RealtimeInterface

Realtime Interface System Operator - DER

Dutch implementation of RfG interface requirements
Technical Specification Document

Netbeheer Nederland

20-02-2024 version 1.0 final

Preface

This document is the result of a common goal, an ambition. It is about contributing to a successful energy transition, about finding solutions for barriers that prevent us from making this transition in time. One such barrier appears to be the limitation of our electricity grid, which is world class, but has not been designed for the energy transition. Although many colleagues are working hard on expanding and reinforcing the grid, other solutions are required to meet the challenges that come with a new kind of energy system. More than ever, we have to work together as system operators, producers, consumers, prosumers, market parties, etc., to ensure grid safety and availability. One of the solutions that allows for safe and better utilization of grid capacity, is the introduction of an interface that allows system operators and grid users to communicate in real-time on energy transportation possibilities and constraints. This interface can serve the mutual interest. For example, it allows for minimizing impact on grid users in case of congestion threats by acting locally. Also, local energy transportation can be made possible, if the local (e.g. weather) conditions permit to do so.

Realizing that an interface specification for distributed energy resources would probably differ from a specification for e.g. residents or public EV chargers, we had to focus on the most urgent grid challenge and corresponding formal (RfG) interface requirements: allow for more distributed energy resources (DER) in the medium voltage grid.

About two years ago, this goal led to the start of the joint development of a nationwide standardized Realtime Interface. Although this project has been started by Netbeheer Nederland, it has been a joint effort with stakeholders right from the start. We were all convinced that a joint effort would benefit the quality and effectiveness of the resulting interface specification, as well as the support for this interface. It was a great joy and honour to work with so many enthusiastic colleagues in the energy sector on this topic. Discussions have been sharp, but never without respect and humour.

This document is the result of our endeavours. We present it proudly, in the knowledge that this specification is just a start but needs to get public to be able to tackle the challenges mentioned above. We are confident that the Realtime Interface is something new that will last for long. It will become part of our new energy system.

“A big thank you to all contributors!”

Thijs Nugteren, chair of the Netbeheer Nederland working group ‘Realtime Interface’

Contents

Document management and distribution

Document management

Version	Date	Changes	Author
0.9	March 25th 2022	Initial document, for review	Technical specification WG
1.0 beta	April 4th 2022	Review changes from coordinating WG, ENCS and different stakeholders	Technical specification WG
1.0 beta2	June 30th 2022	Review testing facility	Technical specification WG
1.0 beta3	December 9th 2022	Changes from Product Development and experience feedback. See attached Change Log	Technical specification WG
1.0 beta4	April 2023	Changes from Product Development and experience feedback. See attached Change Log	Technical specification WG
1.0 final	February 20th 2024	Changes from Field tests, see attached Change Log	Technical specification WG

Distribution

Version	Distribution date	Receivers	Comments
0.9	March 28th 2022	Coordinating WG	
1.0 beta	April 11th 2022	Product development and all other relevant stakeholders	
1.0 beta2	June 30th 2022	Testing facility	
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1.0 beta4	April 21st 2023	Product development and all other relevant stakeholders	Product development version for first practical evaluation
1.0 final	February 20th 2024	Public available via website	Final version for roll-out

1. Introduction

This document, together with the Protocol Implementation Document and SCL-file, forms the specification of the Realtime Interface (version 1.0). Whenever referred to the specification, the reference is to the set of these three documents.

Chapter 1 of this document gives a brief background of the domain of the Realtime Interface specification. The chapter also explains the problem definition, goals and scope related to this document. The document's outline at the end of this chapter provides a broad picture of the entire report.

1.1. Background

The energy transition is ongoing. Increasing amounts of distributed energy resources (DER, in the RfG known as Power Park Module or Synchronous Power Generating Module) such as solar photovoltaic (PV) systems and wind turbines are connected to the power system. The existing transmission and distribution networks are not designed to handle large amounts of DER. For this reason, System Operators in the Netherlands are increasingly confronted with scarce transport capacity and cannot reinforce their grid infrastructure at the same pace as DERs are being installed.

In the Netherlands, System Operators therefore have started to investigate ways to connect larger amounts of DER to the existing infrastructure. Congestion management methods have been implemented as a means to reduce the impact of scarce transmission and distribution capacity whilst reinforcing their transmission and distribution grids and connecting DER without N-1 network redundancy. Regulatory changes have been approved and implemented, enabling System Operators to apply congestion management methods on a large scale to free up capacity in the power system.

One of the tools being developed to enable such use cases is an interface between connected Customers and their System Operator, which allows connected Customers and System Operator to interact. In 2020, the Dutch System Operators, united in Netbeheer Nederland (NBNL), started a project in close collaboration with market parties (Figure 1) to describe a Realtime Interface (RTI). This RTI has the goal to enable System Operators and connected Customers to communicate real-time.

Figure 1: Partners who have contributed to the NBNL RTI project

1.2. Justification

The reason and justification for development and use of a Realtime Interface is as follows:

- The EU network code Requirements for Generators (RfG 2016/631) requires Power Generating Facility Owners to have an interface (input port) in order to be able to reduce active power output, following remote instructions of the System Operator. The System Operator has the right to specify requirements for this interface. This enables remote monitoring, control and provides operational instructions regarding power output. As a result, Grid Connection Owners in the electricity grid need to meet the requirements specified by the System Operator. The System Operators shall specify the requirements of an RTI to facilitate the exchange of information about operating constraints and metering data near real-time.
- To manage scarce transport capacity whilst awaiting grid reinforcements (or to prevent such reinforcements), System Operators may apply congestion management and/or other forms of capacity management. For the sake of operational security and optimal use of available capacity, System Operators need to be able to rely on metering values for monitoring and must be able to communicate operating constraints to Grid Connection Owners real-time.
- The national regulatory framework in the Netherlands, particularly related to capacity management (e.g., congestion management, connecting DER without N-1 network redundancy) has been updated. In November 2022, the new Dutch grid code ('Netcode Elektriciteit') has taken effect, enabling System Operators to actively apply congestion management in their networks. To ensure operational security in the power system and provide an alternative for disconnecting network segments or individual Grid Connection Owners, System Operators see a need for a direct interface between System Operator and Grid Connection Owners to exchange measurement values and operational constraints.
- Until now, no universally adopted standard has been defined for this interface. Some System Operators in neighbouring countries have developed similar RTI systems (e.g., Germany, Belgium, Italy and France), but so far no commercial off-the-shelf solutions are available. The association of Dutch System Operators, united in Netbeheer Nederland (NBNL) has therefore developed and implemented a first harmonised RTI for the Dutch electricity sector. This was designed in cooperation with market participants and Grid Connection Owners to include both a System Operator and customer perspective.
- As a result, the interface between System Operator and Power Generating Facility Owner is, with regards to an RTI, not yet standardized, while this is desirable for large-scale application, both from System Operators' and market parties' perspective.

1.3. Goal of document

The goal of this document is to standardize the interface between System Operators and Power Generating Facility Owners, with regards to an RTI. To this end, the technical specifications for an RTI in the Dutch power system are defined. This document describes the technical specification and architecture of the NBNL RTI, with a focus on RfG category B (1 MW – 50 MW). However, this specification is developed such that it can also be applied for connections with a mix of power generation and consumption as well as for larger connections.

1.4. Scope

This section describes the scope of the technical specification, both from an in- and out-of-scope perspective. The technical specification restricts itself to the interface between the System Operator ("System Operator Endpoint") and the Grid Connection Owner ("Customer Endpoint"), as can be seen in Figure 2.

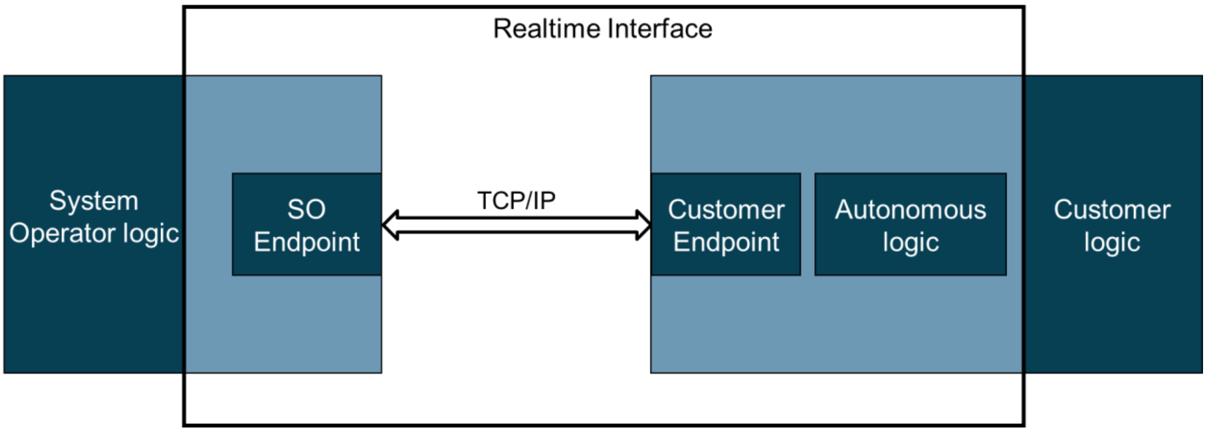


Figure 2: Scope of the Realtime Interface

1.4.1. In scope

This document focuses on connected parties in RfG category B and describes the RTI. This document, together with the PID and SCL file, defines the technical specifications of RTI version 1.0. This version is able to accommodate the basic functionality of capacity management. The RTI allows the System Operator and its connected Customers to exchange signals on the Point of Common Coupling (PoCC).

1.4.2. Out of scope

Out of scope for this specification are parties connected to all other RfG categories (i.e. A, C, D) or Demand Connection Code (DCC). However, in the design of the RTI potential future applications to other RfG categories were taken into account, such that design choices should not block or (heavily) restrict future expansion to other categories.

The RTI allows the System Operator and the Grid Connection Owner to exchange data related to electricity network usage (energy transportation). The technical interfaces between balancing or congestion service providers and Power Generating Facility Owner(s) are also not included in the scope of this specification. Financial interfaces between the various parties are furthermore not part of this technical specification.

Lastly, this document does not describe the use cases for which the RTI can be deployed, nor the framework with agreements within which the use cases can be used (which are developed separately). The focus is on the technical specifications of the interface and how signals are exchanged between both endpoints (see Figure 3).

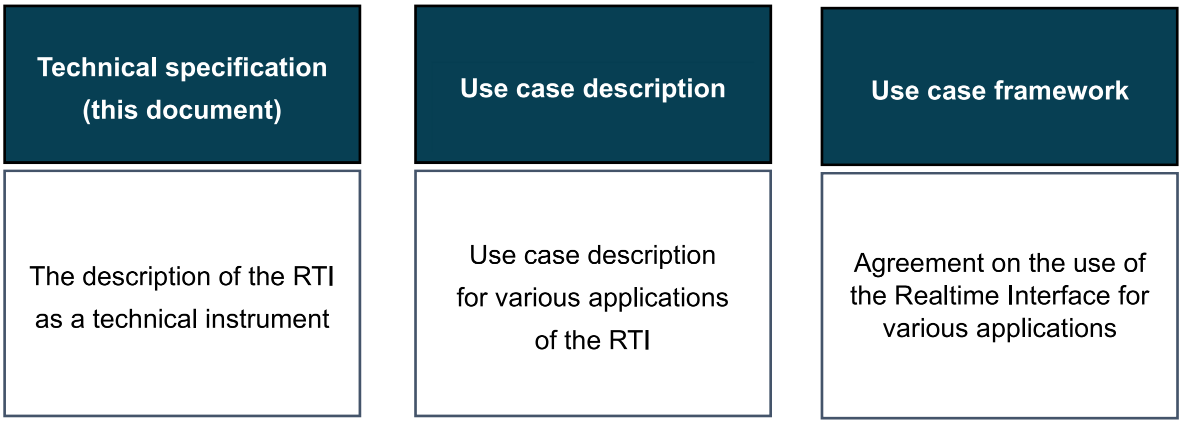


Figure 3: Demarcation between technical specification, use cases and use case framework. The current document is the technical specification on the left.

1.4.3. Application of the Realtime Interface

The RTI will initially and primarily be used to facilitate use cases related to capacity management. Additional use cases, such as voltage quality, and system protection and recovery will be considered and/or facilitated in the future. Considering the capacity management use cases, the initial focus of the RTI is communication in the (near) real-time time-domain. Other use cases in the ahead-of-time domain will be accommodated in future versions of the interface.

1.4.4. Outline

This section gives an outline of each chapter and helps to understand the report better. This document has been organized as follows:

Chapter 2 elaborates on the RTI's position in the overall ecosystem.

Chapter 3 provides the foundation or background on regulation and used models or standards.

Chapter 4 introduces the functional, non-functional and cyber security requirements on the Customer Endpoint.

Chapter 5 elaborates on the expected behaviour of the Customer Endpoint by introducing high-level process descriptions.

Chapter 6 introduces the architecture, data model, and functional behaviour.

Chapter 7 elaborates on ownership and demarcation.

Chapter 8 briefly discusses implementation and compliance verification**.**

The document concludes with several appendices with references, attachment and examples.

2. Position in the ecosystem

This chapter discusses the roles relevant for the RTI, as well as their interactions. In the context of the Realtime Interface, there are several relevant roles:

- **The System Operator:** The Distribution System Operators and Transmission System Operator are responsible for the safe and continuous operation of the distribution and transmission system, respectively.
- **The Grid Connection Owner:** A natural or legal entity with whom a System Operator has a connection agreement i.e. Aansluit- en Transportovereenkomst (ATO).
- **The Power Generating Facility Owner:** A natural or legal entity owning a power-generating facility.
- Other roles such as the **Congestion Service Provider, Balancing Responsible Party** and **Balancing Service Provider** are relevant for market arrangements but out of scope in the context of the RTI.

The interactions between System Operator, Customer Endpoint, Power Generating Facility Owner and congestion or balancing service provider, can be modelled into a simplified triangular flow diagram, which is illustrated in Figure 4.

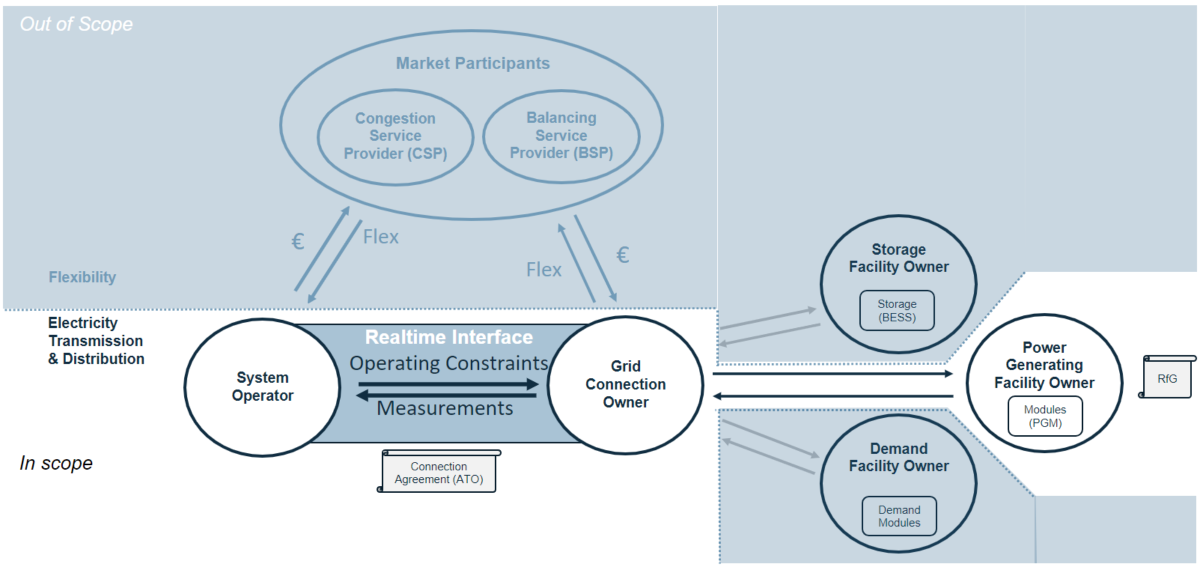


Figure 4: Interface between Service Providers, Power Generating Facility Owner, Grid Connection Owner and the System Operator and the domain of the Realtime Interface.

Figure 4 shows how the scope and positioning of the RTI is placed in the overall ecosystem, but does not touch upon market processes and arrangements with e.g. congestion service providers. The RTI is placed in between the System Operator and Grid Connection Owner in such a way for the System Operator to send instructions to and receive measurements from the Grid Connection Owner. These instructions contain for example operating constraints (e.g. the maximum allowed active power) at the relevant connection point referred to as the Point of Common Coupling (PoCC). It is the responsibility of the Grid Connection Owner to carry out the instruction:

- It is the responsibility of the System Operator to communicate information related to operating constraints via the RTI to the Grid Connection Owner.
- It is the responsibility of the Grid Connection Owner to act upon these operating constraints and communicate with Power Generating Facilities (Owner(s)) accordingly.
- It is the responsibility of the Grid Connection Owner to communicate information related to real-time measurement data via the RTI to the System Operator.
- It is the responsibility of the Grid Connection Owner to communicate information from the System Operator to the Power Generating Facilities and vice-versa. Only the Grid Connection Owner can do so.
- In general, the instruction can be fulfilled by a combination of steering Power Generation Modules and / or demand side management.
- In theory, for specific cases, the instruction may need to be carried out by steering the Power Generation Module according to formal RfG (EU) 2016 requirements. In case multiple Power Generation Facility Owners are present behind one Grid Connection, it is the responsibility of the Grid Connection Owner to ensure the individual and specific Power Generating Facilities carry out the instructions received via the RTI in accordance with the applicable regulatory framework.

RTI version 1.0, which is in scope of this document, will support interaction within the real-time (RT) domain, as seen in Figure 5.

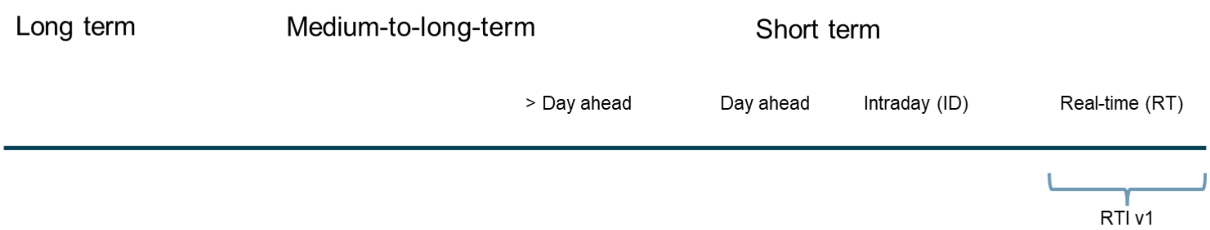


Figure 5: Illustration of the time domain of the RTI

3. Foundation

This chapter describes the background on the applicable regulatory framework and the models and standards this specification is based on.

3.1. Regulatory framework

3.1.1. Requirements for Generators (RfG)

In 2016 the European Union established the European Network Code on Requirements for Generators (RfG). The regulation sets out detailed rules relating to the connection of power generating installations to national electricity networks. These harmonized rules for grid connection for power generating modules facilitate system security, integration of renewable electricity sources, EU wide trade in electricity, and allow for more efficient use of the network and resources.

In this network code, four types of power generating modules (A, B, C, D) are distinguished, based on their maximum power generating capacity. In the RfG code, requirements regarding the real-time exchange of information between System Operator and Power Generating Facility Owner are formulated per power generating module type. The RfG also demands Power Generating Facility Owners to be able to adapt the Power Generating Modules' active and reactive power, according to instructions of the System Operator.

This technical specification implements the interface requirements as formulated in the RfG code for type B (1-50 MW).

3.1.2. Demand Connection Code

The Demand Connection Code (DCC) sets rules for the connection of demand and distribution systems to the electricity system. The DCC is one of the three EU network codes for grid connections, together with the RfG and HVDC. It has the same intentions as the RfG network code, as described above.

The DCC network code specifies the technical requirements for use of demand response in ancillary services. Demand response services provided to system operator System Operators are divided into remotely controlled and autonomously controlled services. As with the RfG, the DCC includes requirements regarding the real-time exchange of information between System Operator and provider of demand response. Also, presence of the capability to adjust power consumption from the network according to instruction of the System Operator is demanded.

This technical specification implements the interface requirement as formulated in the DCC for especially remotely controlled demand response services.

3.1.3. Electricity Grid Code (Netcode Elektriciteit)

The Dutch Electricity Grid Code is established by the Dutch energy regulator: Authority for Consumers & Markets (ACM). The grid code states how the System Operator should behave and what obligations a Grid Connection Owner has. This code describes, among other things, the conditions under which a System Operator must manage its networks, how a company or institution must be connected and how capacity management must be carried out on the network. This code also includes the rules on the import and export of electricity, how system services (ensuring security of supply) must be performed, how the energy balance is maintained, how large-scale disruptions are resolved and how balance responsibility (balancing supply and demand of electricity) is managed.

Among others, the grid code comprises requirements on information exchange between System Operator and Grid Connection Owner, which elaborates on EU network codes, such as RfG**.** Note that the network codes also elaborate on some possible use cases.

These information exchange requirements have been used to shape the technical specification of the Realtime Interface, e.g. regarding the provisioning of measurements by Power Generating Facility Owners.

3.2. Smart Grid Architectural Model - SGAM

3.2.1. Introduction to SGAM

Smart grid related projects often have relatively complicated architecture models, due to the wide diversity of topics that need to be covered (e.g. physical infrastructure, information technology infrastructure, interfacing with different partners). To provide a uniform representation of the high-level architecture over the various topics, the Smart Grid Architectural Model (SGAM) has been developed.

SGAM utilizes a three dimensional model, with a two dimensional base. This base pane covers the different domains and zones of the power system. On the horizontal axis the five domains are covering the electrical energy conversion chain (bulk generation, transmission, distribution, DER, and Customer premises), and on the vertical axis zones are representing the hierarchical levels for management of the power system (process, field, station, operation, enterprise, and market) [CEN2012].

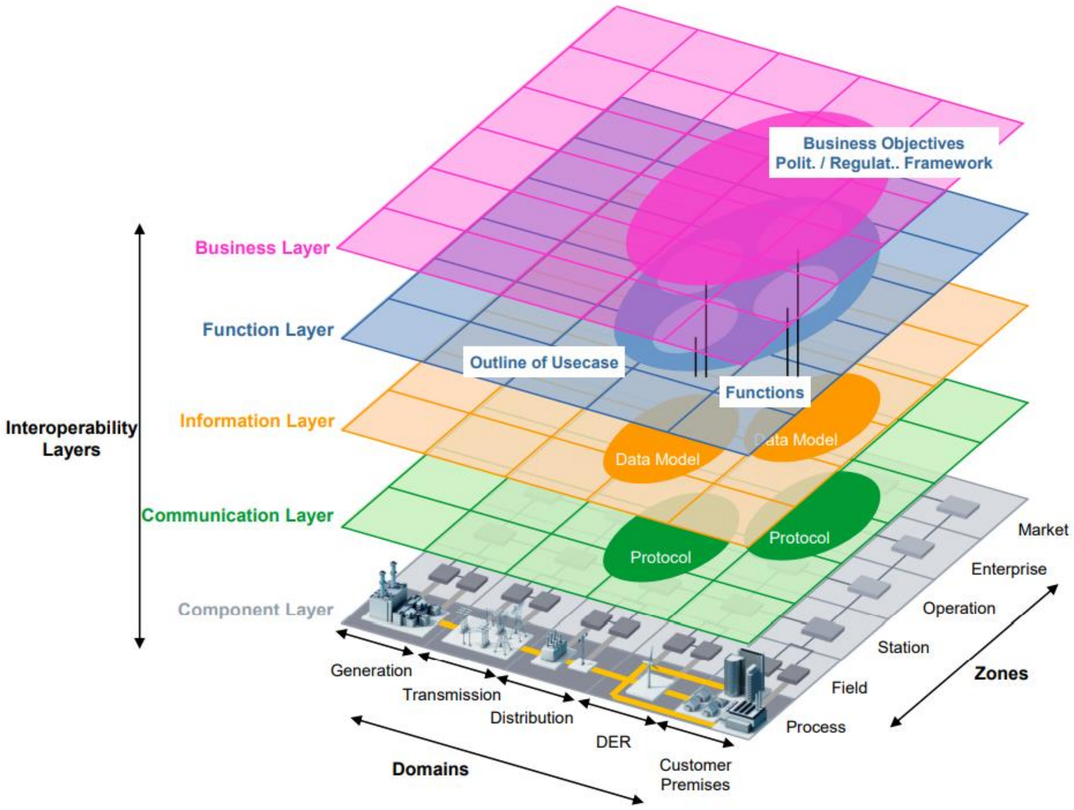


Figure 6: CEN-CENELEC-ETSI Example SGAM

The third dimension is created by adding various layers, describing the aspects of a smart grid. The bottom field provides the physical infrastructure of the smart grid (component layer), the remaining layers are covering the communication protocols, information exchange, main functions of clusters of infrastructure, and the business opportunities of the smart grid [CEN2012].

The main target audiences of the SGAM reference architecture are technical standardization committees, as the reference architecture provides a methodology on the different aspects of a technical standard. The technical specifications and architectural design of the Realtime Interface (RTI) described in this document can be seen as a national standard among Dutch (transmission and distribution) System Operators.

3.2.2. Description of the SGAM elements

This section briefly explains the different domains, zones, and layers in the SGAM, using the reference architecture [CEN2012] as input.

3.2.2.1. Domains

The domain-axis of the SGAM consists of the following domains:

- Bulk generation: representing large-scale generators (e.g. fossil fuel power plants)
- Transmission: representing the infrastructure for the transport of electricity
- Distribution: representing the infrastructure for the distribution of electricity
- DER: representing distributed energy resources (DERs) directly connected to the distribution network
- Customer premises: hosting both producers and consumers of electricity. In this document, customers are typically referred to as Grid Connection Owners.

3.2.2.2. Zones

The zones-axis of the SGAM consists of the following zones:

- Process: includes the physical equipment directly involved in the process of moving energy (both primary and secondary components).
- Field: includes equipment to protect, control and monitor the process (intelligent electronic devices which obtain and/or use process data)
- Station: areal aggregation level for (e.g.) data concentration, function aggregation, substation automation
- Operation: hosting power system control operations in its respective domain. For example, distribution management systems (DMSs) or EV fleet charge management systems
- Enterprise: commercial and organisational processes, services and infrastructure
- Market: possible market operations along the energy conversion chain (e.g. trading markets)

3.2.2.3. Layers

The SGAM consists of the following five layers

- Business: business processes, services and organisations (including interactions) related to a use case
- Function: functionality derived from use cases
- Information: data model / information exchanged between systems and/or actors
- Communication: means of communication between systems and/or actors
- Component: devices, applications, persons and organisations and their interactions

3.3. Introduction to IEC 61850

IEC 61850 is a set of standards that deals with communication networks and systems for power utility automation. It is developed in the late nineties, when the market was dominated by several proprietary standards. The objective was to have an interoperable communication standard and data model. IEC 61850 contains several different parts. The applicable parts are being listed in Attachment [A].

The choice of IEC 61850 for application in the RTI has been made in close collaboration with the different stakeholders. The big advantage of IEC 61850 is the sophisticated data model, as visualised in Figure 7. This data model supports the modelling of the complete chain: from a Physical Device up to detailed Data Attributes. All data which is being exchanged can be related to the asset / Physical Device it belongs to.

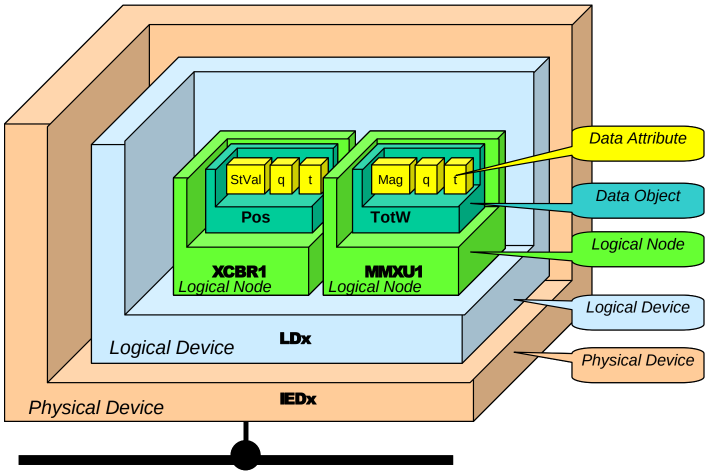


Figure 7: IEC 61850 data model structure, source: IEC 61850-1-1

In October 2021, the latest version of the data model regarding DER has been published, as result of common effort between System Operators, consultants and vendors. This data model is used in the RTI. The fact that it is an IEC standard furthermore helps in applying security measures. See also [www.iec.ch.](http://www.iec.ch)

4. Requirements Customer Endpoint

This chapter describes the requirements that are applicable for the RTI. They are divided in different parts, starting with functional requirements, followed by the non-functional requirements, and concludes with the security requirements. The Grid Connection Owner has the freedom to realize the Customer Endpoint in different ways, as long as it meets the requirements described in this specification.

4.1. Functional Requirements

The functional behaviour of the RTI is described by the requirements below[1]. The IDs of the requirements are derived from a requirement database. Note that all sign conventions (e.g. the meaning of a plus or minus sign) shall be based on the definitions within the applicable IEC 61850 standard. For an implementation example of the P and Q signs, see IEC 61850-7-420 Ed. 2, figure 33. For more detailed implementation information, see the attached Protocol Implementation Document (Appendix A) and SCL file (Appendix B).

ID	[Setpoint-1]
Requirement	Receive a setpoint for the upper limit of generated active power P as a percentage [%] of the maximum capacity
Source	System Operator
Logical Node	DWMX
Description	
Setpoint-1 is the maximum allowed generated active power at the PoCC. The Setpoint is defined as a percentage of the accumulative “Maximum Capacity (MW)” in the PGMD form(s).	

ID	[Setpoint-2]
Requirement	Receive a setpoint for the upper limit of generated active power P in [MW]
Source	System Operator
Logical Node	DWMX
Description	
Setpoint-2 is the maximum allowed generated active power at the PoCC.	

[1] Note that the requirements presented in this specification all have unique IDs and represent a subset of all current, past, and future requirements in a master database. Therefore the numbering might not appear to be consistent. See also www.netbeheernederland.nl/dossiers/realtimeinterface

ID	[Setpoint-3]
Requirement	Receive a setpoint for the upper limit of consumed active power P in [MW]
Source	System Operator
Logical Node	DWMX
Description	
Setpoint-3 is the maximum allowed consumed (load) active power at the PoCC.	

ID	[Setpoint-8]
Requirement	Receive a reason why a setpoint for active power is sent by the System Operator
Source	System Operator
Logical Node	Nested within DWMX
Description	
Setpoint-8 reflects the reason for which use case a setpoint is sent by the System Operator. The reason is represented by an integer value. This requirement is only applicable for [Setpoint-1], [Setpoint-2] and [Setpoint-3]. For more detailed information see chapter 6.3.3.1.	

ID	[Measurements-1]
Requirement	Sent actual active power measurement on PoCC in [MW]
Source	Customer Endpoint
Logical Node	MMXU
Description	
Measurements-1 is the measurement of the actual active power on the PoCC in MW. The value is the total power of all three phases.	

ID	[Measurements-2]
Requirement	Sent actual reactive power measurement on PoCC in [MVAr]
Source	Customer Endpoint
Logical Node	MMXU
Description	
Measurements-2 is the measurement of the actual reactive power on the PoCC in MVAr. The value is the total reactive power of all three phases.	

ID	[Measurements-3]
Requirement	Sent actual phase-neutral and phase-phase measurements on PoCC in [kV]
Source	Customer Endpoint
Logical Node	MMXU
Description	
Measurements-3 is the measurement of the actual phase-neutral and phase-phase voltages on the PoCC for all the three phases in kV. This applies for all three phases individually.	

ID	[Measurements-4]
Requirement	Sent actual current measurement on PoCC in [A]
Source	Customer Endpoint
Logical Node	MMXU
Description	
Measurements-4 is the measurement of the actual current on the PoCC for all the three phases in A. The values of the currents are always absolute values. This applies for all three phases individually.	

ID	[Safe-Mode-1]
Requirement	In case of lost communication for a duration of a configurable time, restrict the generated active power P configurable level in percentage [%] or absolute values [MW]
Source	n/a
Logical Node	DWMX
Description	
Safe-Mode-1 restricts the amount of generated active power in case of a communication interruption on the RTI. The Customer Endpoint falls back to a predefined setpoint. The configurable generation power shall be configured using either the WMaxSetPct or WMaxSet Data Objects. The configurable time shall be exchanged by the WMaxFto Data Object. For more information, see chapter 5.1.	

ID	[Safe-Mode-2]
Requirement	Retrieve safe mode setpoint in either percentage [%] of the maximum capacity or in absolute values [MW]
Source	Customer Endpoint
Logical Node	DWMX
Description	
Safe-Mode-2 is the setpoint to which the Customer Endpoint has to fall back in case of a communication interruption on the RTI. The System Operator should be able to retrieve the actual setpoint value from the Customer Endpoint.	

ID	[Safe-Mode-3]
Requirement	Set safe mode setpoint in either percentage [%] of the maximum capacity or in absolute values [MW] remotely
Source	System Operator
Logical Node	DWMX
Description	
Safe-Mode-3 means the System Operator is able to set the setpoint for the safe mode at the Customer Endpoint through the RTI. The configurable generation power shall be configured using either the WMaxSetPct (percentage) or WMaxSet (absolute value) Data Objects.	

ID	[Safe-Mode-5]
Requirement	After restoring communication, buffered 15 minutes average active power measurements [MW] for the past 8 hours should be pushed to the System Operator ('buffered reporting')
Source	Customer Endpoint
Logical Node	MMXU
Description	
Safe-Mode-5 allows the System Operator to receive measurement values for a period where there was no communication with the Customer Endpoint through the RTI. The measurement values should be presented as 15 minutes average values of the 'TotW' data object, with a maximum time span of 8 hours.	

ID	[Safe-Mode-6]
Requirement	After restoring communication, buffered 15 minutes maximum active power measurements [MW] for the past 8 hours should be pushed to the System Operator ('buffered reporting')
Source	Customer Endpoint
Logical Node	MMXU
Description	
Safe-Mode-6 allows the System Operator to receive measurement values for a period where there was no communication with the Customer Endpoint through the RTI. The measurement values should be presented as 15 minutes maximum values of the 'TotW' data object, with a maximum time span of 8 hours.	

ID	[Safe-Mode-7]
Requirement	After restoring communication, buffered 15 minutes minimum active power measurements [MW] for the past 8 hours should be pushed to the System Operator ('buffered reporting')
Source	Customer Endpoint
Logical Node	MMXU
Description	
Safe-Mode-7 allows the System Operator to receive measurement values for a period where there was no communication with the Customer Endpoint through the RTI. The measurement values should be presented as 15 minutes minimum values of the 'TotW' data object, with a maximum time span of 8 hours.	

ID	[Customer-Configuration-1]
Requirement	Retrieve state of Customers installation
Source	Customer Endpoint
Logical Node	DGEN
Description	
Customer-Configuration-1 is the possibility for the System Operator to retrieve the actual state of the Customer Endpoint.	

ID	[Customer-Configuration-7]
Requirement	Retrieve RTI version information of Customers Endpoint
Source	Customer Endpoint
Logical Node	LLN0
Description	
Customer-Configuration-7 is the possibility for the System Operator to retrieve the RTI version information of the Customer Endpoint. See chapter 6.3.2.1.	

ID	[Customer-Updates-1]
Requirement	The operating system at the Customer Endpoint has to be able to perform updates and/or patches.
Source	Customer Endpoint
Logical Node	n/a
Description	
During the technical life time of the Customer Endpoint, new functionalities may have to be added or security risks may need to be addressed. Therefore, the Customer Endpoint has to be able to perform updates and patches to for example gain new functionalities. See also related requirement ID [Contract-Updates-1].	

4.2. Non-Functional Requirements

The following non-functional requirements[2] have to be implemented.

ID	[Availability-1]
Requirement	
Source	IEC 60870-4 class A1: 99,00%
Logical Node	n/a
Description	
Availability of communication from System Operator Endpoint to Customer Endpoint, based on a time period of at least 6 months, in line with the referred standard chapter 3.2.1.	
ID	[Accuracy-1]
Requirement	Class 1, as described in the IEC 61869 set of standards
Source	Customer Endpoint
Logical Node	MMXU
Description	
Accuracy of measurements, referenced to the measurement values on the PoCC. Note that these values can be measured directly on the PoCC, or can be obtained on another location behind the PoCC. The accuracy always shall be within the stated requirement.	

ID	[Accuracy-2]
Requirement	Maximum deviation with UTC-time of 10 seconds
Source	Customer Endpoint
Logical Node	n/a
Description	
Accuracy of time synchronization. Reference is UTC	

ID	[Accuracy-3]
Requirement	Maximum deviation with UTC-time of 10 seconds
Source	System Operator
Logical Node	n/a
Description	
Accuracy of time synchronization. Reference is UTC	

[2] Note that the requirements presented in this specification all have unique IDs and represent a subset of all current, past, and future requirements in a master database. Therefore the numbering might not appear to be consistent.

ID	[Bandwith-1]
Requirement	Local interface is standard Ethernet (10/100/1000Mbit)
Source	RTI
Logical Node	n/a
Description	
Required bandwidth on the Realtime Interface	

ID	[Response-Time-1]
Requirement	< 4 seconds
Source	RTI
Logical Node	n/a
Description	
Response time communication interface (acknowledge) between System Operator Endpoint and Customer Endpoint (communication line)	

ID	[Response-Time-2]
Requirement	Depends on the agreed use case framework
Source	Customer Endpoint
Logical Node	n/a
Description	
Response time electrotechnical (asset) response at Customer side. Time from receiving setpoint from System Operator to achieving the desired setpoint.	

ID	[Response-Time-3]
Requirement	< 3 minutes
Source	System Operator
Logical Node	n/a
Description	
In case of a power failure: Time to restore communications after energizing the power system.	

ID	[Response-Time-5]
Requirement	< 3 minutes
Source	Customer Endpoint
Logical Node	n/a
Description	
In case of a power failure: Time to restore communications after energizing the power system.	

ID	[Response-Time-6]
Requirement	< 3 minutes
Source	System Operator
Logical Node	n/a
Description	
Time needed to restore communications after a restart of the System Operator Endpoint.	

ID	[Response-Time-8]
Requirement	< 3 minutes
Source	Customer Endpoint
Logical Node	n/a
Description	
Time needed to restore communications after a restart of the Customer Endpoint.	

4.3. Cyber Security Requirements

The following requirements protect the communication between the System Operator Endpoint and the Customer Endpoint in the Version 1.0 of the Realtime Interface. They also protect any devices of the System Operator installed in the Grid Connection Owner premises.

ID	[Network-Segmentation-1]
Requirement	The System Operator Endpoint and the Customer Endpoint shall communicate through a dedicated cabled connection provided by the Customer
Description	
Any equipment used for converting between fibre and ethernet can only be used for the purpose of this connection. At the Customer side, the termination cable shall connect to a network interface of the (e.g. park- or energy management) controller and not to a network device. Under no circumstance shall this cable be disconnected (and connected to a network). This ensures that the System Operator endpoint and the Customer endpoint are the only two hosts in the communication channel. Further, it prevents connections with high risk profile networks, such as wi-fi networks or the Internet.	

ID	[Physical-Security-1]
Requirement	If there must be System Operator equipment in the Grid Connection Owner premises, then the Grid Connection Owner shall provide a separate secure area to place this equipment that only the System Operator can access
Description	
The System Operator should already have a room where they have medium voltage equipment in the Grid Connection Owner location. Where this room exists, it should be used to place the System Operator equipment for the Realtime Interface.	

A compromised Customer Endpoint can be used to compromise the Realtime Interface, the electricity grid or the System Operator Endpoint. Therefore, the following minimum set of measures for the Customer side will be included in the Contract.

ID	[Contract-Segmentation-1]
Requirement	The Customer Endpoint shall not be directly accessible from the Internet on any interface, but only through a secure solution such as a VPN or jump server
Description	
The Requirement Network-Segmentation-1 applies to the Realtime Interface between the System Operator Endpoint and the Customer Endpoint. Feasible and effective solutions must be identified for the other interfaces. For instance, a virtual private network can be used to encrypt and protect the integrity of communications with remote systems or human users over the Internet, and a jump server can force remote human users to use a specific application in the middle of the communication path. These solutions can be used together and/or in combination with other solutions. Further, the overall solution should require multi-factor authentication, restrict the users' access according with their authorizations and allow monitoring of user related activity.	

ID	[Contract-Hardening-1]
Requirement	The administrator of the Customer Endpoint shall replace all default passwords with unique and strong passwords
Description	
This applies at least to the endpoint itself and to all other devices in the same local area network. Strong passwords can be created with effective complexity, length and randomness based on Section 5 of the NIST SP 800-63B. They should be unique for each function in each device.	

ID	[Contract-Updates-1]
Requirement	The administrator of the Customer Endpoint shall have a patching process by which vulnerabilities are solved and updates are applied at least once a year
Description	
This applies at least to the endpoint itself and to all other devices in the same local area network. This requires monitoring vulnerability lists, vendor advisories and new release notes. Ideally, patches and updates should be applied right after they are tested for compatibility issues.	

ID	[Contract-Training-1]
Requirement	The administrator of the Customer Endpoint shall have basic security training and awareness
Description	
A video covering the importance of these measures, how to implement them on a general level and how to test the implementation is available on the website of Netbeheer Nederland.	

The Grid Connection Owner should take complementary measures not directly related with the Realtime Interface scope based on a risk assessment and existing security standards such as ISO 27001 or IEC 62443 to further protect its endpoint and any systems connected to it.

These complementary measures can be based on the requirement sets of European Network for Cyber Security (ENCS) and security advice from WindEurope and SolarPower Europe (see *encs.eu*, *windeurope.org* and *solarpowereurope.org*).

5. Process description

This chapter provides a high-level process description of the expected operational behaviour of the Customer Endpoint. The operational behaviour of the Realtime Interface is defined by two types of processes, which are described in this chapter:

- Core process, responsible for handling setpoints, settings and measurements. This process provides the core functionality of the RTI during a normal operational mode, when the IEC 61850 connection is available. The expectation is the Customer Endpoint will operate within this process most of the time.
- Overall process, responsible for handling different operational modes. To ensure secure operation of the overall power system, the behaviour of individual Customer Endpoints during abnormal operation is described. Abnormal operation includes boot periods, reboot periods and periods during which the IEC 61850 connection is unavailable. The overall process furthermore describes its relationship with the core process.

On critical locations in both processes, a predefined state is set. These states are represented by an enumerical value. The predefined state enumerations are derived from the IEC 61850 standard, but applied in the context of the RTI. The states provide the SO information about the current operational state of the RTI. Not all states have a direct link with the DER status. For a detailed description of the predefined states, see chapter 6.3.3.3.

5.1. Core process Realtime Interface

The core processes of the Realtime Interface consists of three main tasks (see Figure 8).

- Receive new reasons, (safe mode) setpoints and safe mode time-out values and act accordingly on them.
- Periodically send reports (including measurements and settings) to inform the SO endpoint.
- Monitor and report on DER (partial) unavailability. As a result, the Endpoint can have different states within the core process,

For the monitoring on DER (partial) unavailability, a differentiation between full availability and (partial) unavailability of the connected DER is made. (Partial) unavailability, is defined as one or multiple connected DERs is unable to process the operational setpoints. A practical example could be the case of multiple turbines or inverters behind a PoCC.

As long as the RTI is in the operational mode and the IEC 61850 connection is available, the Customer endpoint remains within the core process (see chapter 0).

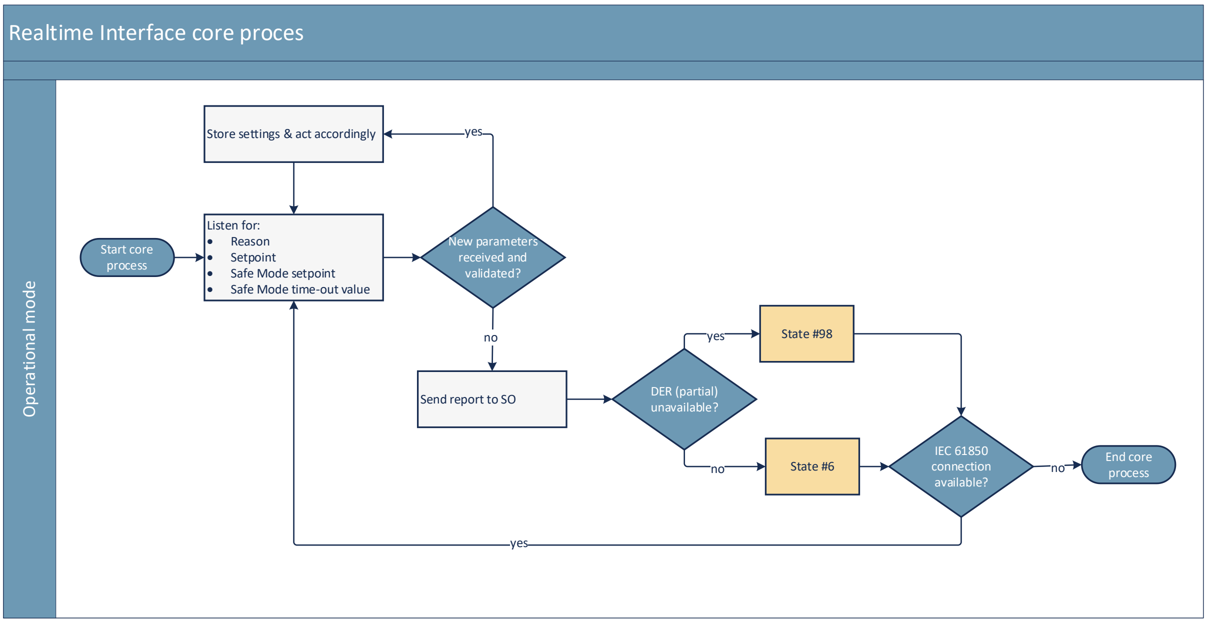


Figure 8: Process description of the core processes of the RTI

5.2. Overall process for controlling operational modes

In the overall process (see Figure 9), the expected behaviour of the Customer perspective is visualised, including its relation to the core process (see chapter 5.1). In principle, the RTI is a transparent connection to exchange signals. Nevertheless, some autonomous behaviour needs to be in place to guarantee safe and efficient operation, during a boot or reboot period, and in case the Customer Endpoint loses its IEC 61850 connection.

The overall process distinguishes four swim lanes, describing four operational modes. The four operational modes are:

- Initial boot mode
- Operational mode
- Safe operating mode
- Reboot mode

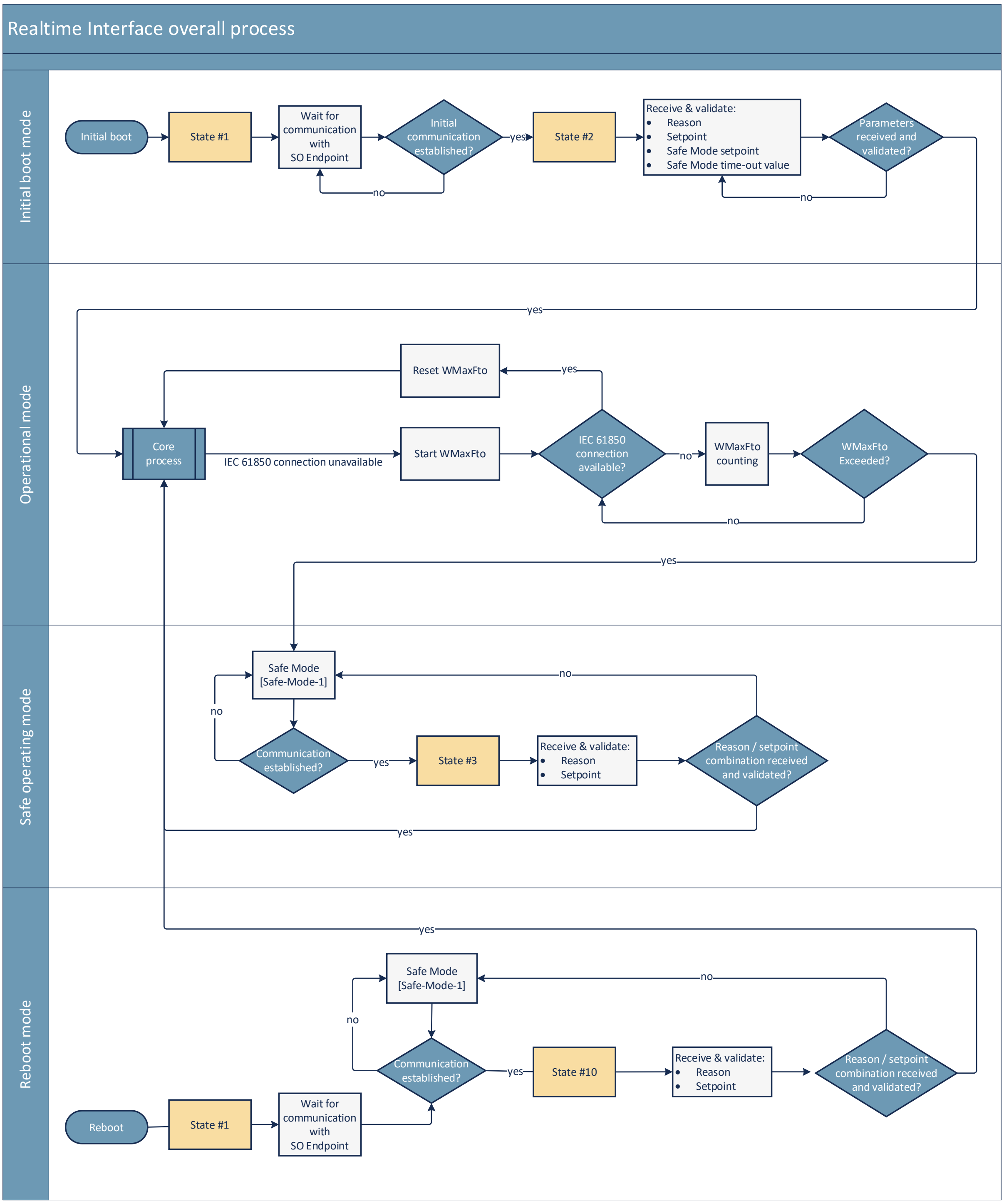


Figure 9: Overall process description of expected behaviour in the four operational modes of the RTI and its relation with the core process.

5.2.1. Initial boot mode

Initial boot mode describes the starting behaviour of the Customer Endpoint in case no previous safe mode settings are available. The Power Generating Facility Owner may not deliver any power to the System Operator until all the following criteria are fulfilled:

- an active IEC 61850 connection with the endpoint of the System Operator is established
- a valid reason and setpoint from the System Operator are received, see chapter 6.3.3.1
- a safe mode setpoint and fallback time setting from the System Operator are received

5.2.2. Operational mode

Operational mode means that the core process for handling setpoints, settings and reports (see chapter 5.1 for the core process) is running. Before entering the operational mode, the Customer Endpoint received the initial operational parameters from the System Operator. The initial operational parameters are:

- Reason
- Setpoint
- Safe Mode setpoint
- Safe Mode time-out value

The operational mode swimlane describes the process related to monitoring the (un)availability the IEC 61850 connection.
The RTI connection is being supervised by the Customer Endpoint. In case the IEC 61850 connection has been lost, the WMaxFto timer shall start. While the connection is lost and the duration of the lost connection is within the parameterized time (LN DWMX, Data Object WMaxFto), the RTI will stay in the operational mode. If and when the parameterized time is exceeded, the Customer Endpoint will change to Safe operating mode.

5.2.3. Safe operating mode

Safe operating mode is reached when the Customer Endpoint has no connection with the System Operator Endpoint for more than a parameterized time (LN DWMX, Data Object WMaxFto), as described in the section about the operational mode. This triggers the safe mode functionality, forcing the Customer Endpoint to the predefined Safe mode setpoint (see chapter 6.3.3.1).

5.2.4. Reboot mode

Reboot mode is only applicable in case the Customer Endpoint starts up with the Safe mode settings still available (e.g. stored in non-volatile memory). In case no safe mode settings are available, initial boot mode is applicable.

Reboot mode can for example be a result of an outage, a restart of the operating system or a firmware upgrade. To prevent damage to the power system, the Customer Endpoint will follow a predefined Safe mode setpoint (see chapter 6.3.3.1). This Safe mode setpoint should be followed until the connection with the System Operator Endpoint is re-established and a valid reason / setpoint combination is received from the System Operator.

6. Architecture

This chapter describes the RTI's architecture using SGAM and elaborates on the applicable IEC 61850 logical nodes. SGAM is followed top-down: in order business layer, function layer, information layer, communication layer and component layer.

6.1. Business Layer

The Business Layer describes the different parties involved with the RTI and the curtailment of generators.

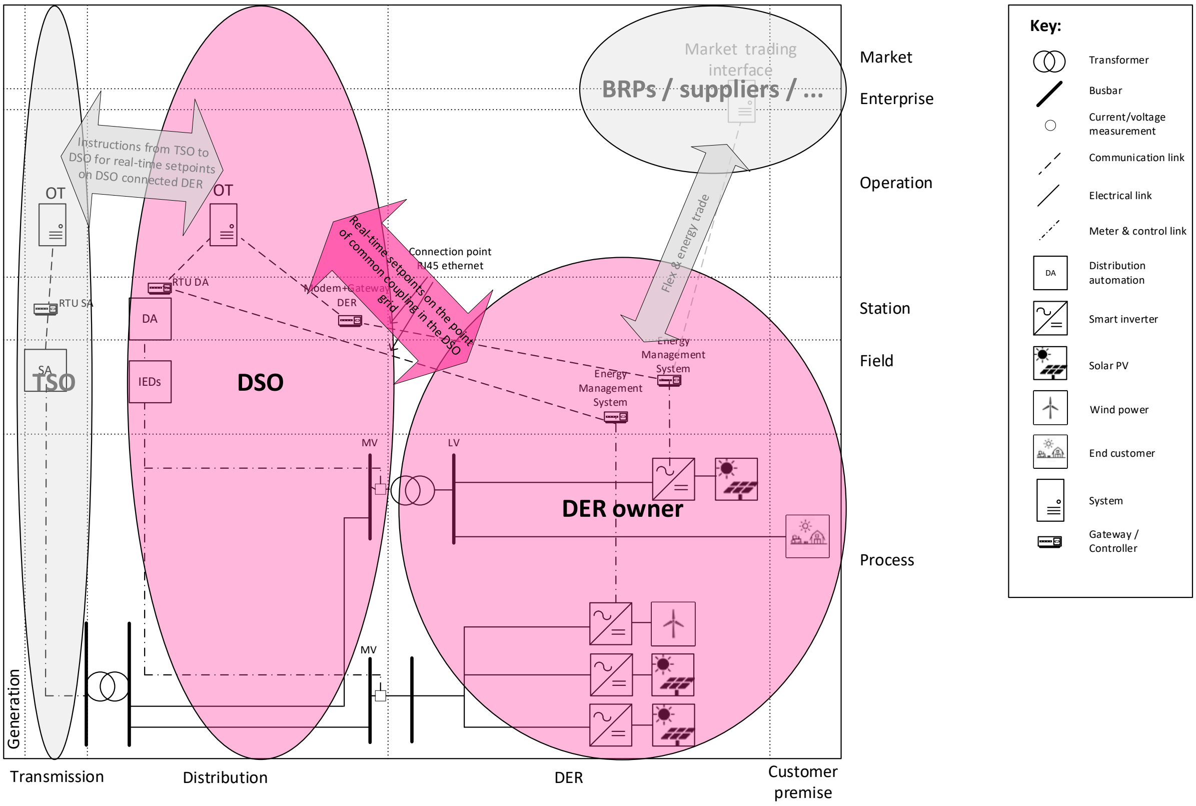


Figure 10: SGAM Business Layer RTI

6.2. Function Layer

The Function Layer describes the function and the interaction of the individual components concerned with the RTI.

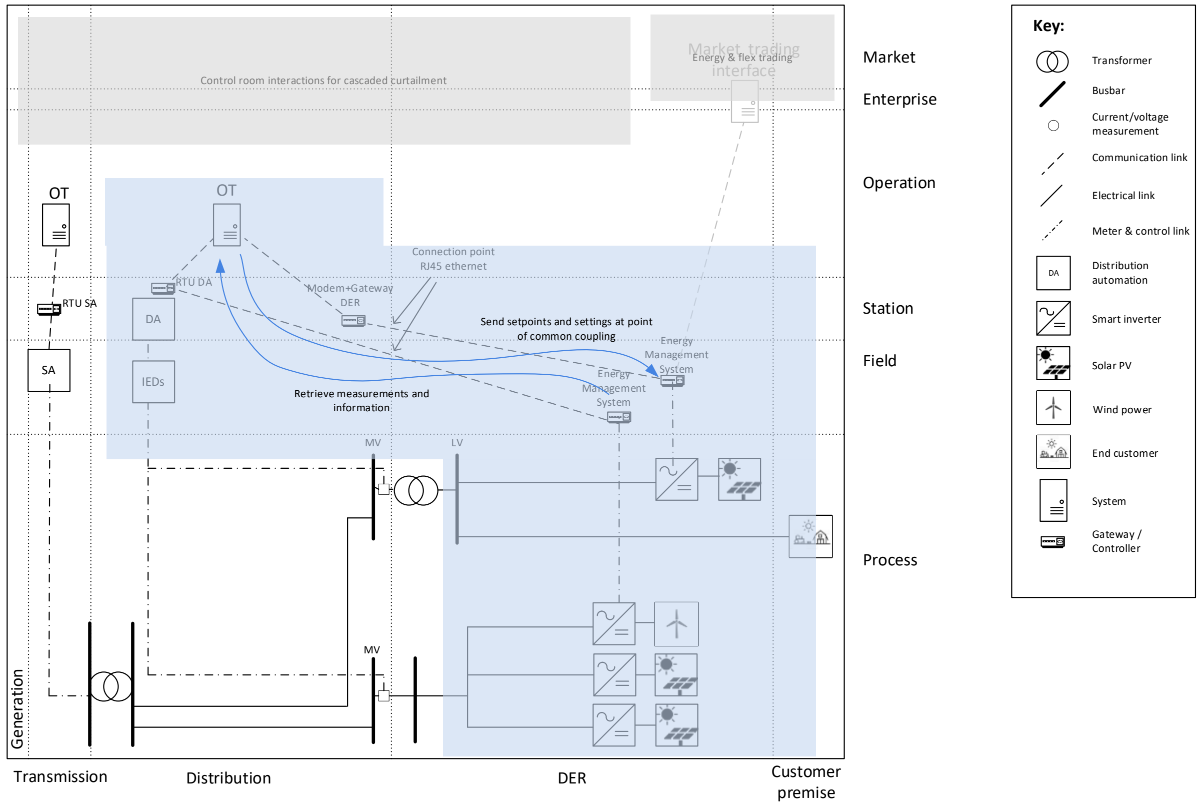


Figure 11: SGAM Function Layer with two different example implementations (blue lines) of the RTI

The Transmission- and Distribution System Operators (TSO & DSO respectively) are responsible for managing the power system. When they foresee that curtailment of a DER is necessary to ensure safe operation of the power system, they send a setpoint through the Realtime Interface towards the DER. When the TSO needs to restrict a Grid Connection Owner in the DSO's grid, the TSO will contact the respective DSO’s operations centre, to relay a curtailment request on behalf of the TSO.

The DER will limit the production of energy on the PoCC, based on the received setpoint of the DSO. The DER shall send measurement values related to the PoCC back towards the DSO.

A DER can also have a connection with market parties like Balance Responsible Parties or energy suppliers to facilitate (flex) energy trading. This function is out of scope of the RTI, see chapter 2.

6.3. Information Layer

IEC 61850 is selected as the basis of the data model for the RTI. The signals that are exchanged on the RTI belong to a logical node that is described in the IEC 61850-7-4 Ed 2 and IEC 61850-7-420 Ed 2. The following chapter describes the logical nodes that are being used.

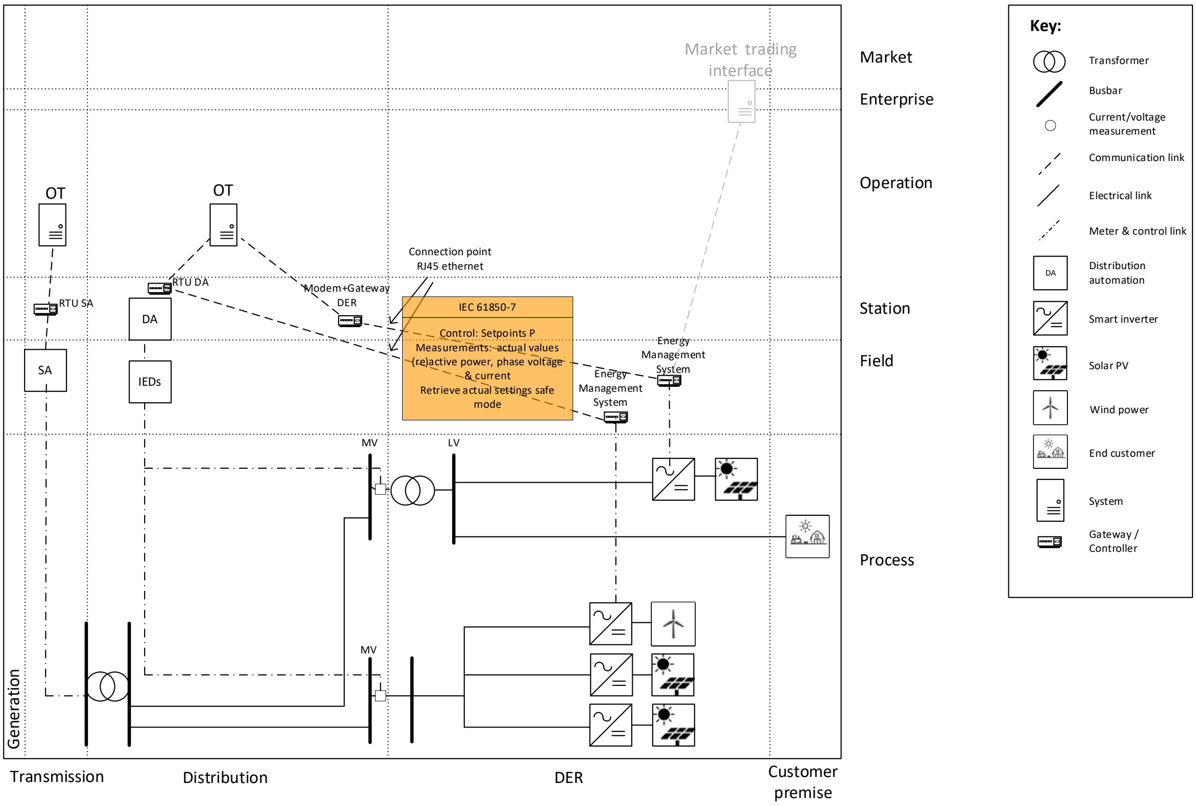


Figure 12: SGAM Information Layer

Note: only the main Data Objects (DOs), related to the core functionality of the Realtime Interface, are described in this chapter. The complete list of Data Objects is being described in the attached IEC 61850 Substation Configuration Language (SCL) file. The SCL file is based on the XML file format, hierarchically modelled, should be used for implementing the RTI on both System Operator and Customer Endpoints.

6.3.1. Physical device

6.3.1.1. LPHD: Physical device information

This logical node models common issues and information for physical devices. The selected DO's identify the physical devices at the Customer Endpoint and represent its current health status.

Data Object Name	Common Data Class	Explanation
PhyNam	DPL	Physical device name plate
PhyHealth	ENS	Physical device health
Proxy	SPS	Indicates if this LN is a proxy
PwrUp	SPS	Power-up detected

6.3.2. Logical device

6.3.2.1. LLN0: Logical node zero

This logical node models common issues and information for logical devices. The selected DOs identify the logical devices at the Customer Endpoint and represent its current health status.

Data Object Name	Common Data Class	Explanation
NamPlt	LPL	Name plate. The configRev attribute reflects the RTI version which is implemented, as required in [Customer-Configuraton-7]. The version shall be named using the following convention: ”major.minor.patch", i.e. RTI v1.0 shall be named as “1.0.0”. The swRev attribute shall reflect the firmware version of the Customer Endpoint and shall be updated in line with applied (security) patches and/or firmware
Beh	ENS	Behaviour
Health	ENS	Health

6.3.3. Logical nodes

6.3.3.1. DWMX: Limit Maximum Active Power operational function

This logical node shall be used to limit the maximum active power at the Grid Connection Owner side. If the setpoint value is negative, consumption (load) is limited. If the setpoint value is positive, the generation is limited. The active power can be given as a percentage or as an absolute value in MW. Percentage values are only supported to limit positive setpoints (limiting the generation). The System Operator shall be able to validate/get the current setpoint value at the Customer side.

Note that only one setpoint to limit the operational active power can be active. E.g. it is not possible to send a negative (limiting consumption) and positive (limiting generation) setpoint together.

The RTI foresees the possibility to receive a setpoint value for limiting the active power as a percentage or absolute value for the operational setpoints - [Setpoint-1], [Setpoint-2], [Setpoint-3] - and safe mode setpoints - [Safemode-2], [Safemode-3].

The Customer Endpoint should internally match the operational setpoints and safe mode setpoints in accordance to the following guidelines, to guarantee consistency in the operational data:

- In case a percentage setpoint is sent, the absolute setpoint is matched accordingly
- In case a positive absolute setpoint (limiting generation) is sent, the percentage setpoint is matched accordingly
- In case a negative absolute setpoint (limiting consumption) is sent, the percentage setpoint is set at 100% (no restriction on the generation side).

Data Objects related to Safe mode (see chapter 5.2.3) are derived from IEC 61850-7-420:2021 Annex F.4. Appendix IV is a RTI specific implementation example of the Safe mode. This Appendix shows that after the fall back time out (WMaxFto) the WMaxSpt(Pct).mxVal shall be set equal to the WMaxSet(Pct).setVal in the Customer Endpoint.

Data Object Name	Common Data Class	Explanation
WMaxSptPct	APC	Setpoint reflecting the maximum of active power as a percentage, as defined in [Setpoint-1]. Its mxVal attribute reflects the value of the setpoint that is requested. Note: The RTI only supports positive values of this Data Object (limiting generation).

WMaxSpt	APC	Setpoint reflecting the maximum limit of active power. Its mxVal attribute reflects the value of the setpoint that is requested. If the value is negative, power consumption is limited. If the value is positive, power generation is limited.
WMaxFto	ING	A fallback timeout delay after which the fallback behaviour should apply. The Customer Endpoint should fallback to WMaxSetPct or WMaxSet.
WMaxSetPct	ASG	Setpoint reflecting the maximum of active power as a percentage, as defined in [Safemode-3]. Its mxVal attribute reflects the value of the setpoint that is requested. Note: The RTI only supports positive values of this Data Object (limiting generation).
WMaxSet	ASG	Setpoint reflecting the maximum limit of active power when the Customer Endpoint is in safe mode. If the value is negative, power consumption is limited. If the value is positive, power generation is limited.
SptReas	INC	Integer which represents the reason for which use case a setpoint is sent by the System Operator

As described in requirement [Setpoint-8], only operational setpoints need a reason. Therefore, a reason code is only applicable to the following data objects: WMaxSpt and WMaxSptPct. Reasons are represented by a specific and unique integer value.

When a setpoint is being sent for the reason of frequency stability, the desired setpoint can only be reached by directly controlling the power generating modules. For this specific setpoint reason, it is not allowed to achieve the desired setpoint at the PoCC by increasing the consumption. For all other setpoint reasons, increasing consumption to reduce net generation on PoCC is allowed.

To properly link a reason to a specific setpoint, the following rules apply:

a) It is only allowed to send a setpoint with a reason.
b) It is not allowed to send multiple reasons applying to one setpoint.
c) Reason and setpoint are sent as separate messages.
d) The reason always has to be sent first.
e) The setpoint shall only be accepted if received within a time window of 10 seconds after receiving the reason.
f) If multiple reasons are received before receiving a setpoint, only the last received reason is valid. Previous reasons are disregarded.

g) A valid reason is an integer number in the range of 0000-9999. Any reason out of this range shall be disregarded.
h) A reason can only be used in combination with one setpoint: For a new setpoint, a new reason has to be sent first.
i) Positive scenario: When a reason-setpoint combination complies with the rules specified in a) up to and including h), the setpoint shall be effectuated by the Customer Endpoint. This results in a change of the mxVal. See Appendix III.
j) Negative scenario: When a reason-setpoint combination does not comply with the rules specified in a) up to and including h), the setpoint is disregarded by the Customer Endpoint. This does not result in a change of the mxVal. See Appendix III.

The explanation of the different reasons can be found on the Netbeheer Nederland website: www.netbeheernederland.nl/realtimeinterface

Appendix III shows different situations in figures.

☞ Note: Version 1.0 of the RTI only supports reasons for limiting active power.

6.3.3.2. MMXU: Measurement

This logical node shall define all the values that have to be measured on the PoCC. In line with the IEC 61850 standard conventions, a positive sign means that the DER unit is generating power.

Data Object Name	Common Data Class	Explanation
TotW	MV	Total active power (total P)
TotVAr	MV	Total reactive power (total Q)
PhV	WYE	Phase to ground voltages (VL1ER, …)
PPV	DEL	Phase to phase voltages (VL1VL2, …)
A	WYE	Phase currents (IL1, IL2, IL3)
AvWPhs	MV	Arithmetic average of the total active power (TotW) in MW value over a period of 15 minutes
MaxWPhs	MV	Maximum magnitude of the total active power (TotW) in MW value over a period of 15 minutes
MinWPhs	MV	Minimum magnitude of the total active power (TotW) in MW value over a period of 15 minutes

The quality bits will be set to invalid if the measurements are not valid or non-existent, e.g. the connection to the measurement sensors is lost/broken or the connection to the measurement source is lost. The only allowed quality bit values are good and invalid.

6.3.3.3. DGEN: DER generating unit

This logical node describes the connected and operational state of the DER and should be implemented only once for the RTI.

Data Object Name	Common Data Class	Explanation
DEROpSt	ENS	Current state of operation of the distributed energy resource.

The following states (a subset of table 11 from IEC 61850-7-420:2021) are used in the context of the RTI as described:

Value	Meaning in RTI context
1	Initial state to define a starting status. Goal of defining this state is to enable observing state changes from this point on.
2	IEC 61850 communication between System Operator Endpoint and Customer Endpoint is established after an initial boot. Communication is available. This state is the trigger for the SO to send: • Reason • Setpoint • Safe Mode setpoint • Safe Mode time-out value
3	IEC 61850 communication between System Operator Endpoint and Customer Endpoint is established within a safe operating mode. Communication is available. This state is the trigger for the SO to send: • Reason • Setpoint
6	Full availability to comply with all possible operational setpoints.
10	IEC 61850 communication between System Operator Endpoint and Customer Endpoint is established after a reboot. Communication is available. This state is the trigger for the SO to send: • Reason • Setpoint
98	(Partial) unavailable. One or multiple connected DERs are unable to process the operational setpoints.

When communicating the DER state through the RTI, literals 4, 5, 7, 8 , 9, 11 are not used. The SO can send a control signal when receiving states 3, 6, 10 and 98. Note that the enumerated items, which corresponds with the Values, are described in the

SCL file conform the IEC 61850-7-420 standard. These enumerations do not correspond with the RTI specific context.

The introduction of these different states is a detailed implementation of the [Customer-Configuration-1] requirement. As a result, all users of the RTI have a common understanding of the current state of the Customer Endpoint. All changes of the state of the Customer Endpoint shall be reported using a data change.

Note that a state is defined on the PoCC, while the state of individual DERs may differ. Therefore, it is important to realize that the state on the PoCC might not represent the state of all individual DERs.

6.3.4. Common Data Classes

The following Common Data Classes (CDC) are supported on the RTI.

Common Data Class	Description
APC	Controllable Analogue Process Value
DEL	Phase to phase measured values for 3-phase system
DPL	Device name plate
ENS	Enumerated status
INC	Controllable integer status
ING	Integer status setting
INS	Integer status
LPL	Logical node name plate
MV	Measured Value
SPS	Single point status
WYE	Phase to ground measured values for 3-phase system

The CDCs are also described in a computer readable format, the attached IEC 61850 SCL file, see Appendix [B].

6.4. Communication Layer

IEC 61850 MMS is selected as the communication protocol for the RTI. More information about IEC 61850 can be found in chapter 3.3.

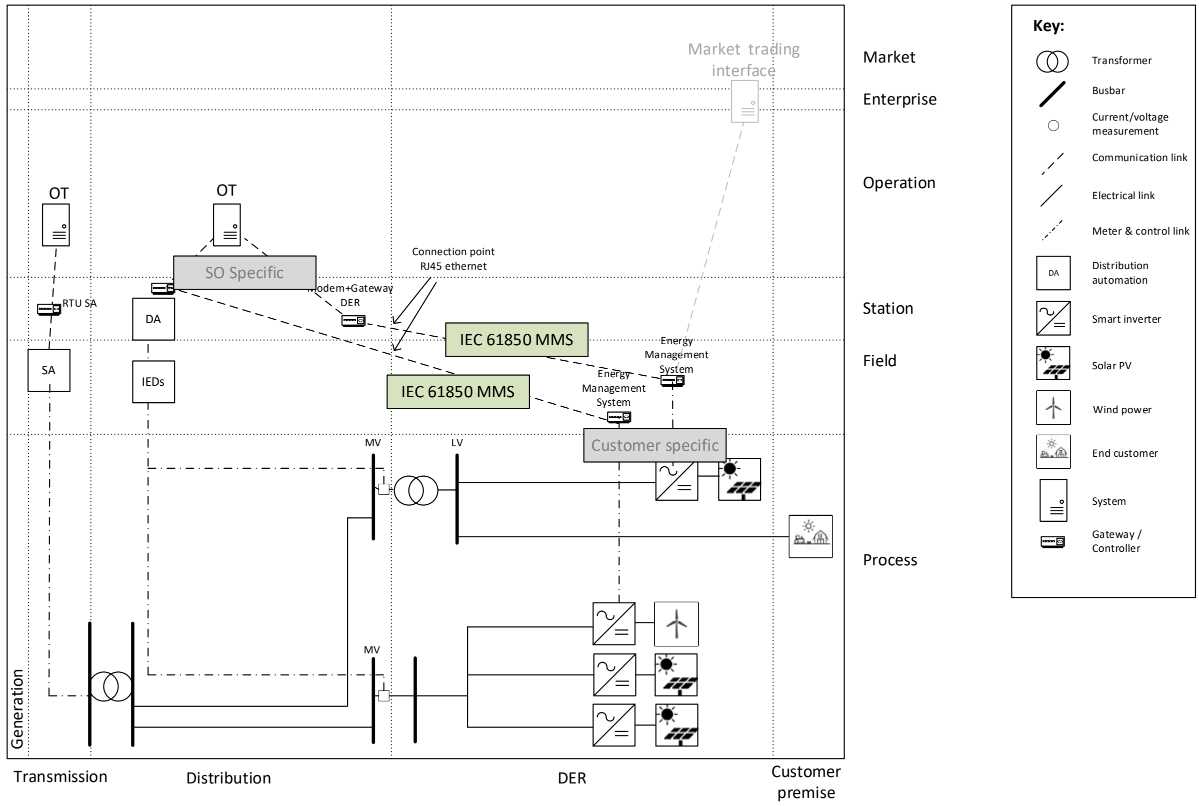


Figure 13: SGAM Communication Layer RTI

IEC 61850 MMS is only being used as protocol for the RTI between the System Operator Endpoint and the Customer Endpoint. The System Operator can specify its own protocol to communicate from the Endpoint towards its central operating systems and likewise, the Grid Connection Owner can specify its own protocol to communicate with the rest of the installation at the Grid Connection Owner's side of the PoCC.

The required TCP/IP information (e.g. IP-address Customer Endpoint, subnet configuration and IP-address gateway) for setting up communication between the SO Endpoint and Customer endpoint, will be provided by the involved SO.

6.5. Component Layer

The Component Layer describes the individual components concerned with the RTI.

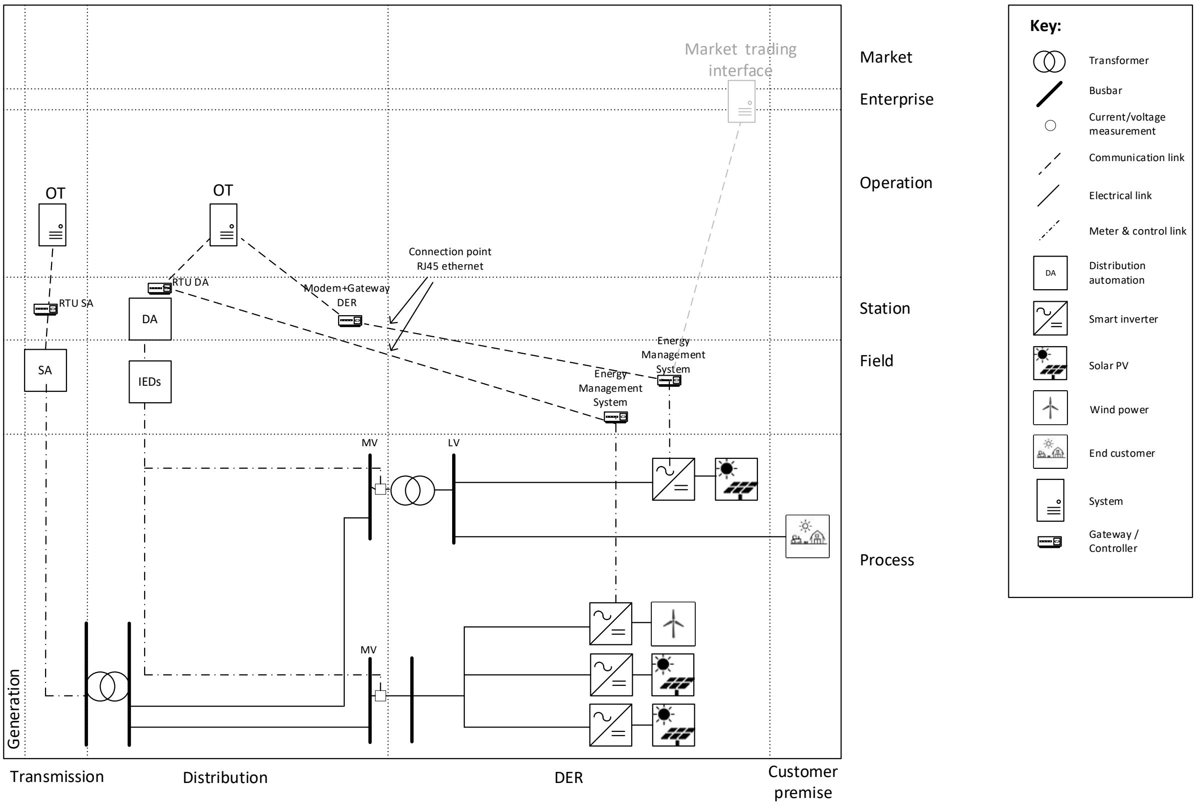


Figure 14: SGAM Component Layer with two different example implementations of the RTI

For version 1.0 of the RTI, the System Operator will place hardware in the MV compartment of the substation at the Customers premises, which is dedicated to the System Operator. The hardware contains an RJ-45 connector where the communication cable (connecting the System Operator Endpoint and Customer Endpoint) has to be connected. The RJ-45 connector at System Operator Endpoint forms the demarcation point between the equipment of the System Operator and the Grid Connection Owner. The Grid Connection Owner has to provide the communication cable between the two endpoints.

In Figure 14, the System Operator’s endpoint or Remote Terminal Unit (RTU) is visualized in different ways, as different implementations are possible on the System Operator’s side. The same applies for the Grid Connection Owner's side; the endpoint can be implemented in a Park Controller, Energy Management system, a separate box or a different architecture. Two variants are visualized: communicating through the same RTU as is used for Distribution Automation (DA), or using a dedicated RTU.

7. Ownership demarcation

The ownership demarcation point is where the System Operator owned and maintained equipment ends and the Grid Connection Owner equipment (including Customer Endpoint) begins. The System Operator is responsible for maintaining and repairing equipment up to this ownership demarcation point.

Figure 15 illustrates an abstracted overview of the (relevant) physical components at a Grid Connection Owner's connection with the RTI. The colours explain the responsibilities. In general, it can be said that the Grid Connection Owner is responsible for the needed space and the connections. The dashed line represents the physical compartments of the SO and the Grid Connection Owner in the secondary substation. The Customer Endpoint can be located in the secondary substation, but can also be located outside the secondary substation. This is why the Customer Endpoint is visualised on the border of the secondary substation.

In practice, the Grid Connection Owner should provide space for the SO Endpoint, the RJ-45 connection to the SO Endpoint and a power supply for the SO Endpoint. Occasionally, it can be necessary for the SO to apply an external antenna. In that case additional modifications have to be made in the secondary substation.

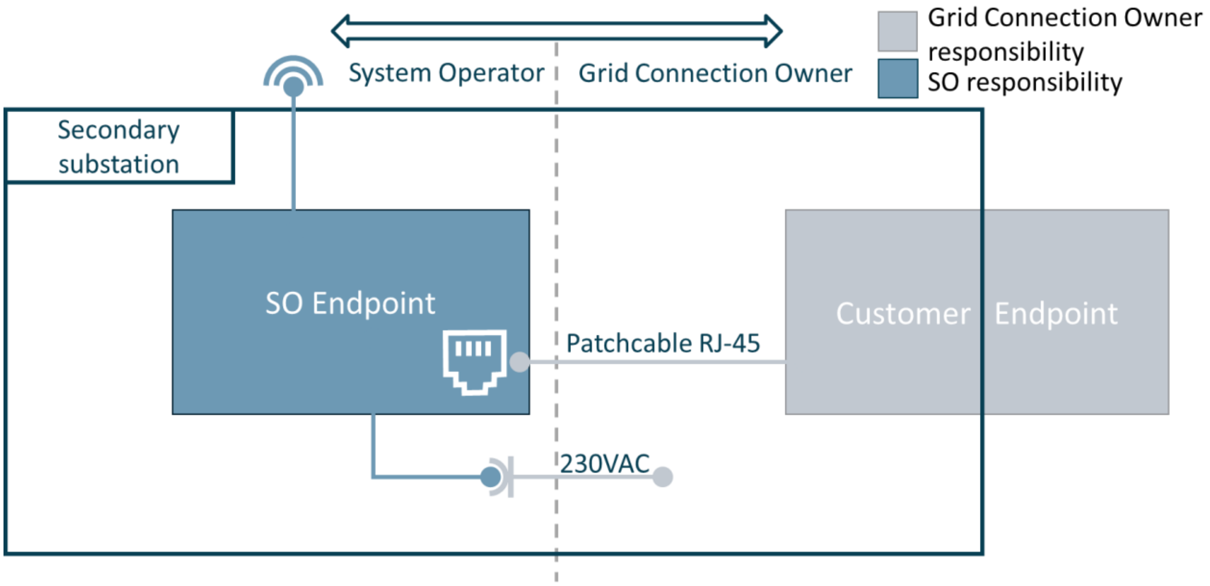


Figure 15: Ownership demarcation and responsibility overview

8. Implementation & compliance verification

The implementation of the RTI can slightly differ from one System Operator to another. The RTI itself is standardized but the physical appearance of the endpoint and the application process can be different. Basically, it starts with the contract request of a Grid Connection Owner. The System Operator will decide if the RTI is applicable and under which conditions.

The first implementation of the RTI with a new product should be compliance tested before being applied. This has to be done via a product conformance test of the Protocol Implementation Document (PID). In addition the System Operator can require a commissioning test. The compliance verification process is described in a separate document available on https://www.netbeheernederland.nl/dossiers/realtimeinterface.

Note that after a compliance verification certificate has been obtained, it may be necessary to follow the process again, when changes to the Customer Endpoint have been made that may influence the behaviour of the Endpoint on the RTI.

In case of a modification that impacts the Realtime Interface functionality, a retest should always be performed. An example of a change is a firmware or software update.

Appendix I Attachments

[A] IEC 61850 Protocol Implementation Document (PID)
[B] IEC 61850 Data Model (Substation Configuration Language, SCL file)
[C] Compliance Verification Document

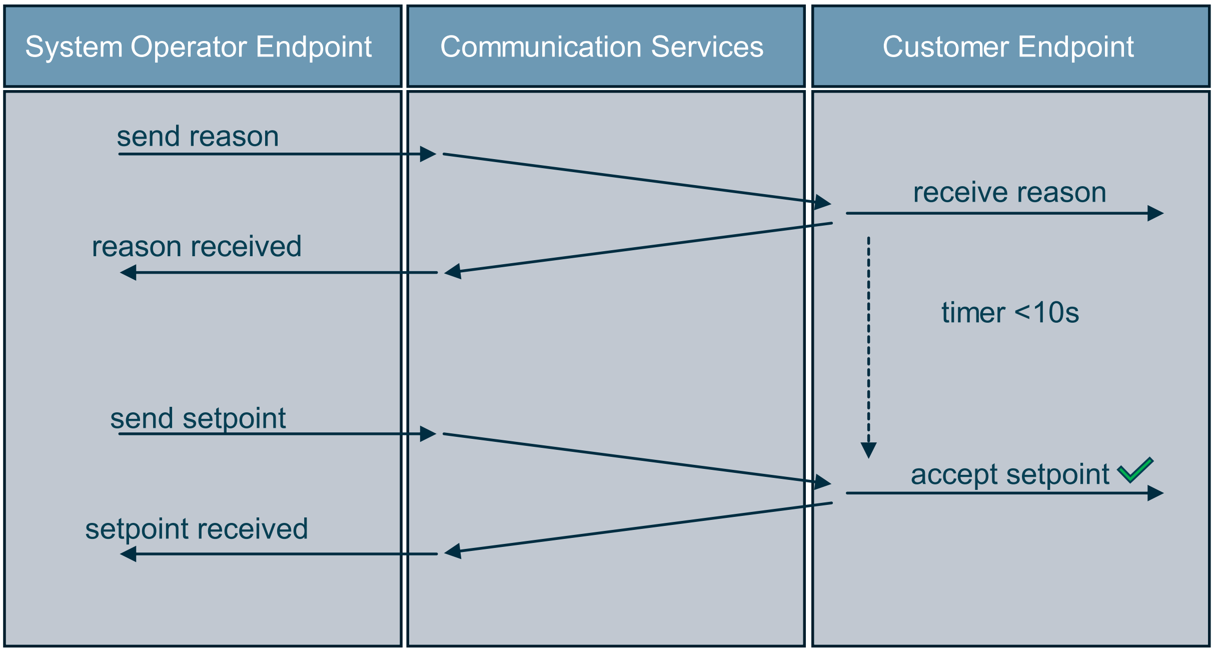
Appendix II Abbreviations

ACM	Autoriteit Consument en Markt
ATO	Aansluit- en Transportovereenkomst / Connection and Transportation Agreement
BRP	Balance Responsible Party
BSP	Balance Service Provider
CDC	Common Data Class
CSP	Congestion Service Provider
DA	Distribution Automation
DCC	Demand Connection Code (EU-Netwerkcode) Verordening (EU) 2016/1388
DER	Distributed Energy Resource
DMS	Distribution Management System
DO	Data Object
DSO	Distribution System Operator
ECP	Electric Connection Point
EMS	Energy Management System
ENCS	European Network for Cyber Security
EV	Electric Vehicle
GOPACS	Grid Operators Platform for Congestion Solutions
HVDC	High Voltage Direct Current
ID	Intraday
IEC	International Electrotechnical Commission
IED	Intelligent Electronic Device
kVA	Kilo Volt-Ampère
kVAr	Kilo Volt-Ampère reactief
kW	Kilowatt
kWh	Kilowatthour
LV	Low Voltage
MMS	Manufacturing Message Specification
MV	Medium Voltage
MVA	Mega Volt-Ampère
MVAr	Mega Volt-Ampère reactief
MW	MegaWatt
NBNL	Netbeheer Nederland
OT	Operational Technology
PoCC	Point of Common Coupling
PGMD	Power Generating Module Document
PID	Protocol Implementation Document
PV	Photovoltaic

RfG	Requirements for Generators (EU-Netwerkcode) Verordening (EU) 2016/631
RT	Real-time
RTI	Realtime Interface
RTU	Remote Terminal Unit
SA	Substation Automation
SCL	Substation Configuration Language
SGAM	Smart Grid Architectural Model
SO	System Operator
TSO	Transmission System Operator
UTC	Coordinated Universal Time
XML	Extended Markup Language

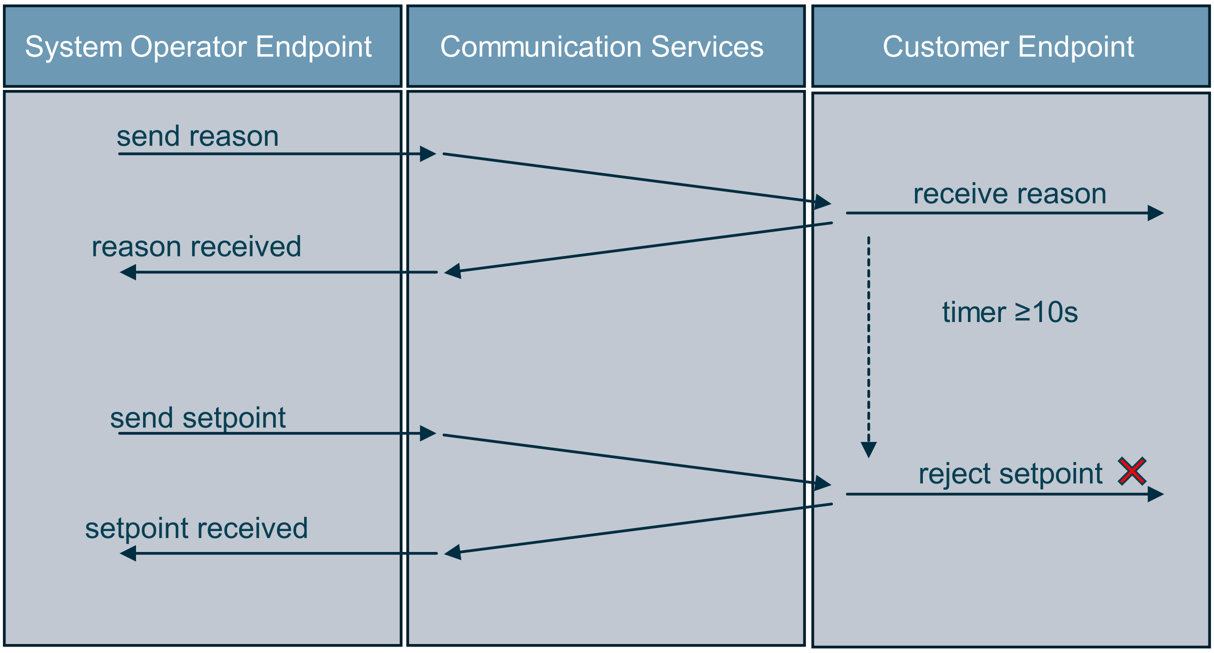
Appendix III Setpoint reasons

Scenario 1: Accept setpoint within the reason valid time.



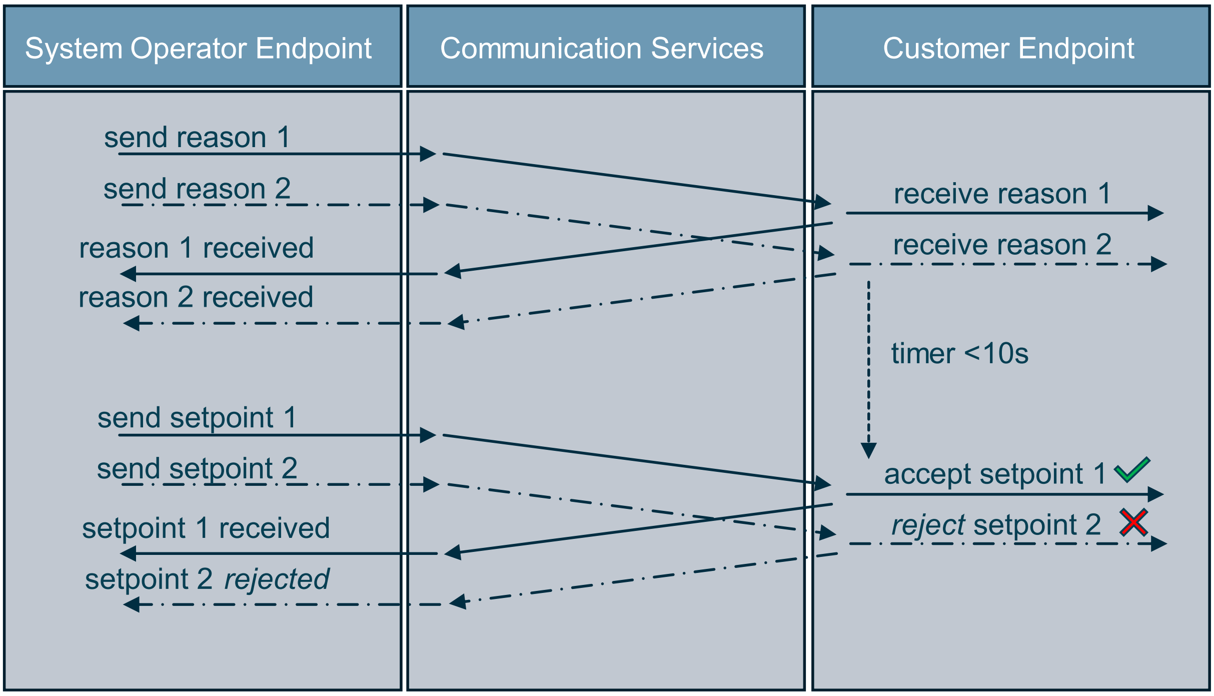
A valid reason is sent by the System Operator Endpoint and received by the Customer Endpoint. The Customer Endpoint also receives a valid setpoint within 10 seconds. The setpoint will be accepted by the Customer Endpoint.

Scenario 2: Exceeding the defined reason time window.



A valid reason is sent by the System Operator Endpoint and received by the Customer Endpoint. The Customer Endpoint also receives a valid setpoint after 10 seconds. The setpoint will be rejected by the Customer Endpoint.

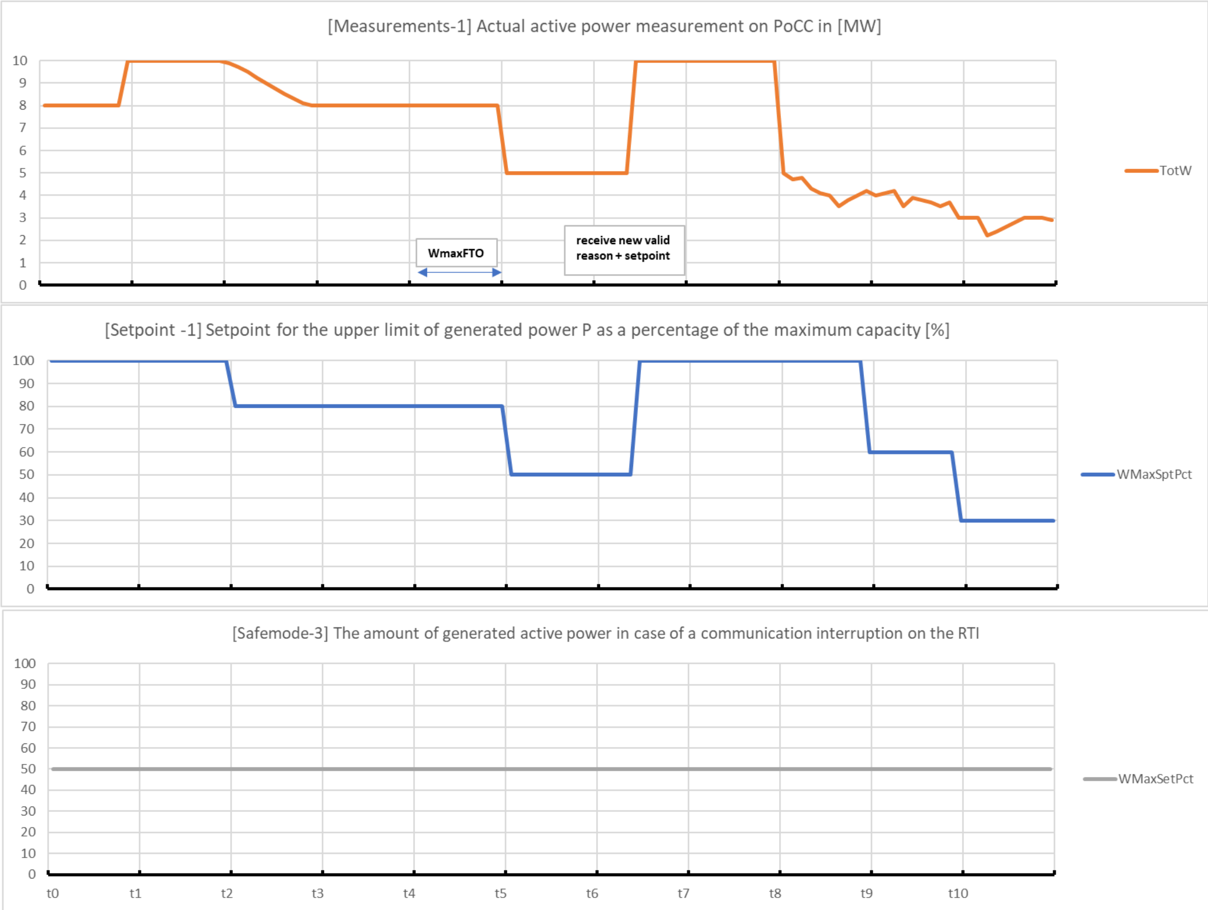
Scenario 3: Match setpoint with multiple received reasons.



Two valid reasons are sent by the System Operator Endpoint and received by the Customer Endpoint. The Customer Endpoint also receives two valid setpoints within 10 seconds. Reason 2 and setpoint 1 forms a valid combination and is accepted by the Customer Endpoint. Reason 1 is overwritten by reason 2, because reason 2 is received before a valid setpoint is received. Setpoint 2 is rejected because every setpoint has to be proceeded by an individual reason.

Appendix IV Customer Endpoint control example

In this appendix, an example is given to clarify the sequence of the expected behaviour of Customer Endpoint, based on signals specified in this technical specification.



Events at given time indicators:

t0-t1	Power change, no control
t2	Setpoint 80%; WMaxSptPct =80%; some time needed for DER to react (TotW)
t3	Setpoint reached
t4	RTI connection lost: WMaxFto (t5-t4) activate safemode
t5	Safe mode active, reduction to WMaxSptPct 50% After fall back time out the WMaxSpt(Pct).mxVal is the WMaxSet(Pct).setVal
t6	Connection restored after "Receive new valid setpoint + reason" go back to operational mode
t7	No control
t8	Production reduces
t9	Setpoint 60 %; WMaxSptPct = 60%; No effect on production power because actual power is lower than setpoint (TotW)
t10	Setpoint 30%; WMaxSptPct = 30%; Limitation possible (production power close to limiting setpoint)

Appendix V References

[ACM2021] ACM, "System Operators must use congestion management more often", August 2021, https://www.acm.nl/en/publications/acm-system-operators-must-use-congestion-management-more-often

[CEN2012] CEN/CENELEC/ETSI Joint Working Group on Standards for Smart Grids, "CEN-CENELEC-ETSI Smart Grid Coordination Group: Smart Grid Reference Architecture," 2012.

[DCC2016] ENTSO-E, "Demand Connection Code", August 2016, https://www.entsoe.eu/network_codes/dcc/

[ENTSOE2020] ENTSO-E/EFET/ebIX, "The Harmonised Electricity Market Role Model (version 2020-01)", 2020

[RfG2016] ENTSO-E, "Requirements for Generators", April 2016, https://www.entsoe.eu/network_codes/rfg/

Appendix VI Changelog

This section contains the main changes from the *previous version* of the specifications.

nr.	Document	Chapter/ Paragraph	Modification
60	Protocol Implementation Document version 1.0 beta 4	R.11	TCP keepalive in R.11 clarified
61	Protocol Implementation Document version 1.0 beta 4	R1, R.35	1. Transport selector Y 0001 Session selector Y 0001 Presentation selector Y 00000001 2: No modification
62	Technical specification version 1.0 beta 4	5.3.3.1	Textual change in enumeration a till j in chapter 5.3.3.1.
63	SCL file version 1.0 beta 4		Remove db from SCL
65	Technical specification version 1.0 beta 4	5.3.3.1	Chapter 5.3.3.1 rephrased
67	Technical specification version 1.0 beta 4	Graph "Appendix: Customer endpoint control example"	Graph updated
68	Technical specification version 1.0 beta 4	Introduction	Various textual changes in chapter 1
69	Technical specification version 1.0 beta 4	Postion in the ecosystem	Various textual changes in chapter 2
72	SCL file version 1.0 beta 4		added originalSclVersion="2023" originalSclRevision="A"> changed configVersion="RTI_V1.0.0"
76	Technical specification version 1.0 beta 4	5.3.3.1	Textual change in enumeration a) till j) in chapter 5.3.3.1.
78	SCL file version 1.0 beta 4		<DynAssociation max="1"/>
80	Technical specification version 1.0 beta 4	5.3.3.1	Textual change in enumeration a) till j) in chapter 5.3.3.1.
82	SCL file version 1.0 beta 4		Substation section removed
83	Technical specification version 1.0 beta 4	new	Chapter 8 about future versions removed from specification
84	Technical specification version 1.0 beta 4	new	Chapter 8 about future versions removed from specification
85	Technical specification version 1.0 beta 4	new	Add clarification to start of chapter 1 of the specification document
94	Technical specification version 1.0 beta 4		Requirement Customer-Configuration-7 added to the technical implementation, with implementation description.
94	Technical specification version 1.0 beta 4	All	Real-Time Interface is replaced with Realtime Interface everywhere
97	Technical specification version 1.0 beta 4	All	New template is applied
100	Technical specification version 1.0 beta 4	4.1	State diagram has been made more specific (chapter 4.3 and 5.3.3.3)
108	Technical specification version 1.0 beta 4	5.3.3	Textual change in chapter 5.3.3.3. Defined the happy and unhappy flow
111	SCL file version 1.0 beta 4	all	Change in line with configRef naming convention, but with underscores. E.g. RTIserver1_0_0 Update PID with naming convention explanation. See also change 125
116	Technical specification version 1.0 beta 4	5.3.3.1	WMaxSptPct & WMaxSetPct clarified regarding negative percentages and internal alignment.
117	Technical specification version 1.0 beta 4	all	remove terms cold and warm start
118	Technical specification version 1.0 beta 4	5.3.3.3	add enumeration #2, new state

120	Technical specification version 1.0 beta 4	4.3	Chapter 4.3.3 changed into a new chapter: Chapter 5 'Process description'
122	Technical specification version 1.0 beta 4	4.1	[Customer-Configuration 7] is added to te specification
123	Technical specification version 1.0 beta 4	5.3.2.1	Explantion added in the table for data attribute configRev
125	PID version 1.0 beta 4	all	Change in line with configRef naming convention, but with underscores. E.g. RTIserver1_0_0 Update PID with naming convention explanation. See also change 111
127	Technical specification version 1.0 beta 4		[Measurements-4], current measurements are absolute values
129	Technical specification version 1.0 beta 4	5.3.3.3	Complete state diagram renewed and split into two separate diagrams
130	PID version 1.0 beta 4	6.1 & table 3	Clearified that the Client can also terminated the communication by use of an abort services.
131	PID version 1.0 beta 4	6.2	Remove the text about dynamic data sets. Only static data sets are used in the RTI.
132	Technical specification version 1.0 beta 4, PID version 1.0 beta 4, Compliance version plan	all	Phase tot phase voltage is added as extra measurement
133	Technical specification version 1.0 beta 4	5.3.3.1 & Appendix IV	Clearified that the WMaxSpt(Pct) value should be equal to the WMaxSet(Pct) value when the Customer Endpoint is in Safe Mode
134	Technical specification version 1.0 beta 4	4.1	Clearified that [Safe-Mode-5], [Safe-Mode-6], [Safe-Mode-7] are related to the data object TotW
135	Technical specification version 1.0 beta 4	5.3.3.2	Clearified how AvWPhs, MaxWPhs and MinWPhs are calculated
137	Technical specification version 1.0 beta 4	5.3.2.1	Clearified which information is expected in the data attribute LLN0.NamPlt.swRef

RealtimeInterface