# Interoperable APIs Specification

*Deliverable D3.4 – version 1.0*

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# EXECUTIVE SUMMARY

Major DSOs are working together with market players and other stakeholders within the Horizon 2020 –LCE-06-2016 project InterFlex to develop an application programming interface (API) to guarantee interoperability between the DSO and aggregator systems. Standardized interfaces will be developed to integrate the platforms of different players. This deliverable gives a brief overview about the protocols used in the different demo sites and places them in the context of existing IEC standards.

Based on the gap identified between existing standards and solutions selected by the different demo sites, we propose a flexibility platform that offers two interoperable APIs that will enable seamless coupling between the IT Systems of Aggregators with the OT systems of the DSO.

Within the work package 3 subtask 3.1.3, interoperable APIs specification, interoperable APIs are specified using unified modelling language formal modelling (D3.4). Furthermore, an open source reference implementation of the APIs is provided (D3.5) and finally, an abstract test suite to validate proper implementation (D3.6) is proposed. In particular, semantic of the data will be consistent with what has been detailed in the present document, while the data syntax will depend on the solution selected during the implementation phase.

The content of this deliverable is intended to be standalone. For further deeper information, we refer the interested reader to the preceding deliverables D3.1 [1] and D3.3 [2].

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| | |
|---|---|
| API | Application Programming Interface |
| ARIB | Association of Radio Industries and Businesses |
| ATIS | Alliance for Telecommunications Industry Solutions |
| BRP | Balance Responsible Party |
| BSS | Battery Storage System |
| CCS | Control Center Server |
| CCSA | China Communications Standards Associations |
| CDPSM | Common Distribution Power System Model |
| CIM | Common Information Model |
| CPO | Charging Point Operator |
| CPMS | Charge Point Management System |
| CPSM | Common Power System Model |
| CS | Control Space |
| CSMS | Charging Station Management System |
| DER | Distributed Energy Resources |
| DMS | Distribution Network Management System |
| DSO | Distribution System Operator |
| EFI | Energy Flexibility Interface |
| EF-Pi | Energy Flexibility Platform and Interface |
| EMP | e-Mobility Provider |
| EMS | Energy Management System |
| EMSP | e-Mobility Service Provider |
| EPRI | Electrical Power Research Institute |
| ETSI | European Telecommunication Standards Institute |
| EV | Electric Vehicle |
| EVSE | Electric Voltaic Supply Equipment |
| FAP | Flexibility Aggregator Platform |
| GMS | Grid Management System |
| ICT | Information and Communication Technology |
| IoT | Internet of Things |
| HTTP | Hypertext Transfer Protocol |
| JSON | Javascript Object Notation |
| LIMS | Local Infrastructure Management System |
| M2M | Machine to Machine |
| MO | Mobility Operator |
| OCA | Open Charge Alliance |
| OCHS | Open Clearing House Protocol |
| OCPI | Open Charge Point Interface |
| OCPP | Open Charge Point Protocol |
| OICP | Open Inter Charge Protocol |
| OpenADR | Open Active Demand Response |
| PICS | Protocol Implementation Conformance Statement |
| PV | Photo Voltaic |
| RFID | Radio Frequency Identification |
| RTU | Remote Terminal Unit |
| SAREF | Smart Appliance Reference Ontology |
| SCADA | Supervisory Control And Data Acquisition |
| SGAM | Smart Grid Architecture Model |
| SIA | Seamless Integration Architecture |
| SMTP | Simple Mail Transfer Protocol |
| SOAP | Simple Object Access Protocol |

| | |
|---|---|
| SSU | Smart Storage Unit |
| TC | Technical Committee |
| TIA | Telecommunication Industry Association |
| TSDSI | Telecommunications Standards Development Society India |
| TTA | Telecommunications Technology Association |
| TTC | Telecommunications Technology Committee |
| TR | Technical Report |
| TSO | Transmission System Operator |
| UML | Unified Modelling Language |
| UpnP | Universal plug and play |
| USEF | Universal Smart Energy Framework |
| WG | Working Group |
| XML | Extensible Markup Language |

# 1 INTRODUCTION

The European Union (EU) Project Interactions between automated energy systems and flexibilities brought by energy market players (InterFlex) is a response to the Horizon 2020 Call for proposals, LCE-02-2016 ("Demonstration of smart grid, storage and system integration technologies with increasing share of renewable: distribution system").

This Call addresses the challenges of the distribution system operators in modernizing their systems and business models in order to be able to support the integration of distributed renewable energy sources into the energy mix. Within this context, the LCE-02-2016 Call promotes the development of technologies with a high TRL (technology readiness level) into a higher one.

InterFlex explores pathways to adapt and modernize the electric distribution system in line with the objectives of the 2020 and 2030 climate-energy packages of the European Commission. Six demonstration projects are conducted in five EU Member States (Czech Republic, France, Germany, the Netherlands and Sweden) in order to provide deep insights into the market and development potential of the orientations that were given by the call for proposals, i.e., demand-response, smart grid, storage and energy system integration.

With Enedis as the global coordinator and CEZ Distribuce as the technical director, InterFlex relies on a set of innovative use cases. Six industrial-scale demonstrators are being set up in the participating European countries. Figure 1-1 shows a map identifying the demo site around the Europe.

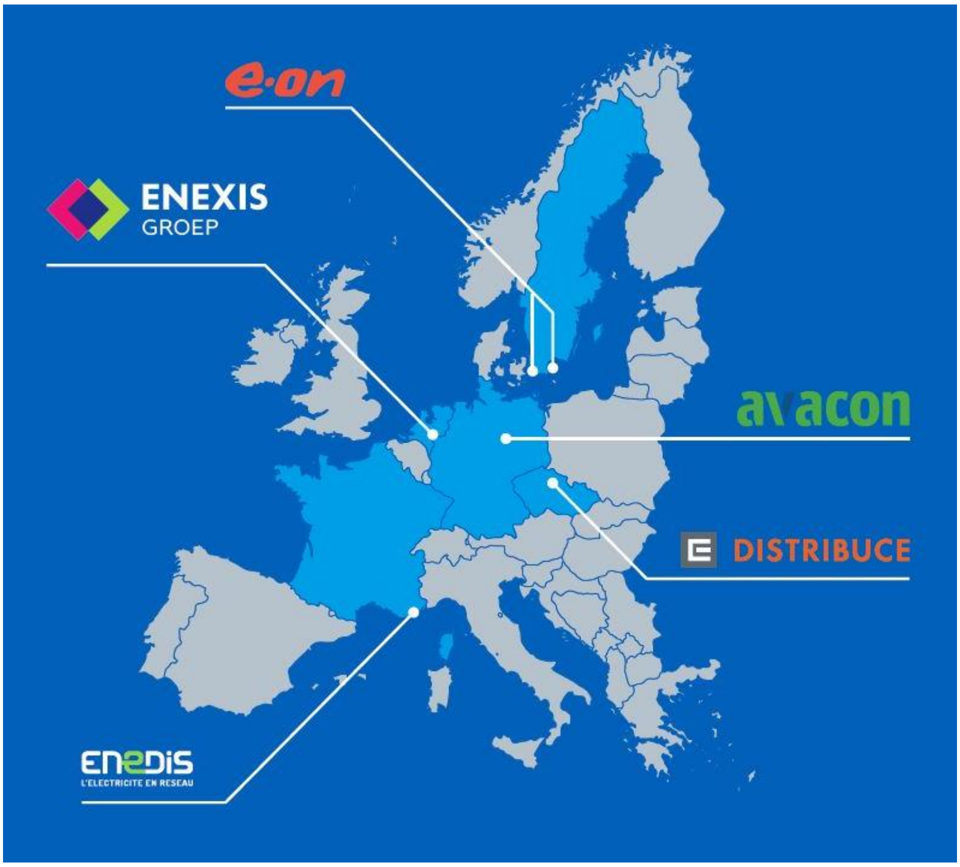


*Figure 1-1 The map identifies the demo sites in the context of this project*

Through these demonstration showcases, the InterFlex will assess how the integration of the new solutions can lead to a local energy optimization. Technically speaking, the success of these demonstrations requires that some of the new solutions, which are today at TRLs 5-7, are further developed reaching TRLs 7-9 to be deployed in real-life conditions.

## 1.1 Scope

The scope of this report is to present the specification of an interoperable APIs for flexibility control that addresses missing or non-coherent functionalities for flexibility negotiation between DSOs and flexibility aggregators. These APIs form the so-called InterFlex API and are a core component of the proposed flexibility cloud platform.

## 1.2 Objectives

The objective of this work is to formally specify the main party of the API that interconnects a DSO to a flexibility aggregator. Our draft of the flexibility cloud platform contains more additional features and services that are covered in other WPs.

## 1.3 Motivation

The enabling of flexibilities in distribution networks requires the additional ICT systems. It is imperative to use standards and norms in order to ensure the highest possible level of interoperability of the various core components in the smart grid infrastructure and thus to increase the integration capability as described in Figure 1-2. The aim of most current standardisation efforts and initiatives (CEN/CENELEC/ETSI M490) is to reach the level of semantic interoperability in order to minimise the integration distance. If no integration distance is present, then an optimal situation is achieved where a plug and play standard is present. The activation of flexibilities via the so-called upper bound, presented in [1, 2] , which includes the aggregator will provide numerous new (market) functionalities, services and applications, which are provided and used by (new) stakeholders [1, 2]. It is noteworthy to refer the reader to deliverable 3.1 for additional information about the clustering of the ICT architecture on the communication layer of SGAM diagrams and the respective decomposition on lower and upper bounds.

Based on the current regulatory status, the aggregator will become an elementary component, as DSOs in several countries are not allowed to own for example storage assets. In addition, based on the number of parties and devices involved in the activation, it is economically appropriate to achieve a high degree of interoperability, to achieve a simple, low-cost and smooth (technical) integration of the systems involved as shown in Figure 1-2.

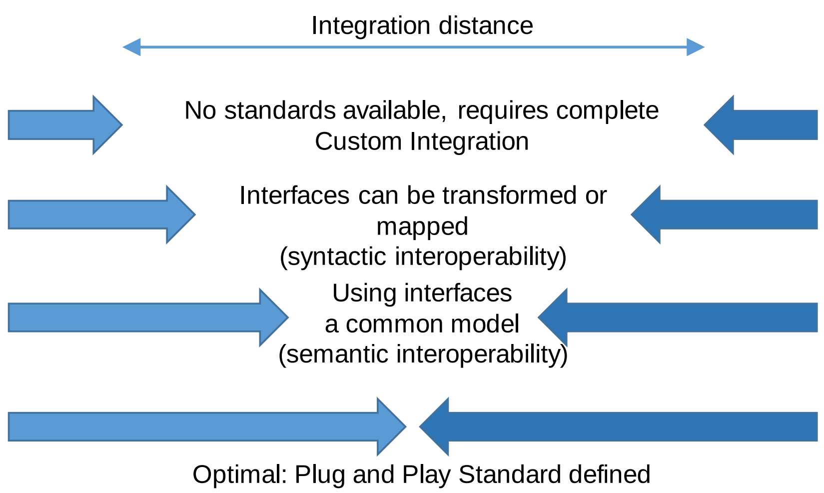


*Figure 1-2 Integration and Standardization*

We will describe the benefits of interoperability in order to motivate the specification of APIs for interoperability as stated in the grant agreement. In deliverables D3.5 and D3.6, we will also put the reference implementation and the abstract test suite into this context.

Figure 1-3 provides an overview of the InterFlex API and an overall flexibility cloud platform that aims at interconnecting aggregators and DSOs. The InterFlex API is the component of the platform that provides the interface between the cloud platform, its internal services and various stakeholders. Besides DSOs and aggregators, additional services can be added to the platform in order to provide basic services. We distinguish between internal services such as data logging and user authentication that are deeply integrated into the platform and external services that can be used to integrate third party data or services such as weather forecast or demand forecast.

The first version of the InterFlex API focuses on providing an interface for flexibility activation. Additional control commands are currently not included in the specification but can be included in future releases. The current specification supports flexibility activating, pricing negotiation, and is designed to include further external services. The platform allows for interconnecting one DSO to multiple aggregators that can control a variety of flexibilities. The flexibility representation is based on the characterization of flexibility as defined by the BRIDGE initiative [3]. It should be noted that the platform is not restricted to the activation of electrical flexibility but also allows for flexibility activation in a cross-carrier energy context.

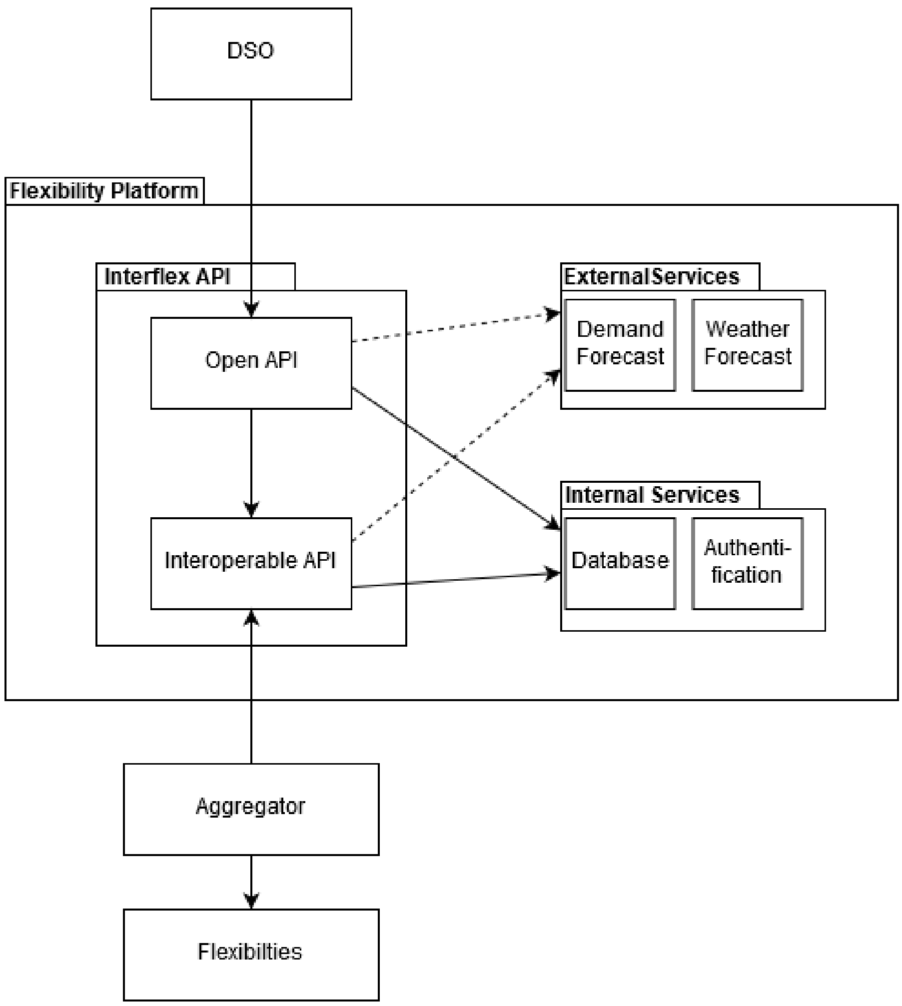


*Figure 1-3 InterFlex API*

## 1.4 Deliverable Organization

The rest of this document consists of four chapters. The following chapter introduces the state-of-the-art protocols which are currently used in the InterFlex demos. Chapter 3 provides a brief summary of the interoperability analysis conducted in D3.3 and resulting recommendations for the InterFlex API that enables flexibility activation between aggregators and DSOs. Chapter 4 addresses these recommendations and presents a formal specification of an API that abstracts flexibility and provides an interoperable interface between aggregators and DSOs. Therefore, we focus on the InterFlex demos that include different flexibility activation mechanisms between aggregators and DSOs, namely the Dutch and the French demos. Chapter 5 aims at illustrating possible interactions between DSOs, flexibility platform, and aggregators during flexibility negotiation and activation. Two different approaches for the interaction between a DSO and aggregators are presented. Chapter 0 finally concludes and summarizes this document.

# 2 STATE OF THE ART

This chapter presents and discusses the protocols that are currently used in the InterFlex demos to connect Aggregators or grid control systems to flexibilities. It should provide the reader of this document with an overview of existing protocols, interfaces and data models in the field of flexibility management.

## 2.1 OneM2M

OneM2M is an organization formed by eight of the world leading standards development organizations, i.e., ARIB (Japan), ATIS (U.S.), CCSA (China), ETSI (Europe), TIA (U.S.), TSDSI (India), TTA (Korea), and TTC (Japan). Its objective is to create a set of technical specifications to create a common M2M layer that can be embedded within software or hardware, and relied upon to connect devices to M2M servers worldwide. Covered needs include security and privacy aspects, standard protocols and APIs, interoperability, application discovery, identification and data management. Each of these needs is covered by one or more specifications, available on [4].

The objective of oneM2M is to cover a large amount of devices, in various domains such as smart cities, smart grids, connected cars, home automation or health. The idea is to provide a common service layer without having to develop a vertical and specific solution for each device.

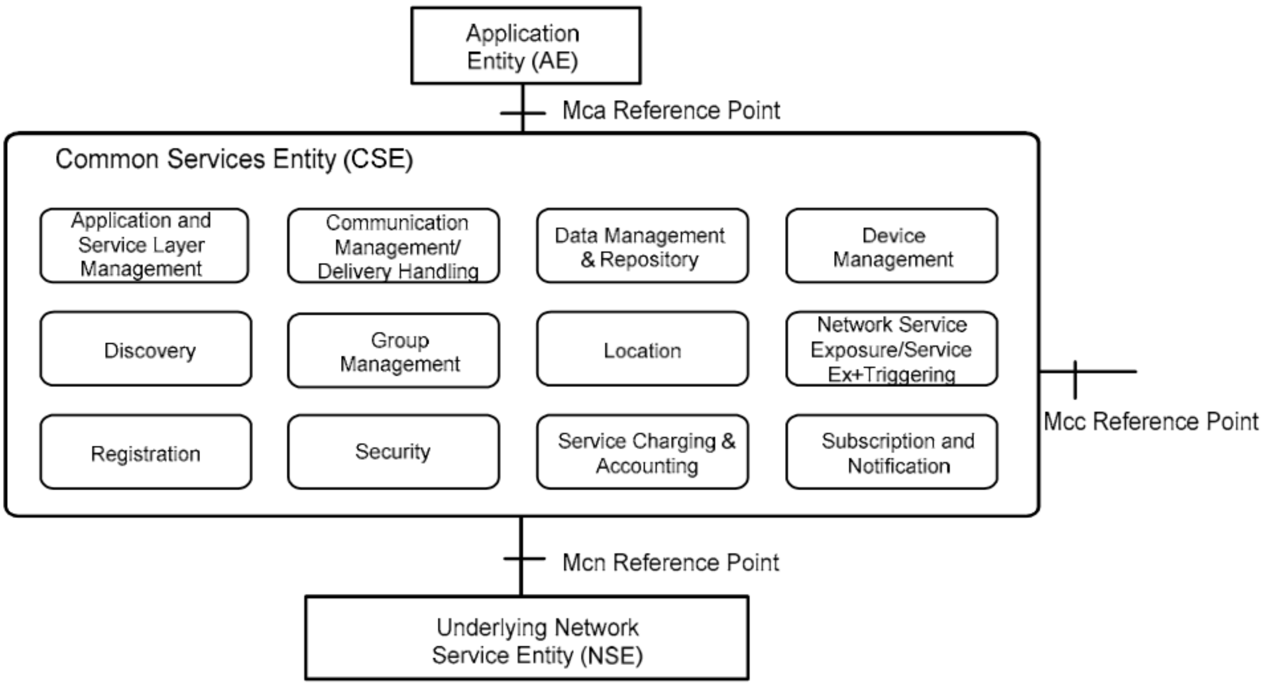


*Figure 2-1: OneM2M common services functions*

The principles of oneM2M architecture are defined in ETSI TS 118 001 [5]. The objective is to shift from a pipe, vertical model to a horizontal, common layer based model. A set of common functions are then handled by the common layer instead of being handled by the devices. Common Services Functions are listed in the Common Services Entity in Figure 2-1. These functions can be hosted in different type of devices. In a typical smart home use case, some of these functions are provided by a Home Management System (a Middle Node in oneM2M architecture), others by an external server (an Infrastructure Node in oneM2M architecture).

Semantics are covered by the Common Service Function Data Management & Repository. A oneM2M base ontology is defined in ETSI TS 118 112 [6] and can be used or overridden to describe semantically oneM2M devices, enabling more interoperability within the oneM2M layer.

The standards of the global organization of OneM2M are available worldwide and are disseminated by the regional standards organizations such as ETSI. A certain amount of both open source and proprietary implementations for OneM2M exist. Open sources projects are listed on [4]. Furthermore, a oneM2M certification has been developed by TTA.

## 2.2 Open Charge Point Protocol

Being in its early stages, the electric vehicle charging market faces variety at different levels. This leads to a competitive atmosphere, which can potentially drive down costs and foster technological improvements. Today, municipalities or private charging providers choose from a multitude of charging station manufacturers and network system vendors. However, this wide choice raises the question of interoperability, or, in other words, the ability of each EV charging station to communicate with a central system, regardless of manufacturer or IT back-end vendor. That is where the Open Charge Point Protocol (OCPP) comes in. OCPP is the industry-supported de facto standard for communication between a charging station and a charging station management system and is designed to accommodate any type of charging [7].

OCPP is an open protocol for communication between charging stations and a managing central system. The OCPP is an international open standard, which was developed in 2009, and now it is supported by majority of stakeholders in the EV industry such as utilities, EV charger manufacturers, and back-office software suppliers [8].

*Table 1 Terminology commonly used for the charging infrastructure*

| Term | Explanation |
|---|---|
| Charging Station | The Charging Station is the physical system where an EV can be charged. A Charging Station has one or more EVSEs. |
| Charging Station Management System (CSMS) | Charging Station Management System: manages Charging Stations and has the information for authorizing users for using its Charging Stations. |
| Electric Vehicle Supply Equipment (EVSE) | An EVSE is considered as an independently operated and managed part of the Charging Station that can deliver energy to one EV at a time. |
| Energy Management System (EMS) | In this context, this is defined as a device that manages the local loads (consumption and production) based on local and/or contractual constraints and/or contractual incentives. It has additional inputs, such as sensors and controls from e.g. PV, battery storage |

As such, the OCPP is designed to be vendor independent, thereby creating the freedom for infrastructure operators in choosing EV chargers and for vendors to supply EV chargers to any infrastructure operator. Thus, it shall allow charging stations and central systems from different vendors to easily communicate with each other [9].

### 2.2.1 OCPP Versions

Till now, several OCPP versions have been released that include OCPP 1.2, OCPP 1.5, OCPP 1.6 , and OCPP 2.0 [7, 8]. Since new functionalities and extensions are offered by OCPP 1.5, the differences between OCPP1.2 and OCPP1.5 are relatively significant. For instance, a local authorization list has been extended that can be synchronized with the Control CCS. If synchronization is not used, the local authorization list will perform as the local white list as in OCPP 1.2. OCPP 1.5 is designed to be implemented with SOAP which uses XML information set for its message format, and relies on application layer protocols such as HTTP for message negotiation and transmission.

OCPP 1.6 is based on OCPP 1.5, with some new functionalities and considerable textual improvements. It introduces new features to accommodate the market:. These features include smart charging, OCPP using JSON over websockets, better diagnostics possibilities, and more charge point statuses, etc. Due to improvements and new features, OCPP 1.6 is not backward compatible with OCPP 1.5. It can be observed that OCPP 1.6 has two different variants, namely OCPP-S for SOAP and OCPP-J for JSON. If a system supports both JSON and SOAP variant, it should be labelled as OCPP 1.6-JS or simply OCPP 1.6.

Furthermore, OCPP 2.0 introduces new functionalities such as device management compared to OCPP 1.6. Due to improvements and some new features, OCPP 2.0 will not be backward compatible with old versions such as OCPP 1.6 or OCPP 1.5.

Most importantly, in OCPP 2.0, following enhancements have been added to harden OCPP against cyber-attacks that include Security profiles (3 levels), Key management for client-side certificates, Securing firmware updates, and Security event log. In case of Authorization, OCPP 1.x was primarily designed for Charging Stations that authorize an EV user using RFID card (see Figure 2-2). If other authorization systems are being used, the CCS needs to be integrated with such authorization mechanisms. OCPP 2.0 will be extended to support several authorization mechanisms including ISO IEC 15118 Plug & Charge [10], payment terminal, smart phones, etc.

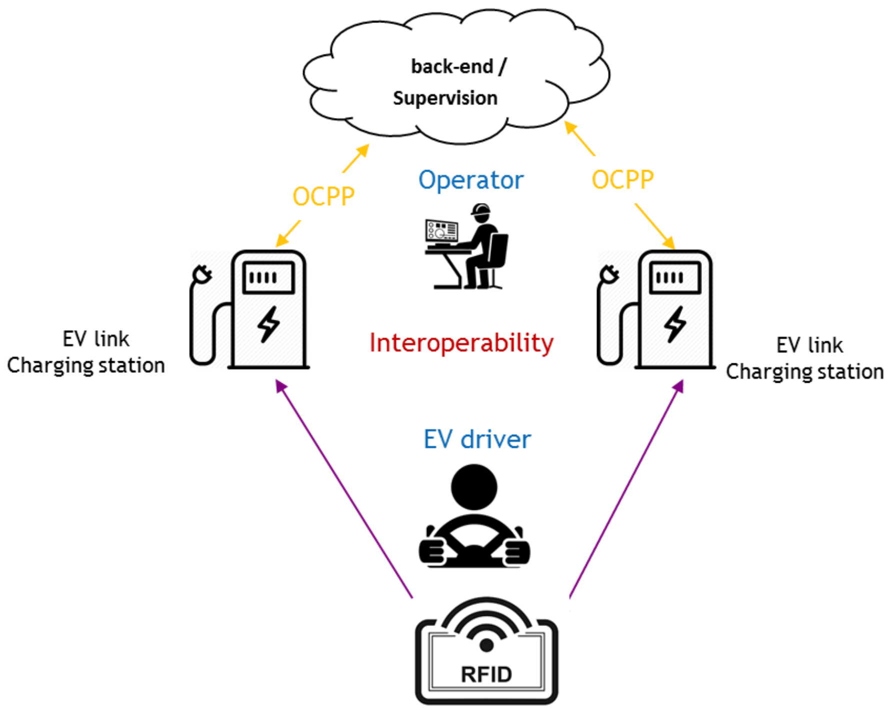


*Figure 2-2: Back-end interoperability across EV charging infrastructure using OCPP and RFID [11]*

### 2.2.2 IEC 63110 – Management of Electric Vehicle (Dis-)Charging Infrastructures

The IEC defined a new standardization initiative by the WG8 as "Management of Electric Vehicles charging and discharging infrastructures" as part of the IEC Technical TC69 which focuses its work on "Electric road vehicles and electric industrial trucks”. The to-be-defined standard is filed under IEC 63110. This initiative aims at internationally standardizing the communication interface between EVSE and a system that is in charge of monitoring and managing the charging station. That system is usually referred to as the Charge Point Operator (CPO) or – as a possible synonym – a Charging Service Operator (CSO) in the e-mobility market. As OCPP 2.0 is going to be one of the foundational inputs for IEC 63110 (next to IEC 61850-90-8), a liaison is set up between the OCA, Open Charge Alliance and the IEC 63110. In the following subsection, more information is provided in this regard [12].

### 2.2.2.1 Relevant related standards and liaisons

As described by Elaad [13], different roles and protocols in the scope of e-mobility exist. This can also be observed more in detail in Figure 2-3. In this figure, the protocols which are easy to position and made for specific purposes are drawn with solid lines. Other protocols such as IEEE 2020.5 and OpenADR (Open Active Demand Response) are more generic and could be suitable for use at different places in the EV market chain. These protocols are visualized with dotted lines. Next to the OCPP as a communication interface between EVSE and CPO, IEC 61850-90-8 can be seen attached to the dotted line. Currently, the IEC 61850 is considered as a global standard in the field of communications for substation automation, called “Communication networks and systems for power utility automation”. IEC 61850-90-8 is a TR issued by the IEC TC57 and specifically addressed at defining so-called “object models for e-mobility” within the scope of those communication networks. The idea is to make charging stations as well manageable next to other grid-connected devices referred to as DER.

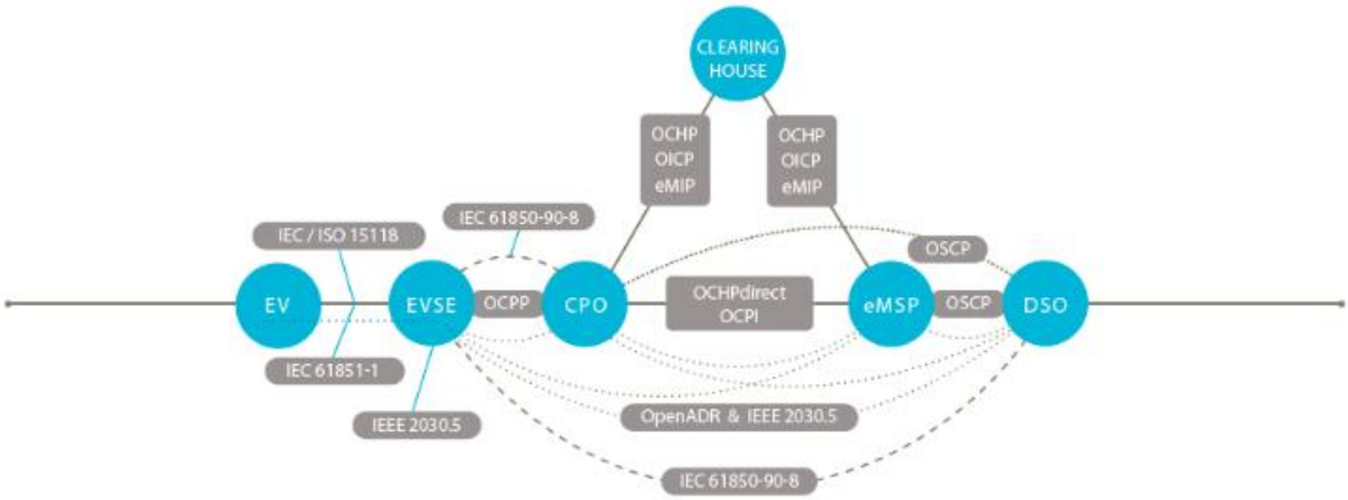


*Figure 2-3: overview of protocols and market roles in the area of e-mobility [13]*

According to this figure, the CPO also needs to take care of exchanging information with a so-called E-Mobility Service Provider (EMSP) – other common synonyms are E-Mobility Provider (EMP) or Mobility Operator (MO) – to authorize a charging process of a customer of an EMSP. The CPO and EMSP need to be in a contractual relationship so that the EMPS’s customer can charge at a charging station operated by a CPO.

This might be realized for instance via the roaming protocols Open Charge Point Interface (OCPI) or Open Clearing House Protocol (OCHP). In order not to have the hassle of setting up bilateral roaming contracts between CPOs and EMSPs, there are also clearing house operators who manage a central roaming platform, such as Hubject which provides its Open InterCharge Protocol (OICP) for those services.

In summary, TC69 defines IEC 63110 and TC57 until now has been in charge of defining amongst others IEC 61850-90-8. However, it has been decided that the responsibility of IEC TR 61850-90-8 will be handed over to WG8 of TC69 to facilitate the harmonization of the e-mobility IEC standards.

## 2.3 SunSpec

SunSpec is a suite of information standards for solar installations produced by the SunSpec Alliance [14]. It is a U.S. based association with U.S. and international members from the Solar PV industry in order to address the main shortcoming of the last decay impeding the broad deployment of solar PV systems, i.e. the lack of interoperable and standard-based renewable energy products in the market. The little flexibility provided by the current solar installations regarding how solar plants are managed, monitored and controlled has made evident the increasing need of a standardization effort between solar component manufacturers and operators. This has led to the idea of SunSpec as described in the SunSpec Alliance White Paper [15].

From that moment, the mission of SunSpec Alliance has been to accelerate the growth of the DER industry, reduce cost, promote innovation and expand the market for renewable power. For that reason, de facto standards (information models, data formats, communication protocols, system interfaces, best practices and other artifacts) have been specified by SunSpec Alliance which enable solar components and energy storage DER power plants to interoperate transparently with system components, software applications, financial systems, and the Smart Grid.

An overview of SunSpec Alliance technology is given in [16], where the SunSpec Alliance Interoperability Specifications are described.

Figure 2-4 depicts the areas of standardization that SunSpec standards address. As shown thereby, PV plants consist of the aggregation of the system devices and other information associated with the system. Devices are represented by a collection of Information Models (*SunSpec Device Models*), which can be used to convey device data between any two communicating entities by mapping them to the appropriate communication protocol (e.g., Modbus, HTTP …). Currently supported device categories include inverters, meters, panels, environmental sensors, string combiners, trackers, energy storage and charge controllers. Generally, PV plants have one or more gateways (*SunSpec Loggers*) which communicate with the SunSpec Device Models and relay the information gathered to servers (*SunSpec Data Store*) which store data permanently and perform vary analytics. Servers also communicate with other servers (*3rd Party Applications*) for reporting, grid operations, data acquisition (SCADA) and other customized applications.

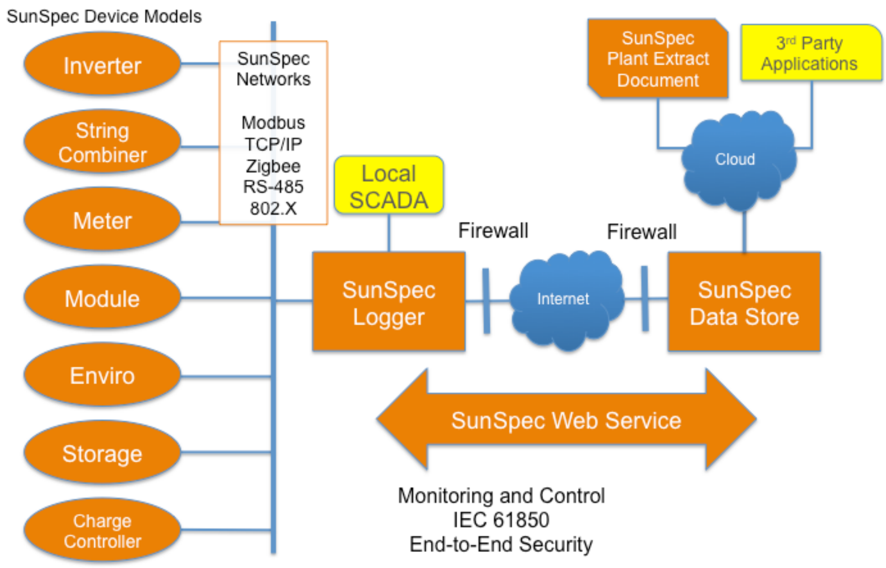


*Figure 2-4 SunSpec architecture* [15]

The communication between devices and loggers (left side of *Figure 2-4*) is governed by the "SunSpec Information Model Specifications" [17], which regulate the information flow in SunSpec through a set of *Information Models*, representing functionalities implemented by devices or plants. Each Information

Model is uniquely defined and contains a well-known identifier (ID) and length. This allows a client to browse the contents of a device description and skip Information Models with unrecognized ID values. SunSpec device definitions are constructed by concatenating a collection of SunSpec Information Models. The SunSpec device definition structure is:

- Common Model
- Standard Model(s)
- Vendor Model(s)
- End Model

Each SunSpec-compliant device definition includes at least three of the SunSpec Information Models: Common and End Models which are mandatory, and at least one Standard or Vendor Model.

SunSpec Information Models are communication protocol agnostic: they have been mapped to Modbus TCP/RTU, HTPP/XML, OPC and other protocols.

On the other hand, the communication between Loggers and Servers as well as Servers and other Servers (right side of *Figure 2-4*), is typically on the Internet, running standard internet protocols such as HTPP. This communication is governed by the SunSpec Model Data Exchange [18] and Plant Information Exchange specifications, to which the reader may reference for further details.

A key feature of the SunSpec approach is flexibility that allows vendors to extend the capabilities of a device type or develop new device types. Moreover, SunSpec definition techniques allow for the creation of new SunSpec Standard and Vendor Models.

All SunSpec implementations are declared by the vendor in a Protocol Implementation Conformance Statement ("PICS"), which specifies the details of a specific implementation and is used for verifying the conformance to SunSpec standards. Of course, products incorporating SunSpec specifications must pass a certification test in order to be deemed "SunSpec certified", which is led by TÜV Rheinland.

In the scope of InterFlex, SunSpec has been used in Use Case 4 of the CZ demo [19], where the aim is increasing DER hosting capacity in LV grids thanks to the installation of smart PV inverters with energy storage solutions (batteries), in order to allow peak shaving of PV production and securing power quality. In the Use Case, SunSpec is deployed as a medium for communication between selected devices (please see the SGAN) in all the three analyzed scenarios, where active power injection is performed:

- upon DSO's request (in case of emergency)
- in case of under voltage in the distribution network
- in case of under frequency in the distribution network.

In all these scenarios, SunSpec is used as a medium for:

- discharging command (Local hardware ↔ PV Inverter)
- battery discharging (PV Inverter ↔ Battery)

In addition, as reported in table 1 of [2], based on the analysis of the demo interfaces, SunSpec appears to be a candidate as recommended standard for the interface between:

- Aggregator ↔ DER (Inverter)
- Inverter ↔ Battery Management System.

## 2.4 Energy Flexibility Interface

The Energy Flexibility Interface (EFI) [20] is a communication protocol developed and maintained by the non-profit Flexiblepower Alliance Network aiming at the interoperable control of various smart appliances that can offer flexibility (e.g., solar panels, heating, electric vehicle charging). The interface is part of the so-called Energy Flexibility Platform. Both components together form a runtime environment enabling the interaction of various smart grid applications on one side with smart appliances on the other side. Figure 2-5 illustrates the high-level design of the Energy Flexibility Platform & Interface (EF-Pi).

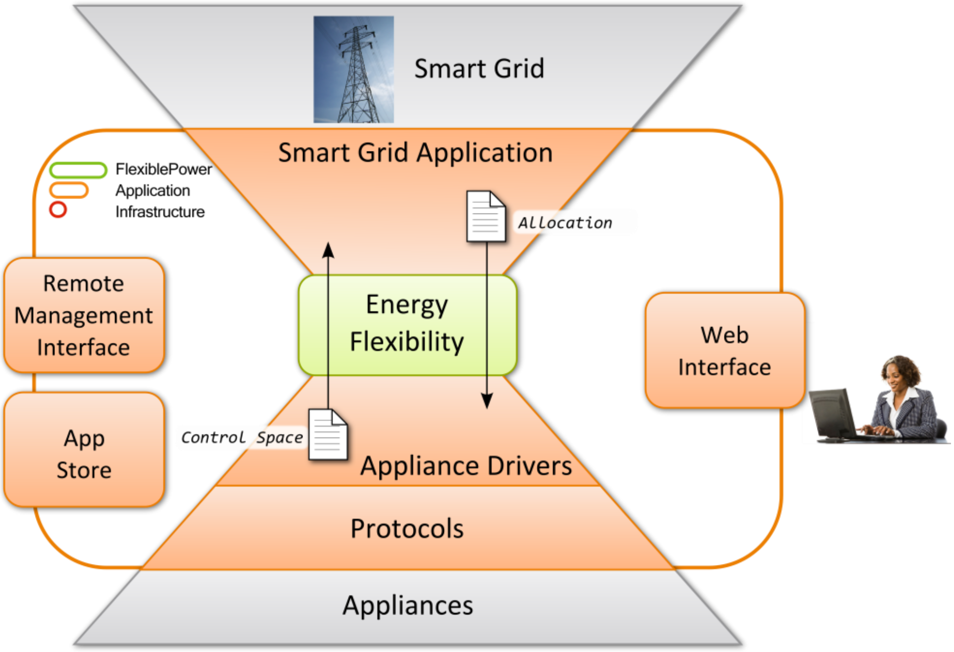


*Figure 2-5 Energy Flexibility Platform & Interface Architecture Overview [21]*

A key functionality of the Energy Flexibility Platform & Interface is its ability to abstract energy flexibilities from vendor dependent implementations, by relying on vendor specific appliance drivers. These drivers can be connected to their respective appliances by any physical layer protocol such as Zigbee, Z-Wave, PLC, WiFi, Ethernet or a proprietary protocol. To the upper layers, the appliance drivers provide abstract models of the underlying energy flexibility (flexibility potential) by means of so-called *control space* (CS) elements. EFI distinguishes four different control spaces [21]:

- Uncontrollable CSs that do not offer flexibility but are measurable.
- Time-shiftable CSs that support flexible scheduling but are constrained by a deadline.
- Buffer/Storage CSs offering flexible production or consumption but are bounded to a buffer limit.
- Unconstrained CSs offering flexible production and not bound to a buffer, e.g. gas generators.

On the upper layers, smart grid applications can use the control space elements to determine a suitable usage profile of the device. Based on the usage profile, the upper layer can request an abstract device behaviour, e.g. turning it on or off, by means of so-called *allocations*. Upon allocation, the appliance drives translate the abstract allocation to a device specific control sequence and send it to appliances.

The Energy Flexibility Platform & Interface are open source in order to encourage the development of further appliance drivers and the development of new applications [20]. Therefore, the alliance also provides additional developer documentation, reference implementations and usage guidelines.

Flexiblepower Alliance Network currently maintains EFI specification, but it is currently in the process of being developed into an international standard for ISO/IEC.

In the scope of InterFlex, EFI is used in two use cases of the Dutch demo site. In the first use case, it is exemplary used to bargain flexibility of a central storage system. In the second use case, it is used to connect a charging point management system with an aggregator. [1]

## 2.5 Universal Smart Energy Framework

Universal Smart Energy Framework (USEF) [22] aims to give positive business use case for flexibility market players. It also describes flexibility market interactions with three variables:

1. Supply
2. Demand
3. Shifts in timing of demand and supply

Furthermore, USEF describes the existing and the new market roles, with their responsibilities and interactions. The key player in this flexibility market is the USEF aggregator, whose role is to cluster available flexibility and offer it to the market. In some EU countries, aggregators already exist, but they do not offer flexibility to DSOs. This is an issue that USEF addresses, and is also what the Dutch InterFlex demo directly addresses.

There are three distinguishable layers in the USEF interaction model [23]:

1. Physical transport of energy
2. Energy supply chain layer (aligned with the European liberalized energy market model)
3. Flexibility supply chain (with participants: Aggregators, Prosumers, BRPs, TSOs and DSOs)

These layers are depicted in *Figure 2-6*, and this represents well the idea of USEF: USEF fits on top of most energy market models, extending existing processes to offer the integration of both new and existing energy markets. USEF interaction model combines the supply value chain interaction model with the flexibility value chain interaction model *[23]*.

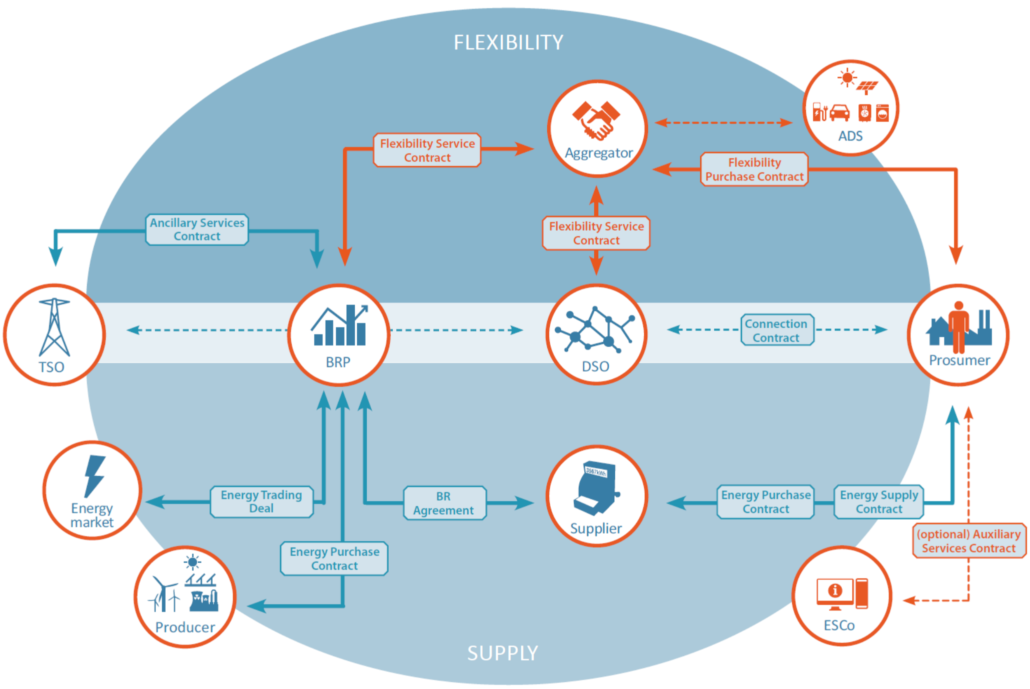


*Figure 2-6*: USEF interaction model

USEF framework is open source, and can be downloaded from github [24]. This is not a fully operational plug and play implementation, but rather a framework to set and guard open standard. In order to do that, framework offers full access to all the specifications, design and implementation guidelines, as well as the reference implementation. This reference implementation supports communication amongst all the players with included structures and exemplary code.

USEF is used in all three use cases of the NL InterFlex demo [25]. However, the InterFlex NL demo flexibility market mechanism deviates from the USEF market mechanism in two ways:
Firstly, the NL demo market is a market between aggregator and DSO only, because BRP and TSO are out of scope.

Secondly, the NL demo introduces a new concept called “the sanctions”. Sanction price is introduced since it is not guaranteed that the offered flexibility is actually delivered by the aggregator during operation. The idea behind the sanction price is that it is an enabler for aggregators to bid in flexibility where the guarantee on delivery is not 100% guaranteed [26].

## 2.6 IEC Core Standards for “Smart Grids”

The IEC 61968/61970 ( [27] and [28] ) and IEC 61850 ( [29]) standards belong to the core standards in the future Smart Grid, which is reflected in the detailed investigations of the international studies [30] and [31]. The IEC 62357 "Seamless Integration Architecture" (SIA), which is recommended several times in these studies, is used and connects both previously mentioned standard families and should therefore also be used for an architecture view. The acceptance and active standardization work on these standards is high worldwide. In addition, they already belong to the established standard families that are currently available.

### 2.6.1 IEC 62357 Seamless Integration Architecture

The technical report IEC 62357 - TC 57 Architecture - Part 1: Reference Architecture for TC 57" [32] structures a large number of the recommended and internationally considered indispensable standards for the implementation of a Smart Grid. Technological topics such as the integration of communication solutions, but also the cross-cutting topics of security and data management are considered, and are represented by a layered architecture using International Electrotechnical Commission (IEC) standards. Each layer as well as each the relevant standards are analysed and described in detail. Furthermore the possibilities of a desired seamless integration on the basis of this architecture. of communication across diverse systems, from which the following can be deduced the term "Seamless Integration Architecture" (SIA) is also derived.
The "Technical Committee" (TC) 57 in the IEC deals in detail with the system aspects and processes, which are thus also included in the scope of application. of the reference architecture:

- SCADA (Supervisory Control and Data Acquisition) and Network Operation
- energy management
- distribution network automation
- Communication with the customer
- measurement data collection
- Protection, monitoring and control functions in switchgears
- Data collection, data storage and asset data management
- network extension planning
- Operational resource planning and optimization
- Construction and maintenance

Within these fields, the focus of the TC 57 architecture is on abstract data models and generic interfaces. This also includes the view of abstract modeling and mapping of the data models to Technologies for concrete implementation. Basically, the SIA can be divided into three areas (A to C) according to Figure 2-7.

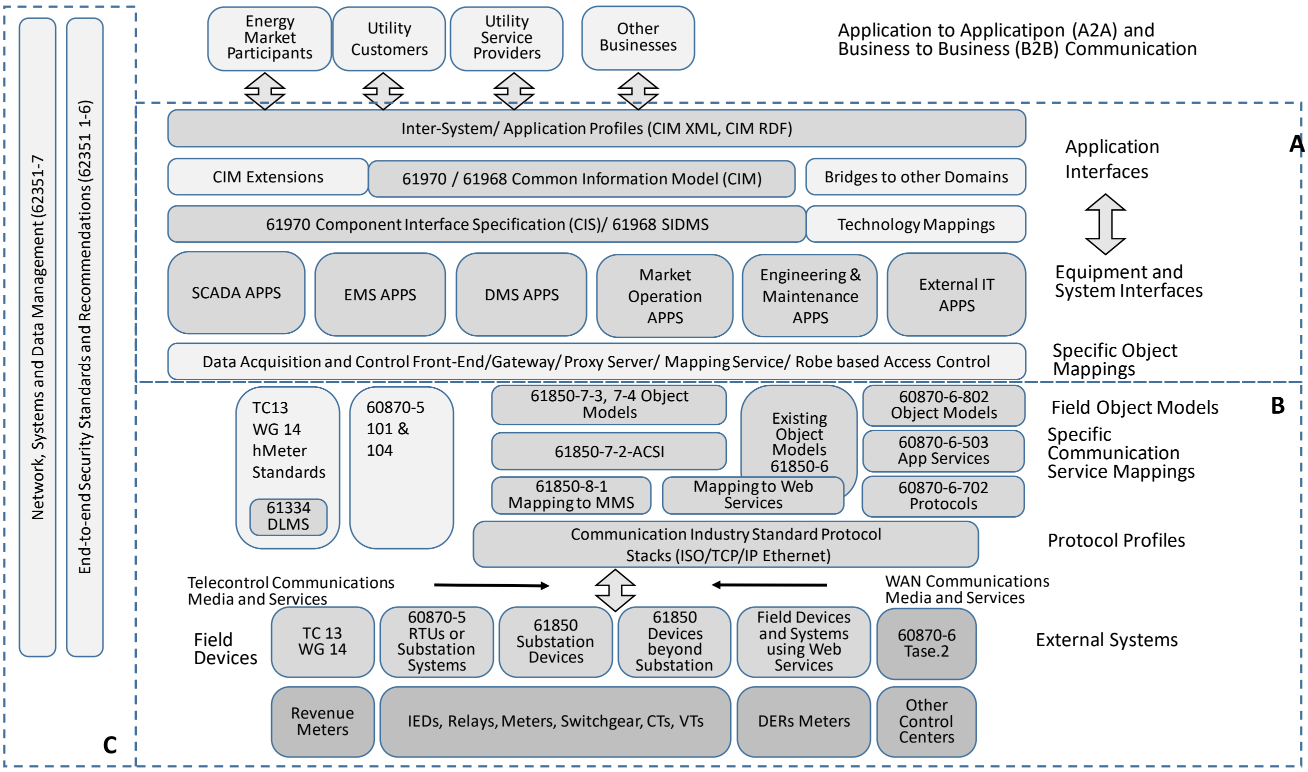


*Figure 2-7 Extended mapping of Seamless Integration Architecture*

Area A mainly contains (IT) standards for business integration, data models and applications that require a high degree of abstraction. This is generally referred to as "integration of business partners and applications". The "Common Information Model" (CIM - IEC 61970) is also positioned in this area.

Area B deals with the "Integration of Energy Systems", and covers mainly standards, which are more in line with the more technical Communication to devices in the field, such as measuring devices, intelligent end devices, switches, transformers, decentralized generation plants as well as further various Control systems. The IEC 61850 covers a large part of the communication models and mappings

Area C deals with Cross-sectional topics such as "Security and Data Management" to ensure consistently secure communication (end-to-end security). These topics are mainly is covered by the IEC 62351 standard family, which is designed for each horizontal layer and offers individual (security) solutions.

### 2.6.2 IEC 61968/61970 CIM

The Common Information Model (CIM) as the basis for the IEC 61968 and IEC 61970 series of standards was developed in the mid-1990s by the Electric Power Research Institute (EPRI) as CCAPI in the USA and handed over to the IEC in 1996, which continued the work at international level [33]. The CIM standard family is particularly important in the area of standardization of system interfaces and data models for network management as well as the integration of applications into the IT system landscape of an energy supply company [34].

The standards are mainly maintained by the Working Group (WG) 13 "EMS Application Interfaces" and WG 14 "System Interfaces for Distribution Management" from IEC/TC 57 "Data models, interfaces and information exchange for the planning and operation of energy supply systems".

The aim of CIM is to minimise costs and reduce time expenditure in the integration of applications in and with energy management systems (EMS). In addition, investment protection for systems is provided by standardization and effective operation is ensured. In this context, the CIM is to be understood as an integration framework that enables seamless integration on the vertical value chain by providing both different interfaces and a single Data models for "Energy Management Systems" (EMS) as well as for distribution network management systems (DMS) are defined and standardized.

The vision to create the CIM standard family was one of the main objectives, to offer the manufacturers of system components the possibility of individual to sell modular system components and enable power utilities, products from a wide range of manufacturers. This is especially true for the market situation at that time, in which the supplier became dependent on the manufacturer, which were forced to be replaced by the development of monolithic systems with proprietary databases and inter-application messages.

For customers, this meant the need to choose products and services that do not necessarily offer the most suitable solution for the respective application but only as a compatible solution to the existing System.
During the development of CIM, it quickly became clear that even completely standardized and technology-independent interfaces were not sufficient for individual functions. It turned out that above all a common vocabulary (i.e. semantics) is of particular importance for a successful integration. The concept of a common information model was therefore included in the development of the standard and seen as a first step. The aim here is to map the real world of the power supply infrastructure in a data model. The CIM offers the possibility to map the most common physical and non-physical objects of the energy domain. For these objects there are respective correspondences in a UML data model [34].

In addition to the actual CIM, which is reflected in the standards IEC 61970-301 [35] and IEC 61968-11 [36], two interface standards have also been developed. The first is the so-called GID (Generic Interface Definitions), which represents a technology-independent interface that is used for certain classes and data, and on the other hand the SIDMS family (System Interfaces for Distribution Management) which is based on the function blocks of IEC 61968 and XML-based messages and associated use cases [37].

Three large use cases (according to [38]) currently exist for CIM:

- Exchange of topology data: The CIM can be used to exchange profiles (that is, a subset of objects and relations) from the entire data model) for modelling topologies can be defined. There are two standardized profiles for modelling Transmission (CPSM) and distribution (CDPSM) networks. With the help of the Standards for serialization in XML and RDF can support static and dynamic data, which can be exchanged via the power grid.
- XML-based message exchange: The CIM provides standardized interface definitions for the exchange of messages. and XML schemas to create a standard-compliant to ensure the exchange of messages. These specifications can be used for the Creation of an SOA can be used.
- Coupling of EMS/DMS systems: In addition to the XML-based message exchange, further interfaces are available to connect various systems and exchange data.

### 2.6.3 IEC 61850 – Communication networks and systems for power utility

IEC 61850 was initially developed with a focus on protection applications and automation of substations. Meanwhile, it is also the most important family outside substations for the exchange of information in electrical power supply with decentralized generators.

Substations are important nodes in these networks. In these, the load flow is controlled and monitoring and controlling network control points can access the power network. In addition, the majority of the existing protective devices for the safe operation of the power grid are installed there. In view of these functions, it is hardly surprising that distributed systems for the automation of substations generate and distribute a wide range of information and data volumes (measured values and status information) (switching commands and parameters). The information and the exchange of information are the necessary basis for distributed control technology with a large number of intelligent devices.

The IEC 61850 series of standards uses unified communication to cover the exchange of information between and on all three typical levels, i.e. between the process level, field level and station level. IEC 61850 defines (see Figure 2-8) the following essential abstract aspects of a communication:

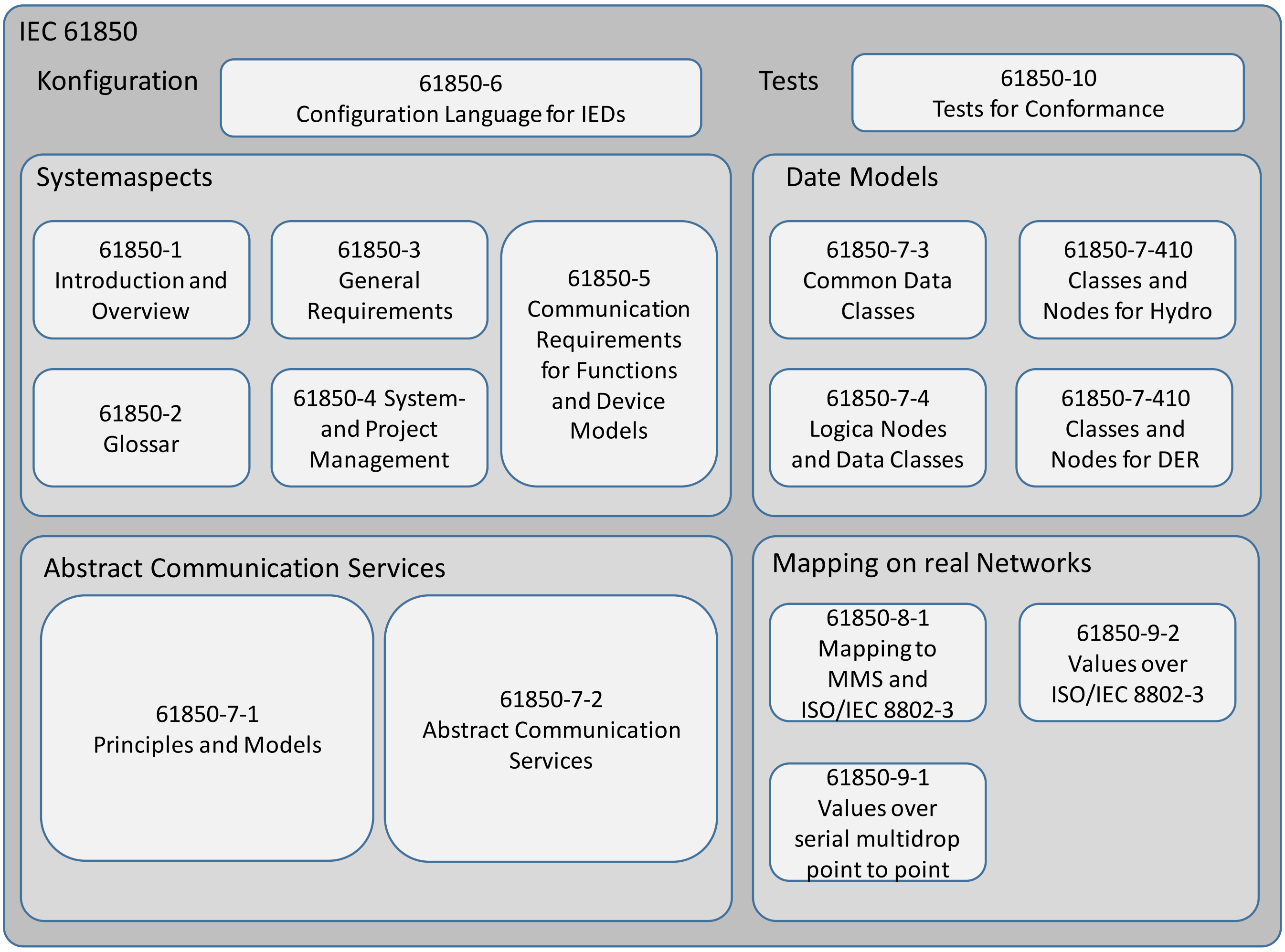


*Figure 2-8 Structure of IEC 61850 - logical model*

The main objective of the IEC 61850 series of standards is communication interoperability of instrumentation and control equipment. That means the possibility that two or more Intelligent Electronic Devices (IEDs) from a single source, and or several manufacturers in the IEC 61850 series of standards and can interpret and use this information unambiguously, to implement the functionality required by the application. IEC 61850 was originally developed for substations – then the series of standards was supplemented by wind specific definitions. These have been published in the IEC 61400-25 series of standards. The extensions are published under a separate number, because the "IEC TC 88 -Wind Turbines" is responsible for the topic of wind energy.  Next, extensions for applications in hydro power plant technology (hydro models) were developed and published under IEC 61850-7-410. As a further important extension, information from the field of decentralized power generation were published.

### 2.6.4 Harmonization of Standards - CIM and IEC 61850

Due to heavy data exchanges between CIM and IEC 61850, the need for harmonizing the standards has emerged as a high priority issue to improve interoperability of involved systems in a smart grid. Among many aspects involved in the harmonization, connectivity, which is concerned with physical connections of equipment, forms the base. The harmonization between the two standards has as goal to:

- Improve the interoperability of applications using both data models.
- Simplify engineering with improved quality through largely automatic conversion of data models
- Act as a basis for continuous communication from station to network management
- Enable the full use of the advantages of semantics

Both standards rely on the exchange of configuration information based on XML and use an abstract service model and UML for documentation. Differences can be found in the basic concepts (inheritance - CIM vs. aggregation - IEC 61850), the structure (associative vs. hierarchical), and the naming convention. Also relationships between the models and rules for mapping of information objects between the two standards do not exist.

IEC TS 62361-102:2018 outlines a technical approach for solving the aforementioned challenges and achieving effective information exchange between power system installations governed by IEC 61850 and business systems integrated with IEC CIM standard data exchanges. Based on a selected specific set of use cases, but also with the goal of creating a framework that will extend successfully to other use cases in the future. This document includes proposals to ‘harmonize’ the two standards by adapting or extending existing information models and/or defining new models, where such changes will enable more effective communication.

## 2.7 OpenADR

OpenADR is an open-source smart grid communications standard used for demand response applications [39]. It is typically used in demand response scenarios when specific signals are sent to cause devices to be turned off during periods of higher demand, in the InterFlex context it is used in by Dutch Demo. The OpenADR standard, currently at version 2.0b, prescribes the information exchange between utilities and energy management control systems.

OpenADR uses a service-oriented architecture (SOA) in which all interactions occur between entities called virtual top nodes (VTNs) and virtual end nodes (VENs), as shown in Figure 2-9 [40].

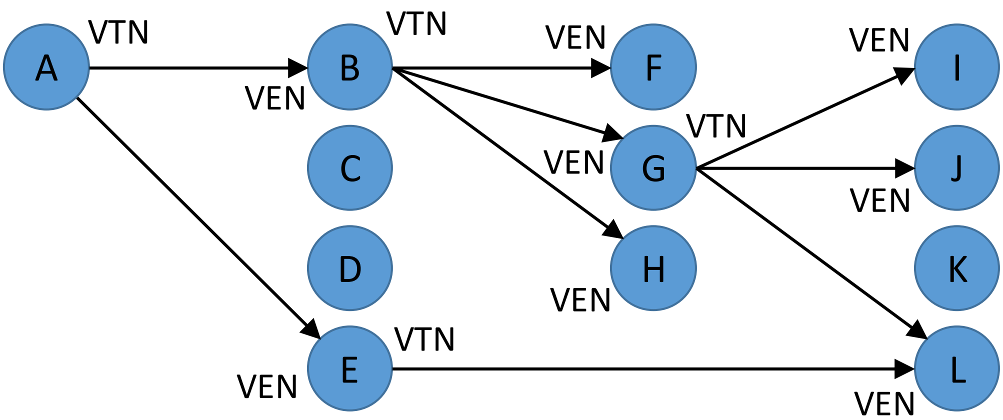


*Figure 2-9 OpenADR service-oriented architecture [40]*

In general, the VTNs send demand response signals to the VENs and there is a hierarchical relationship between VTNs and VENs, where in some cases a node can be a VEN and a VTN at the same time. This model therefore supports the notion of intermediaries such as aggregators, which are common within existing demand response implementations.

Up to now, two profiles of OpenADR have been developed. Profile A is targeted towards low-end devices and is limited to a simple implementation of OpenADR enabling only the notification of the VEN of upcoming DR events and sending the demand response signals from the VTN to the VEN. Profile B is targeted toward fully functional control systems and devices and enables feedback and additional services. It includes the opt out for the VEN from DR events and the information reporting to the VTN. This information is typically used to by the VTN to both predict and monitor the behavior of the demand-side loads associated with the VEN. An additional profile, namely OpenADR 2.0c, is in development to implement an even more complete version of OpenADR specifically aimed at aggregators.

The standard allows a response signal to the DR event to travel back from VENs to the VTNs, and, in addition, other information can also be exchanged related to DR events, such as event name and identification, event status, operating mode, various enumerations characterizing the event, reliability and emergency signals, renewable generation status, market participation data and test signals [40]. The implementation of the services is baded on standard-based IP communications such as HTTP and XML Messaging and Presence Protocol (XMPP).

The demand-response signals are the means by which a VTN interacts with a VEN in order to influence or change the load profiles of the demand-side loads associated with the VEN. The OpenADR specification supports a wide range of different types of demand-response signals such as direct load control, or price incentives.

The data models and the services of OpenADR are derived from OASIS Energy Interoperation 1.0 standard [41] that describes information and communication model to coordinate energy supply, transmission, distribution, and use, including power and ancillary services, between any two parties, such as energy suppliers and customers, markets and service providers, in any of the domains defined in the Smart Grid. From the security perspective, OpenADR 2.0 aims to conform with the NIST Cyber Security requirements and follows the guidelines provided by the “Security Profile for OpenADR.
At the moment OpenADR 2.0 is limited to electrical DR. It would be important to consider the relation to other energy sources used e.g. for heating and cooling in a cross-carrier energy context to apply DR also to other energy sources.

## 2.8 Smart Appliance Reference Ontology

SAREF (Smart Appliance REFerence ontology) is an ontology that was created to address the issue of fragmentation and the need for interoperability in the smart appliances and Internet of Things (IoT) industry; it was first designed for energy efficiency use cases. The main objective of SAREF is to improve energy efficiency of Smart Appliances through Energy Management Systems.

It is an interoperability enabler as it gives a common language for devices. SAREF is not designed to replace existing communication protocols, but instead to provide a common translation of the information coming from existing protocols. The ontology was created from an analysis of some of the main energy devices standards, such as Universal Plug and Play (UpnP) or Zigbee Home Automation.

SAREF is a common language meant to ease the interoperability of devices by mapping their current data model to it. This allows to make one mapping with SAREF per data model, instead of one mapping with each other data model per data model. An intuitive representation of the advantage brought by SAREF ontology is shown in Figure 2-10.

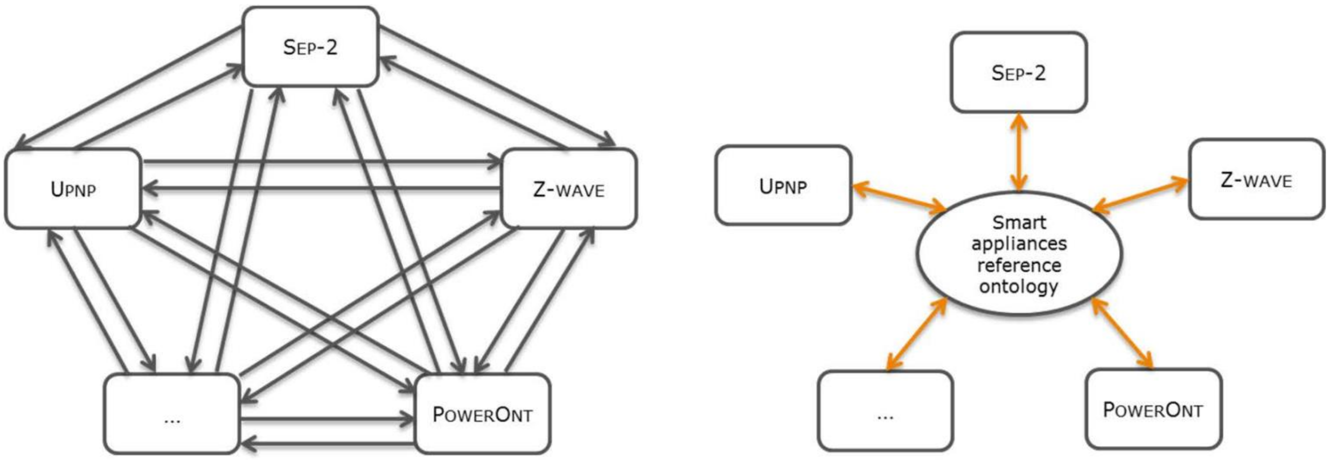


*Figure 2-10: Reducing the number of data mappings with SAREF*

SAREF ontology is also future proof as it was designed to be easily extended and three main extensions were released to be more specific: SAREF4ENER for energy domain, SAREF4BLDG for Smart Buildings, SAREF4ENVI for environment. Other extensions for Smart Cities, Agriculture and Industries are currently under development, turning SAREF into a semantic reference for many IoT devices.

SAREF focuses on the concept of device, defined as “a tangible object designed to accomplish a particular task in households, common public buildings or offices. In order to accomplish this task, the device performs one or more functions” [42]. The role of SAREF is then to provide a standard way to describe devices and their characteristics. Figure 2-11 shows the main classes of SAREF ontology.

SAREF ontology is written in Web Ontology Language (OWL) [43], and its instantiations are using the Turtle syntax [44]. An application example would be describing different devices managed in a home gateway. Examples of instantiations and use cases can be found in ETSI TR 403 111 [45].

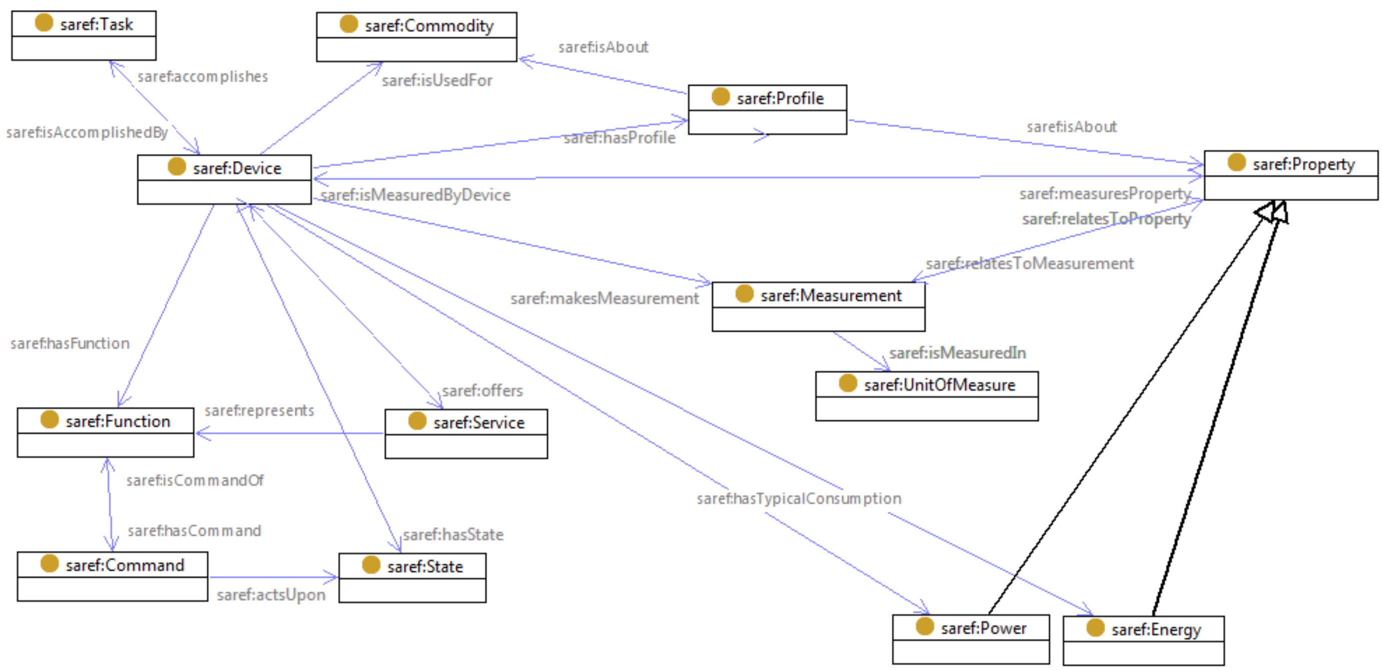


*Figure 2-11: Main classes of SAREF ontology*

## 2.9 Summary and Additional Complementary Information

This chapter offered a summary of current standards or emerging standards, which would interact with the interoperable API specification. This specification would bridge the interoperability gap between the the different standards involved when an a so called upper bound flexibility solution is targeted. Current state of the art standards presented in this chapter are OneM2M, which focuses on the Internet of Things (IOT) and Machine to machine (M2M) communication.

Followed by this the OCPP protocol was presented which is used in the Dutch Demo for communication between charging station and a central system.

While the former two protocols are aimed on device level functionality, the Universal Smart Energy Framework (USEF) is geared towards the flexibility market interactions. It provides a market model for the trading flexibility and is used in the Dutch Demo.

The Smart Appliance Reference Ontology (SAREF) creates a common vocabulary to interact with smart IoT devices with the goal of enabling semantic interoperability. Together with IEC 61850, the Common Information Model (CIM) (IEC61970 and IEC 61968) model is one of the main Smart Grid standards used today.

The CIM model is an ontology model that allows the exchange of information of the electric grid among different software applications. IEC61970-301 describes the components of a power system at an electrical level and relationships between each one, and IEC 61968-11 defines semantics of other aspects of power system software data exchange. While the former originates from the control room IEC 61850 originates from the substation which has become practically the common language standard in electrical power engineering, thus every further development has to be compatible with it.

In addition to this state-of-the-art review, the complementary information which comes from the work of the European Commission Smart Grid Task Force – Expert Group 3 might be considered.
The focus of this Expert Group was on:
- analysing existing market models and corresponding actors,
- identifying the gaps of the European legislative framework,
- finding the potential fields of action which should be covered soon at a European level

with the objective of deploying an explicit Demand Response framework in Europe.

Broad different categories were analysed, e.g., customer perspective and market access; flexibility product design; measurement and validation of flexibility products; technical solutions and platforms to satisfy Smart Grid needs for flexibility. For each of those categories, barriers were identified and recommendations were proposed after analysing a set of 41 European Use Cases. The final report of the Expert Group is expected to be published during the first quarter of 2019.

# 3 INTERFLEX RECOMMONDATIONS

During the course of some workshops with different InterFlex demos, the system architectures of demos have been identified based on the SGAM interoperability analysis conducted in deliverable D3.1 [1]. Meanwhile and during the first period of the project, contributors of T3.1 highlighted the critical interfaces from the interoperability or cyber security perspectives with some recommendations in D3.3 [2]. However, based on collected demo feedbacks, few interoperability and cyber-security issues were effectively faced during the demonstrator period. The criterion for selecting a critical interoperable interface is related to the nature of the interface in which different actors are involved, or the lack of a clear standard in industry, or the immaturity of a selected solution for the respective interface. In addition, the criterion for selecting a critical cyber secure interface is related to the easy access to the information exchange, or the dependency of the interface on legacy protocols, or the exchange of personal data. This information can be observed in Table 2. It is noteworthy that in Appendix 1. InterFlex demo SGAMs – Communication layers, the SGAM diagrams (the communication level) of the InterFlex use cases with the respective Interface IDs could be found. For the complete access to the interface data base and the SGAM diagrams of different demo structures, please refer to D3.1. Furthermore, the criteria for selecting an interface is excessively explained in D3.3.

*Table 2 Summary of the implementation of state-of-the-art solutions in different InterFlex demos*

| Interface ID | From device | To device | Initial recommendation | Solution in demo | Criticality | Flex. API |
|---|---|---|---|---|---|---|
| NL 1.1a | RTU SSU | SSU | Use SUNSpec 800-series as an industry standard | Modbus | Inter-operability | Demo uses Activation of Flexibility via API |
| NL 1.1b | RTU PV | PV | Use SUNSpec 800-series as an industry standard | Modbus | Inter-operability | |
| NL1.4 | FAP DER | GMS | Define a standard for connection between DSO and aggregator (based on USEF) | USEF+ (extended USEF) | Inter-operability | |
| NL2.1 | Controller CP | Charging Station | | OCPP over wired internet or GPRS/LTE | Cyber security | |
| NL2.2 | CPMS | Controller CP | | OCPP over wired internet or GPRS/LTE | Inter-operability | |
| NL2.4 | CPMS | FAP | | OCPI | Cyber security | |
| NL2.4 | FAP EV | GMS | Define a standard for connection between DSO and aggregator (based on USEF) | USEF+ (extended USEF) | Inter-operability | |
| NL3.2 | FAP | GMS | Define a standard for connection between DSO and aggregator (based on USEF) | USEF+ (extended USEF) | Inter-operability | |

| Interface ID | From device | To device | Initial recommendation | Solution in demo | Criticality | Flex. API |
|---|---|---|---|---|---|---|
| FR1.6 | RTU SSU | SSU | Use SUNSpec 800-series as an industry standard | Modbus TCP | Inter-operability | |
| FR3.3 | Flexibility market platform | Flexibility aggregator (Engie or EDF) | Define a standard for connection between DSO and aggregator (based on USEF or CIM) | XMPP, CIM Market | Inter-operability | Demo uses Activation of Flexibility via API |
| FR3.4 | RTU SSU | SSU | Use SUNSpec 800-series as an industry standard | Modbus TCP | Inter-operability | |
| FR3.5 | Flex aggregator (Engie) | Load | Use simple relay-wire or smart appliances protocols such as SAREF | KIWI/TOPKAPI HTTPS | Inter-operability | |
| FR3.7 | Gas IT server | Hybrid load (water boiler) | Use simple relay-wire or smart appliances protocols such as SAREF | 3G | Inter-operability | |
| FR3.8 | Flex aggregator (EDF) | Load | Use simple relay-wire or smart appliances protocols such as SAREF | TCP/IP, SMS or SMTP | Inter-operability | |
| SE3.22 | Supplier Cloud System | Demand Side Response System (local EMS) | Consider as aggregator and rely on USEF or new standards (see above | REST communication is mostly vendor specific. SETUP Standards is highly welcomed. | Inter-operability | |
| SE3.32 | Microgrid Controller | DSO SCADA | Rely on a public profile/data model of Modbus, or define a standard? Or rely on SUNSpec? | Based on Modus serial with a specific data model for data exchange. | Inter-operability | |
| DE.5 | Smart Meter Gateway | Control Box | USEF could be implemented | IEC61850 (over LTE/4G) considering the technical guidelines in the Smart Meter Framework | Inter-operability | No Activation of Flexibility by API used in Demo |
| DE.6 | Gateway admini-strator | Smart Meter Gateway | USEF could be implemented | IEC61850 (over LTE/4G) considering the technical guidelines in the Smart Meter Framework | Inter-operability | |

| Interface ID | From device | To device | Initial recommendation | Solution in demo | Criticality | Flex. API |
|---|---|---|---|---|---|---|
| DE.9a | Smart Grid Hub | Smart Meter Gateway | USEF could be implemented | IEC61850 (over LTE/4G) considering the technical guidelines in the Smart Meter Framework | Inter-operability | |
| DE.9b | Smart Meter Gateway | Smart Grid Hub | USEF could be implemented | IEC61850 (over LTE/4G) considering the technical guidelines in the Smart Meter Framework | Inter-operability | No Activation of Flexibility by API used in Demo |
| DEx.x Connection between switchbox and appliances | Switchbox | Appliance | Use simple relay-wire or smart appliances protocols such as SAREF | Solution implemented using relay wires | Inter-operability | |
| CZ3.3 | SSU Ripple Control Receiver | Smart EV Charger RTU | Rely on existing control signal protocol such as OCPP for EVSE | Ripple control system for sending the command from our SCADA towards the charging stations installations. Other functions of smart charging stations are autonomous. Meaning of ON/OFF signal is determined just by the wiring between ripple control receiver and RTU or the charging stations. | Inter-operability | |
| CZ4.3 | SSU Ripple Control Receiver | SSU | Rely on existing control signal protocol such as OCPP for EVSE | | Inter-operability | |

In addition, by looking at the SGAM diagrams, two solutions exist for each cross-zone and cross-domain information exchange between different actors and devices in each demonstration. Field zone devices are typically involved in such cases in practice. Access to such field zone devices, therefore, is either possible via a dedicated field zone counterpart in the neighbouring domain (lower bound connection), or via a higher level counterpart to and from there down to the device (upper bound connection). This is shown in Figure 3.1.

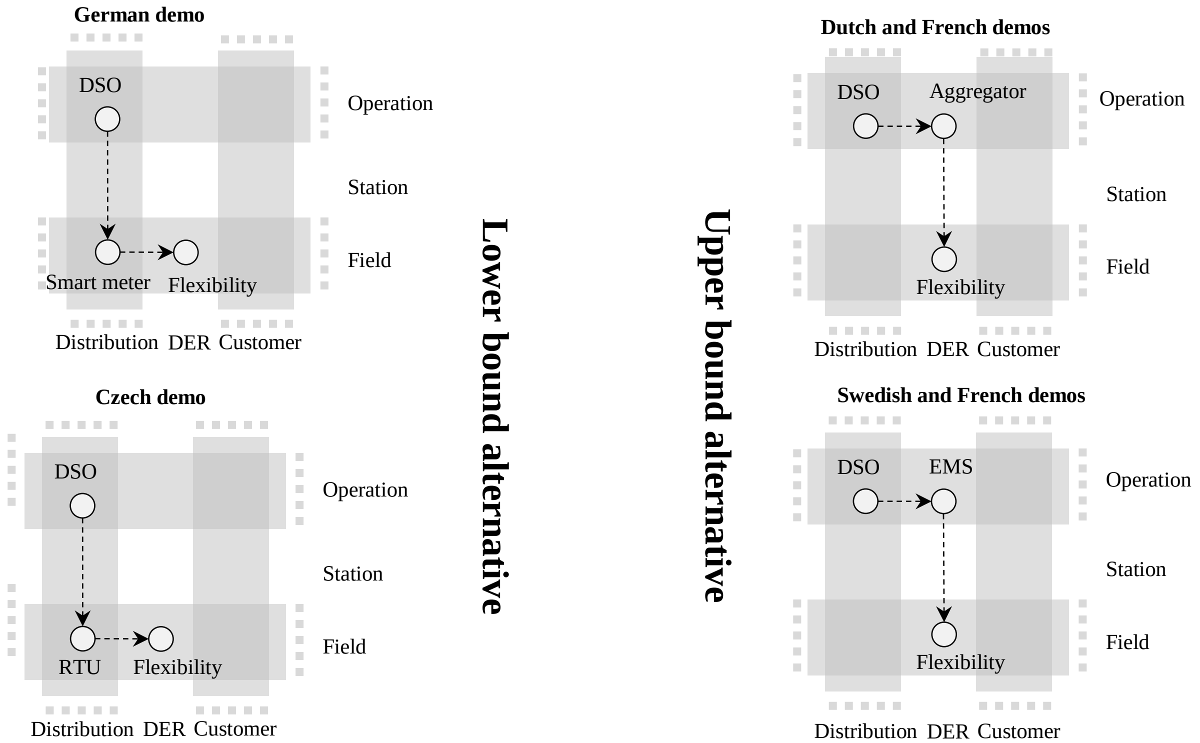


*Figure 3-1 The realization of cross-domain and cross-zone communication links into upper and lower-bound alternatives*

As observed in **Erreur ! Source du renvoi introuvable.**, current state-of-the-art protocols and interfaces are covered excessively in all InterFlex demos and there are examples for both upper bound and lower bound solutions for the critical interfaces. However, to provide a unified interface to stakeholders in a flexibility market, this report focuses on the upper bound alternatives including DSO-aggregator-flexibility (Dutch and French demos) or DSO-EMS-Flexibility (Swedish and French demos). This needs a detailed specification of an interoperable API to close the interoperability gap in the flexibility activation chain. The following chapters will provide more information about the specification of the proposed interoperable API and its interaction with different stakeholders.

# 4 API SPECIFICATION

This chapter provides the specification of the interoperable flexibility API that was specified in the scope of the InterFlex project. The API aims at abstracting characteristic properties of flexibilities in order to provide a unified interface to stakeholders such as DSOs or TSOs. Furthermore, the API aims at reducing the communication overhead between its stakeholders by storing flexibility offers and requests in an integrated data base service. The following subsection presents a more detailed description of the overall API functionality. Subsection 4.4 describes the formal specification used throughout this document.

## 4.1 InterFlex API Functionality

The InterFlex API aims at abstracting the characteristic properties of underlying flexibilities based on [3] and offering a unified, cross-carrier flexibility activation interface. Therefore, the InterFlex API design consists of two separate APIs that work closely together in order to connect stakeholders at the upper layer (e.g. DSO) with the stakeholders accessing the platform from the lower layer (e.g. aggregator). As explained in Chapter 3, the main focus is supporting upper-bound links. More specifically, the scenario of a DSO negotiating flexibility with one or multiple flexibility aggregators, i.e. DSO-aggregator-flexibility platform, serves as main input for this report. However, with minor modifications the proposed InterFlex API can also be used in the DSO-EMS-flexibility-platform.

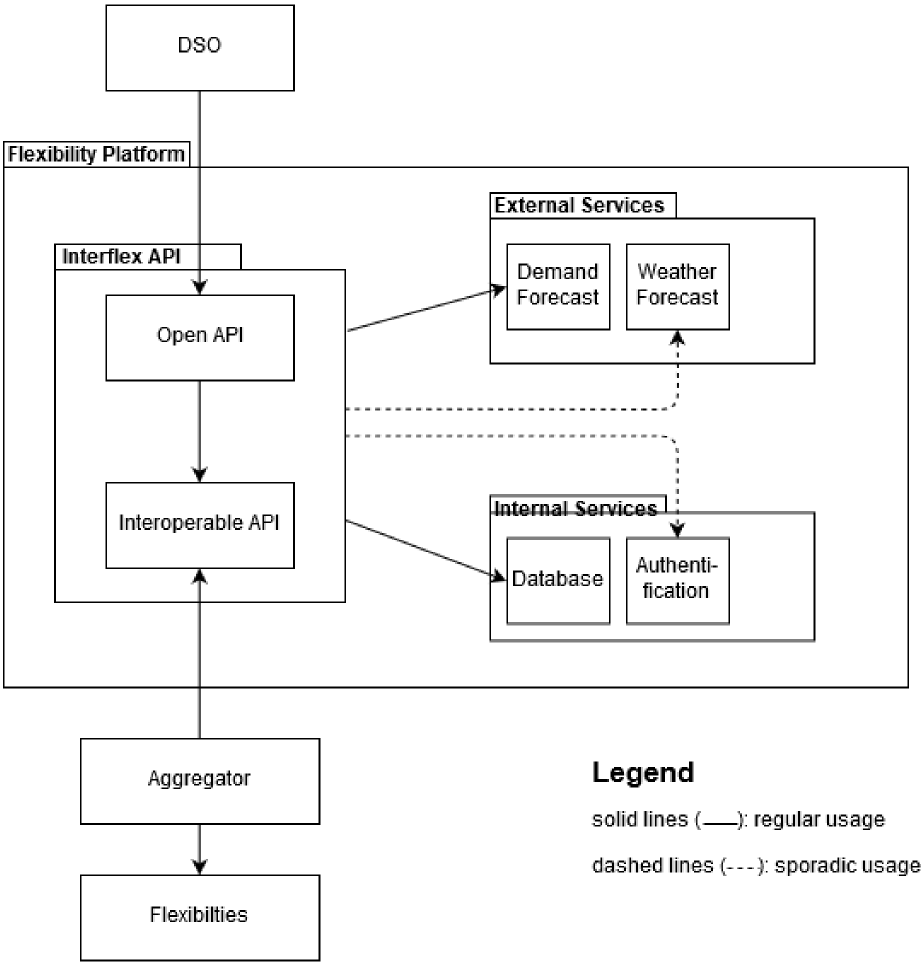


*Figure 4-1 Flexibility platform and InterFlex API design concept*

As depicted in Figure 4-1, the DSO uses the upper layer of the InterFlex API, from now on referred to as *open API*, to connect to the flexibility cloud platform. Aggregators connect to the lower layer of the InterFlex API, referred to as *interoperable API*, using the interface that is specified in the following section. Within the cloud platform, both APIs can contact internal and external services such as database services or forecast services. The main abstraction of the flexibilities takes place at the aggregator level. An aggregator can use a homogenous or heterogeneous pool of flexibilities, e.g., BSS, EV Charging, Heat pumps, etc. and might utilize a variety of different interfaces to connect to the flexibility devices. However, the aggregator only reveals abstract flexibility offers to the interoperable API. In doing so, the abstraction of flexibilities is included into the aggregation process and the aggregators are responsible for mapping their provided flexibilities to the flexibility offers specified within the interoperable API.

## 4.2 Formal UML Representation

In the scope of this report, UML diagrams are used to illustrate the relation and interaction of data objects. The main motivation of the UML diagrams is to provide an overview of the relation between the defined data-modls expected to occur in typical requests/responses during flexibility negotiation. In addition, a table containing a more detailed description of the individual attributes accompanies each UML diagram.

In this subsection, we will provide a brief introduction to UML diagrams and how to read them. This shall improve the readability of the document. Figure 4-2 provides an exemplary UML representation of two data objects A and B. The arrow indicates that DataObjectA makes use of DataObjectB. Each data object is labeled with its internal attributes and additionally a table containing a short description is provided for each new data object, e.g. in Table 3.

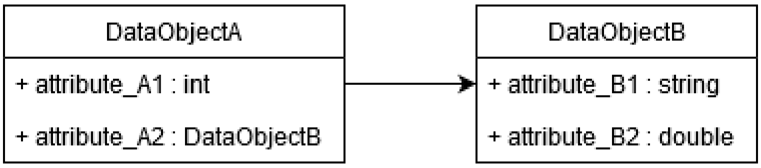


*Figure 4-2 Exemplary UML diagram*

*Table 3 Exemplary attribute description table*

| Object | Name | Type | Description |
|---|---|---|---|
| DataObjectA | attribute_A1 | int | Attribute description |
| | attribute_A2 | DataObjectB | Attribute description, of type DataObjectB (documented blow) |
| DataObjectB | attribute_B1 | string | Attribute description |
| | attribute_B1 | double | Attribute description |

## 4.3 API Stakeholder Connections

For a better understanding of the InterFlex API and the interaction with its stakeholders, the interconnections of the stakeholders will be discussed in the following subsections. A UML-like representation is used to illustrate which stakeholder interacts with which part of the API.

### 4.3.1 Aggregator Connection

As discussed above, aggregators are responsible for abstracting the characteristics of underlying flexibilities prior to posting a flexibility offer the InterFlex Flexibility Platform via the InterFlex API. Therefore, an aggregator connects to flexibilities with any of the various Interface introduced in Chapter 2. Furthermore, the aggregator can apply its own business logic to aggregate available flexibilities. The aggregated flexibilities can be abstracted according to the data objects specified in the following sections and be posted to the Flexibility Platform as a *flexibility offer*. Figure 4-3 illustrates the dependencies between the aggregator, flexibilities, the InterFlex API and the aggregation logic.

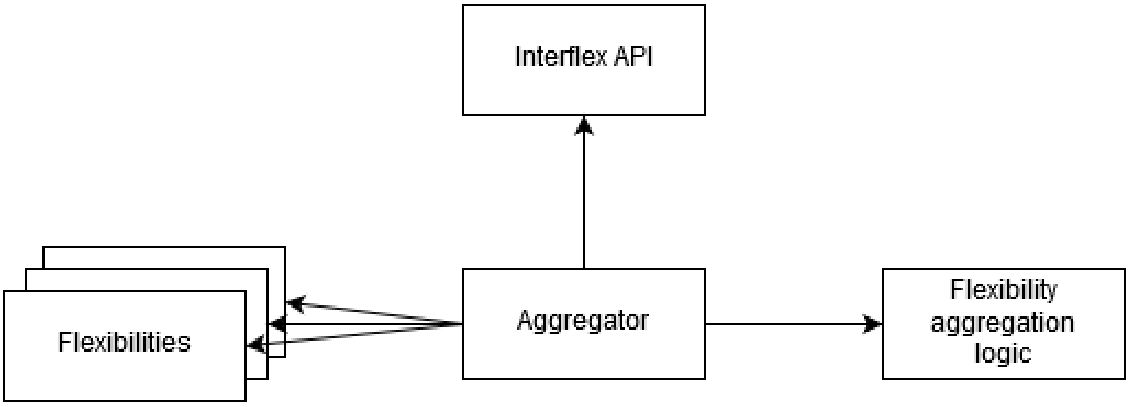


*Figure 4-3 Aggregator interaction with InterFlex API*

### 4.3.2 DSO Connection

The DSO is another main stakeholder of the API and connects to the InterFlex Flexibility Platform via the InterFlex API. Afterwards, the interface can either be used to visualize currently available flexibility for the operator or can be fed into any control logic that automatically requests and activates flexibility. However, connecting the flexibility platform to any other DSO system may raise cyber security issues that are out of scope for this report. Figure 4-4 illustrates the dependencies between the DSO, the DSO's Operator interface, the InterFlex API and the flexibility activation logic.

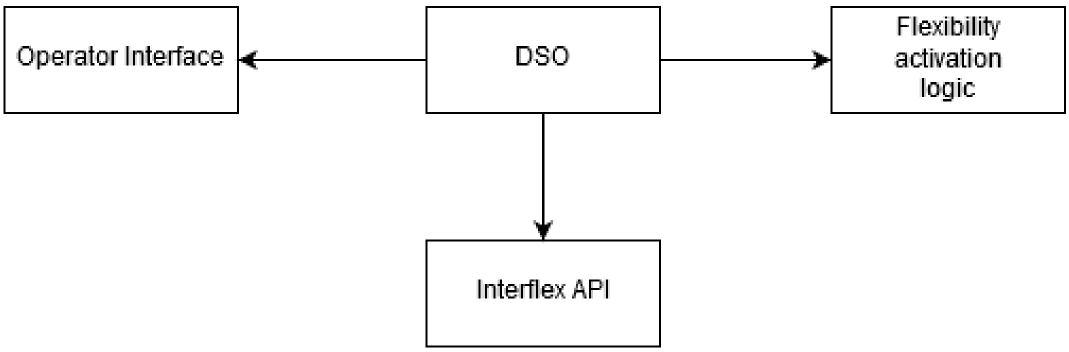


*Figure 4-4 DSO Interaction with InterFlex API*

### 4.3.3 Internal and External Services

The InterFlex Flexibility Platform does not only aim at interconnecting the DSO with several aggregators but also at caching the latest flexibility offers and providing all stakeholders with common input data such as forecasts. This should be realized by means of internal and external services. Internal services are related to internal data of the platform such as a database service or an authentication service. External services allow third parties to provide all platform users equally with a common service or data. Details of the service interfaces are finalized during the reference implementation phase and are considered out of scope for this report.

## 4.4 API Functionality Specification

This section provides the formal specification of the InterFlex API. The first subsection introduces common data objects that are included in all API calls. The subsequent sections present the most fundamental data objects and API calls that are considered minimum requirements for flexibility negotiation.

### 4.4.1 Common InterFlex API components

Figure 4-5 shows the skeleton of any data object that is involved in an InterFlex API call. Upon initialization of the API a metadata object is created that contains the currently utilized version of the API as well as an unique identifier for the current entity that is using the API. This skeleton can be extended with one or more specific data objects contain data that are more specific to the respective API call. If necessary, the extended data object can use the authenticator object in order to authenticate against the internal authentication service of the flexibility platform.

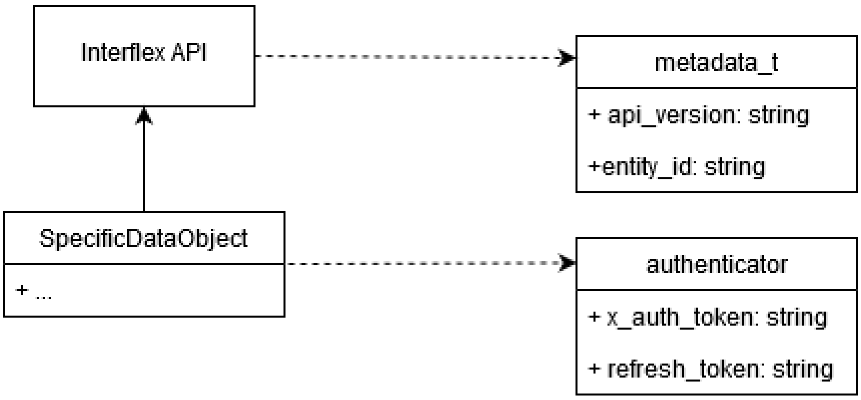


*Figure 4-5 Common API data object*

*Table 4 Description of Common API data object*

| Object | Name | Type | Description |
|---|---|---|---|
| metadata_t | api_version | string | Used version of the API, e.g. v1.0 |
| | entity_id | String | A unique identifier for the entity that is using the API, e.g. aggregator |
| authenticator_t | x_auth_token | string | Token for authentication |
| | refresh_token | string | Contains a refresh token |
| SpecificDataObject | … | | A specified data object |

### 4.4.2 Entity Authentication

In order to ensure integrity of the data inside the flexibility platform the interface contains a basic authentication mechanism. This mechanism allows for the assignment of individual roles and privileges to different entities. It should be noted that this mechanism is not intended to ensure the cyber security of the entire platform.

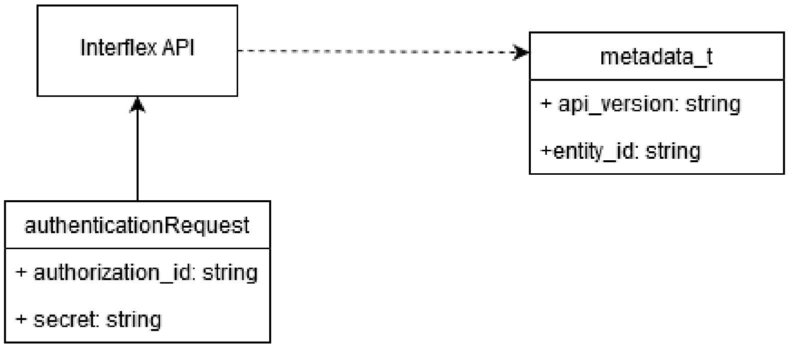


*Figure 4-6 Authentication request object*

*Table 5 Description of authentication request object*

| Object | Name | Type | Description |
|---|---|---|---|
| authentication request | authorization_id | string | A user identifier, e.g. user name |
| | secret | string | The secret (password) of the user |

If the entity (user) can be identified by the internal authentication service of the flexibility platform, an authenticationResponse is returned. The authenticationResponse contains a token that can be used to authorize further API transactions until the token expires. Furthermore, the object contains the role the server has assigned to the requesting entity.

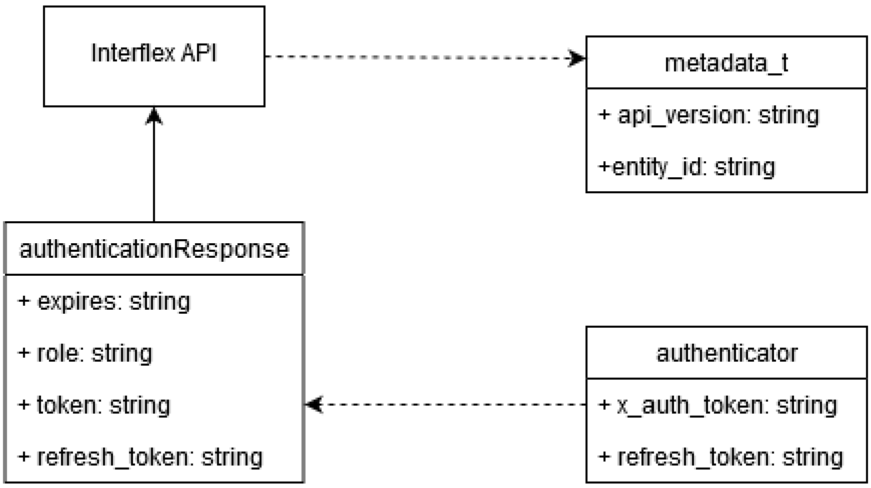


*Figure 4-7 Authentication response object*

*Table 6 Description of authentication response object*

| Object | Name | Type | Description |
|---|---|---|---|
| Authentication *response* | expires | string | Date and time of token expiration |
| | role | string | Role of the user, e.g. aggregator, DSO |
| | token | string | Token to be used for further authentication |
| | refresh_token | string | Respective refresh token |
| authenticator | x_auth_token | string | Authentication token |
| | refresh_token | string | Refresh token |

Finally, the authenticator object is derived from the authenticationResponse object, allowing further API transactions for a token-based authentication.

### 4.4.3 Flexibility Offer

In order to offer flexibility to the system operator, the aggregator creates a FlexibilityOffer object (cf. Figure 4-8) and posts it to the flexibility platform. The object represent a flexibility offer and is stored in the internal database service of the flexibility platform. The offer contains a unique identifier allowing the aggregator and the DSO to relate the FlexibilityOffer to a possible FlexibilityActivationRequest during the negotiation. Furthermore, the FlexibilityOffer contains an expiration date and a segment identifier that represents the affected segment of the grid. The amount of flexibility and its price are encoded in the flexibility_t and the price_t data objects. The former represents the amount of flexibility, the granularity flexibility can be requested at, and the respective unit. The used characterization of flexibility is based on the definition provided in [3].

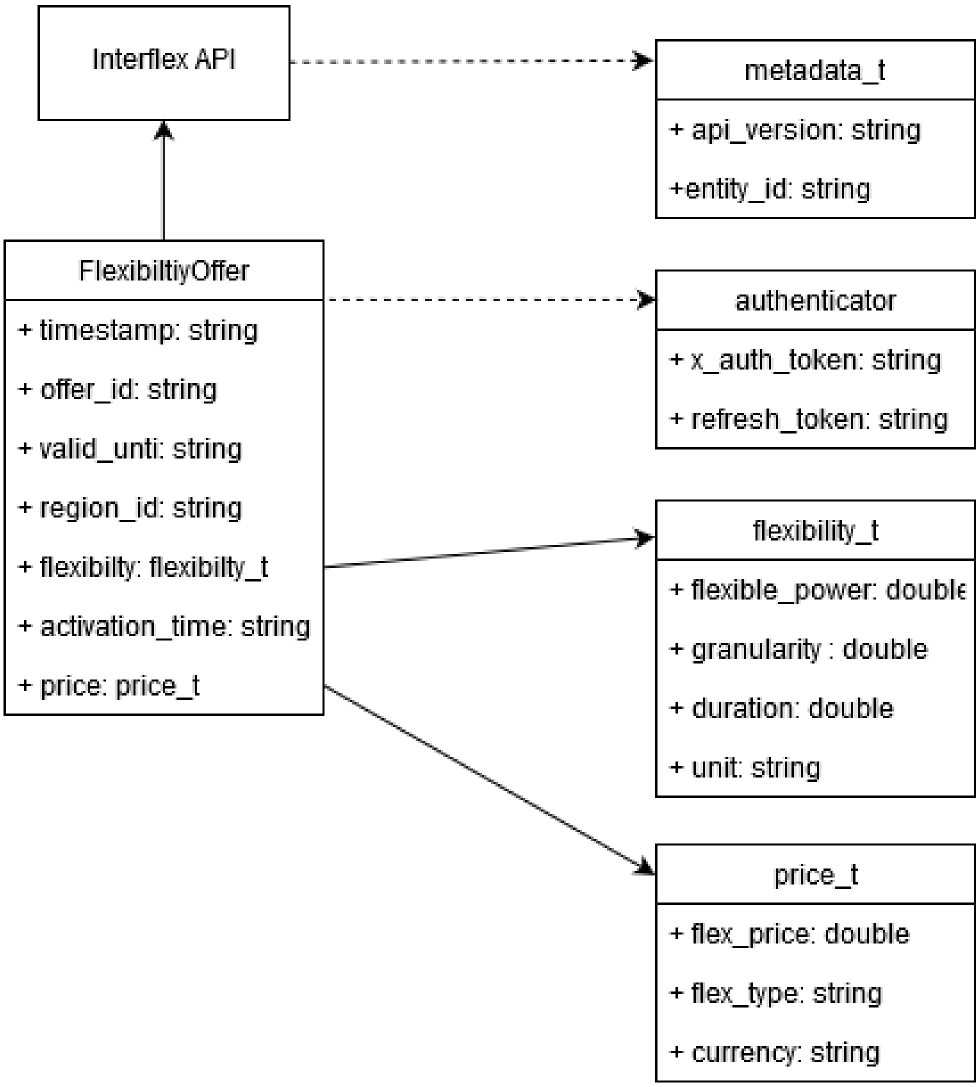


*Figure 4-8 FlexibilityOffer object*

*Table 7 Description of flexibility offer object*

| Object | Name | Type | Description |
|---|---|---|---|
| FlexibilityOffer | timestamp | string | Time when offer was created (in ISO 8601 CET) |
| | offer_id | string | Unique identifier for each offer object |
| | valid_until | string | Time when the offer expires (in ISO 8601 CET) |
| | region_id | string | An identifier for the affected grid segment |
| | flexibility | flexibility_t | Object containing information about the offered flexibility |
| | activation_time | string | |
| | price | price_t | Object containing pricing information related to the offer |
| flexibility_t | flexible_power | double | Amount of available flexibility (kW) |
| | granularity | double | Granularity in which flexibility can be activated (0 refers to continuous values) |
| | duration | string | Duration of flexibility action (h) |
| | unit | string | Unit of flexibility |
| price_t | flex_price | double | Price of the offered flexibility |
| | flex_type | string | Specifies which kind of flexibility is offered |
| | currency | string | Specifies the currency of the price |

### 4.4.4 Flexibility Request

FlexibilityRequests (cf. Figure 4-9) are intended for DSOs to request flexibility offers from the flexibly platform. Therefore, a DSO or a comparable stakeholder sends a FlexibilityRequest to the platform and the platform returns a list of all available offers. The offer_deadline and region_id attributes allow for a preselection of matching offers by the platform prior to forwarding suitable offers.

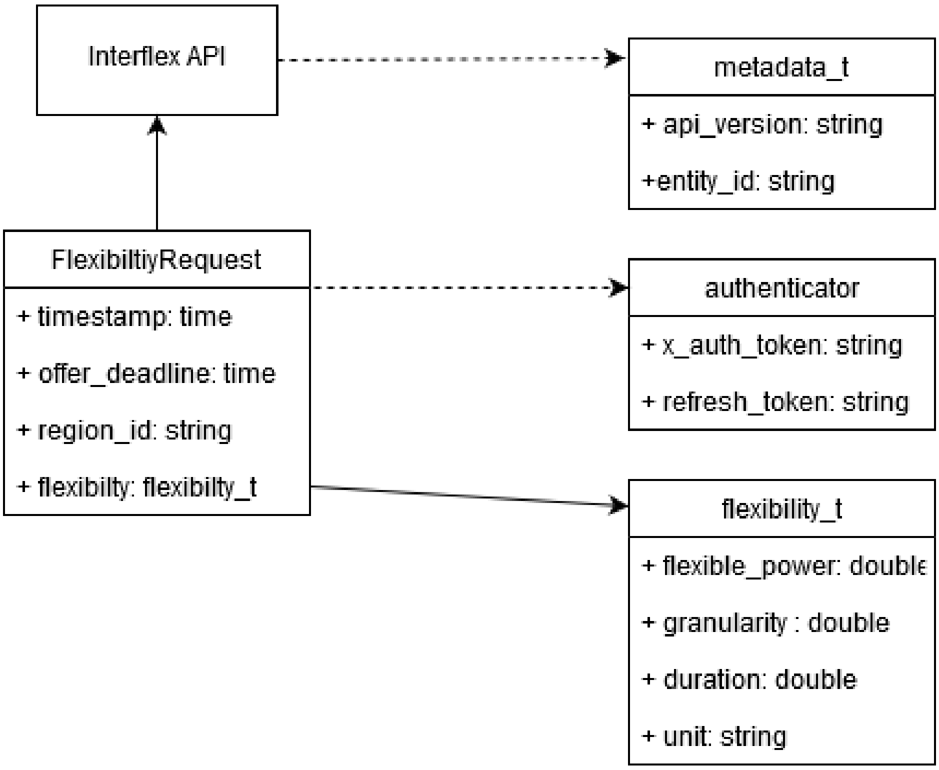


*Figure 4-9 Flexibility request object*

*Table 8 Description of flexibility request object*

| Object | Name | Type | Description |
|---|---|---|---|
| Metadata | metadata | metadata_t | Cf. Section 4.4.1 |
| Authenticator | authenticator | authenticator_t | Cf. Section 4.4.2 |
| FlexibilityRequest | timestamp | string | Time when flexibility was requested (in ISO 8601 CET) |
| | offer_deadline | string | Deadline until when flexibility need to be available (in ISO 8601 CET) |
| | region_id | string | Identifier for the affected grid segment |
| | flexibility | flexibility_t | |
| flexibility_t | flexibility | double | Amount of required flexibility |
| | ~~granularity~~ | double | - Not used in this case - |
| | duration | double | Duration flexibility is required (h) |
| | unit | string | Unit of flexibility |

### 4.4.5 Flexibility Activation Request

Having received the flexibility offers from the flexibility platform, the DSO can select one or many of the offers based on its internal business logic. Afterwards, the DSO creates a FlexibilityActivation (cf. Figure 4-10) object that represents its order and sends it to the flexibility platform.

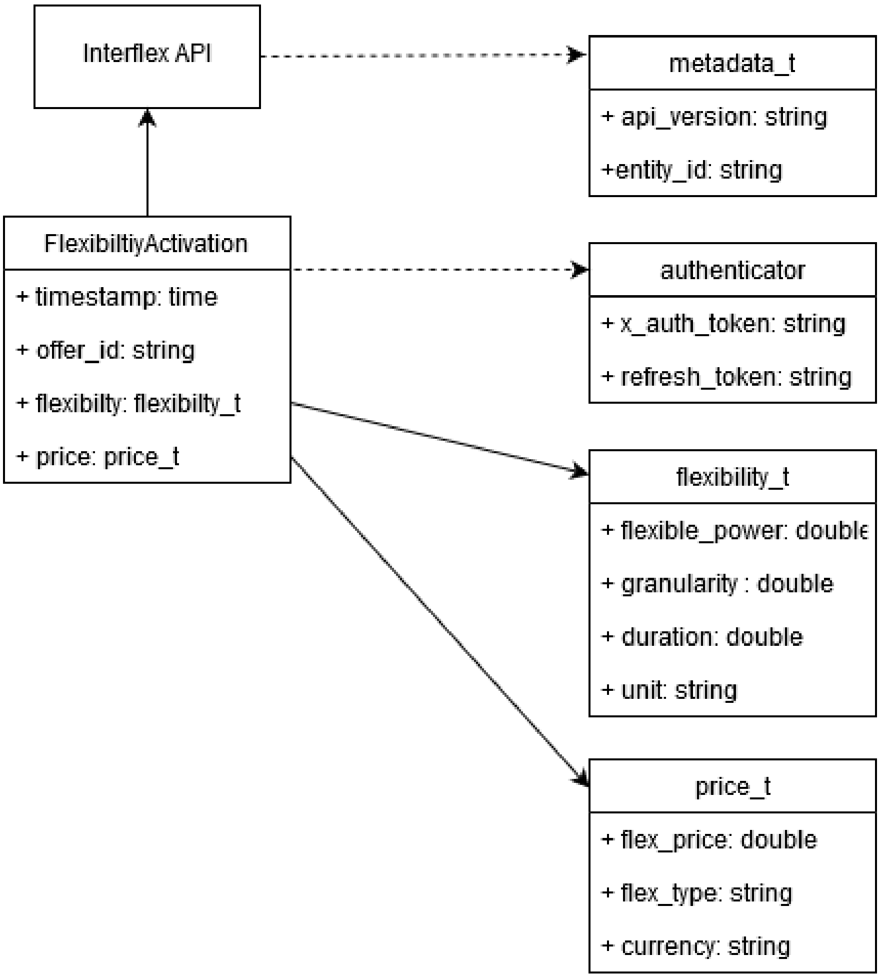


*Figure 4-10 Flexibility activation object*

*Table 9 Description of flexibility activation object*

| Object | Name | Type | Description |
|---|---|---|---|
| Metadata | metadata | metadata_t | Cf. Section 4.4.1 |
| Authenticator | authenticator | authenticator_t | Cf. Section 4.4.2 |
| FlexibilityActivation | timestamp | string | Time when activation was requested (in ISO 8601 CET) |
| | offer_id | string | Identifier of offer object this activation request refers to |
| | flexibility | flexibility_t | Amount of flexibility to be activated |
| | price | price_t | Pricing information |
| flexibility_t | flexibility | double | Amount of flexibility to be activated |
| | ~~granularity~~ | double | -Not used in this case- |
| | unit | string | Unit of flexibility |
| price_t | flex_price | double | Price of provided flexibility |
| | flex_type | string | Specifies which kind of flexibility is provided |
| | flex_price | double | Price of the provided flexibility |

### 4.4.6 Flexibility Activation Acknowledgment

Aggregators shall use flexibility Activation Acknowledgments (FlexibilityActivationACKs) in order to acknowledge the activation of flexibility according to the flexibility activation request. Figure 4-11 provides the according UML diagram.

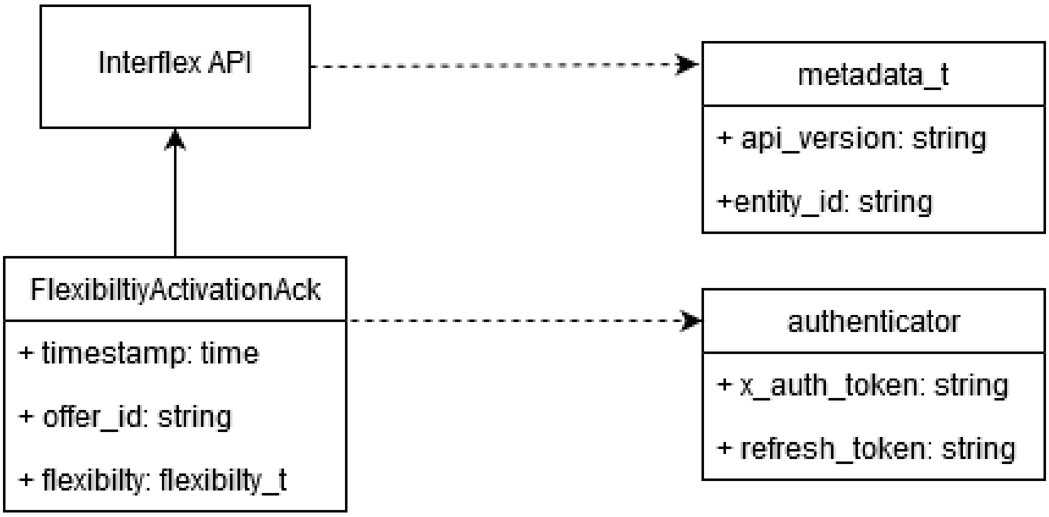


*Figure 4-11 Flexibility activation acknowledgment object*

*Table 10 Description of flexibility activation acknowledgment object*

| Object | Name | Type | Description |
|---|---|---|---|
| Metadata | metadata | metadata_t | Cf. Section 4.4.1 |
| Authenticator | authenticator | authenticator_t | Cf. Section 4.4.2 |
| FlexibilityActivationACK | timestamp | string | |
| | offer_id | string | |
| | flexibility | flexibility_t | |

### 4.4.7 Flexibility Activation Unacknowledgment

Aggregators can use flexibility Activation Unacknowledgments (FlexibilityActivationNACKs) to indicate that the activation of flexibility according to the flexibility activation request failed. Figure 4-12 provides the related UML diagram.

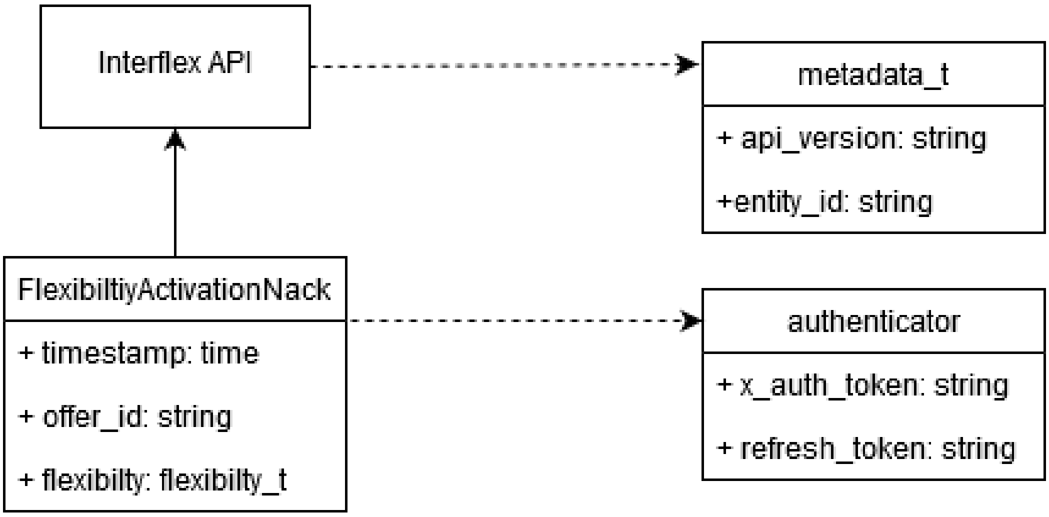


*Figure 4-12 Flexibility Activation Unacknowledgment*

*Table 11 Description of flexibility activation unacknowledgment*

| Object | Name | Type | Description |
|---|---|---|---|
| Metadata | metadata | metadata_t | Cf. Section 4.4.1 |
| Authenticator | authenticator | authenticator_t | Cf. Section 4.4.2 |
| FlexibilityActivationNACK | timestamp | string | |
| | offer_id | string | |
| | flexibility | flexibility_t | |

## 4.5 Summary

This chapter presents the formal specification of the InterFlex API and the data objects that are used to abstract flexibility, flexibility offers and flexibly request. In this first release of the specification, the InterFlex API mainly focuses on the flexibility negotiation between Aggregators and DSOs but is designed to be extendable for future use cases. The specification should be used as input for the development of a reference implementation and might be updated and extended during the implementation phase.

# 5 API INTERACTIONS

This chapter presents the interactions between different stakeholders of the InterFlex API by means of sequence charts. The first subsection provides a description of sequence charts and the representation chosen for this report. The second and third subsections illustrate possible interactions between a DSO and an aggregator during flexibility negotiation. We identified two different approaches of negotiation, a request-based and an offer-based approach. For each approach, a simplistic scenario involving a DSO and one aggregator is presented to show the necessary interactions. It shall be noted that the API itself is not limited to these approaches.

## 5.1 How to read sequence charts

Sequence charts can be used to illustrate interactions between different objects in a time sequence. Figure 5-1 shows a simplistic example of a sequence chart that represents the interaction between two entities called Entity A and Entity B. The vertical arrows represent timelines and the horizontal arrows represent interactions between them. In this example, Entity A sends a request to Entity B. Afterwards, entity B reacts on this request by performing a suitable action. Finally, Entity B sends a response back to Entity A.

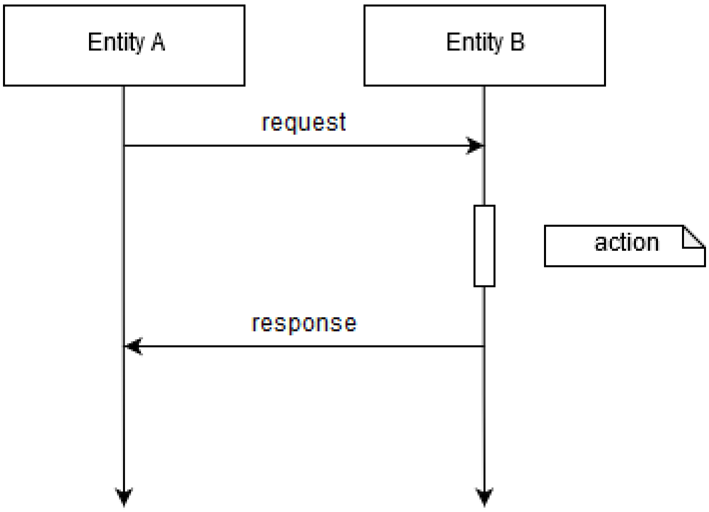


*Figure 5-1 Exemplary Sequence Chart*

Throughout this chapter, sequence diagrams of this kind are used to illustrate the interactions of DSOs and Aggregators with the flexibility platform via the InterFlex API. The interactions are labeled with the data objects that are exchanged during that interaction according to the specification in Chapter 4. It should be noted that all system and platform initialization steps are neglected in the sequence charts for the sake of simplicity. The same holds for proprietary connections between an aggregator and its flexibilities.

## 5.2 Request-based flexibility negotiation between DSO and aggregator

In the request-based flexibility negotiation approach, the DSO initiates the negotiation by posting a flexibility request to the flexibility platform. The platform forwards the request to all aggregators and returns a collection of all flexibility offers to the DSO.

**Erreur ! Source du renvoi introuvable.** depicts all interactions during the request-based flexibility negotiation approach using an exemplary scenario with one DSO and one aggregator. The scenario can be extended by adding further aggregators to the flexibility platform.

In the request-based flexibility negotiation approach, DSOs trigger the negotiation by posting a flexibility request to the flexibility platform. The platform stores the request and forwards it to all connected aggregators. Upon reception of a flexibility request, the aggregators evaluate the available flexibility assets and submit a flexibility offer to the flexibility platform. The flexibility platform collects all flexibility offers and finally returns a list of all flexibility offers to the DSO.

Based on its internal business logic, the DSO selects one of the received flexibility offers and posts a flexibility activation request to the flexibility platform. The platform does not limit the DSO to selecting one offer; it is also feasible to post several flexibility activation requests in order to obtain an even larger flexibility.

The flexibility platform forwards the flexibility activation requests to the aggregator(s). Based on the flexibility request, the aggregator(s) can send individual control commands to the affected flexibilities. Once the flexibility is active, an acknowledgment message is send to the DSO via the flexibility platform.

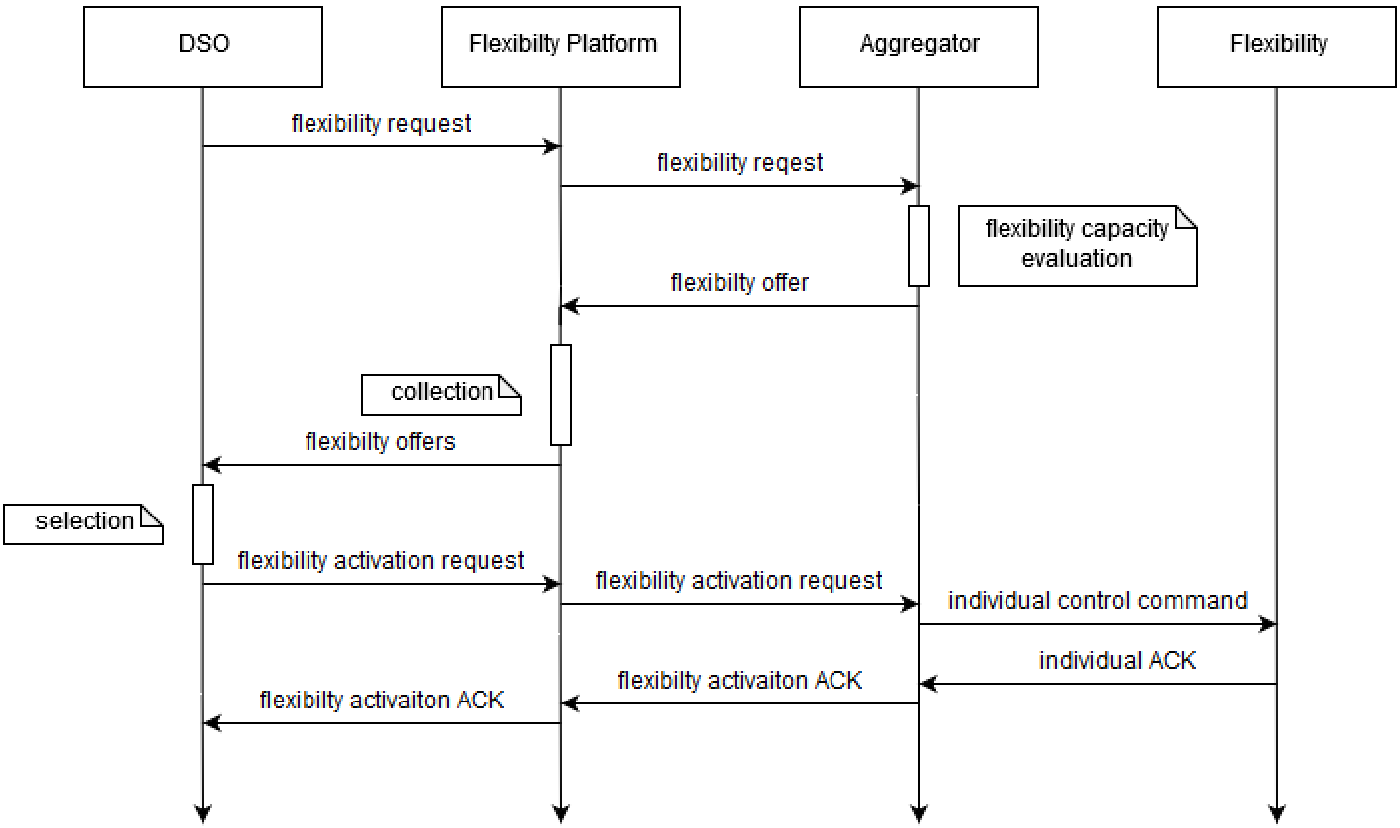


*Figure 5-2 Request-based flexibility negotiation between DSO and aggregator*

## 5.3 Offer-based flexibility negotiation between DSO and aggregator

As an alternative to request-based flexibility negotiation, it might also be feasible to implement an offer-based flexibility negotiation approach. In the offer-based flexibility negotiation approach, aggregators can autonomously post flexibility offers to the flexibility platform and continuously update their bid. The platform provides a collection of the latest flexibility offers on demand of the DSO.

Figure 5-3**Erreur ! Source du renvoi introuvable.** depicts all interactions that are involved when the offer-based flexibility negotiation approach is implemented. The same principle applies when multiple

Aggregators are connected to the platform but for simplification, only one Aggregator is included in this example.

Firstly, the Aggregator has to post a flexibilitly offer to the Flexibility Platform. This can be typically done once after connecting to the platform and can be updated each time the available flexibly changes. The flexibility platform stores the offer internally by means of the internal database service. Afterwards, the DSO posts a flexibility request to the flexibility platform. Upon this request, the platform collects all available and valid flexibility offers from its internal database and returns this collection to the DSO.

The DSO can select one or several of these offers based on its internal business logic. It should be noted that it can be also reasonable to combine several offers in order to fulfill the current flexibility needs. After making this decision, the DSO sends one (or multiple) flexibility activation request to the flexibility platform. The flexibility platform receives the flexibility activation requests and forwards them to the Aggregator that made the offer.

Based on the flexibility activation request, the Aggregator selects its flexibility assets and sends control commands to the flexibilities in order to fulfil the flexibility need of the DSOs. It should be noted that the Aggregator can use any standard protocol or even a propriety interface to connect to the flexibilities as long as the Aggregator is able to map the InterFlex flexibility activation request to suitable control commands.

As soon as the Aggregator receives an acknowledgment from the flexibility a flexibility activation ACK can be send back to the Flexibility Platform, respectively the DSO, via the InterFlex API. If the flexibility aggregation fails, a flexibility activation NACK is returned instead.

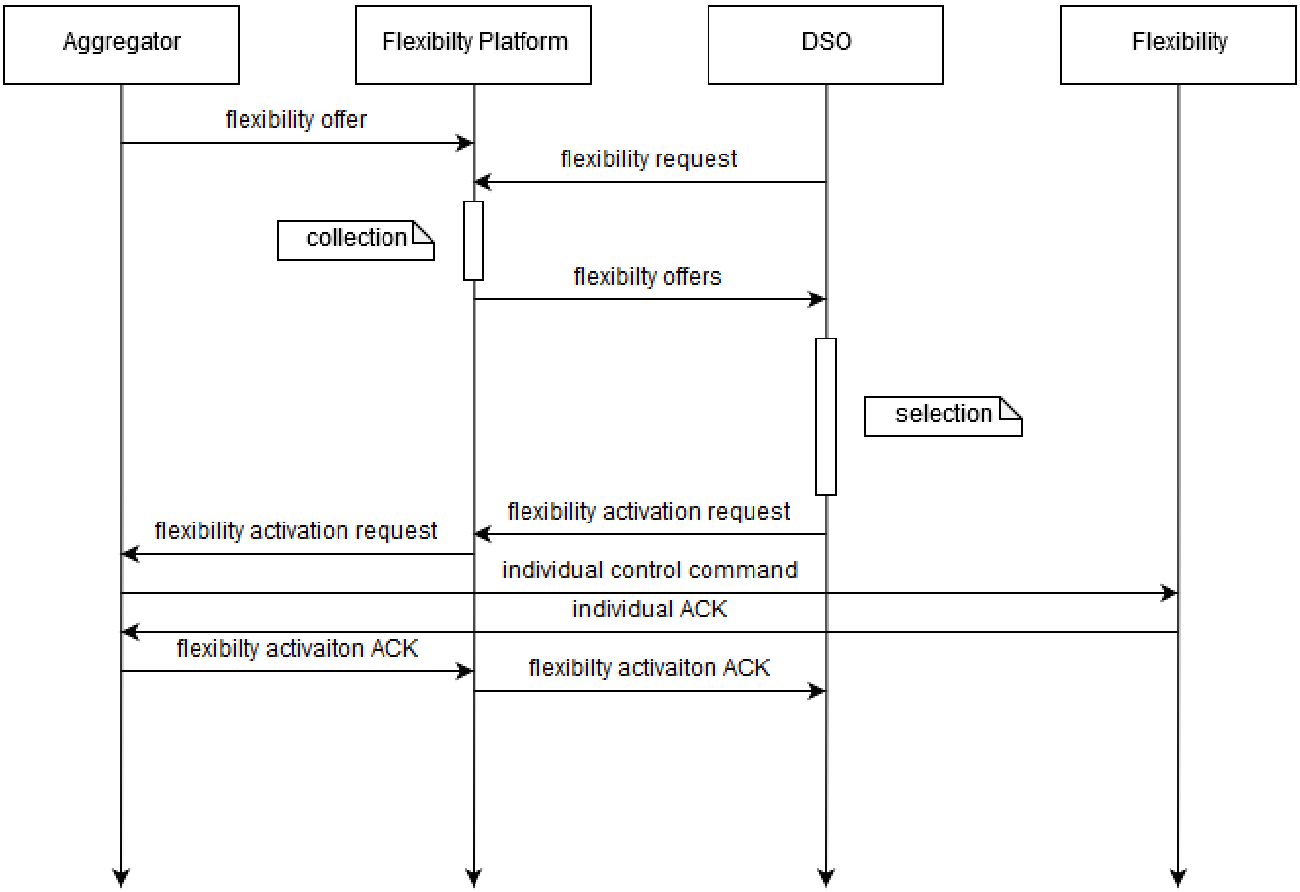


*Figure 5-3 Offer-based flexibility negotiation between DSO and aggregator*

## 5.4 Summary

This chapter provides on overview of the possible and necessary interactions between the stakeholders of the InterFlex API. We identified two different negotiation patterns for flexibility activation. In the request-based approach, aggregates respond a flexibility offer to a flexibly request of the DSO. In the offer-based approach, aggregators individually post their current offer to the platform and the DSO receives the latest collection of offers on demand. In both approaches, the flexibility platform serves as a broker for flexibility offers and flexibility activation requests. The platform is designed to be scalable and allows one DSO to connect to multiple aggregators simultaneously. The platform allows the DSO to select the flexibility offers based on its own internal business logic or even to combine the offers of multiple aggregators if the DSO requires more flexibility that a single aggregator can offer.

# 6 CONCLUSIONS

Presented document gives a brief overview of the state of the art of existing protocols and their usage throughout the InterFlex demos. It outlines the need of interoperable APIs to close the so-called interoperability gap. Therefore a cloud-based flexibility platform is proposed that offers two interfaces connecting the upper and the lower layer of the platform with stakeholders such as DSO and flexibility aggregator. Furthermore, the platform can serve as a minimal flex market place during flexibility negotiation. Alternatively, other flexibility market services could be integrated as external services to the flexibility platform.

The first version of the formal InterFlex API specification (this document) is mainly based on InterFlex demos that include an aggregator on the link between DSO and flexibility assets. The API was designed with a special focus on supporting the relation of one DSO to multiple aggregator simultaneously.

The document describes the formal specification of the InterFlex API and the data objects that are used to abstract flexibility, flexibility offers and flexibly request and lays the foundation for the upcoming deliverable that will present the open reference implementation of the specified API. As an input for that, Chapter 5 provides sequence charts of possible interactions between the DSO and related aggregators.

In the scope of this work different flexibility negotiation patterns have been identified, namely offer-based and request-based flexibility negotiation. The latter is realized by storing flexibility offers in an integrated data base service and forwarding all available offers to a DSO on-demand. While reducing the communication overhead between different stakeholders. Furthermore, the InterFlex API is filling the gap of cross carrier support that is not included in other standardized interfaces yet.

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# A. APPENDIX – ADDITIONAL API FUNCTIONALITIES

## Appendix 1. InterFlex demo SGAMs – Communication layers

### German demo

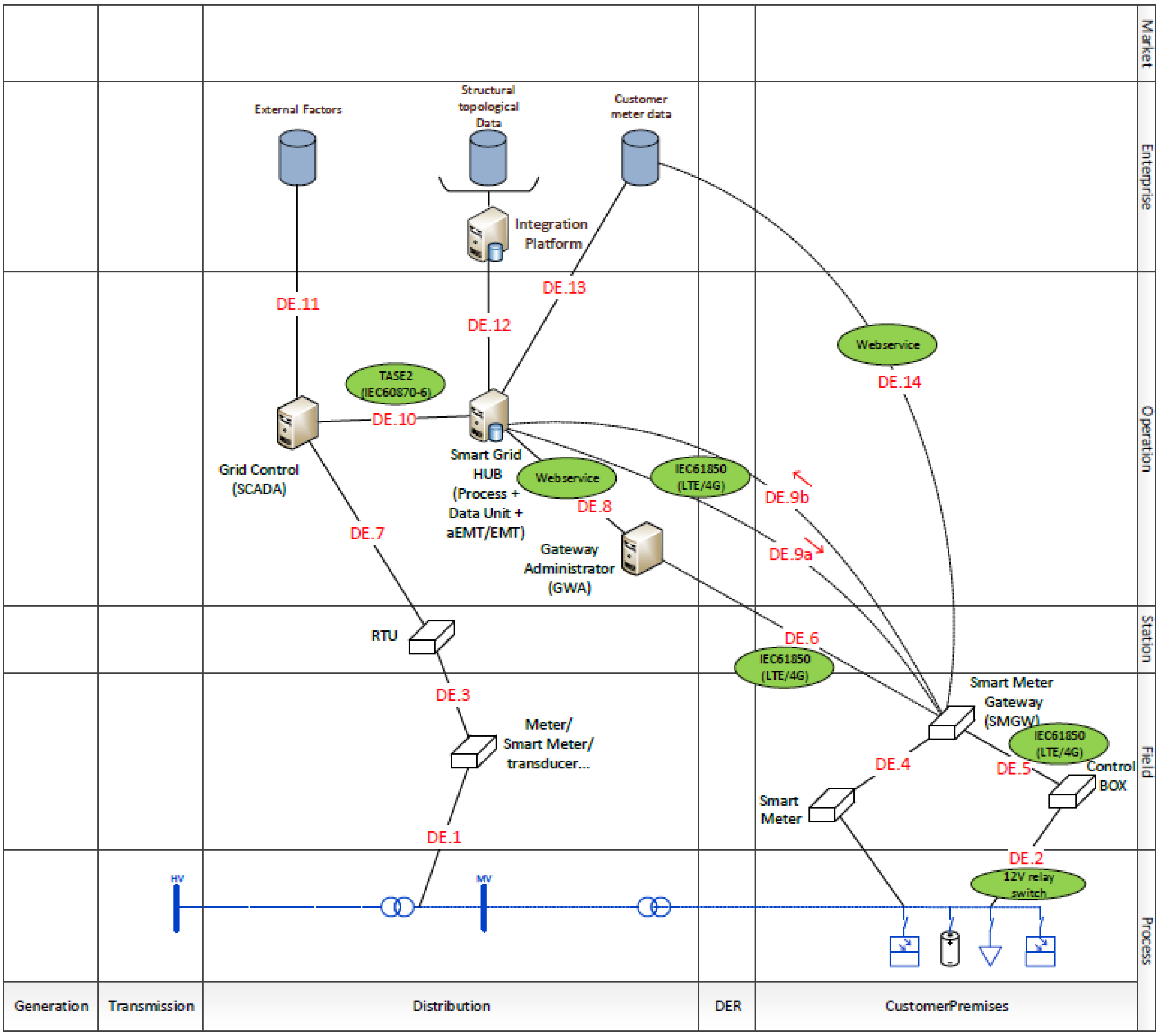


*Figure 0-1 Communication layer of German demo SGAM – All Use Cases*

## Swedish demo

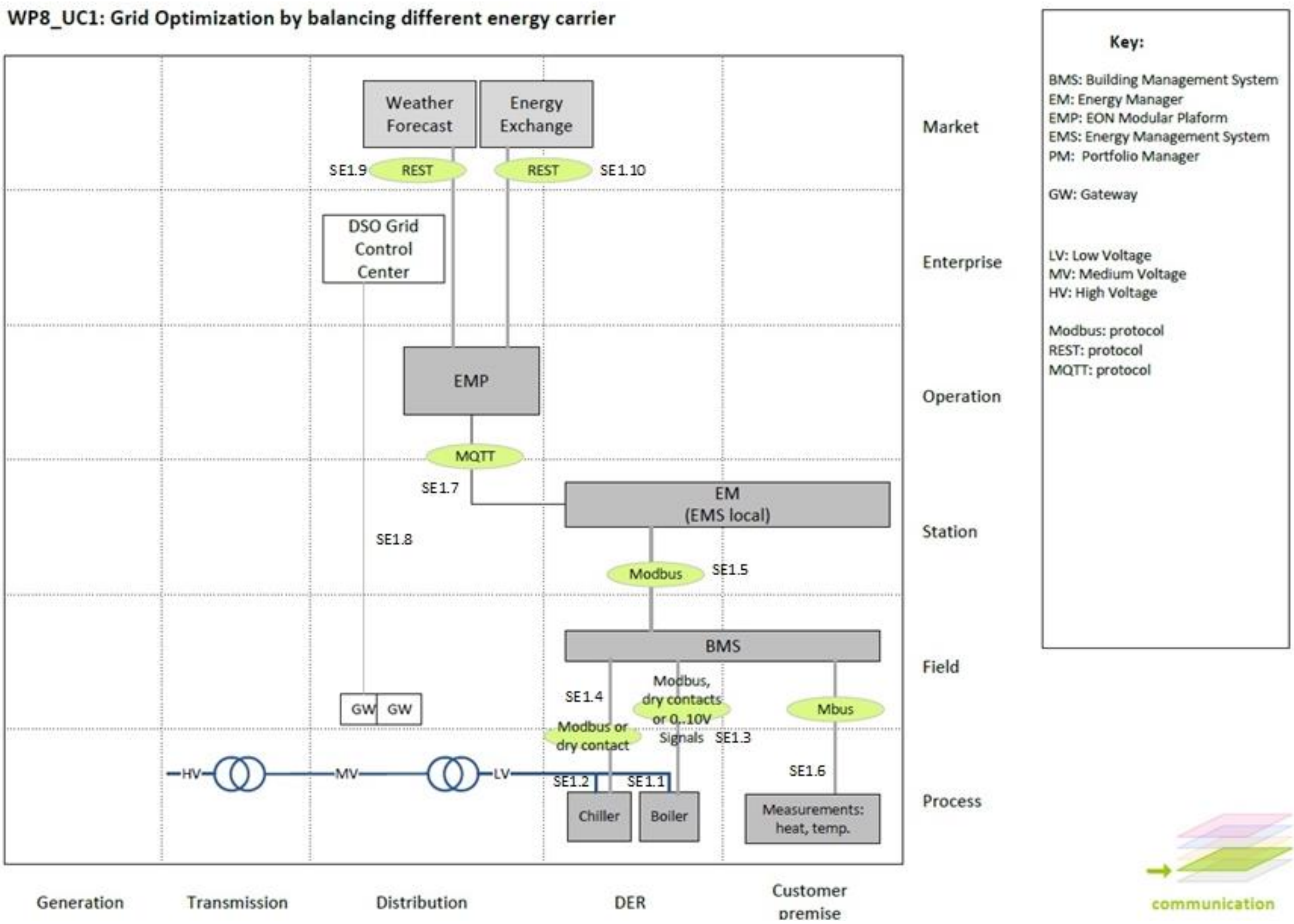


*Figure 0-2 Communication layer of Swedish demo SGAM – Use Case #1*

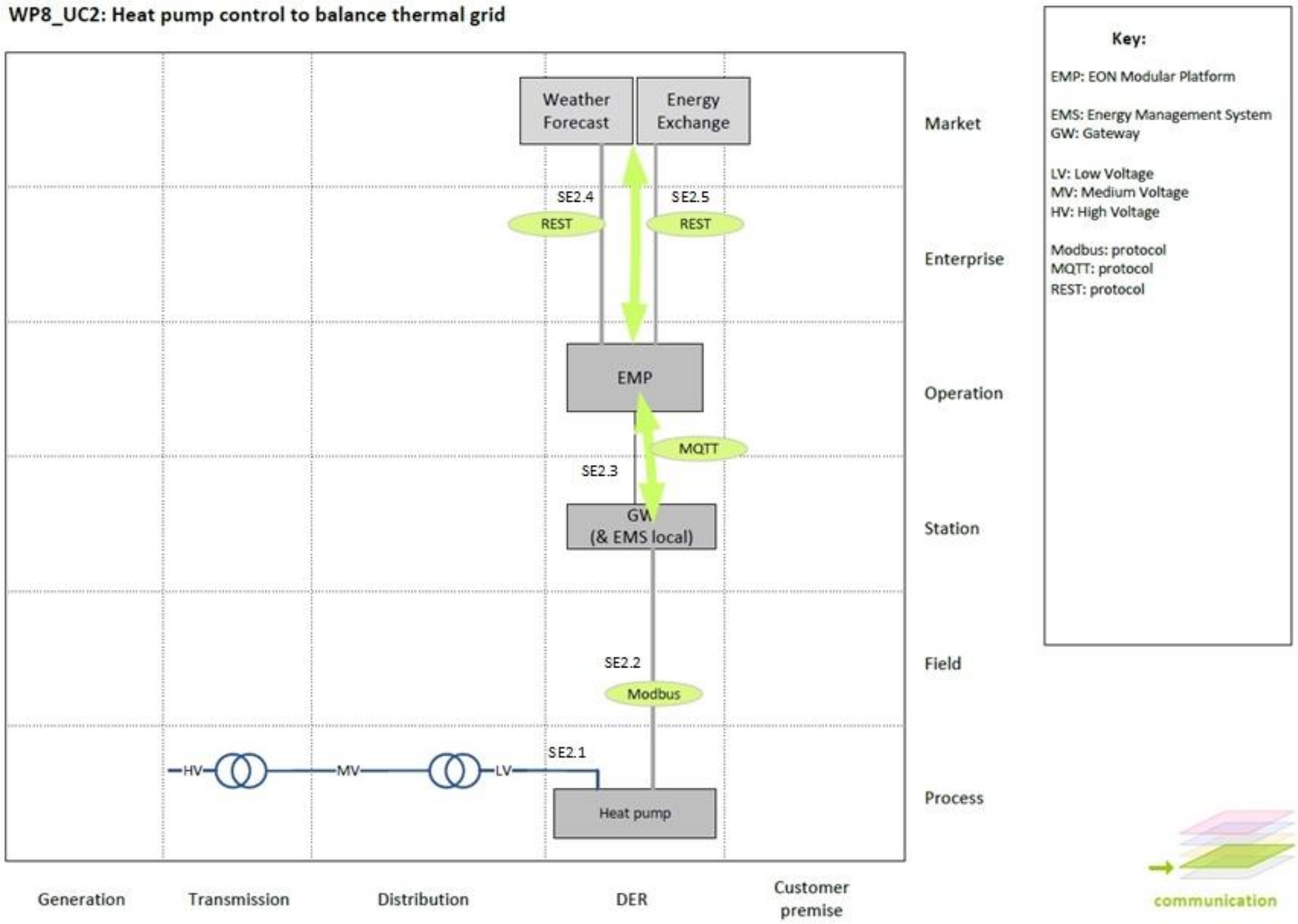


*Figure 0-3 Communication layer of Swedish demo SGAM – Use Case #2*

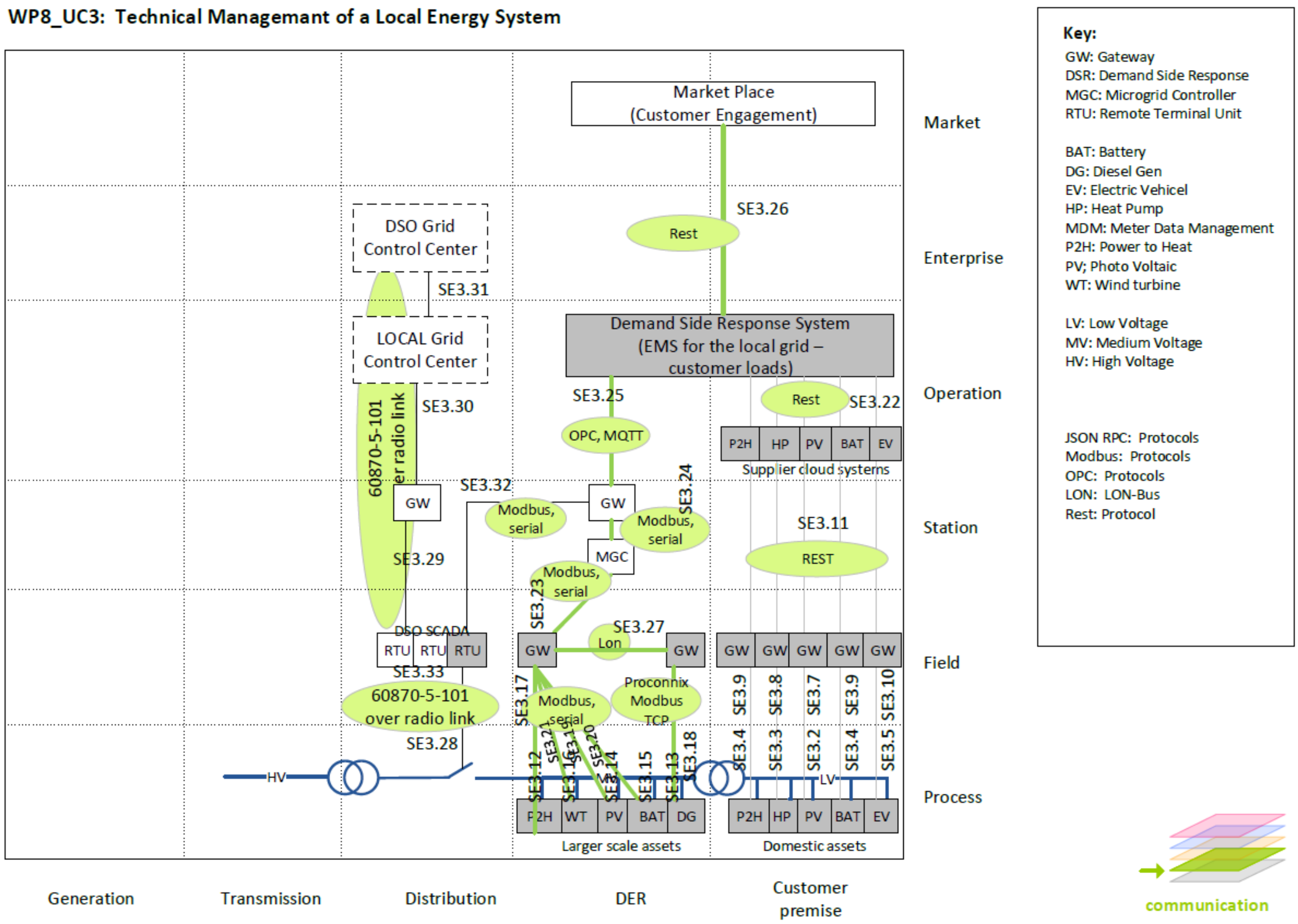


*Figure 0-4 Communication layer of Swedish demo SGAM – Use Case #3*

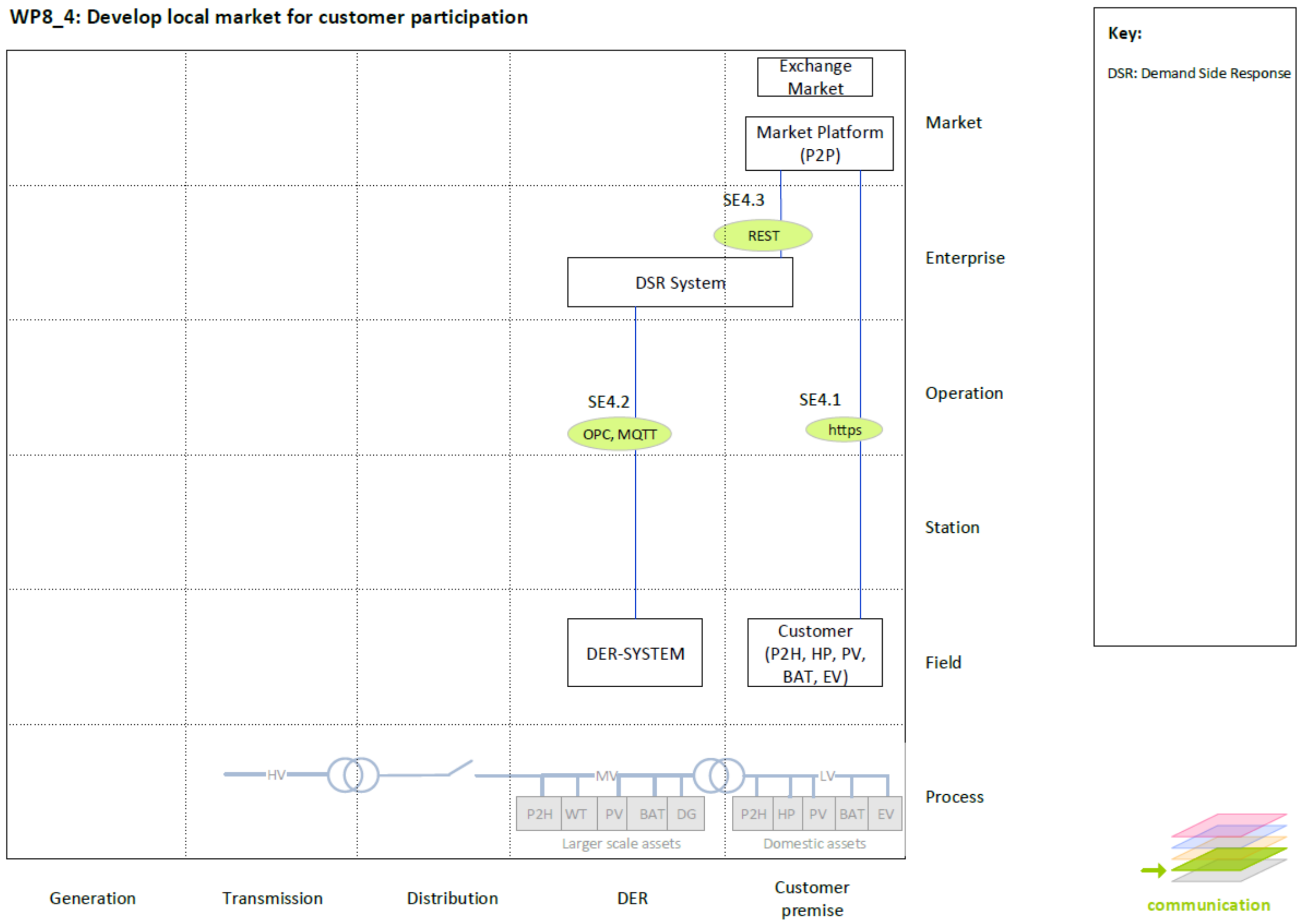


*Figure 0-5 Communication layer of Swedish demo SGAM - Use Case #4*

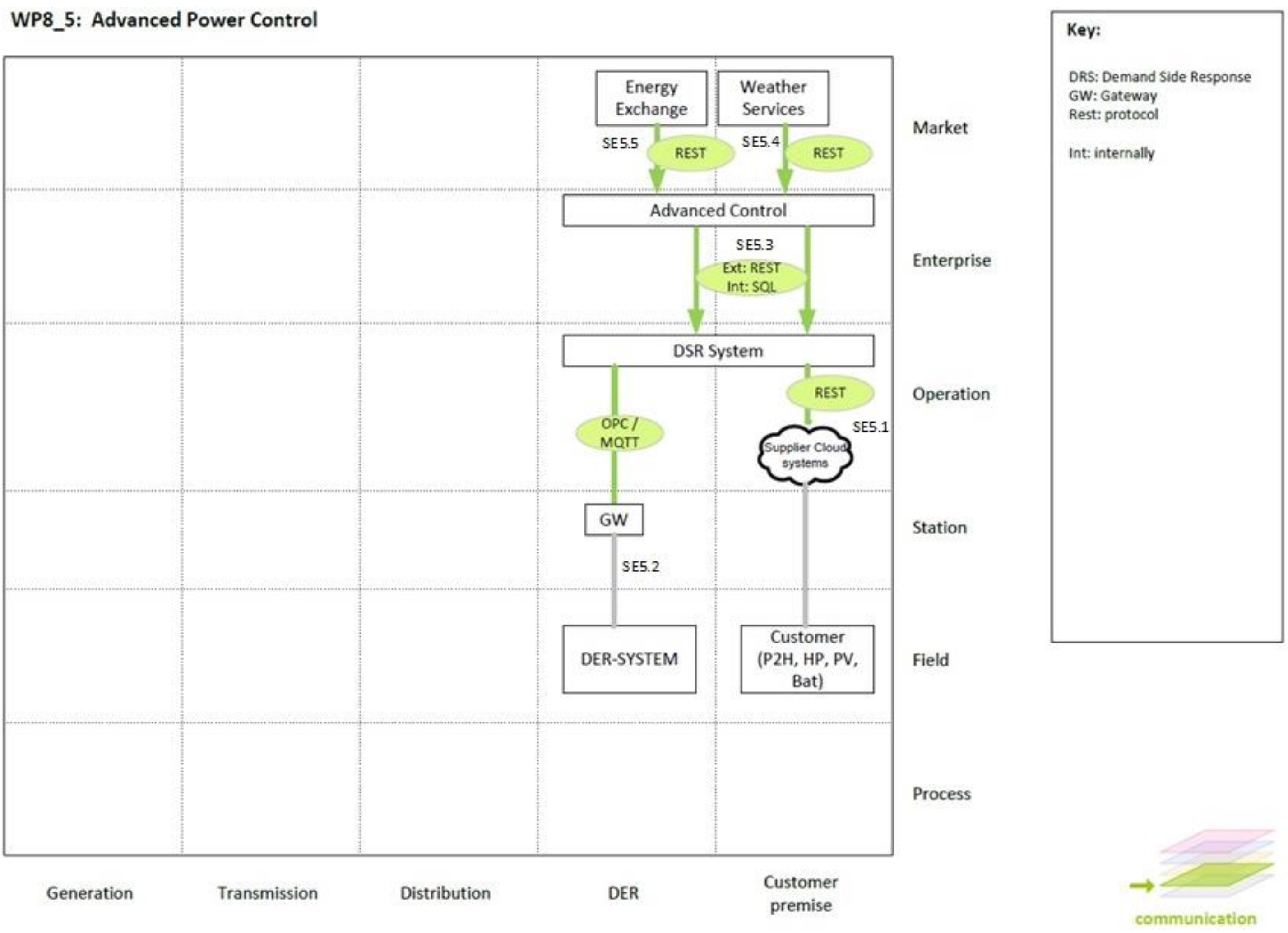


*Figure 0-6 Communication layer of Swedish demo SGAM – Use Case #5*

## Czech demo

**WP6 Use-Case #1a**

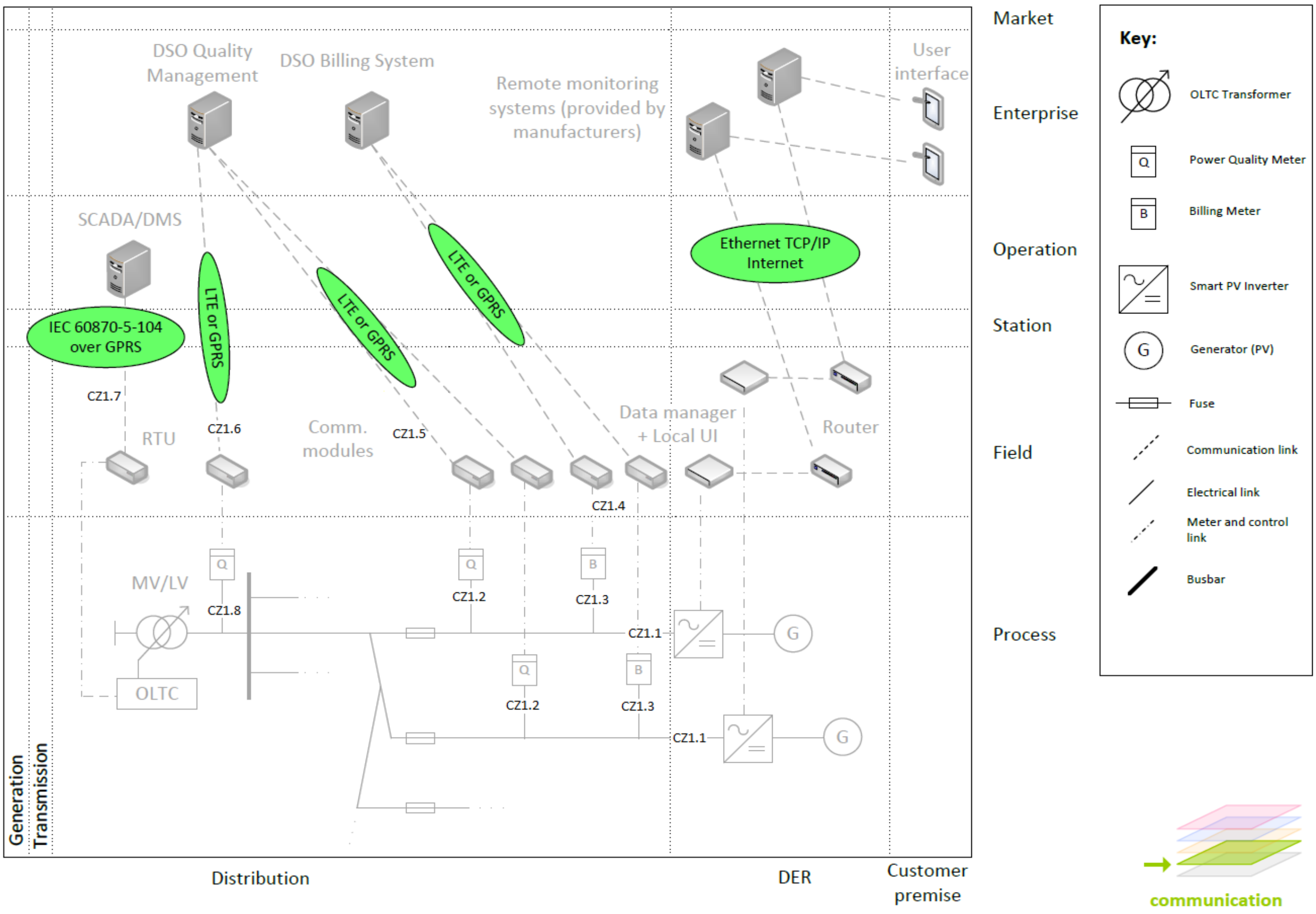


*Figure 0-7 Communication layer of Czech demo SGAM - Use Case #1a*

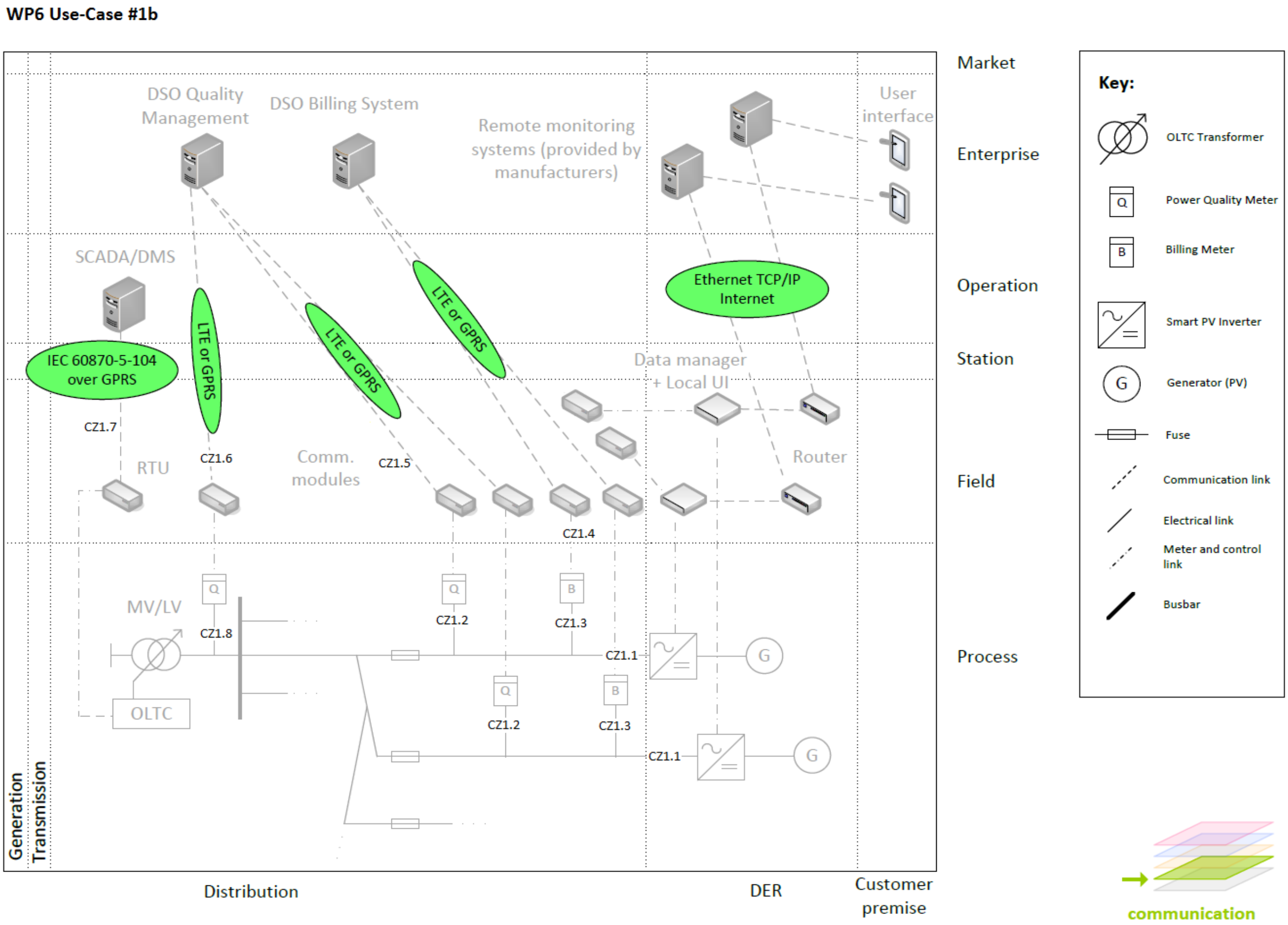


*Figure 0-8 Communication layer of Czech demo SGAM – Use Case #1b*

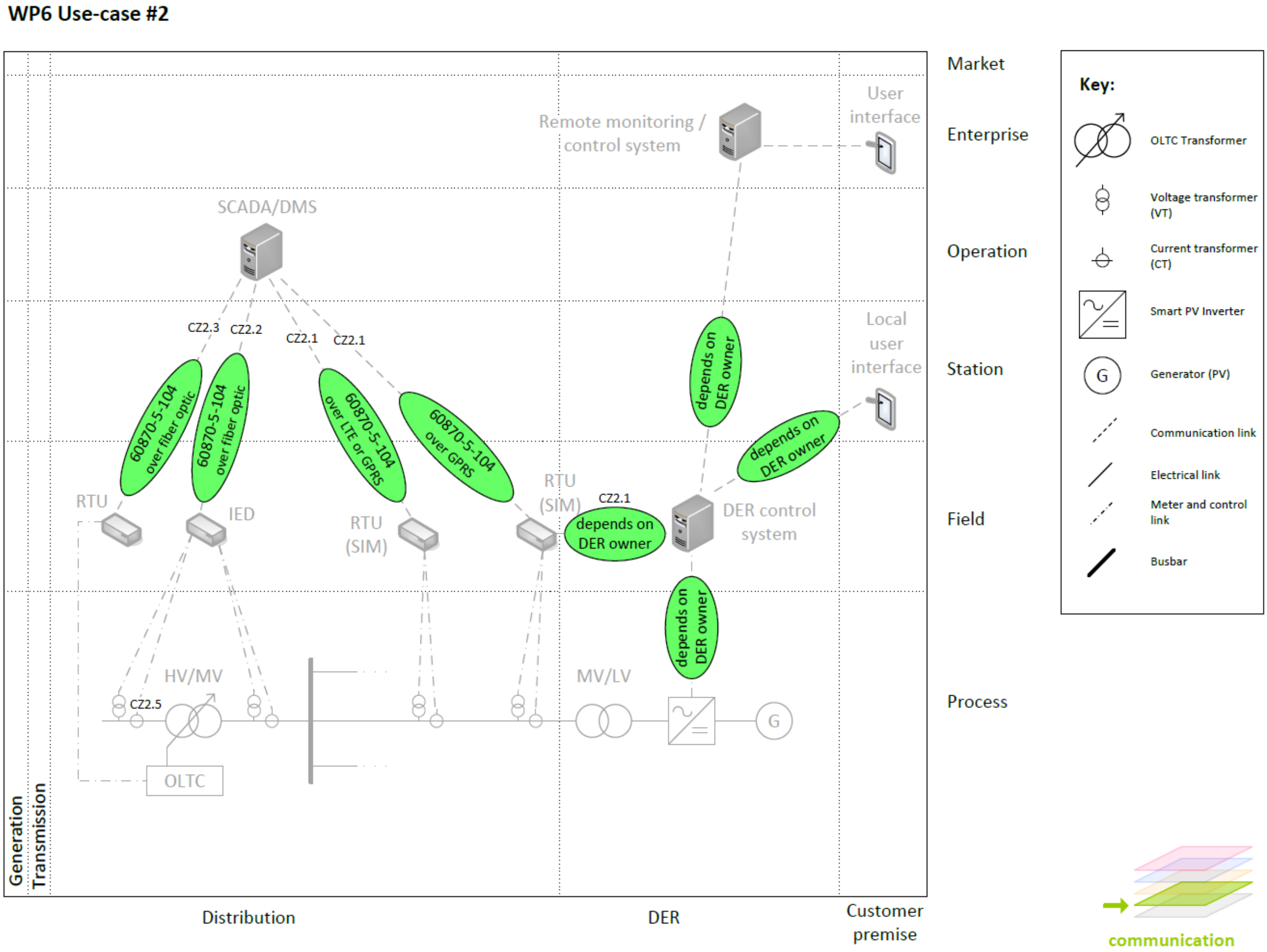


*Figure 0-9 Communication layer of Czech demo SGAM - Use Case #2*

**WP6 Use-case #3a**

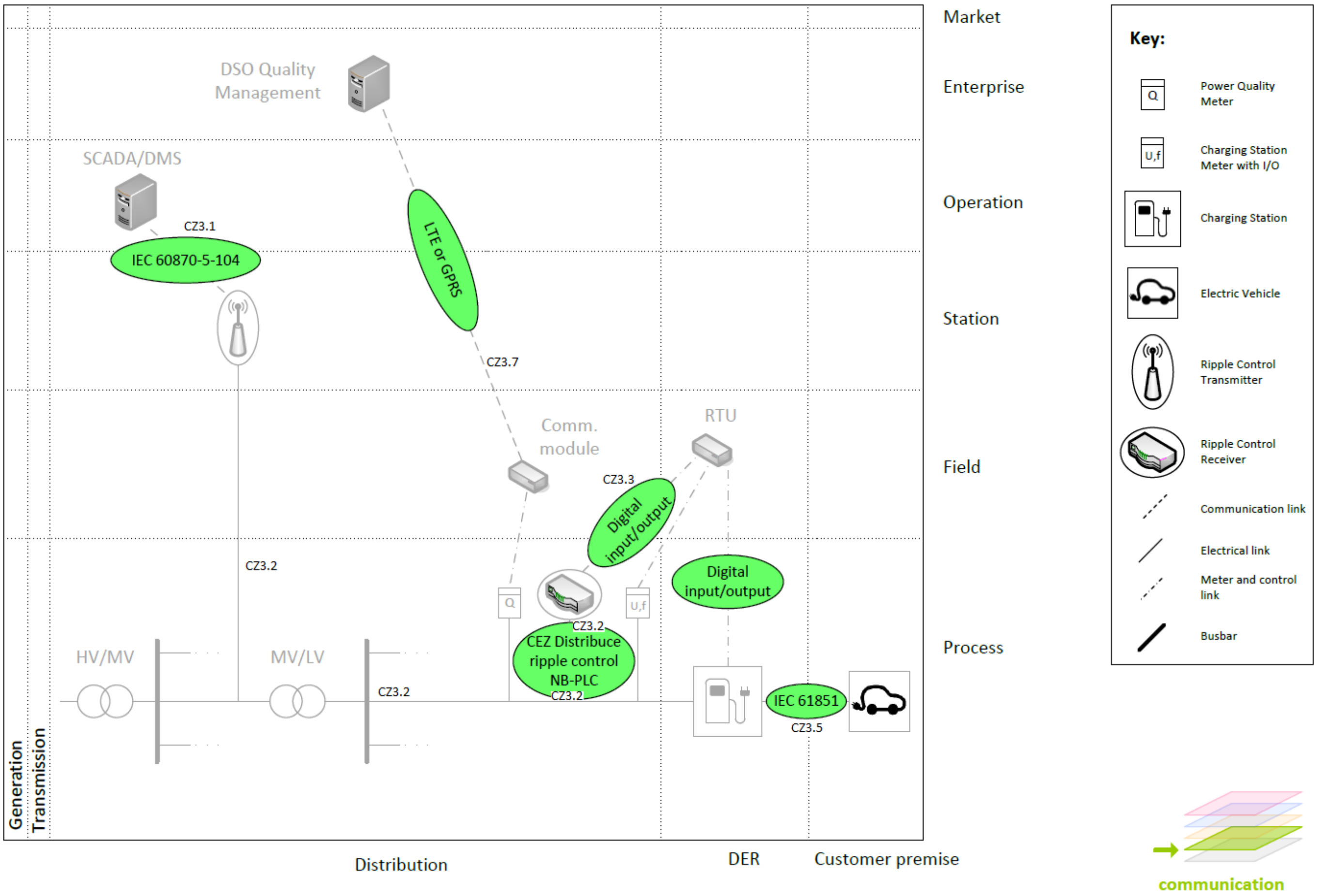


*Figure 0-10 Communication layer of Czech demo SGAM – Use Case #3a*

**WP6 Use-case #3b**

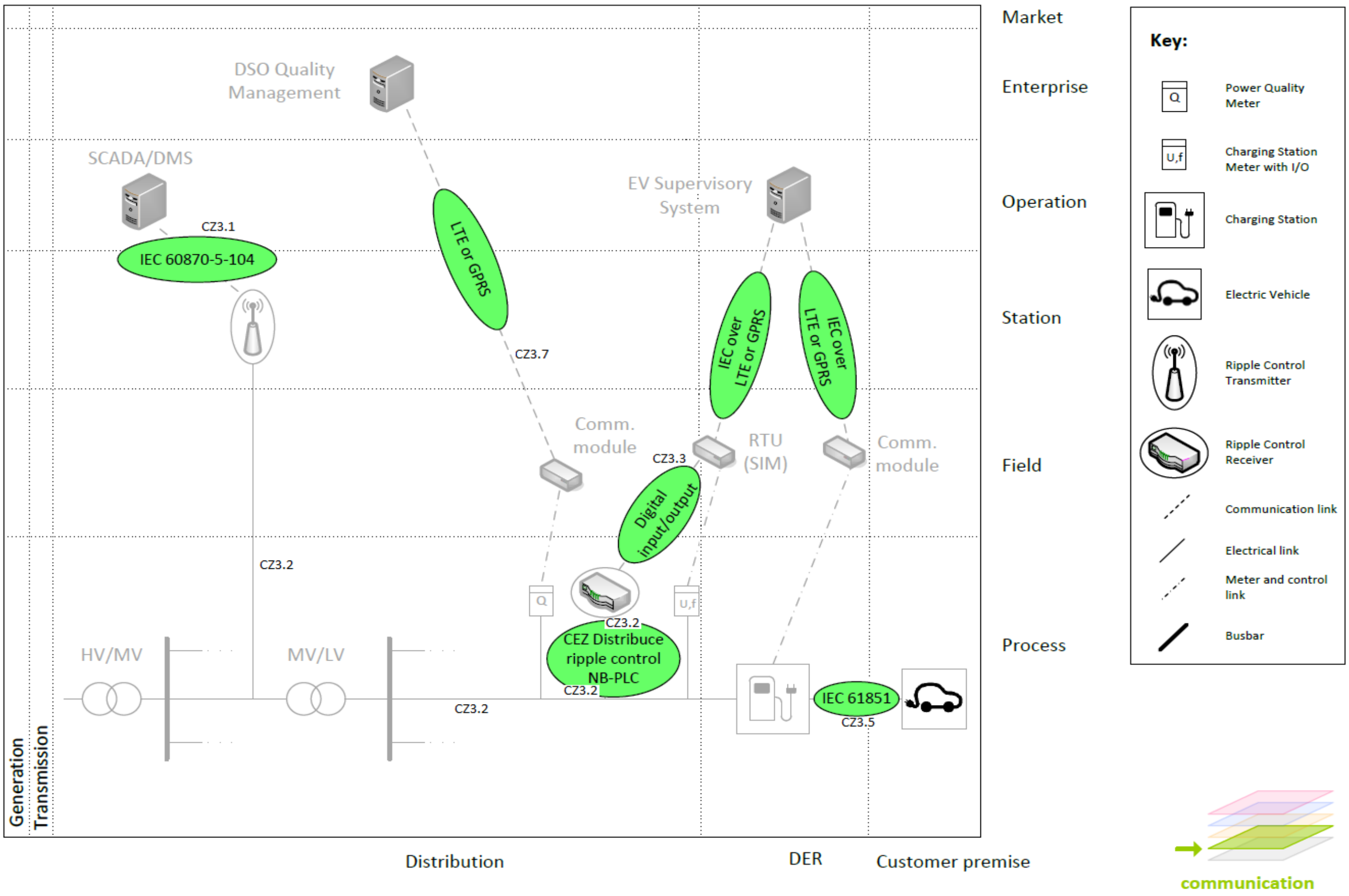


*Figure 0-11 Communication layer of Czech demo SGAM - Use Case #3b*

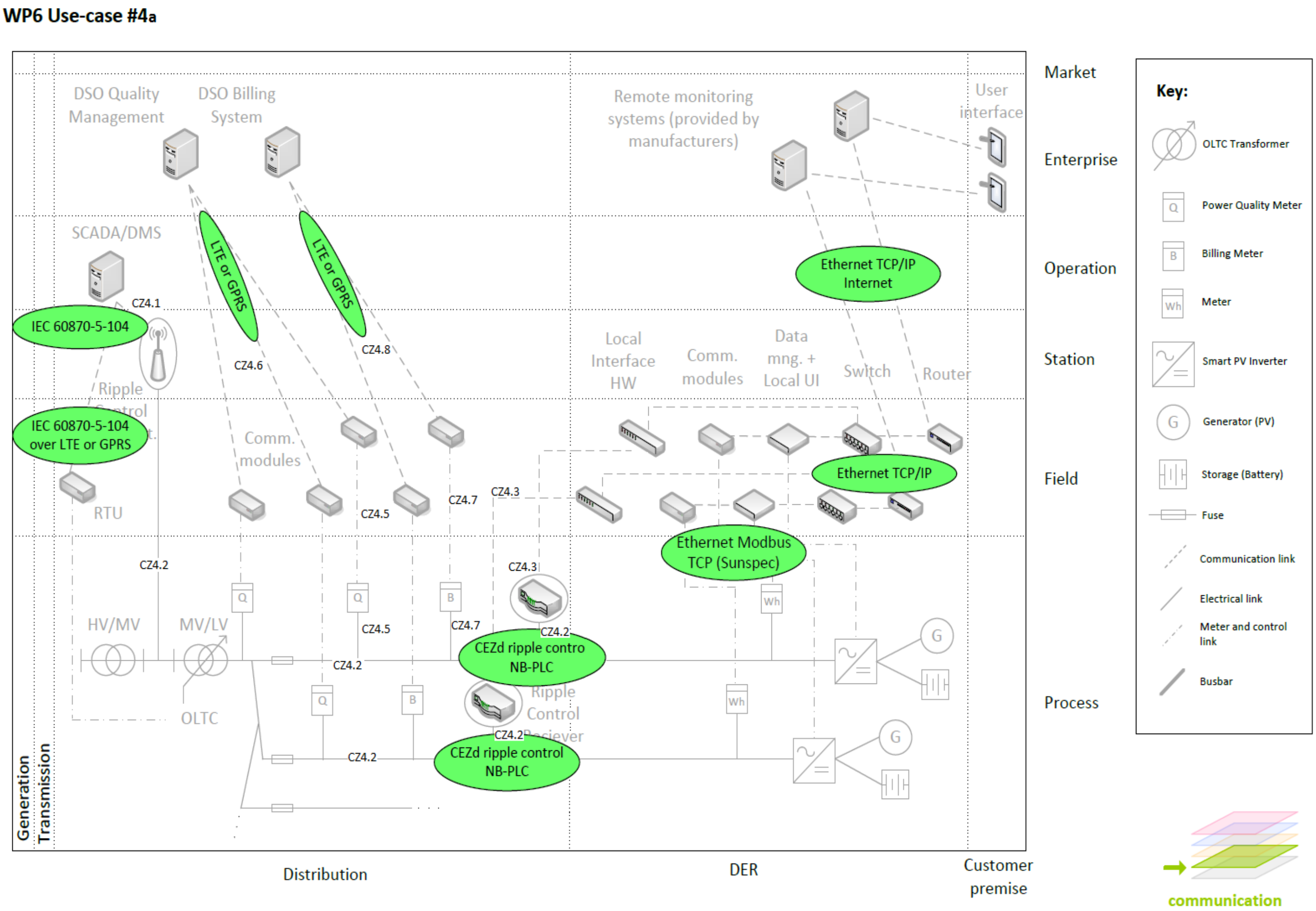


*Figure 0-12 Communication layer of Czech demo SGAM - Use Case #4a*

**WP6 Use-case #4b (Schneider)**

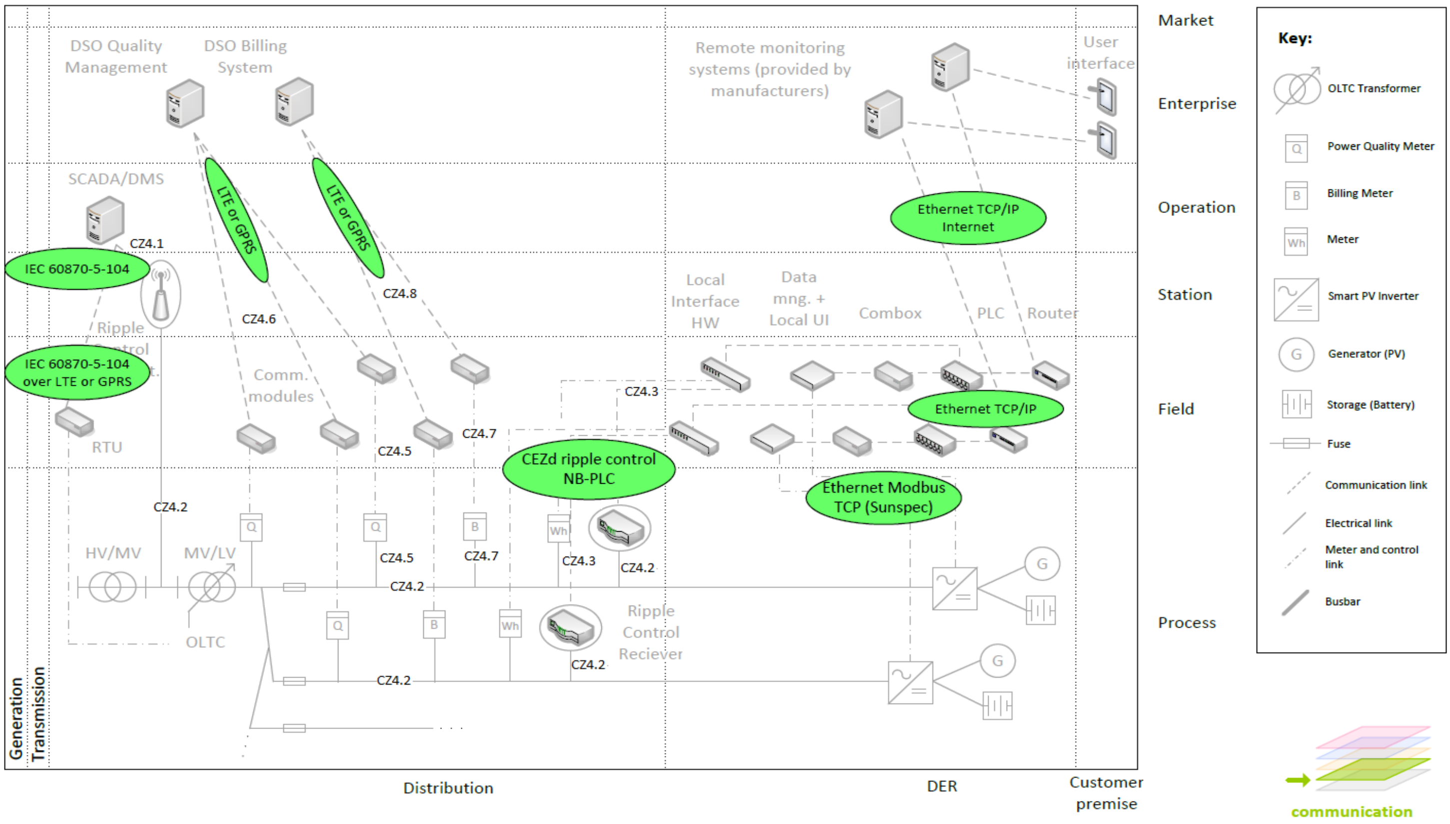


*Figure 0-13 Communication layer of Czech demo SGAM - Use Case #4b*

## Dutch demo

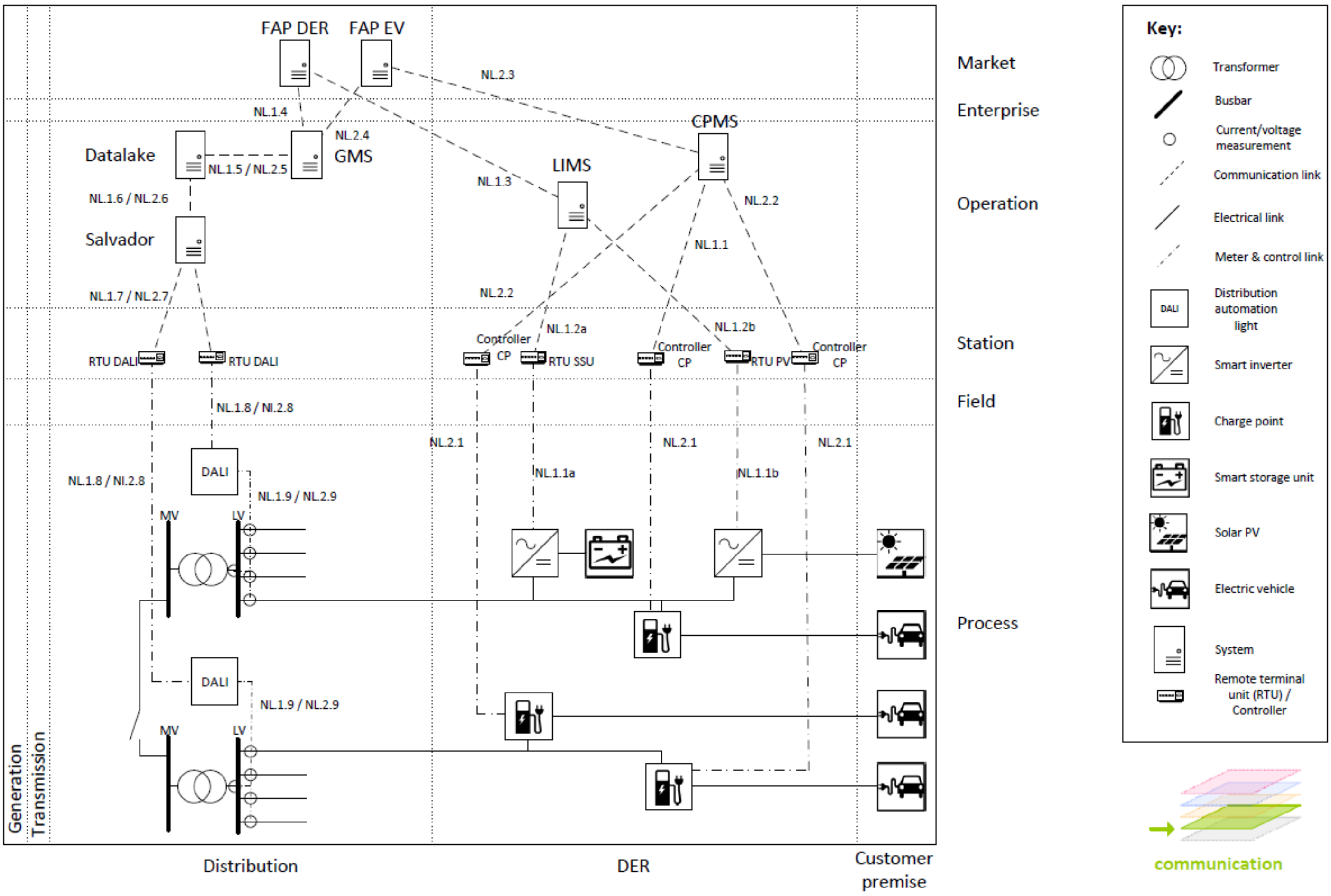


*Figure 0-14 Communication layer of Dutch demo SGAM – All Use Cases*

## French demo

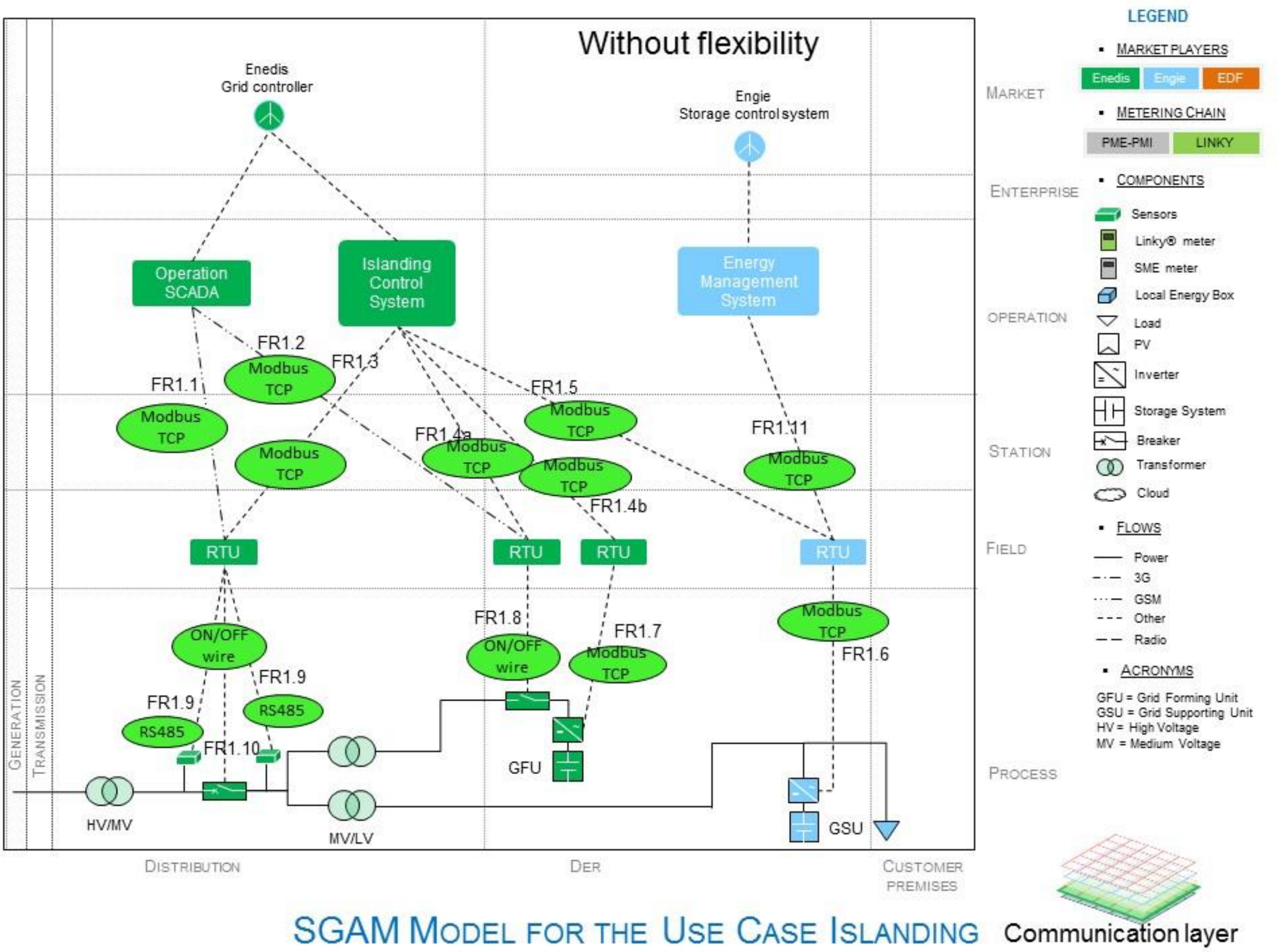


*Figure 0-15 Communication layer of French demo SGAM – Use Cases #1 (without felxibilty)*

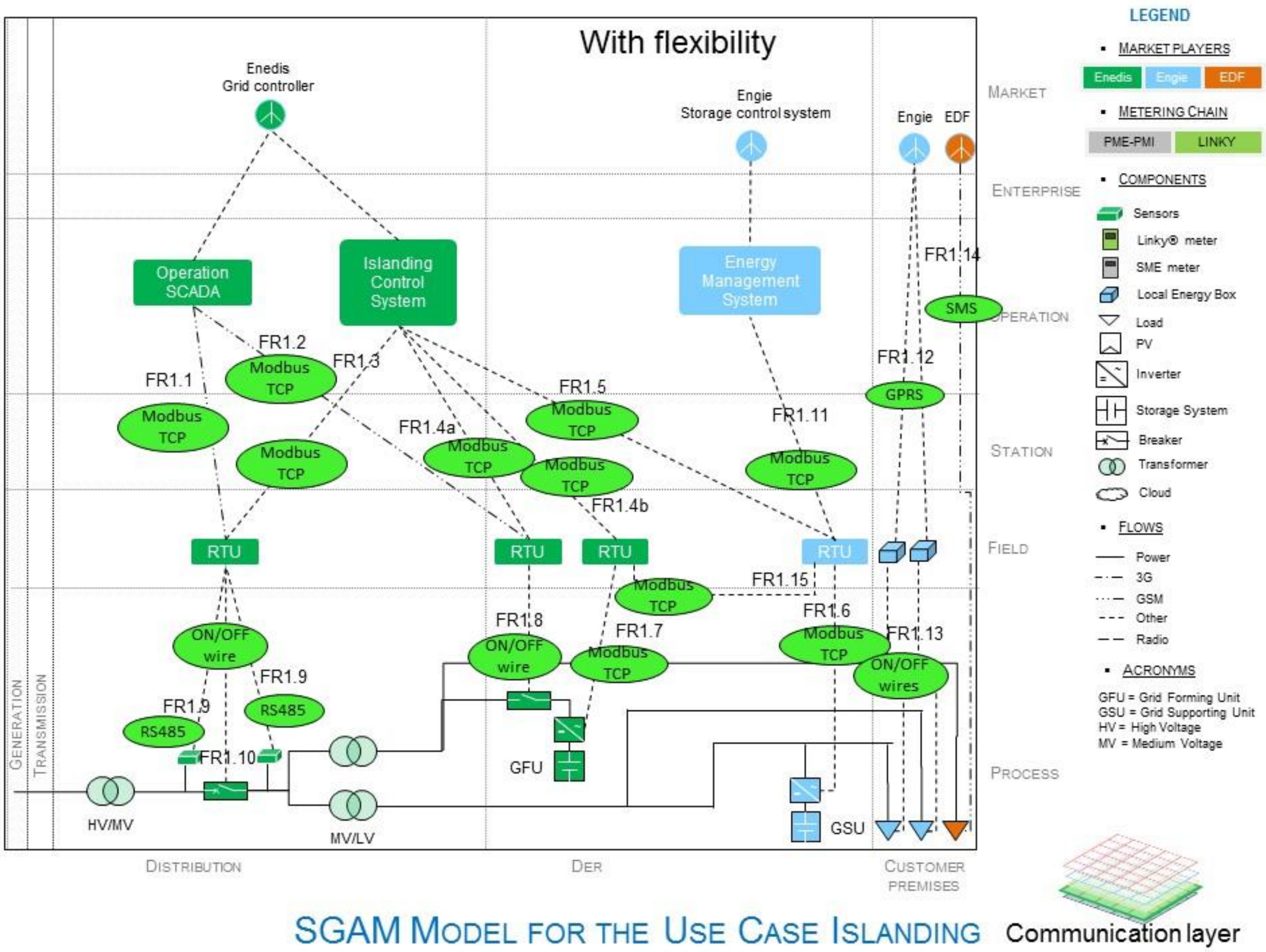


*Figure 0-16 Communication layer of French demo SGAM – Use Cases #1 (with felxibilty)*

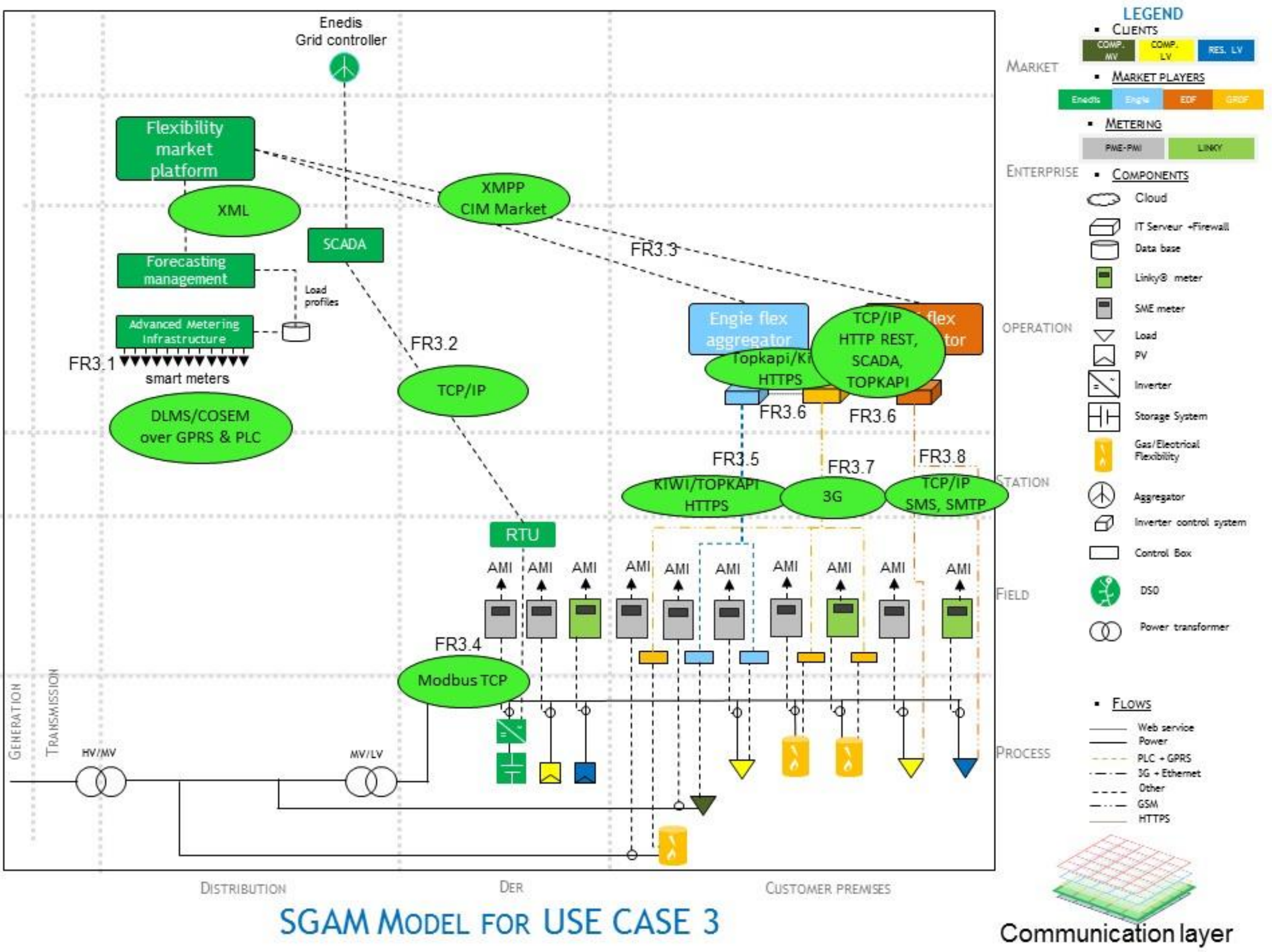


*Figure 0-17 Communication layer of French demo SGAM – Use Cases #3*