devices. Additional logical nodes may be modeled in a substation on each level based on the requirements for the distributed functions (e.g. protection, control, measured value analysis, etc.).
Beyond that, referencing for necessary function types (*LNType*) occurs on the logical node level.

5.1.2. Specification of function types

Typing of logical nodes (LNs)

The logical node types are declared on the basis of the distributed functions in a substation as predefined in the *substation* area. In the so-called *DataTypeTemplates* area of the .*SSD* file, the individual logical function types (*LNType*) are formed with the obligatory and optional data objects specified in the standard.

Typing of data classes

The data classes are defined as structured information types in the so-called *DataTypeTemplates* area of the .*SSD* file on the basis of the commands, nominal values, messages, measured values, and counter values necessary in substations. The individual data objects (*DOType*), data attributes (*DAType*), and enumerations (*EnumType*) are formed based on the obligatory and optional information units specified in the standard.
The structure of the data objects and data attributes is important for the communication between the IEDs and serves the purpose of ensuring non-reactive interchangeability of the devices.

Specification of the IED structure

The static structure of an IED is defined in the "*IED*" area of an .*SSD* file while taking into consideration the range of functions of a specific device. This process includes the user-specific definition of the required logical devices (*LDevice*) with a group of instances of logical nodes, DataSets, and Controlblocks.

Instantiation of logical nodes

When instantiating the logical nodes in the "*IED*" area of the .*SSD* file, the associated instances of the data objects (*DOI*) and data attributes (*DAI*) can be defined with the respective values for the runtime behavior of the represented sub-functions.

```
<LN lnClass="CSWI" lnType="LNType_CSWI" inst="7" prefix="QA1">
<DOI name="Pos" >
                <DAI name="ctlModel">
                <Val>4</Val>
</DAI>
        <DAI name="sboTimeout">
                <Val>20000</Val>
</DAI>
        <DAI name="operTimeout">
<Val>1500</Val>
</DAI>
</DOI>
</LN>
```

Listing 1: Configuration attributes for the definition of the SBOw control model

Listing 1 shows the instance of the logical node *CSWI* with data object *Pos* and the configuration attribute ctlModel set to "*sbo-with-enhanced-security*" with *Timeout* parameter for the control function of switchgears.

5.1.3. Specification of service model

Defining logical communication interfaces of an IED

The logical communication interfaces for an exchange of information with the required communication services are defined in the "*IED*" area of the .*SSD* file under the corresponding instance of the logical node "*LLN0*". The grouping of information objects is done in the DataSets and the Controlblocks are linked with the respective DataSets.

The order of the references (*FCDA* elements) in a DataSet is important for the communication between the IEDs and serves the purpose of ensuring non-reactive interchangeability of the devices.

Modeling communication relationships between the logical nodes

The communication relationships necessary for an exchange of information between the sub-functions (*LNs*) within an IEC 61850 application are defined with the *Input* and *ClientLN* elements of the SCL.

5.1.4. Provision of specifications of an IEC 61850 communication system

The multisupplier specification of requirements for an IEC 61850 communication system in a data model is provided via the *.SSD* file to the subsequent engineering processes for the implementation of manufacturer-specific system solutions.
The product-specific data models from the *.SSD* file can be specified in the *.ICD* or *.IID* files.

5.2. Approach: Bottom-up

The IEDs are configurable to a great extend (services, see below). The IED configurator allows for the creation of complete IED templates from the operator perspective.
In specific projects, these templates are used, the devices configured, and the IIDs passed to the station configurator. There the superordinate relationships are engineered and the result is loaded into the devices via the resulting SCD and IED configuration tool.
The bottom-up engineering process specifies the multisupplier requirements of an IEC 61850 communication system of a station automation system in substations based on a product-driven engineering approach in an .SSD file.

5.2.1. Adopting manufacturer-specific IED data models

The IED data models in *.ICD* or *.IID* files are provided by the respective manufacturers to allow them to be adopted in a system configuration tool.

Typing of logical nodes (LNs)

The logical node types are declared on the basis of the functions implemented in a manufacturer-specific device (IED). In the so-called *DataTypeTemplates* area of the *.ICD* or. *IID* file, the individual logical function types (*LNType*) are formed with the obligatory and optional data objects specified in the standard.

Typing of data classes

The data classes are defined as structured information types in the so-called *DataTypeTemplates* area of the *.ICD* or *.IID* file on the basis of the commands, nominal values, messages, measured values, and counter values necessary in the manufacturer-specific device (IED). The individual data objects (*DOType*), data attributes (*DAType*), and enumerations (*EnumType*) are formed based on the obligatory and optional information units specified in the standard.
The structure of the data objects and data attributes is important for the communication between the IEDs and serves the purpose of ensuring non-reactive interchangeability of the devices.

Manufacturer-specific IED structure

The static structure of an IED is defined in the "*IED*" area of an *.ICD* or *.IID* file while taking into consideration the range of functions of specific devices. This process includes the definition of the required logical devices (*LDevice*) with a group of instances of logical nodes and if necessary the DataSets and Controlblocks.

5.2.2. Defining the system data model

The hierarchy of the primary technology in substations is described in the *substation* area of the *.SCD* file consisting of system, voltage level, fields, and the logical node as a representative of the primary technical devices. Additional logical nodes may be modeled in a substation on each level based on the requirements for the distributed functions (e.g. protection, control, measured value analysis, etc.).
In addition, referencing for necessary manufacturer-specific function types (*LNType*) occurs on the logical node level based on the *.ICD* or *.IID* files imported in the system configuration tool.

5.2.3. Defining the service model

Defining logical communication interfaces of an IED

The logical communication interfaces for an exchange of information with the required communication services are defined in the "*IED*" area of the *.SCD* file under the corresponding instance of the logical node "*LLN0*". The grouping of information objects is done in the DataSets and the Controlblocks are linked with the respective DataSets.
The order of the references (*FCDA* elements) in a DataSet is important for the communication between the IEDs and serves the purpose of ensuring non-reactive interchangeability of the devices.

Modeling communication relationships between the logical nodes

The communication relationships necessary for an exchange of information between the sub-functions (*LNs*) within an IEC 61850 application are defined with the *Input* and *ClientLN* elements of the SCL language.

Provision of the configuration of an IEC 61850 communication system

The configuration of an IEC 61850 communication system in a data model is provided via the *.SCD* file to the subsequent engineering processes for the implementation of manufacturer-specific system solutions.
In this process, the IED data models from the *.SCD*file can be adopted in the manufacturer-specific IED configuration tools.
The IEC 61850 offers a broad variety of options for the above mentioned templates, including a full description of communications.

- Description of the single line diagram (single line) -substation section
- Description of the information objects from a functional perspective -substation section
- Description of the services -IED section
- Description of the communication parameters -IED section
- Description of the information objects from a product perspective -IED section
- Description of the data and attributes of the information objects -data type templates
- Description of the DataSets for reports and GOOSE -IED section
- Description of the communication relationships
- Assignment of reports with static DataSet to clients, such as control center, HMI -IED section
- Assignment of information received externally within the devices (inputs) including indication of the service transmitting the information -IED section

The DKE document describes the topic of engineering tool requirements in more detail (DKE AK952.0.1 TG3 Anforderungen an IEC 61850 Engineeringwerkzeuge, 2011). Chapter 3.3 of this document defines and discusses various engineering process options (A-E).
The approach mentioned in chapter 5.1above could therefore be implemented with the engineering process options C-E of the DKE document (DKE AK952.0.1 TG3 Anforderungen an IEC 61850 Engineeringwerkzeuge, 2011) since these options include the device specification within the *.SSD* file.

5.3. Explanation of the individual file sections

5.3.1. Substation Section

This section can describe a single line diagram of the primary system and it lists the primary devices and functions that are part of the communication processes, including their information objects under the "functional naming" aspect (with the respective reference to data types).

5.3.2. IED Section

This section includes the elements, which must be described for an individual device.

- Services the device provides
- Listing information objects included in the IED under the "product naming" aspect
- (incl. mapping (generated via nomenclature) for functional naming in the substation section)
- Description of the DataSets configured in the device for communication
- Specification of the communication method for these DataSets
  - **to clients (automation system, e.g. central HMI**) specific reports, with information about trigger conditions and type of report (buffered, unbuffered)
  - **for communication between devices** via GOOSE, with the option of defining which device GOOSE subscribes to
- Assignment of external signals to logical nodes in the device (in the so-called input section)

5.3.3. Data Type Templates

This describes the characteristics of the logical nodes: Data type templates
e.g. which optional data and/or attributes are used.

5.3.4. Communication Section

This section includes information about the communication relationships between the participating devices.

5.4. Comparison of the engineering processes

5.4.1. Top-down engineering process

Advantages

- With the joint IEC 61850 data model, the user describes neutrally and unambiguously in the specification stage which data (on attribute level) the functions of a station automation system (SAS) must provide through which services (GOOSE, reports, etc.) by the respective manufacturer-specific devices (IEDs).
- Better interchangeability of SAS components with the multisupplier definition of the internal device structure (IED)
- Reduction of the variety of manufacturer-specific solutions of an SAS through the cross-project unification of the IEC 61850 data models
- From the user perspective, a more systematic selection of components for integration in an SAS system
- Operational requirements for the SAS (IEC 61850 information exchange) can be taken into consideration early on
- Time expenditure and cost of integrating the SAS can be reduced by creating an IEC 61850 test model in time
- Avoiding repeat work and inconsistencies when processing and exchanging the IEC 61850 data models between user and manufacturer
- Engineering tools for system configuration can be used independently of manufacturer
- Neutral documentation of the entire communication for clients and applications

Disadvantages

- Significant effort and relevant technical knowledge necessary for the first-time definition of the IEC 61850 data model in the specification stage of an SAS

Prerequisites

- Relevant expertise (IEC 61850 standard, SCL, UML, etc.) is required to create the model description
- Manufacturer-specific tools must be able to import the entire model description from the *.SCD* file without any limitations
- The manufacturer-specific devices must be freely configurable (flexible) in their internal structure without any additional device or tool costs. This must already be verified when selecting the devices.

5.4.2. Bottom-up engineering process

Advantages

- The user only describes the exchange of information (services) between the SAS components based on the existing manufacturer-specific device structures (*ICD* or *IID* files).
- No in-depth knowledge of the formation of the logical node types (LNType), data objects (DOType), data attributes (DAType), and enumerations (EnumType) in the *.ICD* or *.IID* files necessary

- No additional development costs for manufacturers

Disadvantages

- Essentially no interchangeability of SAS components (e.g. different manufacturers) based on the manufacturer-specific definition of the internal device structure
- From the user perspective, a more limited selection of components for integration in an SAS
- Inconsistencies in working with the IEC 61850 data models with manufacturer-specific expansions in SCL scheme (private elements) can only be eliminated by using manufacturer-specific engineering tools (system configurations).
- Manufacturer independent engineering tools (system configuration) cannot be used

5.4.3. Conclusion for top-down and bottom-up engineering processes

With the completely free description options of an IEC 61850 station automation system, the top-down engineering process provides the best selection of SAS components with the goal of ensuring interchangeability of devices.

5.5. Transfer of functional naming to flexible product naming

The functional naming (FN) is defined in the *substation* area of the *.SSD* file with the elements *Substation*, *VoltageLevel*, *Bay*, *ConductionEquipment*, *SubEquipment*, *Function*, and *Subfunction*.
The product naming (PN) is defined in the "*IED" area of the .SSD*, *.SCD*, *.ICD*, or *.IID* files as part of an object reference for the distinct identification of an information object with the elements *IEDName*, *LDeviceInst*, *LNPrefix*, *LNClass*, and *LNInst* by the manufacturer.
The product naming (PN) is defined in the "*IED" area of the .SSD*, *.SCD*, *.ICD*, or *.IID* files as part of an object reference for the distinct identification of an information object with the elements *IEDName*, *LDeviceInst*, *LNPrefix*, *LNClass*, and *LNInst* by the manufacturer.
A transfer of the FN into the flexible PN allows for function-specific naming of objects with the relevant object reference in order to provide users with their perspective in real communication as well (automated transfer of functional texts from the description files, e.g. in analysis tools).
Due to the varying number of elements of FN in the substation area, generalized modeling rules cannot be issued here. Users will need to determine their own modeling rules in the specific context of their applications with the respective values of the FN elements. When transferring the FN to the flexible PN, the object reference must not exceed 69 characters (37 characters in Ed. 1).

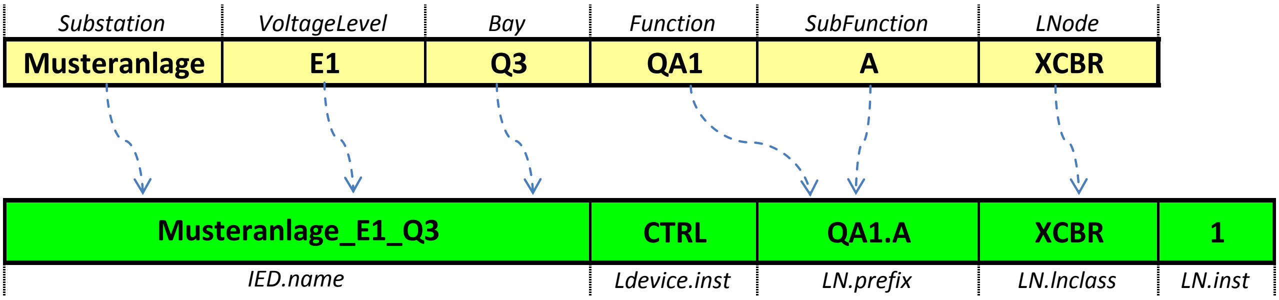

Fig. 5: Example of functional naming being related to flexible product naming

For further examples, recommendations, and conclusions regarding the transfer of FN to flexible PN, refer to the detailed descriptions in the DKE document (DKE AK 952.0.1 TG1 Modellierung, 2011).

6. Implementation of applications

There are only very few instances in the IEC 61850 standard (e.g. automatic recloser function) that describe how exactly an application is implemented in practice.
One of the reasons for this lack of detail is that the major aspects that are important for applications are not part of the IEC 61850 standard.
When implementing applications in the context of station automation, such as cross-field interlocking, the following elements are important and must be taken into consideration:

- Basic application concept (not part of the IEC 61850) logic procedure (Boolean logic, topology analysis), distribution of functions (centralized, decentralized), …, free and/or block signals, …
- Sequences, i.e. the sequence of information exchange events between the logical nodes in different IEDs (not part of IEC 61850) as necessary for the application
- Logics, e.g. which elements are interlocked in which manner (not part of IEC 61850)
- Behavior of the applications in certain scenarios, e.g. how is interlocking conducted if essential information is missing or not recognized as current (blocking or situational reactions) (not part of IEC 61850)
- Information objects that are exchanged between the participating IEDs (elements according to IEC 61850); number and type of objects depend on the specific application concept
- The distribution of information, i.e. which server and/or client receives which information (depends on the specific application concept)
- Services used to transmit the information (services of IEC 61850);
  The specific application concept determines which services is the most suitable.

Important:
The elements of IEC 61850 do not describe the implementation of the application itself but rather "only" the communication necessary for the process (distribution, participating information objects, and services used to communicate the information).

The term function, which users often use synonymously with application, is defined differently in the context of IEC 61850. In the standard, functions are described with the element "logical node".
Thus while the distance protection function, which is described by the PDIS node, defines the information of activation phase L1, there is no description of the algorithm that generates this information from the physical input variables current and voltage.
It is up to the users to ensure that the devices selected for the implementation of their application (in addition to the elements of IEC 61850) meet the necessary requirements on the application level (e.g. performance, logic elements, functionalities, analysis) in order to achieve the desired results.
DKE describes applications in more detail and provides advice on implementation using IEC 61850 (DKE AK 952.0.1 TG2 Weitere Applikationen mit Diensten der IEC61850, 2011) (DKE AK 952.0.1 Applikationen mit Diensten der IEC61850, 2008). The description of applications is also being further developed on international standard level.
Since the series of standards doesn't make restrictions to applications, special attention must be paid to system-wide interoperability. This is further illustrated by the "InterOP" research project by FGH e.V., where the majority of irregularities regarding this system-wide interoperability was caused by the applications. This was either due to the varying degrees of how the standard was implemented in the devices or due to

manufacturer-specific restrictions, which then lead to more restrictive system solutions. Interoperability could not be achieved directly without further definitions or specifications.

In order to achieve system-wide interoperability as efficiently as possible, we recommend systematically following the recommendations in the FGH InterOP Test Report.

7. Illustration using select examples

The dependency of the application implementation on the choice of communication elements, such as communication concept or communication services is shown in examples below .

7.1. Basic application concept

Three concept variations were identified for the implementation of station-wide applications

- Central in station unit — central function in a client
- Central in dedicated bay unit — central function in a server, IED
- Decentralized in bay units — decentralized function in servers, IED

The basis of these variations is described in great detail in the DKE document (DKE AK 952.0.1 TG2 Weitere Applikationen mit Diensten der IEC61850, 2011), chapter 3, and (DKE AK 952.0.1 Applikationen mit Diensten der IEC61850, 2008), chapter 4).
The interlocking example will be used again in order to illustrate the benefits and drawbacks.

7.2. Example: interlocking

In the context of substations, interlocking is intended for the operation of primary switching devices (circuit breakers, isolators, earth electrodes, fuse switches).
Its goal is to prevent breakers or earthing switches from being activated. Their primary purpose is to protect the system.
In interlocking, we distinguish between bay interlock and station interlock. Bay interlocking refers only to the switching devices of a field. In station interlocking, the cross-field interlocking conditions are analyzed. Therefore, station interlocking is important for IEC 61850 because communication between the participating devices only takes place there. Information objects are required for station interlocking:

- Commands, with origin (e.g. HMI or remote)
- Position feedback
- Warning and fault messages
- Measured values
- Release information
- …

As indicated above, there are different approaches for implementing interlocking

- ***Centralized approach:*** Centralized station interlocking as a central function in a client on station level or in a server on bay level.
- ***Decentralized approach:*** Station interlocking as a decentralized function distributed on several servers on bay level.

7.2.1. Centralized approach

Centralized station interlocking in a client

Description

- The interlocking logic is in a client on station level, e.g. the gateway for connecting the control center. Another option is implementation in HMI.
- Field units with information for station interlocking send this information to the station unit with a report.
- The station unit analyzes the information of the field units and generates a release if all conditions have been met.
- The release is sent to the relevant field units via "Control" service. Based on this information, the switching operations are released or blocked.

Advantages

- The system can easily be expanded because the interlocking logic must be only adjusted for one device.
- Service and maintenance tasks are easier to manage in a centralized concept than in a decentralized concept because there are no functional dependencies between the individual field units.

Disadvantages

- A failure detection for reports and control services is not described in the standard (e.g. timeout analysis (typ. 20s) for the IP connection). Individual solutions must be developed for this purpose in order to have the information necessary for interlocking available immediately in case of changes.
- In the event that a client for the interlocking logic fails, the cross-bay interlocking function must be forgone.
- In the case of bus loads from message showers, it is important to ensure that the central unit can process the information within the required time frame.
- Logical nodes must be implemented in the field units, with data objects that can be set via control model to receive the release signals.

Centralized station interlocking in a server

Description

- In this version, the interlocking logic is centralized in a server on bay level (bay unit).
- Status information for station interlocking is sent from the other bay units to the the unit with the centralized logic via GOOSE.
- The bay unit analyzes the bay unit information received via GOOSE and generates a release if all conditions have been met.
- The release is then communicated to the respective participants via GOOSE again. Based on the received GOOSE message, a switching action can now be performed or not performed.

Advantages

- The system can easily be expanded because the interlocking logic must be adjusted for only one device.
- Service and maintenance tasks are easier to manage in a centralized concept than in a decentralized concept because there are no functional dependencies between the individual field units.
- Special definitions for data exchange are not necessary due to the use of Multicast information.
- Automatic failure detection has already been implemented in the GOOSE service.

Disadvantages

- Just like the solution with a station unit, failure of the field unit with the central interlocking logic leads to a failure of the cross-bay station interlocking.
- The central bay unit must be able to both provide and subscribe the needed number of GOOSE messages.

7.2.2. Decentralized approach

Decentralized station interlocking in multiple servers

Description

- The interlocking logic is distributed on several serves on bay level (bay units).
- The status messages of the individual bay units are provided to all other bay units via GOOSE (publisher, subscriber), i.e. each bay unit then has **all** of the relevant information.
- Based on this information, each bay unit now determines whether an internal release can be generated or not.

Advantages

- Special definitions for data exchange are not necessary due to the use of Multicast information.
- Automatic failure detection has already been implemented in the GOOSE service.

Disadvantages

- Expansions require a lot of effort because the maintenance and possibly testing must be performed on all participating bay units and not just on one central unit.
- Commissioning, service, and maintenance tasks are time-consuming because dependencies are created between the bay units as part of this concept.

Recommendation

The authors believe that the option "Central in dedicated bay unit" should be favored as a solution for station interlocking.

- Communication with GOOSE, as its mechanisms allow for secure and easy communication without further specifications, thus also making communication easier to monitor than reports (due to it being cyclic).
- Expansion, commissioning, and service can be managed efficiently because only few components are affected.

For consistency purposes, all comprehensive functions within the substation control technology should be implemented using the same concept so that the processes associated with these types of applications and devices can be designed in the same manner.
This means that cross-bay applications are placed centrally in a server selected for this purpose, while the exchange of information with the devices participating in the application and the included logical nodes occurs via GOOSE communication.

7.3. Dependency of application implementation on choice of information objects

Once a specific concept has been selected, in our case "Central in dedicated bay unit", this still leaves elements for the implementation that are necessary for application design.
Thus it leaves open the question whether all relevant switching devices of the substation receive their release signals from the central logic or whether a distribution approach is taken, in which the devices that are part of cross-bay interlocking receive superordinate release information from the central function, which is then taken into account in internal bay interlocking in the bay unit, which the affected device is linked to.
Another key factor for design is also which particular information objects - and objects of which type - are transmitted.
One possible approach is for each bay to send **all** relevant information to the field device with the central station function (e.g. position feedback of the devices in the field) and only then to generate links in the field device with the central station function (e.g. for the information that the bay is activated).
Another option is that this information is already formed in the bay and then transmitted to the field device with the central station function.
The transfer of information from the field device with the central station function back into the bays is then handled in the same manner.

In this scenario, one release signal (or a block signal, depending on the logic concept) per device or linked information, such as release for busbar change, can be sent.
Depending on the solution, different information elements will be required.
Another aspect to be considered in the choice:
The authors believe that for the interlocking function, the intermediate state is transmitted as well when the switchgear is running. This is in contrast to position feedback being transmitted to clients, such as control centers, where this is generally not desired.
The requirement here is that the position feedback of the C... nodes and X... nodes is performed as well without intermediate state suppression.

Selection of possible nodes from the standard:
Position feedback for interlocking: X... node, e.g. via circuit breaker
XCBR.pos.stVal
Position feedback for transfer to clients: C... node, eg.g circuit breaker CSWI.pos.stVal
Free or block signal (individual devices or cross-device)
CILO.enaOpn.stVal
CILO.enaCls.stVal
Alternative for superordinate signals (e.g. release for busbar change in busbar systems)
GAPC. Ind1.stVal
To be able to control the behavior of applications, the qualifiers must be transmitted as well (attribute quality).
One could determine, for example, that an interlocking logic only sends release signals for information with "valid" quality, while it blocks for "questionable" or "invalid" quality.

7.4. Dependency of applications on function sequences

The following example of a solution for the application "1 of n" test (double acting block) shows how necessary a description of the function sequence is for the application.
Quote from (DKE AK 952.0.1 TG2 Weitere Applikationen mit Diensten der IEC 61850, 2011), chapter 3.1 Application:
"The '1 of n' test ensures that in substations, only a primary switching device, such as a circuit breaker, disconnector, or earthing switch, can be operated within the particular section for which the function is to be valid (i.e. within a bay, station section, or the entire system). This ensures that there are always unambiguous feedback messages for the interlock check.
It is therefore a subfunction of station interlocking and will be considered synonymous with the term "double acting block" in this context.
For the implementation of this double acting block, IEC 61850 provides a mechanism via the attribute "stSeld", which is included in the CDC for controllable data and thus also in the CSWI node, which is used to control the primary devices."

Attention; Please note that the element stSeld is only described as optional in the standard. When realizing a scenario, one must therefore ensure that it is actually implemented.

The DKE paper (DKE AK 952.0.1 TG2 Weitere Applikationen mit Diensten der IEC61850, 2011), chapter 3.7, describes the option "Decentralized station interlocking in bay units".
This document explains the "Central in dedicated field unit" option preferred by the authors.
The challenge this application presents is ensuring that the above mentioned functionality can be provided while essentially issuing commands to several switching devices in different bays at the same time.
Both the processing times for the devices playing a role in the functions and transmission times for the information to be exchanged must be taken into account.

One must also define on which voltage level or for which command type the "1 of n" control is valid based on the operator's philosophy.

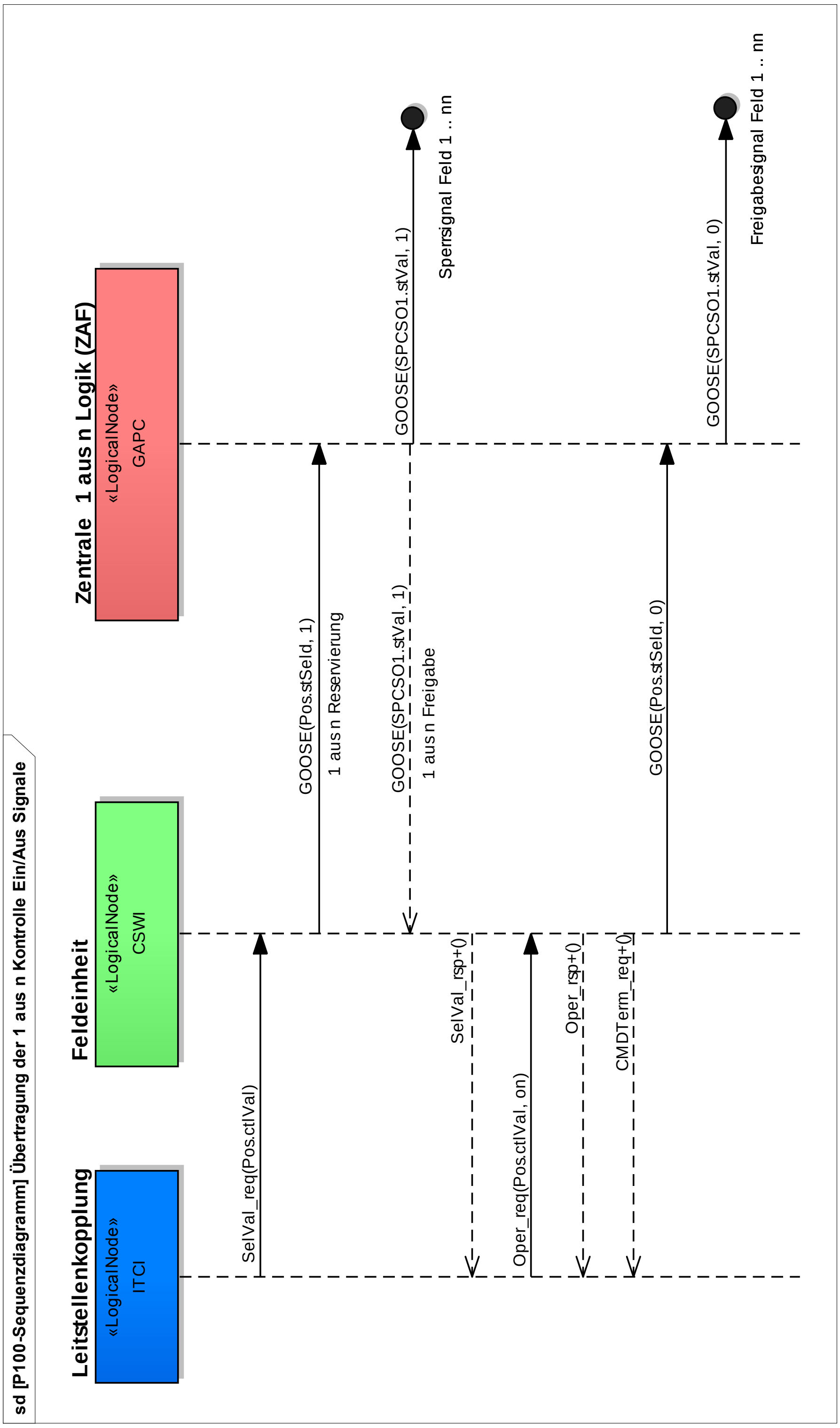

Fig. 6: Example of the centralized approach of the "1 of n" test

For additional details and boundary conditions, please see the DKE paper [(DKE AK 952.0.1 TG2 Weitere Applikationen mit Diensten der IEC61850, 2011)](), chapter 3.

8. Interchangeability approach

8.1. Different operating models

"Uniform" users do not exist anymore. Operators can rather be divided into three general categories depending on the number of stations, resources, expertise, business policy, etc.:

- With full service
  The services for the initial setup but also for the service of the system in operation are performed by the service providers. The operator defines functional requirements but leaves the specific solution up to the supplier.
- With turnkey, but service performed by the company's own personnel
- Only hardware is purchased. Engineering and service provided by own personnel, very detailed specifications on how functions are realized.

It was found that the more companies use their own staff to handle processes, the more they use their "own" profile.

- New build (incl. replacements)
- Expansion
- Operation
- Maintenance (only plays a minor role in control technology)
- Fault clearance

These companies often feature a large number of systems and generally utilize extensive standardization with regards to information models, applications, and processes.
For some operators, this standardization goes as far as having the concepts provide for the use of equivalent products from different suppliers (theoretically even mixed within one system), so that **interchangeability** with regards to incorporation of the device in the system is achieved (today this is already possible, for example with IEC 60870-5-103 for protection applications or with IEC 60870-5-104 for control technology applications). Standard IEC 61850 only pursues interoperability as a goal.
With this approach, even very complex use cases could be managed efficiently. It involves exchanging a device in the event of faults, though the replacement device will no longer be a 1:1 match of the original (either because a replacement by the original supplier is no longer available or because the product from the same supplier has undergone further development in the meantime and is therefore no longer identical, for example from a modeling perspective (assignment of logical devices)) (for details, see Appendix A).
Based on this requirement, the following demand is made:
With respect to communication to the exterior, the replacement device acts exactly the same as the device being replaced, so that no changes in parameterization are necessary in the other components of the control technology system.
The goal must be for the exchange to be as non-reactive as possible.

Why do the authors believe that this aspect is so important?
In light of the added stress that a device failure can produce, the replacement process must be as easy to manage and trace as possible. This particularly affects, for example, the transfer of the IEC 61850 relevant engineering data from the *.SCD* file part of the device to be replaced.
Other non-affected system components should not have to be adjusted as well because it would involve devices having to be reloaded, restarted, and thus also the entire control technology system having to be restarted.
Though this will or would be supported and facilitated by intelligent tools (especially when utilizing IEC 61850), depending on the individual risk assessment, it would still require more or less elaborate checks of the entire system.
In the other scenario, the authors suppose that a check of the entire system would be prevented and only the replaced device would have to be checked.
This is, of course, based on the assumption that the devices utilized in that scenario include the same basic functions (i.e. a device with a distance protection function can only be replaced by a device that supports this function as well) and that they are also able to implement the applications as described in the respective chapter.
In the authors' opinion, this level of interchangeability demands the highest level of system performance.
Systems that can meet these requirements are thus also suitable for the other approaches of the different operator models (e.g. turnkey without specifications).
This paper focuses primarily on achieving this level of interchangeability.
If in a specific case, a device is to be exchanged for a device of a different type or manufacturer, it is important to note that generally not only will the configuration of the communication need to be adjusted but also further features of the device (protection settings, switching device runtimes, etc.). The effort involved may, however, be reduced significantly by means of suitable processes (engineering approach) for such configuration adjustments through replacement devices selected specifically for this purpose and ideally even tested in the system environment. In this preselection process, the devices are identified based on type and requirements.

8.2. Aspects to take into consideration with interchangeability

Basic prerequisites (to be determined in advance when selecting replacement devices etc.):

- The devices must always include the same range of functions based on the user requirements.
- The behavior of applications to be realized with the devices - as listed in the respective chapter - must be identical in the way they are perceived (time responses, evaluating logic, etc.).
- The utilized services must be available in the devices and must be configured in a manner that produces the same behavior.
- The information objects used for communication (regardless of whether they are used through GOOSE or report) must all be available (important for the use of optional objects or private elements, which are therefore forbidden).
- The transmission of information via the services must be identical with regards to structure, design, and content.
- Services must be able to be accessed in the same manner and with the same parameters.
- Identical hardware interfaces (communication and process, supply), see also (DKE AK952.0.1 TG3 Anforderungen an IEC 61850 Engineeringwerkzeuge, 2011) Tables 8, 9

8.3. Effects of the device structure

As described above, the product structure (IED.LD. ...) is used when transmitting information via the station bus.
The elements of this structure (LD) are applied, for example, to group LN (logical nodes) and to address services, e.g. for controls, either as command for switching devices or for information transfer, such as with the service report via Controlblocks.
The standard does not contain details regarding the name of the IED or the name and number of LD (logical devices) implemented in an IED. It is up to the manufacturers to structure and name their specific devices. The only thing that is predefined is the number of characters allowed for the individual structure elements and the length of the entire character string.

In order to achieve interchangeability, the authors believe that there are only two options here:

- Specific IED names and logical devices are agreed upon between (ultimately all) operators and manufacturers.
- The name of the IEDs and the name and number of the logical devices can be configured, although a reasonable limitation of the number of LDs should be defined from a device technology perspective (e.g. max=10). The devices must allow free allocation of LN instances and naming of the LNprefix (flexible PN).

While it is the authors' understanding that the first option would require significant coordination efforts, the second option already has a basis in the relevant elements in the standard and only needs to be implemented in the devices.
The standard provides the element ConfLdName for this purpose, which describes the capacity of an IED to support the configurability of the LD name.
Another aspect related to the structure of the devices is the use of functionalities, which are transmitted hierarchically to the subordinate structure elements, e.g. from elements mapped in LLN0, a node created on LD level and which contains the GOOSE Controlblocks or the controllable data attribute LocKey of a LD, which causes the nodes in the device to switch, for example to location.
In LocKey (LDx.LLN0.LocKey.stVal (TRUE) (SPS)), for example, the status is transmitted to all of the existing controllable objects in the LD.
If like in the previous realization of bay units, this switch in a device should only affect the primary switching devices of the device, its C... and X... nodes representing the switching devices should be pooled in one device.
This particularly applies to the circuit breaker, which is often not modeled in the LD containing the switching devices, especially in combined devices, but rather in the LD with the protection nodes.
The same applies to the mod data object.
The attribute stVal can take on the values: on, on-blocked, test, test/blocked, off.
This affects the behavior of the functions represented by the logical node, e.g. being switched on or off or set to "test" for testing purposes.
Thus it is important that the elements, which should react together to these types of centralized elements from the user perspective, are also situated together in a LD.

8.4. Effects of communication elements and parameters

8.4.1. Example: GOOSE

In Multicast communication on Layer 2, MAC addresses play an important role for addressing and identifying.
Two MAC addresses are used in communication, one Multicast address of the GOOSE message for subscription in the recipient and one source address of the sender device.
Once device MAC addresses have clearly been assigned to a hardware interface, this source address may not be analyzed on application level in the target devices with respect to absence of a reaction because it changes when the devices of the sending party are exchanged.
This is also necessary in order to facilitate testing with simulation devices. However, a test to determine whether the correct communication partner has sent this GOOSE is no longer possible.

8.4.2. Example: Parameter confRev

This value, which is used both with GOOSE and in communication with report, is a numerical indicator that is to ensure the data consistency of the DataSet transmitted via report or GOOSE for the communicating parties. This value is present in each Controlblock.
The value is changed in each Controlblock if a DataSet referenced on it is changed:

- An element of the DataSet is deleted
- The DataSet is reorganized
- The attribute value in the DataSet is changed

The parameter usage can be configured. According to different suppliers, it is either only transmitted when communication is established for the respective service or transmitted with every GOOSE and/or report transmission and then analyzed in the recipient (client if report or other server if GOOSE).
This helps detect and eliminate inconsistencies in information transfer, which might have far-reaching consequences due to misinterpretation.
What makes an analysis so challenging is that, when replacing a defective device that can no longer read the current status of the confRev, this mechanism must be designed in a way that allows all communication partners (client **and** servers) to resume communication with the replaced device.
The problem is that a potentially large number of different confRev values must be entered (which are either documented or read from the communication partners) or a mechanism must be developed, which sets all partners online back to a uniform start value for analysis.
The authors do not recommend analyzing the parameter because the complex set of actions involved in this approach bears a significant risk for the functionalities of the entire system in operation.

Important: When modifying the DataSets, one must ensure, for example by strictly adhering to certain processes, that the DataSets deposited in the replacement device are exactly the same as those of the old device.

8.4.3. Example: Design of DataSets

In communication with IEC 61850, information is transmitted in DataSets.
A DataSet is a grouping of information which is to be transmitted with the same characteristics (e.g. measured values, to a particular client, for a particular function, with the same Controlblock). DataSets reference the data model!
Elements of a DataSet can be defined either on data level or on attribute level.
To guarantee interchangeability (without adjusting communication parameters), the design (order of attributes) must be absolutely identical because during the actual transfer, only the modified attribute content including the position in the DataSet are transmitted. Any change in the order will therefore lead to misinterpretation in the recipient.
The authors have identified the following methods for achieving an identical design:

- Definition of the DataSet on attribute level:

This process indicates only those elements of a data object (data attributes) explicitly which are to be transmitted in a DataSet.
Whether a data element contains further optional elements that may affect the order is therefore irrelevant.
Example: common data class (CDC) "MV", optional element "range"

7.4.2 Measured value (MV)

Table 30 defines the common data class "measured value".

Table 30 – Measured value

MV class					
Data attribute name	**Type**	**FC**	**TrgOp**	**Value/Value range**	**M/O/C**
DataName	Inherited from GenDataObject Class or from GenSubDataObject Class (see IEC 61850-7-2)				
DataAttribute					
			measured attributes		
instMag	AnalogueValue	MX			O
mag	AnalogueValue	MX	dchg, dupd		M
range	ENUMERATED	MX	dchg	normal|high|low|high-high|low-low	O
q	Quality	MX	qchg		M
t	TimeStamp	MX			M
			substitution and blocked		
subEna	BOOLEAN	SV			PICS_SUBST
subMag	AnalogueValue	SV			PICS_SUBST
subQ	Quality	SV			PICS_SUBST
subID	VISIBLE STRING64	SV			PICS_SUBST
blkEna	BOOLEAN	BL			O
			configuration, description and extension		
units	Unit	CF	dchg	see Annex A	O
db	INT32U	CF	dchg	0 … 100 000	O
zeroDb	INT32U	CF	dchg	0 … 100 000	O
sVC	ScaledValueConfig	CF	dchg		AC_SCAV
rangeC	RangeConfig	CF	dchg		GC_CON_range

Fig. 7: Table 30 "Measured value" from IEC 61850-7-3 Ed. 2

- Definition on data level:

With this option, **all** of the attributes intended for transmission (FC functional constraint) of a data element are transmitted with an event.

If the data elements in devices of different manufacturers differ, for example in the varying use of optional elements, the engineering must then ensure the identical design.

The order of the data attributes can either be influenced in the device tool (order and labeling for transmission) or the device utilizes the tools to transfer the specification for the design of a data element as it is described in the template section.

However, the following limitation must be taken into consideration when choosing a DataSet design option:

With respect to reporting, the standard states that for modeling on attribute level, only those attributes are transmitted, for which a trigger option has been defined.

This is not the case for time stamp t (TimeStamp) (see also example above).

Thus it is **not** transmitted.

In the authors' opinion, it should be a basic requirement of control technology systems that during the transfer of information objects, the exact associated time stamp as recorded at the source is transmitted as well. This is necessary, for example, in order to know the exact sequence of action for an event when analyzing protection events. The time stamp of the report is not enough for this purpose.

For this reason, the authors believe that only the more elaborate second method can be used for design at this time.

With regards to interchangeability for reporting, they recommend also transmitting the associated time stamp of an event when modeling on attribute level.

9. Testing (without process bus)

9.1. Client-Server

When using the IEC 61850 for communication in substations, it is still important that the different test activities and controls, especially with regards to protection functions, continue to be performed without affecting the system components in operation at that time.
The deliberate suppression of messages etc. was implemented for protocols, for example IEC 60870-5-103, by means of the so-called "message/measured value block". A "command block" was utilized as well. With IEC 61850, this concept can no longer easily be used because there are no longer just two communicating parties (so-called "master" and "slave") but rather a multitude of controlling and monitoring communication parties (so-called "clients") that may be connected to the field control and protection devices (so-called "servers") via the bus.
The standard offers a variety of options for test scenarios and its mapping in the data model. For testing with IEC 61850, Section 7-4 has defined different modes. These may be set up to LN level. The standard defines five states:

- On
- On-blocked[1]
- Test
- Test/blocked
- Off

These modes may also be applied to LLN0. LDMod (=LLN0.Mod) is derived from LLN0.Mod. The different combination options then result in the value for the behavior of the individual node (LNBeh Value according to IEC 61850-7-4).
The system provides for the following five states and reactions:

9.1.1. Mode state "on"

In the "on" state, the application assigned to the LN operates in normal operation, where all communication services are supported and receive updated values.
➔ (to use for) **"normal operation"**

9.1.2. Mode state "on-blocked"

In the "on-blocked" state, the application assigned to the LN operates in normal operation, but there is no output to the process. All communication services work and receive updated values.
In addition, each data attribute has a qualifier (q), the application of which is regulated as well (Table A.2 in 7-4). Incoming data (GOOSE or Control) with the qualifier q=normal are processed normally, while qualifier q=test is ignored.
➔ (to use for) **"output blocked"**

[1] Called "blocked" in Edition 1

9.1.3. Mode state "test"

In the "test" state, the application assigned to the LN operates in normal operation, where all communication services are supported and receive updated values. However, data objects with the q=test qualifier are transmitted. Control commands or GOOSE with the q=test qualifier are only accepted by the LNs in "test" or "test/blocked" mode. There is output to the process.
➔ (to use for) **"test with test simulator and output"**

9.1.4. Mode state "test/blocked"

This state corresponds to the "test" mode with the only difference being that there is no output to the process. All communication services work and receive updated values.
➔ (to use for) **"test with test simulator without output"**

9.1.5. Mode state "off"

In "off" state, the application assigned to the LN is not active. There is no data output to the process.
➔ (to use for) **"deactivate function - negative test, no message transmission"**

9.2. GOOSE

If GOOSE is used, there are different options for transmitting test or simulation qualifiers.
In Edition 2, a "simulated bit" ("S-Bit") was introduced into the GOOSE (and sampled values), which allowed the subscribing IED to differentiate between real and simulated (i.e. sent by a test set) GOOSEs. The differentiation takes place in the logical node of class LGOS (IEC 61850-7-4), which represents the GOOSE reference.
An entire physical device (PD) can also be put in "simulation" state in addition to the modes listed under 9.1. If this switch occurs, simulated GOOSEs (for example from a test set) should be used instead of the original GOOSE. In practice, however, this mechanism is only recommended for test devices.
For test mode, the authors recommend switching to the logical device level at this point in time. Future devices and test scenarios may require a switch on LN level.
The use of the mechanisms described here is recommended.
In combination with the mechanisms described in the previous chapter, this creates complex test scenarios, which are still in progress at DKE as this document is being written.

10. Test tools

10.1. Introduction

Tests are required for the different stages in the lifecycle of a station automation system. This chapter will describe the requirements for the tools to be used in the process. We distinguish between three different options. The first option (Network analyzers) describes the recording and analysis of the data traffic in the station control technology. Test clients are required to analyze the data model. This also allows for a clear illustration of the recorded traffic. The sequence of individual services can be summarized and analyzed in detail, and the control technology can be simulated. This requires tools as in "Test Clients (function testing)". For a deterministic specification of the time response and for tests to be performed together with protection tests, realtime-capable systems (see chapter "Test devices (Test sets)") are necessary.
For all tests and analyses, the use of the station's *.SCD* files is recommended and defined as a requirement for test tools.

10.2. Network analyzers

Well-known IT tools can be used to analyze network traffic. Both commercial software and freeware programs, such as Wireshark®, are available for this purpose. This software features a highly detailed presentation. Its factory settings and available plug-ins increase legibility through plain text display. Nonetheless, it should likely only be handled by specialists and experiences users.
The tools are to facilitate a depiction of the network traffic from the user perspective, i.e. based on the abstract services, such as report and control.

10.3. Test Clients (function testing)

Test clients are used to analyze data models and to test client/server communication (e.g. reports). They can simulate control technology, for example. In addition, they can also visualize, record, and simulate GOOSE telegrams.

Requirements:

- Support of "selfdescription" (= reading the data model from an IED using the services GetXXDirectory and GetXXDefinition)
- Option of importing *.SCL* files in order to easily access IEDs
- Integration of SCL data with the selected data model
- Recording options for values (e.g. tripper options for reports, control services)
- Enable/disable GOOSE and reports
- Attribute polling
- Generate dynamic DataSets in IED
- Visualize network traffic from the perspective of the abstract services
- "Sniffing" communication of other clients and servers
- Subscribing of multiple GOOSE

- Display GOOSE DataSet with naming of individual elements
- Display report DataSet with naming of individual elements
- Finding GOOSE even with unknown details (GOOSE, Multicast, ... = sniffer functionality)
- Record several GOOSE
- Simulate GOOSE, even several
- Display data traffic and services on abstract level

10.4. Test devices (Test sets)

Test sets are needed to analyze the reaction of an IED to errors in the communication network and to determine time responses of realtime communication with GOOSE. This applies particularly in combination with protection testing. A PC cannot perform realtime tests.

Requirements:

- Testing must be possible in mixed constellations (conventional wiring and GOOSE)
- GOOSE subscription
- GOOSE simulation
- Option to import *.SCL* files to configure the test set
- To test large configurations with a multitude of GOOSEs (e.g. for interlocking), it must be possible to simulate or subscribe more than 100 elements of a GOOSE.
- Option of working in different subnets (isolating GOOSE)
- To facilitate the test of all performance classes according to IEC 61850-5, Type 1A of class P2/P3 is required here.
- Preparation for referencing sampled values would be preferred for future applications
- VLAN support (priority and VLAN-ID)
- Synchronization with various time references (PTP-IEEE 1588, PPS, IRIG-B, ...)

11. Outlook

This section lists several topics as examples of content that goes beyond the scope of this paper:

11.1. Topics related to stations

- Process bus
  With the introduction of the process bus, the following topics must be discusses as well:
  - Network topology
  - Realtime requirements
  - Availability aspects
  - Testing (without test switch)

- Control center connection
  The IEC 61850 standard addresses the topic of control center connection under the keyword "seamless communication" with the following aspects:
  - Harmonizing CIM modeling
  - Technical realization via Gateway

- Security
  Since ethernet technologies are utilized for the 61850 communication, a discussion of IT security is of utmost importance as publications on this topic confirm, for example the ISO 27000 series of standards, IEC 62351, BDEW white paper incl. recommendations, and BSI publications.

- Engineering tools
  The efforts involved in station automation is shifting further and further away from the hardware towards engineering, also with respect to the integration of products from different manufacturers. The authors believe that the development of these tools has only progressed to a limited degree at this time. Furthermore, efficient integration of communication with IEC 61850 in the overall engineering process of substations must be possible as well.

- Sustainable documentation
  Development of methods that integrate the existing standardized descriptions of IEC 61850 in sustainable documentation of the entire substation system.

11.2. General

By now, many other fields have taken on the structure, methods, and elements of the standard for their own applications.
This includes model descriptions for:

- wind energy plants
- distributed energy ressources (DER)

This is why IEC 61850 is also a core standard for smart grid (DKE - Kompetenzzentrum Normung E-Energy/Smart Grids).

However, in contrast to classic station automation, this context also brings up other aspects and requirements for communication that are currently being discussed and cannot be taken into consideration in this paper.
The authors believe that the expected mass market will raise the requirements for standardization and multisupplier profiling.

12. Appendix

During the development of this user recommendation, different solutions were brought up for some of the sections and their conformance with the standard was verified by consulting the respective parts of the standard.
Since there is often more than one solution for the various functionalities of different users, this appendix describes recommendations based on the respective services for guidance. It further includes information that was deemed to be helpful for decision-making now or for the future as a result of the discussions and experiences.
The detailed references to the standard are furthermore intended to provide assistance for the event that a different solution than the one recommend is to be implemented.
If elements of services are listed here without a recommendation and/or specific use case, they were merely added in order to present a complete list.

12.1. Appendix A - Use cases for device replacement

The goal is to restore the function and the communication required for it without reconfiguring the parts of the system that have not failed. Only the defective component is to be replaced and the replacement device is to be engineered. Ideally, the target conditions will be achieved again.
For non-identical devices, it is assumed that the replacement device will at least include the required elements and functions of the defective device.

Use case: Replace device with one that ...	Hardware	Functions	Firmware version	Software	SCL files
is completely identical (1).	=	=	=	=	=
features a new firmware version (2).	=	=	≠	=	=
features a modified software version (3) (change function).	=	≠	=	≠	=
consists of modified hardware (4).	≠	=	=	=	=
features a modified software version (5) (change data model / communication).	=	=	=	≠	≠
features additional functions (6).	=	≠	=	≠	≠
features additional functions (7).	=	≠	≠	≠	≠
is similar (8).	≠	≠	≠	≠	≠

Firmware: in this context an operating system
Software: in this context the logic of the device, e.g. also protection algorithm
Cases 1-7: same supplier
Case 8: different supplier possible as well

1st use case:
The defective device is replaced with a completely identical device. The replacement device is loaded with the manufacturer-specific parameter file and possibly also the *.CID* file, the way it was parameterized when starting the system. Only the replacement device is parameterized in order to avoid the entire system being changed. The target state is restored.

➔ Load device with backed up original state

2nd use case:
The defective device is replaced with a device with modified firmware (e.g. changed due to security patch). For this process, it is assumed that neither the protection/control technology functions nor communication nor the data model have changed.
If necessary, the specific parameterization and configuration file must be recreated using the device configuration tool (no new IEC 61850 device data model). Then as in 1:
➔ Load device with load file created from backed up original state (in device configuration tool)

3rd use case:
The defective device is replaced with a device with modified software with respect to functions (e.g. protection algorithm). This example is a scenario in which the change does not affect communication or the data model or where a downgrade of the EC 61850 perspective to the old version is possible. If the device manufacturer can guarantee this, possibly after a downgrade, this use case can be treated like the 1st use case.
➔ Device is possibly downgraded in the device tool (then same as use case 1) or possibly loaded with other functional parameters as in use case 2.

4th use case:
The defective device is replaced with a device with modified peripheral hardware (e.g. more binary input etc.). For this process, it is assumed that neither the software (function, communication, data model) nor the firmware have changed. If the device manufacturer can guarantee that, this use case can be treated similar to the 2nd use case.
➔ Adjust device configuration to modified hardware, then load with load file created from backed up original state (in device configuration tool)

5th use case:
The defective device is replaced by one with a modified software version, which results in an (unnecessary) expansion of communication and the data model (e.g. IEC 61850 Ed. 2, e.g. new services, new nodes) (though the assumption is that the device is downward compatible). It is further assumed that a downgrade to the old condition is no longer possible.
Not to be assumed:
A previously used node is no longer available.
A previously used service is no longer available.
As in use case 2:
➔ Load device with load file created from backed up original state (in device configuration tool)

6th use case:
The defective device is replaced with a device with modified software (expanded functions and change to the data model and communication). As in use case 2:
➔ If these changes do not have any effect on the system, only device engineering is needed here as well.

7th use case:
The defective device is replaced with a device with both modified firmware and software (expanded functions and change to the data model and communication).
It is further assumed that a downgrade to the old condition is no longer possible. As in use case 2:
➔ If these changes do not have any effect on the system, only device engineering is needed here as well.

8th use case:

The defective device is replaced with a similar device with hardware, firmware, and software different from the previous device (e.g. new device generation or different manufacturer).

➔ A test is performed in advance in order to determine whether the replacement device can even provide the required functionalities. If this is the case, a device configuration is generated in the device tool based on the configuration of the device to be replaced.

12.2. Appendix B - Report Controlblocks

Introduction

Report is a client server service for the purpose of transmitting data compiled in so-called DataSets from the server (e.g. field device) to a client (e.g. control technology). This transmission follows certain trigger conditions (e.g. change of a data object). We distinguish between buffered and unbuffered reports (see chapter 4.1).

Elements

The following section describes the elements for buffered reports (**B**RCB…), with notes in the places where there are deviations for the unbuffered reports (**U**RCB…).

BRCBName

Freely assignable name within the structure.

Used for reference building, together with the path it is unambiguous.

Must be assigned.

e.g. "position feedback"

BRCBRef

Path name of the BRCB in the structure (LDName/LNName. BRCBName).

Is needed to be able to address the BRCB from the client (e.g. activate).

Example:

Product structure: IED/Control/LN0.Stellungsmeldungen

Function structure: Musterstadt.110kV.QA1/Control/LN0.Stellungsmeldungen

Recommendation: Reports are stored under the LN0 of a logical device

RptID

Freely assignable name for the **unambiguous** identification within the entire control technology system.

If this entry is missing (because it is optional) or the empty string " " is entered, the BrcbRef is entered instead.

Only this ID is sent for identification with communication with clients!

Recommendation: Use value not equal to "0" ("own" identifiers)

Examples: E1_position feedback for field =E1
E2_position feedback for field =E2
…

RptEna

The report is released for transmission with this parameter (=TRUE).

Activate:

Set by the client with service SetBRCBValues (RptEna=TRUE).

DataSet

A DataSet is a grouping of information objects, which are influenced by the addressed services and parameters alike.

The parameter DataSet indicates for which DataSet the BRCB is used.

Example:
Path name:
Product structure: IED/Control/LN0.position
Function structure: Musterstadt.110kV.QA1/Control/LN0.position
The path name is not relevant for transmission. It is recommended to set the parameters of the OptFlds, which are responsible for transmitting the path in the telegram, to "FALSE".

data-set-name	= FALSE
data-reference	= FALSE

Options for assigning BRCB to a DataSet

- Via entry in the SCD
- Client sets the value with service SetBRCBValues

ConfRev
Numerical indicator, which ensures data consistency of the DataSet transmitted with the report for the communicating parties.
The value is modified if:

- An element of the DataSet is deleted
- The DataSet is reorganized
- The attribute value in the DataSet is changed

OptFlds
Parameter that determines whether optional elements will be used, which are then integrated in the report and thus transmitted

OptFlds	
sequence-number	seqNum
report-time-stamp	timeStamp
reason-for-inclusion	reasonCode
data-set-name	DataSet
data-reference	dataRef
buffer-overflow	bufOvfl
entryID	entryID
conf-revision	confRev

BufTm
Value in ms (1 ms -1h) regulates the wait time for transmission of a report that was triggered by an event. This report then includes all objects that have also changed in this time frame, for example as a result of the first trigger event (reason: reduced bus load). Otherwise (for value 0 (= default in the standard) only the triggering object is transmitted, while any additional change triggers its own report.
SqNum
After the report is activated, this is increased by 1 with each transmission.

TrgOps
This parameter indicates which trigger option initiated the report.

data-change	dchg
quality-change	qchg
data-update	dupd
integrity (see IntgPd)	period
general-interrogation (see GI)	gi

IntgPd
Value in ms:
An indication of >0 causes all values integrated in the DataSet to be transmitted after x ms. A value of 0 means that the function will not be used.
If it is used, the TrgOps integrity (period=TRUE) must be set in addition.
(control technology terms for cyclical or forced transmission, e.g. after 5s (value IntgPd = 5000))
For the very common spontaneous transmission, it must be set to IntgPd=0.
GI
(no need for profiling)
Parameter for triggering a general query
Client set with service SetBRCBValues (GI=TRUE)
(upon response, the status is automatically set back to "FALSE again)
PurgeBuf (only for buffered reports)
(no need for profiling)
Parameter for deleting the memory/buffer
Client set with service SetBRCBValues (PurgeBuf=TRUE)
(upon realization, the status is automatically set back to "FALSE again)
EntryID (only for buffered reports)
(no need for profiling)
Can be used for communication control for active/inactive switching or for repeat communication.
TimeOfEntry (only for buffered reports)
(no need for profiling)
Time stamp for the element EntryID. Indicates when it was generated internally.
It is used whenever a time stamp is to be sent for a BRCB.
ResvTms (only for buffered reports)
The value of this attribute can regulate whether a BRCB is only reserved for specific clients (value= -1), whether it is freely available (value=0) or whether it is reserved dynamically (value=>0).
Resv (only for unbuffered reports)
If the value of the attribute = true, then this URCB is reserved exclusively for the client that set the value to true (regardless of whether data is being transmitted or not). Otherwise (value = false) the report can be reserved by any client by setting the attribute RptEna.

IED services necessary for the function (service capabilities)

Introduction
Section 6 of the standard (Table 11) lists the capabilities of IEDS and their description in the substation configuration language (SCL).
The following section will list the services used in the environment of reports.

Service capability ConfReportControl

This describes the capability to configure specifications for report Controlblocks via the SCL.

max –	the maximum number of instantiable report Controlblocks. If this is equal to the number of preconfigured instances, then no new instances can be created. If it is higher than the number of preconfigured instances, the project engineer is allowed to create more instances, even for new types up to this limit.
bufMode –	unbuffered, buffered, both; the buffer mode allowed to configure for new Controlblock types.
bufConf –	boolean. TRUE means, the *buffered* attribute of preconfigured report Controlblocks can be changed via SCL.

Service ReportSettings

This services makes it possible to define if and from where the indicated parameters can be set.

cbName –	Controlblock name
datSet –	data set reference
rptID –	report identifier
optFields –	optional fields to include in report
bufTime –	buffer time
trgOps –	trigger options enable
intgPd –	integrity period
resvTms –	if true, the ResvTms attribute exists at all buffered Controlblocks.

Service capability GetCBValues

With the help of this service, a client can read the values of the attributes used in a report Controlblock.

Example:

The example shows what the authors believe to be a reasonable specification for a buffered report as it may be used for the communication of position feedback from primary devices to control centers or pendant control.

Select ReportControlblock attributes:

BRCBName		position feedback
rptID		E1_position feedback
datSet		position
confRev		0
buffered		true
bufTime		20
OptFlds		true
	seqNum	true
	timeStamp	true
	reasonCode	true
	DataSet	false
	dataRef	false
	bufOvfl	true
	entryID	false
	confRev	true
TrgOps		
	dchg	true
	qchg	true
	dupd	true
	period	false
	gi	true

12.3. Appendix C - GOOSE

Introduction

GOOSE (Generic Object Oriented Substation Event) is used to transmit data in realtime between field and protection devices. The transmission is implemented as Multicast, meaning that it is unconfirmed and that a sender ("publisher") distributes this information repeatedly in the network, where an unlimited number of recipients ("subscribers") can access this information and use it for their purposes.
Note: Using the GSSE ("UCA-GOOSE") also specified according to IEC 61850-7-2 is not recommended. Therefore it is not described here.

Elements

GoCBName ObjectName
Instance name of an instance of GoCB
Profiling like in report.

GoCBRef ObjectReference
Path name of an instance of GoCB
Profiling like in report.

GoEna
Enabled (TRUE) | disabled (FALSE)
No profiling necessary.

Destination MAC-Address
ISO/IEC 8802-3 address for issuing a virtual target address. Its use is recommended for structuring purposes.

AppID
This application is recommended for structuring. For limitations of the values range, see Section 8-1.

DatSet ObjectReference
No profiling necessary.

ConfRev
Usage like for report.

NdsCom
GoCB requires further configuration.
Profiling not possible since it is a status message.

Simulation
The 'Simulation' bit from Ed.2 has a different meaning than the GOOSE 'Test' bit in Ed.1. It is recommended that only test devices (test sets) send this bit to the devices to be tested in the actual process. For the test, these then need to be in simulation mode.

Services

SendGOOSEMessage
Send GOOSE message

GetGoReference
Retrieve the FCD/FCDA of a specific member of DATA-SET associated with the GOOSE message.

GetGOOSEElementNumber
Retrieve the position of the member in the DATA-SET associated with the GOOSE message of a FCD/FCDA.

GetGoCBValues
Retrieve the attributes of a GoCB

SetGoCBValues
Write the attributes of a GoCB

IED services necessary for the function (service capabilities)

GSESettings
The GSE Controlblock attributes for which online setting is possible with service
SetGsCBValues respective SetGoCBValues:
The attribute’s meaning is:
cbName – Controlblock name
datSet – data set reference
appID – application identifier
dataLabel – value for the object reference if the corresponding element is being sent
(applies only to GSSE Controlblocks)

GSEDir
GSE directory services according to IEC 61850-7-2. This capability has no attributes.

GOOSE
This element shows that the IED can be a GOOSE server or client according to IEC 61850-7-2.
The attribute meaning is:
max = maximum number of GOOSE Controlblocks, which are configurable for
publishing (max=0 means the device is only a GOOSE client).

12.4. Appendix D - Control

Introduction

The standard describes Control as the control of data in external connections, devices, or output by a client. For this service, there are no Controlblocks like for GOOSE and report.

Services

The standard describes individual services and utilizes state machines for description. The services of the Control Model include:

- Select (Sel)
- SelectWithValue (SelVal)
- Cancel
- Operate (Oper)
- TimeActivatedOperate (TimOper)
- CommandTermination (CmdTerm)

Depending on the application, the controlled object may vary in behavior. The standard describes all four cases:
Case 1: Direct control with normal security (**direct-operate**)
Case 2: SBO control with normal security (**operate-once** or **operate-many**)
Case 3: Direct control with enhanced security (**direct-operate**)
Case 4: SBO control with enhanced security (**operate-once** or **operate-many**)
The difference between "normal" and "enhanced" security lies in the feedback upon (non-)execution of a command. The service CommandTermination is therefore only used with enhanced security.

Service parameter

T EntryTime
No profiling.

Test Status
Use recommended.

Check Condition
No profiling.

Add Cause
AddCause – additional cause diagnosis (Table 53 in IEC 61850-7-2)
The use of this feature is recommended.

TimOperRsp – TimeActivatedOperate response
TimOperRsp timer-activated | command-executed

Specification of the utilized services

The services themselves do not require specification, as they have been sufficiently described in section 7-2.
The data attributes involved have been included in 7-3 in the utilized CDCs. No profiling necessary.

- **ctlVal** (the value to be controlled)
- **operTm** (the time when to operate for the **TimeActivatedOperate** service);

- **origin** (indicating who issued the service);
- **ctlNum** (control sequence number).

IED services necessary for the function (service capabilities)

Not available.

12.5. Appendix E - File Transfer

Application

File Transfer is another service of the IEC 61850, which can be used to transfer the files saved in the IED (primarily disturbance records).

Description as an abstract service (ACSI) according to Section 7-2

The definition of the class is included in Section 7.2.

Table 56 – FILE class definition

FILE class		
Attribute name	**Attribute type**	**Value/value range/explanation**
FileName	VISIBLE STRING255	
FileSize [0..1]	INT32U	
LastModified	TimeStamp	
Services GetFile SetFile DeleteFile GetFileAttributeValues		

Specific mapping (SCSM) according to Section 8-1

Options
The class "File" is mapped - like others - on MMS according to IEC 61850-7-2. Using FTP (File Transfer Protocol) is possible but not further described in the standard. Furthermore, FTP is not recommended due to its security limitations.
Using the described MMS file services is therefore recommended instead.

MMS file transfer

- Profile

No need for profiling.

- COMTRADE

Files in accordance with IEEE C37.111(1999) (COMTRADE) must be stored in a "COMTRADE" directory. The file extensions should follow the suffix pattern indicated in IEEE C37.111(1999) (HDR, CFG, and DAT). No additional files are to be stored. Use of ZIP files is discouraged as well.

Present situation

The MMS file transfer is performed with manufacturer tools.
The LD directory or the root level are used for file storage.

12.6. Appendix F - "Signal mapping" from IEC 60870-5-103 to IEC 61850

The tables listed below were created by group of protection technology experts (inside FNN).
Today, the transmission protocol IEC 60870-5-103 is a much used standard for serial communication between digital protection devices and digital station control technology.
Users are very familiar with its signal-oriented structure and contents.
It describes protection devices with function types, e.g. *128 for distance protection* as well as the signals with information numbers, e.g. *64 for stimulation L1*.
In contrast, the communication standard IEC 61850 pursued an object-oriented approach, i.e. functionally related information objects, e.g. *PDIS.Str.phsA for stimulation L1* , are summarized under the logical node *PDIS for distance protection function*.
Due to this approach and the many new opportunities it offers, the level of complexity of IEC 61850 has increased compared to IEC 60870-5-103.
To allow (protection) users to switch to the "world" of IEC 61850 more easily, the authors have enclosed a table of signals of IEC 60870-5-103 as associated with the information objects of IEC 61850.

Table Protection Information

lfd. Nr		IED.LD	PDIS	PDIF	PTOC	RREC	PSCH	PTOV	PTUV	PTEF	PWDE	PSDE	PTOF	PTUF	PTRC	RFLO	RPSB	RBRF	RSYN	RDIR	MMXU	103_Fkt-Typ DEZ	**103_Info-Nr. D**	103_Typ	61850-Adresse (nach 7.4:2010)	Bemerkungen
		Gerät_allg	Distanzschutz	Differenzialschutz	Überstromzeitschutz	AWE	Signalvergleich	Überspannungsschutz	Unterspannungsschutz	Erdschlusswischer	E-Watt	Erdschlussrichtung	Überfrequenz	Unterfrequenz	Auslösung_allgmein	Fehlerorter	Pendelerfassung	Schalterversageschutz	Synchronabfrage	Fehlerrichtung	Messwerte					
	Zustandsmeldungen																									
1	AWE aktiv					x																128	16	1	RREC.Mod.stVal	RM ein/ aus, Status AWE
2	Schutzsignalübertragung aktiv						x																17	1	PSCH.Mod.stVal	RM ein/ aus, Status Signalvergleich
3	Schutz aktiv		x	x	x			x	x	x	x		x	x									18	1	PTRC18.Mod.stVal	RM ein/ aus, mindestens eine Schutzfunktion ist aktiv
4	Schutz aktiv		x																				18*	1	PDIS.Mod.stVal	RM ein/ aus, Distanzschutzfunktion aktiv
5	Schutz aktiv			x																			18*	1	PDIF.Mod.stVal	RM ein/ aus, Differenzialschutzfunktion aktiv
6	Schutz aktiv				x																		18*	1	PTOC.Mod.stVal	RM ein/ aus, Differenzialschutzfunktion aktiv
7	Schutz aktiv							x															18*	1	PTOV.Mod.stVal	RM ein/ aus, Überspannungsschutzfunktion aktiv
8	Schutz aktiv								x														18*	1	PTUV.Mod.stVal	RM ein/ aus, Unterspannungsschutzfunktion aktiv
9	Schutz aktiv									x													18*	1	PTEF.Mod.stVal	RM ein/ aus, Erdschlusswischerschutzfunktion aktiv
10	Schutz aktiv										x												18*	1	PDEW.Mod.stVal	RM ein/ aus, E-Watt-Schutzfunktion aktiv
11	Schutz aktiv												x										18*	1	PTOF.Mod.stVal	RM ein/ aus, Überfrequenzschutzfunktion aktiv
12	Schutz aktiv													x									18*	1	PTUF.Mod.stVal	RM ein/ aus, Unterfrequenzschutzfunktion aktiv
13	Rückstellen der LED-Anzeigen	x																					19	1	LLN0.LEDRs.stVal	EM Anzeigen zurückgestellt
14	Sperre der Überwachungsrichtung	x																					20	1	LLN0.Mod.stVal=test	Melde- und Messwertsperre
15	Testbetrieb	x																					21	1	LLN0.Mod.stVal=test	
16	Parametrierung vor Ort																						22	1		wird nicht benötigt
17	Kennlinie 1	x																				128	23	1	LLN0.SGCB.ActSG=1	
18	Kennlinie 2	x																				128	24	1	LLN0.SGCB.ActSG=2	
19	Kennlinie 3	x																				128	25	1	LLN0.SGCB.ActSG=3	
20	Kennlinie 4	x																				128	26	1	LLN0.SGCB.ActSG=4	
21	Eingang 1																					128	27	1	nach Funktion	anwenderdefinierte Meldung 1
22	Eingang 2																					128	28	1	nach Funktion	anwenderdefinierte Meldung 2
23	Eingang 3																					128	29	1	nach Funktion	anwenderdefinierte Meldung 3
24	Eingang 4																					128	30	1	nach Funktion	anwenderdefinierte Meldung 4
	Überwachungsmeldungen																									
25	MW-Überwach I																				x	128	32	1	MMXU.A	Auswertung der Qualitätsbits
26	MW-Überwach U																				x	128	33	1	MMXU.PhV	Auswertung der Qualitätsbits
27	Drehfeldüberwachung																				x	128	35	1	MMXU	
28	Auslösekreis-überwachung	x													x							128	36	1		Verwendung unklar
29	UMZ-Notbetrieb		x																			128	37	1	PTOC.Mod.stVal=1 & PDIS.Mod.stVal=1	siehe Info-Nr. 18
30	UMZ-Notbetrieb			x																		128	37	1	PTOC.Mod.stVal=1 & PDIF.Mod.stVal=1	siehe Info-Nr. 18
31	VT-Automatenfall	x																				128	38	1	TVTR.FuFail.stVal =1	
32	Schutzsignalübertragung gestört						x															128	39	1	PSCH.Mod.stVal =1	
33	Warnung Sammelmeldung	x																				128	46	1	CALH.GrWrn.stVal	
34	Störung Sammelmeldung	x																				128	47	1	CALH.GrAlm.stVal	vorzugsweise über Lifekontakt
	Erdschlussmeldungen																									
35	Erdschluss L1									x													48*	1	PTEF.Op.ACT.phsA	
36	Erdschluss L1										x												48	1	PDEW.Op.ACT.phsA	
37	Erdschluss L2									x													49*	1	PTEF.Op.ACT.phsB	
38	Erdschluss L2										x												49	1	PDEW.Op.ACT.phsB	
39	Erdschluss L3									x													50*	1	PTEF.Op.ACT.phsC	
40	Erdschluss L3										x												50	1	PDEW.Op.ACT.phsC	
41	Erdschluss Vorwärts									x												128	51*	1	PTEF.Str.dirGeneral =1	
42	Erdschluss Vorwärts										x											128	51*	1	PDEW.Str.dirGeneral =1	
43	Erdschluss Vorwärts											x										128	51	1	PSDE.Str.dirGeneral =1	
44	Erdschluss Rückwärts									x												128	52*	1	PTEF.Str.dirGeneral =2	
45	Erdschluss Rückwärts										x											128	52*	1	PDEW.Str.dirGeneral =2	
46	Erdschluss Rückwärts											x										128	52	1	PSDE.Str.dirGeneral =2	
47	Erdschluss											x													PSDE.Str.general	Uo+, unselektive Erdschlusserfassung, da-dn-Spannung > 30V

lfd. Nr		IED_LD	PDIS	PDIF	PTOC	RREC	PSCH	PTOV	PTUV	PTEF	PWDE	PSDE	PTOF	PTUF	PTRC	RFLO	RPSB	RBRF	RSYN	RDIR	MMXU	103_Fkt-Typ DEZ	**103_Info-Nr. D**	103_Typ	61850-Adresse (nach 7.4:2010)	Bemerkungen
		Gerät_allg	Distanzschutz	Differenzialschutz	Überstromzeitschutz	AWE	Signalvergleich	Überspannungsschutz	Unterspannungsschutz	Erdschlusswischer	E-Watt	Erdschlussrichtung	Überfrequenz	Unterfrequenz	Auslösung_allgmein	Fehlerorter	Pendelerfassung	Schalterversageschutz	Synchronabfrage	Fehlerrichtung	Messwerte					
	Störfallmeldungen																									
48	Anregung L1														x							128	64	2	PTRC.Str.phsA	
49	Anregung L1		x																			192	64"	2	PDIS.Str.phsA	
50	Anregung L1			x																		192	64"	2	PDIF.Str.phsA	
51	Anregung L1				x																	192	64"	2	PTOC.Str.phsA	
52	Anregung L1							x														192	64"	2	PTOV.Str.phsA	
53	Anregung L1								x													192	64"	2	PTUV.Str.phsA	
54	Anregung L2														x							128	65	2	PTRC.Str.phsB	
55	Anregung L2		x																			192	65"	2	PDIS.Str.phsB	
56	Anregung L2			x																		192	65"	2	PDIF.Str.phsB	
57	Anregung L2				x																	192	65"	2	PTOC.Str.phsB	
58	Anregung L2							x														192	65"	2	PTOV.Str.phsB	
59	Anregung L2								x													192	65"	2	PTUV.Str.phsB	
60	Anregung L3														x							128	66	2	PTRC.Str.phsC	
61	Anregung L3		x																			192	66"	2	PDIS.Str.phsC	
62	Anregung L3			x																		192	66"	2	PDIF.Str.phsC	
63	Anregung L3				x																	192	66"	2	PTOC.Str.phsC	
64	Anregung L3							x														192	66"	2	PTOV.Str.phsC	
65	Anregung L3								x													192	66"	2	PTUV.Str.phsC	
66	Anregung N														x							128	67	2	PTRC.Str.neut	
67	Anregung N		x																			192	67"	2	PDIS.Str.neut	
68	Anregung N			x																		192	67"	2	PDIF.Str.neut	
69	Anregung N				x																	192	67"	2	PTOC.Str.neut	
70	Anregung N							x														192	67"	2	PTOV.Str.neut	für Erdschlussüberwachung
71	General-Auslösung														x							128	68	2	PTRC.Tr.general	
72	General-Auslösung		x																			128	68"	2	PDIS.Op.general	
73	General-Auslösung			x																		128	68"	2	PDIF.Op.general	
74	General-Auslösung				x																	128	68"	2	PTOC.Op.general	
75	General-Auslösung							x														128	68"	2	PTOV.Op.general	
76	General-Auslösung								x													128	68"	2	PTUV.Op.general	
77	General-Auslösung												x									128	68"	2	PTOF.Op.general	
78	General-Auslösung													x								128	68"	2	PTUF.Op.general	
79	Auslösung L1														x							128	69	2	PTRC.Tr.phsA	
80	Auslösung L1		x																			128	69"	2	PDIS.Op.phsA	
81	Auslösung L1			x																		128	69"	2	PDIF.Op.phsA	
82	Auslösung L1				x																	128	69"	2	PTOC.Op.phsA	
83	Auslösung L1							x														128	69"	2	PTOV.Op.phsA	
84	Auslösung L1								x													128	69"	2	PTUV.Op.phsA	
85	Auslösung L1												x									128	69"	2	PTOF.Op.phsA	
86	Auslösung L1													x								128	69"	2	PTUF.Op.phsA	
87	Auslösung L2														x							128	70	2	PTRC.Tr.phsB	
88	Auslösung L2		x																			128	70"	2	PDIS.Op.phsB	
89	Auslösung L2			x																		128	70"	2	PDIF.Op.phsB	
90	Auslösung L2				x																	128	70"	2	PTOC.Op.phsB	
91	Auslösung L2							x														128	70"	2	PTOV.Op.phsB	
92	Auslösung L2								x													128	70"	2	PTUV.Op.phsB	
93	Auslösung L2												x									128	70"	2	PTOF.Op.phsB	
94	Auslösung L2													x								128	70"	2	PTUF.Op.phsB	
95	Auslösung L3														x							128	71	2	PTRC.Tr.phsC	
96	Auslösung L3		x																			128	71"	2	PDIS.Op.phsC	
97	Auslösung L3			x																		128	71"	2	PDIF.Op.phsC	
98	Auslösung L3				x																	128	71"	2	PTOC.Op.phsC	

lfd. Nr		IED.LD	PDIS	PDIF	PTOC	RREC	PSCH	PTOV	PTUV	PTEF	PVDE	PSDE	PTOF	PTUF	PTRC	RFLO	RPSB	RBRF	RSYN	RDIR	MMXU	103_Fkt-Typ DEZ	**103_Info-Nr. D**	103_Typ	61850-Adresse (nach 7.4:2010)	Bemerkungen
		Gerät_allg	Distanzschutz	Differenzialschutz	Überstromzeitschutz	AWE	Signalvergleich	Überspannungsschutz	Unterspannungsschutz	Erdschlusswischer	E-Watt	Erdschlussrichtung	Überfrequenz	Unterfrequenz	Auslösung_allgmein	Fehlerorter	Pendelerfassung	Schalterversageschutz	Synchronabfrage	Fehlerrichtung	Messwerte					
	Störfallmeldungen																									
99	Auslösung L3							x														128	**71***	2	PTOV.Op.phsC	
100	Auslösung L3								x													128	**71***	2	PTUV.Op.phsC	
101	Auslösung L3												x									128	**71***	2	PTOF.Op.phsC	
102	Auslösung L3													x								128	**71***	2	PTUF.Op.phsC	
103	Auslösung durch UMZ-Notbetrieb	x	x	x																		128	**72**	2		nicht notwendig, ist in die Auslösung L1, L2, L3, N und General-Auslösung zu integrieren
104	Fehlerort X in Ohm															x						128	**73**	4	RFLO.FltZ.stVal	Fehlerort X in Ohm primär
105	Fehlerort l in km															x									RFLO.FltDiskm.stVal	Fehlerdistanz in km
106	Fehler vorwärts / Leitung																			x		128	**74**	2	RDIR.Dir.dirGeneral = 1	
107	Fehler vorwärts / Leitung		x																			128	**74***	2	PDIS.Str.dirGeneral = 1	
108	Fehler vorwärts / Leitung				x																	128	**74***	2	PTOC.Str.dirGeneral = 1	
109	Fehler vorwärts / Leitung														x							128	**74***	2	PTRC.Str.dirGeneral = 1	
110	Fehler rückwärts / SS																			x		128	**75**	2	RDIR.Dir.dirGeneral = 2	
111	Fehler rückwärts / SS		x																			128	**75***	2	PDIS.Str.dirGeneral = 2	
112	Fehler rückwärts / SS				x																	128	**75***	2	PTOC.Str.dirGeneral = 2	
113	Fehler rückwärts / SS														x							128	**75***	2	PTRC.Str.dirGeneral = 2	
114	Schutzsignalübertragung Signal gesendet						x															128	**76**	2	PSCH.ProTx.stVal	
115	Schutzsignalübertragung Signal empfangen						x															128	**77**	2	PSCH.ProRx.stVal	
116	Stufe 1		x																			128	**78**	2	PDIS1.Str.general	Fehlerimpedanz in Zone 1 eingemessen
117	Stufe 2		x																			128	**79**	2	PDIS2.Str.general	Fehlerimpedanz in Zone 2 eingemessen
118	Stufe 3		x																			128	**80**	2	PDIS3.Str.general	Fehlerimpedanz in Zone 3 eingemessen
119	Stufe 4		x																			128	**81**	2	PDIS4.Str.general	Fehlerimpedanz in Zone 4 eingemessen
120	Stufe 5		x																			128	**82**	2	PDIS5.Str.general	Fehlerimpedanz in Zone 5 eingemessen
121	Stufe 6		x																			128	**83**	2	PDIS6.Str.general	Fehlerimpedanz in Zone 6 eingemessen
122	Generalanregung														x							128	**84**	2	PTRC.Str.general	
123	Generalanregung		x																			192	**84***	2	PDIS.Str.general	
124	Generalanregung			x																		192	**84***	2	PDIF.Str.general	
125	Generalanregung				x																	192	**84***	2	PTOC.Str.general	
126	Generalanregung							x														192	**84***	2	PTOV.Str.general	
127	Generalanregung								x													192	**84***	2	PTUV.Str.general	
128	Schalterversager																	x					**85**	2	PBRF.Op.general	
129	Auslösung Messsystem L1														x							176	**86**	2	PTDF.Tr.phsA	genutzt für Trafodiff, angeregte Phase
130	Auslösung Messsystem L2														x							176	**87**	2	PTDF.Tr.phsB	genutzt für Trafodiff, angeregte Phase
131	Auslösung Messsystem L3														x							176	**88**	2	PTDF.Tr.phsC	genutzt für Trafodiff, angeregte Phase
132	Auslösung Messsystem E														x							176	**89**	2	PTDF.Tr.neut	genutzt für Trafodiff, angeregte Phase
133	Auslösung I>				x																		**90**	2	PTOC1.Op.general	
134	Auslösung I>>				x																		**91**	2	PTOC2.Op.general	
135	Auslösung I>>>				x																				PTOC3.Op.general	
136	Auslösung IN>				x																		**92**	2	PTOC1.Op.neut	
137	Auslösung IN>>				x																		**93**	2	PTOC2.Op.neut	
138	Auslösung IN>>>				x																				PTOC3.Op.neut	
	AWE Meldungen																									
139	LS EIN durch AWE					x																128	**##**	1	RREC1.Op.general	KU
140	LS EIN durch Langzeit-AWE					x																128	**##**	1	RREC2.Op.general	LU
141	AWE gesperrt																					128	**##**	1	RREC1.Mod.stVal=1	
	Betriebsmesswerte																									
142	Strom L1																				x		**144 bis 1**	3.1, 3.2, 3.3	MMXU.A.phsA	Primärwerte
143	Strom L2																				x				MMXU.A.phsB	Primärwerte
144	Strom L3																				x				MMXU.A.phsC	Primärwerte
145	Strom N																				x				MMXU.A.neut	Primärwerte

lfd. Nr		IED_LD	PDIS	PDIF	PTOC	RREC	PSCH	PTOV	PTUV	PTEF	PWDE	PSDE	PTOF	PTUF	PTRC	RFLO	RPSB	RBRF	RSYN	RDIR	MMXU	103_Fkt-Typ DEZ	103_Info-Nr. DEZ	103_Typ	61850-Adresse (nach 7.4:2010)	Bemerkungen
		Gerät_allg	Distanzschutz	Differenzialschutz	Überstromzeitschutz	AWE	Signalvergleich	Überspannungsschutz	Unterspannungsschutz	Erdschlusswischer	E-Watt	Erdschlussrichtung	Überfrequenz	Unterfrequenz	Auslösung_allgmein	Fehlerorter	Pendelerfassung	Schalterversageschutz	Synchronabfrage	Fehlerrichtung	Messwerte					
	Störfallmeldungen																									
146	Spannung L1E																				x				MMXU.PhV.phsA	Primärwerte
147	Spannung L2E																				x				MMXU.PhV.phsB	Primärwerte
148	Spannung L3E																				x				MMXU.PhV.phsC	Primärwerte
149	Spannung L12																				x				MMXU.PPV.phsAB	Primärwerte
150	Spannung L23																				x				MMXU.PPV.phsBC	Primärwerte
151	Spannung L31																				x				MMXU.PPV.phsCA	Primärwerte
152	Spannung Uen																				x				MMXU.PhV.neut	U da-dn in Prozent
153	Wirkleistung P																				x				MMXU.TotW	Primärwerte
154	Blindleistung Q																				x				MMXU.TotVAr	Primärwerte
155	Frequenz f																				x				MMXU.Hz	Primärwerte
	allg. Befehle in Steuerrichtung																									
156	Wiedereinschaltung EIN/AUS					x																	16	20	RREC.Mod.ctlVal	BF ein / aus, AWE-Fkt ein-/ausschalten
157	Schutzsignalübertragung EIN/AUS						x																17	20	PSCH.Mod.ctlVal	BF ein / aus, Signalvergleich ein-/ausschalten
158	Schutz EIN/AUS																						18	20		darf nicht gemacht werden!
159	Rückstellen der Anzeigen	x																					19	20	LLN0.LEDRs	wird nicht gebraucht!
160	Kennlinie 1	x																				128	23	20	LLN0.SGCB.ctlVal=1	
161	Kennlinie 2	x																				128	24	20	LLN0.SGCB.ctlVal=2	
162	Kennlinie 3	x																				128	25	20	LLN0.SGCB.ctlVal=3	
163	Kennlinie 4	x																				128	26	20	LLN0.SGCB.ctlVal=4	

Table Control and Monitoring

lfd. Nr	VDEW_RL Stationsleittechnik MS von 1998	103_Fkt-Typ DEZ	103_Info-Nr. DEZ	103_Typ	61850-Adresse	Bemerkungen
	Typ 1: Kombigerät Feldeinheit für Schutz, Steuerung und Überwachung					
	Befehle					
1	Q0 EIN/AUS	240	160	20	QA1CSWI.Pos.ctlVal	aus Empfehlungen zum -103er Protokoll
2	Q1 EIN/AUS	240	161	20	QB1CSWI.Pos.ctlVal	aus Empfehlungen zum -103er Protokoll
3	Q2 EIN/AUS	240	162	20	QB2CSWI.Pos.ctlVal	aus Empfehlungen zum -103er Protokoll
4	Q8 EIN/AUS	240	163	20	QC8CSWI.Pos.ctlVal	aus Empfehlungen zum -103er Protokoll
5	Q9 EIN/AUS	240	164	20	QB9CSWI.Pos.ctlVal	aus Empfehlungen zum -103er Protokoll
6	QX EIN/AUS	...	...	...	QXxCSWI.Pos.ctlVal	aus Empfehlungen zum -103er Protokoll
7	AWE EIN/AUS	128/160	16	20		siehe Schutzinformationen
	Meldungen					
8	Q0 EIN/AUS	240	160	1,7,9,11,12,13,20,21	QA1CSWI.Pos.stVal	aus Empfehlungen zum -103er Protokoll
9	Q1 EIN/AUS	240	161	1,7,9,11,12,13,20,21	QB1CSWI.Pos.stVal	aus Empfehlungen zum -103er Protokoll
10	Q2 EIN/AUS	240	162	1,7,9,11,12,13,20,21	QB2CSWI.Pos.stVal	aus Empfehlungen zum -103er Protokoll
11	Q8 EIN/AUS	240	163	1,7,9,11,12,13,20,21	QC8CSWI.Pos.stVal	aus Empfehlungen zum -103er Protokoll
12	Q9 EIN/AUS	240	164	1,7,9,11,12,13,20,21	QB9CSWI.Pos.stVal	aus Empfehlungen zum -103er Protokoll
13	QX EIN/AUS	...	...	...	QXxCSWI.Pos.stVal	aus Empfehlungen zum -103er Protokoll
14	Warnung	240	46	1,7,9		siehe Schutzinformationen
15	LS AWE bereit	240	180	1,7,9	QA1XCBR.CBOpCap.stVal=4	aus Empfehlungen zum -103er Protokoll
16	Schalterfall	240	200	1,7	QA1CALH1.GrAlm.stVal	aus Empfehlungen zum -103er Protokoll
17	Störung Antriebsspannung	240	181	1,7,9	QABCZAXN1.EEHealth.stVal=3	aus Empfehlungen zum -103er Protokoll
18	Störung Steuerspannung	240	182	1,7,9	QABCZAXN2.EEHealth.stVal=3	aus Empfehlungen zum -103er Protokoll
19	SF6-Verlust	240	183	1,7,9	SIMG.InsLevMin.stVal	aus Empfehlungen zum -103er Protokoll
20	Störung Zählung	240	184	1,7,9	MMTR.Health.stVal=3	aus Empfehlungen zum -103er Protokoll
21	AWE EIN/AUS	128/160	16	1,7,9		siehe Schutzinformationen
22	Generalanregung	128/160	84	1,7,9		siehe Schutzinformationen
23	Anregung L1	128/160	64	1,7,9		siehe Schutzinformationen
24	Anregung L2	128/160	65	1,7,9		siehe Schutzinformationen
25	Anregung L3	128/160	66	1,7,9		siehe Schutzinformationen
26	Schutz AUS-Kommando	128/160	68	1,7		siehe Schutzinformationen
27	Erdschluss vorwärts	128/160	51	1,7		siehe Schutzinformationen
28	Erdschluss rückwärts	128/160	52	1,7		siehe Schutzinformationen
29	AWE ausgeführt	128/160	128	1,7		siehe Schutzinformationen
30	Spannungswandler Automatenfall	128/160	38	1,7,9		siehe Schutzinformationen
31	Störung	128/160	47	1,7,9		siehe Schutzinformationen
	Messwerte					
32	IL2	128/160	144	2,7		siehe Schutzinformationen
	Typ 2: Feldeinheit für Steuerung und Überwachung ohne Schutzfunktion (zusätzliche Informationen zu Typ 1)					
	Befehle					
33	Lüfter EIN/AUS	240/128	175	20	CCGR.CECtl.ctlVal	aus Empfehlungen zum -103er Protokoll
34	Reserve	240/128	176	20		aus Empfehlungen zum -103er Protokoll
35	Reserve	240/128	177	20		aus Empfehlungen zum -103er Protokoll
36	Reserve	240/128	178	20		aus Empfehlungen zum -103er Protokoll
	Meldungen					
37	Lüfter EIN/AUS	240	175	1,7,9,11,12,13,20,21	CCGR.CECtl.stVal	aus Empfehlungen zum -103er Protokoll
38	Dauererdschluss L1	240/128	48	1,7,9		siehe Schutzinformationen

lfd. Nr	VDEW_RL Stationsleittechnik MS von 1998	103_Fkt-Typ DEZ	103_Info-Nr. DEZ	103_Typ	61850-Adresse	Bemerkungen
	Typ 1: Kombigerät Feldeinheit für Schutz, Steuerung und Überwachung					
	Befehle					
39	Dauererdschluss L2	240/128	49	1,7,9		siehe Schutzinformationen
40	Dauererdschluss L3	240/128	50	1,7,9		siehe Schutzinformationen
41	Erdschluss <5 s	240	190	1,7,9	PTEF.Str.general	aus Empfehlungen zum -103er Protokoll
42	Erdschluss hochohmig	240	191	1,7,9	PSDE.Str.general	aus Empfehlungen zum -103er Protokoll
43	Transformator Temperatur	240	185	1,7,9	SIML.TempAlm.stVal	7.4, 5.14.5
44	Transformator Gefahr	240	186	1,7,9	CALH.GrAlm.stVal	aus Empfehlungen zum -103er Protokoll
45	UMZ AUS	240	201	1,7		siehe Schutzinformationen
46	Distanzschutz AUS	240	202	1,7		siehe Schutzinformationen
47	Differentialschutz AUS	240	203	1,7		siehe Schutzinformationen
48	Unterfrequenz AUS	240	204	1,7		siehe Schutzinformationen
49	Störung	240	47	1,7,9		siehe Schutzinformationen
50	Warnung	240	46	1,7,9		siehe Schutzinformationen
	Messwerte					
51	IL1	240/128	148	nicht genutzt		siehe Schutzinformationen
52	IL2	240/128	148	2,7		siehe Schutzinformationen
53	IL3	240/128	148	nicht genutzt		siehe Schutzinformationen
54	U1N	240/128	148	2,7		siehe Schutzinformationen
55	U2N	240/128	148	2,7		siehe Schutzinformationen
56	U3N	240/128	148	2,7		siehe Schutzinformationen
57	Wirkleistung P	240/128	148	2,7		siehe Schutzinformationen
58	IE	240/128	147	nicht genutzt		siehe Schutzinformationen
59	UNE	240/128	147	2,7		siehe Schutzinformationen

	Typ 3: Feldeinheit für Transformatoren- und E-Spulen-Regelung (für Traforegelung)					
	Befehle					
60	Automatik EIN/AUS	241	210		ATCC.Auto.ctlVal	aus Empfehlungen zum -103er Protokoll
61	Kennlinie 1/Kennlinie 2	241	211	20	ATCC.VRed1.ctlVal / ATCC.VRed2.ctlVal	aus Empfehlungen zum -103er Protokoll
62	Stufung Höher	241	212	20	ATCC.TapChg.ctlVal oder YLTC.TapChg.ctlVal	aus Empfehlungen zum -103er Protokoll
63	Stufung Tiefer	241	213	20	ATCC.TapChg.ctlVal oder YLTC.TapChg.ctlVal	aus Empfehlungen zum -103er Protokoll
	Meldungen					
64	Automatik EIN/AUS	241	210	1,7,9,11,12,13,20,21	ATCC.Auto.stVal	aus Empfehlungen zum -103er Protokoll
65	Kennlinie 1/Kennlinie 2	241	211	1,7,9,11,12,13,20,21	ATCC.VRed1.stVal / ATCC.VRed2.stVal	aus Empfehlungen zum -103er Protokoll
66	Stufung Höher	241	212	1,7,9,11,12,13,20,21	ATCC.TapChg.stVal oder YLTC.TapChg.stVal	aus Empfehlungen zum -103er Protokoll
67	Stufung Tiefer	241	213	1,7,9,11,12,13,20,21	ATCC.TapChg.stVal oder YLTC.TapChg.stVal	aus Empfehlungen zum -103er Protokoll
68	Blockierung (bei 110-kV-Erdschluß)	241	214	1,7	ATCC.LTCBlk.stVal=true	Blockierung wird in Praxis nicht angewendet
69	Störung Stufenschalter	241	215	1,7,9	YLTC.Health.stVal=3	aus Empfehlungen zum -103er Protokoll
70	Überstromblockierung	241	216	1,7,9	ATCC.LTCBlk.stVal=true	Blockierung wird in Praxis nicht angewendet
71	Automatik AUS Grenzwert U<	241	217	1,7,9	ATCC.LTCBlk.stVal=true	aus Empfehlungen zum -103er Protokoll
72	Automatik AUS Grenzwert U>	241	218	1,7,9	ATCC.LTCBlk.stVal=true	aus Empfehlungen zum -103er Protokoll
73	Automatik AUS Grenzwert U>>	241	219	1,7,9	ATCC.LTCBlk.stVal=true	aus Empfehlungen zum -103er Protokoll
74	Endstellung Hoch	241	220	1,7,9	YLTC.EndPosR.stVal	aus Empfehlungen zum -103er Protokoll
75	Endstellung Tief	241	221	1,7,9	YLTC.EndPosL.stVal	aus Empfehlungen zum -103er Protokoll
76	Störung	241	47	1,7,9		siehe Schutzinformationen
77	Warnung	241	46	1,7,9		siehe Schutzinformationen

lfd. Nr	VDEW_RL Stationsleittechnik MS von 1998	103_Fkt-Typ DEZ	103_Info-Nr. DEZ	103_Typ	61850-Adresse	Bemerkungen
	Typ 1: Kombigerät Feldeinheit für Schutz, Steuerung und Überwachung					
	Befehle					
	Messwerte					
78	IL2	241/128	144	2,7		siehe Schutzinformationen
79	U12	241	150	2,7		siehe Schutzinformationen
80	U23	241	150	2,7		siehe Schutzinformationen
81	U31	241	150	2,7		siehe Schutzinformationen
82	IE	241/128	147	nicht genutzt		siehe Schutzinformationen
83	UNE	241/128	147	2,7		siehe Schutzinformationen
84	Potentiometerstellung	241	151	2,7		wird in Praxis beim Trafo nicht angewendet
	Stufenstellung					
85	Stufenstellung	241	152	1,2,7,9	YLTC.TapPos.ctlNum	aus Empfehlungen zum -103er Protokoll
	Typ 3: Feldeinheit für Transformatoren- und E-Spulen-Regelung (für E-Spulen-Regelung)					
	Befehle					
86	Automatik EIN/AUS	241	210		ANCR.Auto.ctlVal	aus Empfehlungen zum -103er Protokoll
87	Kennlinie 1/Kennlinie 2	241	211	20		wird in der Praxis für E-Spulen regelung nicht benötigt
88	Stufung Höher	241	212	20	ANCR.TapChg.ctlVal oder YEFN.TapChg.ctlVal	aus Empfehlungen zum -103er Protokoll
89	Stufung Tiefer	241	213	20	ANCR.TapChg.ctlVal oder YEFN.TapChg.ctlVal	aus Empfehlungen zum -103er Protokoll
	Meldungen					
90	Automatik EIN/AUS	241	210	1,7,9,11,12,13,20,21	ANCR.Auto.stVal	aus Empfehlungen zum -103er Protokoll
91	Kennlinie 1/Kennlinie 2	241	211	1,7,9,11,12,13,20,21		wird in der Praxis für E-Spulen regelung nicht benötigt
92	Stufung Höher	241	212	1,7,9,11,12,13,20,21	ANCR.TapChg.stVal oder YEFN.TapChg.stVal	aus Empfehlungen zum -103er Protokoll
93	Stufung Tiefer	241	213	1,7,9,11,12,13,20,21	ANCR.TapChg.stVal oder YEFN.TapChg.stVal	aus Empfehlungen zum -103er Protokoll
94	Blockierung (bei 110-kV-Erdschluß)	241	214	1,7	ANCR.LTCBlk.stVal=true	aus Empfehlungen zum -103er Protokoll
95	Störung Stufenschalter	241	215	1,7,9	YEFN.Health.stVal=3	aus Empfehlungen zum -103er Protokoll
96	Überstromblockierung	241	216	1,7,9		wird in der Praxis für E-Spulen regelung nicht benötigt
97	Automatik AUS Grenzwert U<	241	217	1,7,9		wird in der Praxis für E-Spulen regelung nicht benötigt
98	Automatik AUS Grenzwert U>	241	218	1,7,9		wird in der Praxis für E-Spulen regelung nicht benötigt
99	Automatik AUS Grenzwert U>>	241	219	1,7,9		wird in der Praxis für E-Spulen regelung nicht benötigt
100	Endstellung Hoch	241	220	1,7,9		gibt es in 61850 im LN YEFN nicht
101	Endstellung Tief	241	221	1,7,9		gibt es in 61850 im LN YEFN nicht
102	Störung	241	47	1,7,9		siehe Schutzinformationen
103	Warnung	241	46	1,7,9		siehe Schutzinformationen
	Messwerte					
104	IL2	241/128	144	2,7		wird in der Praxis für E-Spulen regelung nicht benötigt
105	U12	241	150	2,7		wird in der Praxis für E-Spulen regelung nicht benötigt
106	U23	241	150	2,7		wird in der Praxis für E-Spulen regelung nicht benötigt
107	U31	241	150	2,7		wird in der Praxis für E-Spulen regelung nicht benötigt
108	IE	241/128	147	nicht genutzt	YEFN.ECA	
109	UNE	241/128	147	2,7		siehe Schutzinformationen
110	Potentiometerstellung	241	151	2,7	YEFN.ColPos	
	Stufenstellung					
111	Stufenstellung	241	152	1,2,7,9	YEFN.ColTapPos.ctlNum	aus Empfehlungen zum -103er Protokoll

Table Additional Messages

lfd. Nr		IED, LD Gerät_allg	PDIS Distanzschutz	PDIF Differenzialschutz	PTOC Überstromzeitschutz	RREC AWE	PSCH Signalvergleich	PTOV Überspannungsschutz	PTUV Unterspannungsschutz	PTEF Erdschlusswischer	PWDE E-Watt	PSDE Erdschlussrichtung	PTOF Überfrequenz	PTUF Unterfrequenz	PTRC Auslösung_allgmein	RFLO Fehlerorter	RPSB Pendelerfassung	RBRF Schalterversageschutz	RSYN Synchronabfrage	RDIR Fehlerrichtung	MMXU Messwerte	103_Fkt-Typ DEZ	**103_Info-Nr. DEZ**	103_DataUnit	61850-Adresse	Bemerkungen
	zusätzliche Meldungen / Meldungen für Störschriebe																									
1	Auslösung Idiff>			x																					PDIF1.Op.general	genutzt für Trafodiff
2	Auslösung Idiff>>			x																					PDIF2.Op.general	genutzt für Trafodiff
3	Auskommando E-Diff																								PDIF.Str.neu	
4	Rush L1																								PHAR1.Str.phsA	Trafo
5	Rush L2																								PHAR1.Str.phsB	Trafo
6	Rush L3																								PHAR1.Str.phsC	Trafo
7	Übererregung																								PVPH1.Str.general	Trafo
8	Sättigung erkannt L1																								GGIO1	für Störschriebe als Binärspuren z.B. im Differenzialschutz
9	Sättigung erkannt L2																								GGIO2	für Störschriebe als Binärspuren z.B. im Differenzialschutz
10	Sättigung erkannt L3																								GGIO3	für Störschriebe als Binärspuren z.B. im Differenzialschutz
11	LS AWE gesperrt (unverzögert)																					priv	priv		XCBR.CBOpCap	privater Bereich
12	Buchholzschutzauslösung																					priv	priv		SIML.GasFlwTr	privater Bereich
13	Buchholzwarnung																					priv	priv		SIML.GasInsAlm	privater Bereich
14	Aus durch Mitnahme																					priv	priv		PSCH.	
15	Ringleitungsüberwachung angesprochen																					priv	priv			
16	Batterie Erdschluss																					priv	priv		GGIO	
17	Batterie Spannung zu niedrig																								ZBAT.BatLo	
18	Batterie Spannung zu hoch																								ZBAT.BatHi	
19	Eigenbedarf gestört																					priv	priv		GGIO	
20	Lichtbogenschutz angesprochen																					priv	priv		SARC.FADet	

Meldungen aus dem privaten Bereich sind hier beispielhaft aufgeführt. Diese müssen projektbezogen den Datenobjekten der LN entsprechend der IEC 61850 zugeordnet werden. Datenobjekte die nicht in der IEC 61850 definiert sind können als GGIO beschrieben werden.

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