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Executive Summary

The OPENTUNITY project its entirety is driven by three core strategic objectives, for the achievement of which, the innovative solutions and technologies to be developed within the project, contribute directly.

- SO1. Decarbonization of EU society:
- SO2. Citizen and stakeholder empowerment:
- SO3.Ensure quality of supply in a context of increase of RES:

This deliverable was developed under WP2 that targets to develop an interoperable, secure and flexible architecture for OPENTUNITY use cases developed in T2.1.

To bring this challenging task into a successful completion, the Smart Grid Architecture Model (SGAM) framework and underlying methodology have been applied to analyse and design the architecture of OPENTUNITY innovations and use cases in systematic and unified manner. More specifically the various innovations that will be developed in the project are linked with the aforementioned objectives as business cases as well as with the actors involved in the project, in a SGAM business layer diagram. In the same diagram these business cases are linked with the UCs defined in T2.1.

Each particular UC is then modelled and analysed from different aspects using the rest four layers of SGAM framework, producing an analytic and detailed object, where the role of each stakeholder is clearly defined. In the function layer, the high level overview of the UC is presented, analysing the actors involved, the sequence of actions that take place in the UCs. The information layer presents the various components in each UC and the information exchange between them, the information models and the data standards applied. Finally, the communication layer presents the communication protocols used for the interaction of the various assets and the component layer their connectivity in the physical domain.

In addition, an extension of SGAM to include blockchain technologies has been briefly discussed and an example use case has been included in the annexes section to present how blockchain can be introduced to SGAM and how different is the modelling compared to the conventional SGAM modelling presented in section 5.

Copyright statement

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2 INTRODUCTION

2.1 Purpose of the document

This document is part of the work carried out in Work Package 2 (WP2) and specifically the development of an open, secure and flexible architecture. This WP will define the basis for the project implementation generating and compiling all the relevant data that will be required for the future steps of the project (mainly the technical Work Packages). As one may observe on the figure below, the outcome of WP2, and here more specifically will feed into all the following WPs, thus ensuring a robust and holistic framework for the deployment of OPENTUNITY.

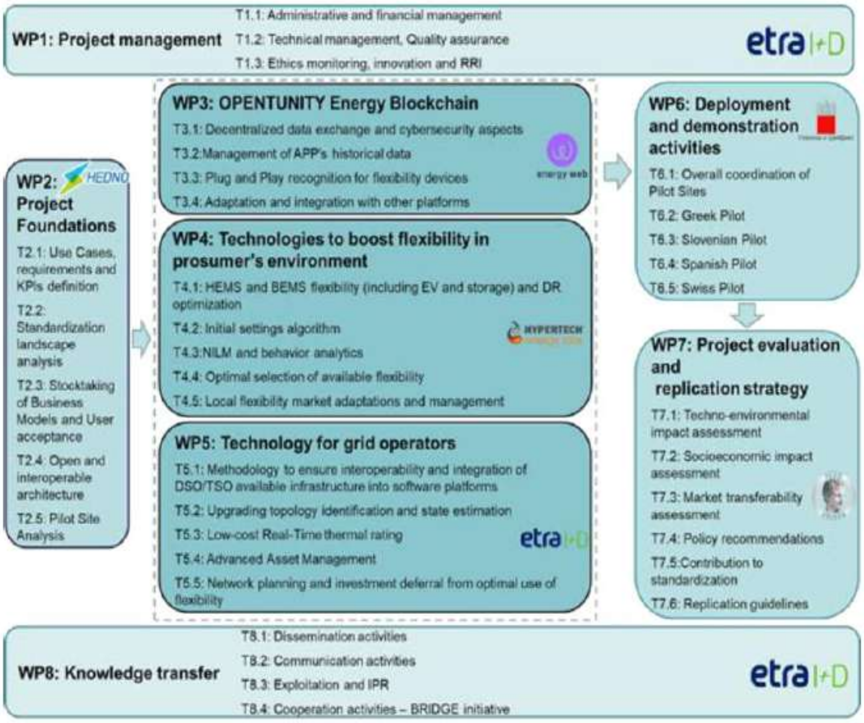

Figure 1. Work Package Structure for the OPENTUNITY project [1]

2.2 Scope of the document

The scope of this document is to present the results related to the architecture of the use cases to be developed and tested in the course of the OPENTUNITY project. The deliverable presents the results of T2.4 focusing on the development of an open, secure and flexible architecture. The architecture is mapped on the strategic objectives of the project, the actors involved and use cases developed in T2.1. In addition, the main characteristics of components' interfaces are defined with general description of information to be exchanged between them and with external ICT systems.

To provide and consistent and systematic approach to the modelling of the use cases and the description of the proposed OPENTUNITY architecture, the Smart Grid Architecture Model (SGAM) framework was extensively utilized. The power of SGAM is that it allows for the unified modelling of the different use cases by analyzing them into layer. Starting from the highest SGAM layer (Function Layer), this refers to the UC high level overview, the actors involved and the actions that take place. Next comes the Information Layer deals with the information objects and data models exchanged between UC actors/functions. The Communication Layer refers to the protocols used for the exchange of information between the model entities and is followed by the last one, the Component layer, the physical layer of the grid, which includes the system equipment, communication infrastructure and network devices.

2.3 Structure of the document

The deliverable D2.3 is organized as follows. Section 3 presents an overview of the Smart Grid Architecture Framework (SGAM) and how it can be extended to include blockchain technologies, section 3 links project objectives with the defined actors, innovations and use cases defined in T2.1. Moreover, the modelling of the use cases according to SGAM is described in Section 5 and the different layers and diagrams for each use case are analyzed. Finally, conclusions are made in Section 6, and references and acronyms in section 7.

3 SMART GRID REFERENCE ARCHITECTURE

3.1 The Smart Grid Architecture Model Framework

Interoperability acts as the main player in Smart Grid applications. To this end, interoperability needs to be defined in the context of smart grid architectural models, in which it is applied. A prominent definition describes interoperability as the ability of two or more devices to exchange information and use that information for correct cooperation, regardless of their vendor [2]. Thus, two or more systems (devices or components) are interoperable, if the two or more systems are able to perform cooperatively a specific function by using information which is exchanged, as it is depicted in Figure 1.

GridWise Architecture Council [3] introduced the interoperability categories representing a widely accepted methodology to describe requirements to achieve interoperability between systems or components. The modelling process of different smart grid functionality scenarios (Use Case scenarios) can be quite a challenge, considering the number of actors and systems involved. The Smart Grid Architecture Model (SGAM) framework is an architectural structure in three dimensions, which provides a safe and systematic way of modelling and analysing different UCs, without disrupting the smooth operation of the individual processes. The role of the different actors (stakeholder entities) involved can be clearly defined, while the final outcome of the process should consist of an analytic model, where UC details are clearly depicted. Before proceeding to a more in-depth analysis of the SGAM framework, it should be noted that universality, localization, flexibility, scalability and extensibility are the basic principles upon which the framework is based.

While every UC can be analysed from many different aspects, the coherency of the whole process is guaranteed through the tight and analytic communication flows between the different SGAM layers, zones and domains (these terms are further analysed below). As depicted below (Figure 2), when modelling a UC scenario, three main categories interoperate between each other, while many cross-cutting issues (Figure 3) are also taken under consideration, describing the relationships between them.

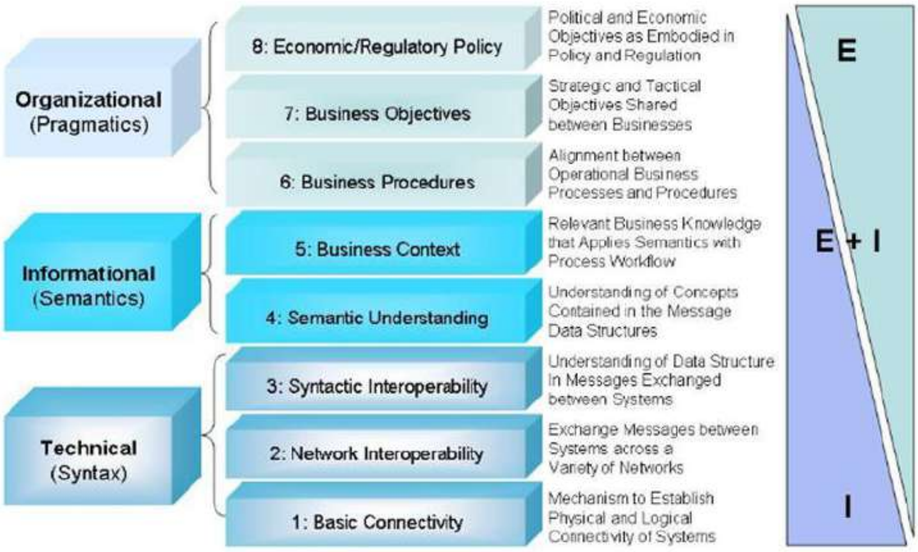

Figure 2. Interoperability Framework Categories [3]

The three main interoperability categories (Organisational, informational and technical) contain 8 subcategories which are mapped in the SGAM framework under 5 'layers', or levels which encapsulate the typical SG operational periods, This way the first dimension (1D) of the 3-dimensional SGAM modelling framework is complete. These five layers represent summarized version of the interoperability categories. Each layer covers the smart grid plane, which is spanned by electrical domains and information management zones. This model intends to represent on which zones of information management interactions between domains can take place. It allows the presentation of the current state of implementations in the electrical grid, but furthermore depicts the evolution to future smart grid scenarios, by supporting the principles universality, localization, consistency, flexibility and interoperability. The description of each one of the five interoperability layers is presented in Table 1.

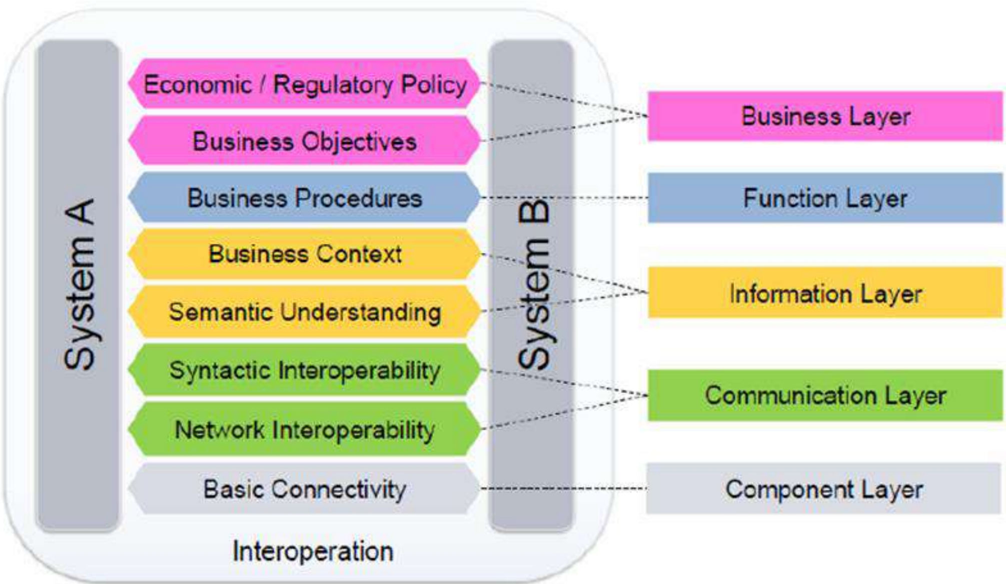

Figure 3. Interoperability layers groups

Table 1. Interoperability Layers description [3]

Layer Name	Description
Business Layer	The business layer represents the business view on the information exchange related to smart grids. SGAM can be used to map regulatory and economic structures and policies, business models, business portfolios of market parties involved. Additionally, business capabilities and business processes can be represented in this layer.
Function Layer	The function layer describes functions and services including their relationships from an architectural viewpoint. The functions are represented independent from actors and physical implementations in applications, systems and components. The functions are derived by extracting the use case functionality which is independent from actors.
Information Layer	The information layer describes the information that is being used and exchanged between functions, services and components. It contains information objects and the underlying canonical data models. These information objects and canonical data models represent the common semantics for functions and services in order to allow an interoperable information exchange via communication means.
Communication Layer	The role of the communication layer is to describe protocols and mechanisms for the interoperable exchange of information between components in the context of the underlying use case, function or service and related information objects or data models.
Component Layer	The emphasis of the component layer is the physical distribution of all participating components in the smart grid context. This includes system actors, applications, power system equipment, protection and tele-control devices, network infrastructure and any kind of computers.

The SGAM Layers mentioned above are then merged with a 2-dimensional plane (Figure 5) resulting to the final, complete structure of the framework [4]. The SG plane can be described by two axes: the electrical processes (domains) and the information management viewpoints (zones) (Figure 4). Although an in-depth analysis of the SG plane is not considered essential, a quick preview of the different domains and zones involved should be provided (Table 2). In the domain axis, first comes the Bulk Generation domain, which refers to the high voltage generation of electricity and is followed by the Transmission domain, involving the complete infrastructure and Organisation processes for the transportation of the high voltage energy produced. The Distribution domain is then transmitting this energy under medium to low voltage. The Distributed Energy Resource domain refers to the DERs connected to the distribution grid. Lastly, the Customer Premises refers to endpoint of energy delivery, at low voltage level.

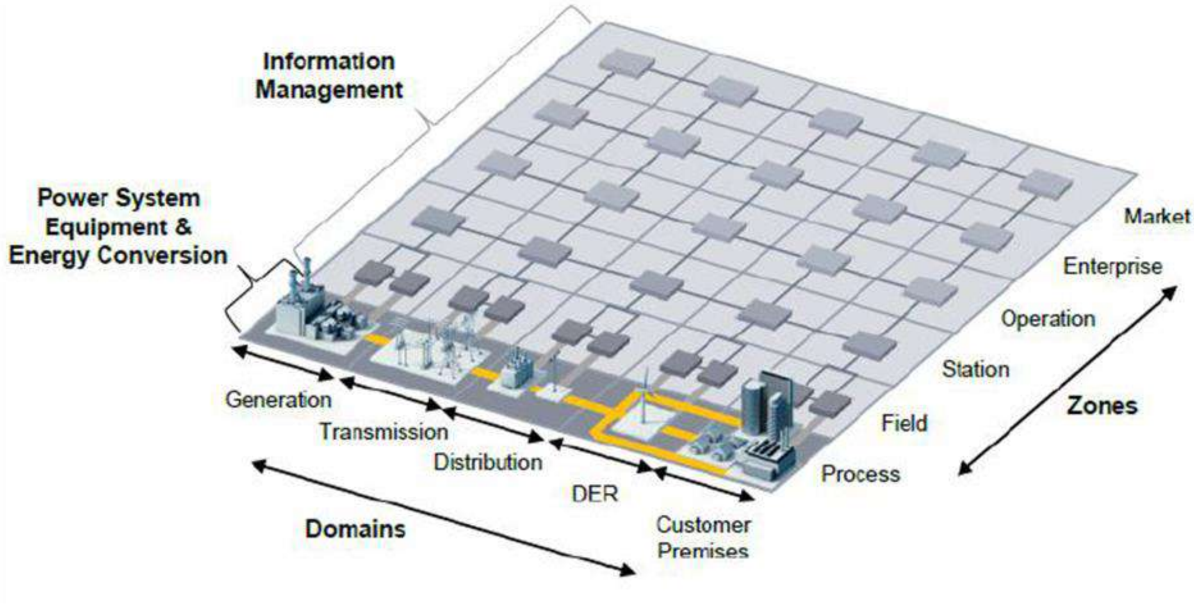

Figure 4. Smart Grid plane [4]

The six hierarchical zones of the SG plane are designed to support the framework coherency by following a similar conceptual pattern. The first zone, known as the Process zone, refers to the transformation of energy and the physical equipment involved. Next comes the Field zone for protection, control and monitoring if this equipment. This is followed by the Station zone focusing on the substation level, followed in turn by the Operation zone for the control of the operation systems in the grid. Finally, closer to the business aspects of the activities, the Enterprise zone and Market zone refer to the enterprise level and commercialization of the total amount of electricity produced and distributed, respectively.

Table 2. SGAM Zones

Zone	Description
Process	Physical, chemical or spatial transformations of energy (electricity, solar, heat, water, wind, etc.) and the physical equipment directly involved. (e.g. generators, transformers, circuit breakers, etc).
Field	Equipment to protect, control and monitor the process of the power system, (e.g. protection relays, bay controller, etc).
Station	Representing the areal aggregation level for field level (e.g. for data concentration, functional aggregation, substation automation, local SCADA systems, plant supervision, etc)
Operation	Hosting power system control operation in the respective domain (e.g. distribution management systems (DMS), energy management systems (EMS) in generation and transmission systems, etc).
Enterprice	Commercial and organizational processes, services and infrastructures for enterprises (utilities, service providers, energy traders) such as asset management, logistics, work force management, staff training, etc
Market	Reflecting the market operations possible along the energy conversion chain (e.g. energy trading, mass market, retail market, etc)

Having presented the hierarchical, multi-axial structure of the SGAM Framework, the modelling process of use cases is the following: Generally, the first step should be the validation of the UC scenario available information. This is characterized as the "analysis" phase, where it is confirmed that the necessary UC details (such as the UC objective, UC diagrams, actor names and types, information exchanged and requirements, etc.) are present. The SGAM framework is established by merging the concept of the interoperability layers defined with the previous introduced smart grid plane. This merge results in a model which covers three main dimensions (Figure 5):

- Domain
- Interoperability (Layer)
- Zone

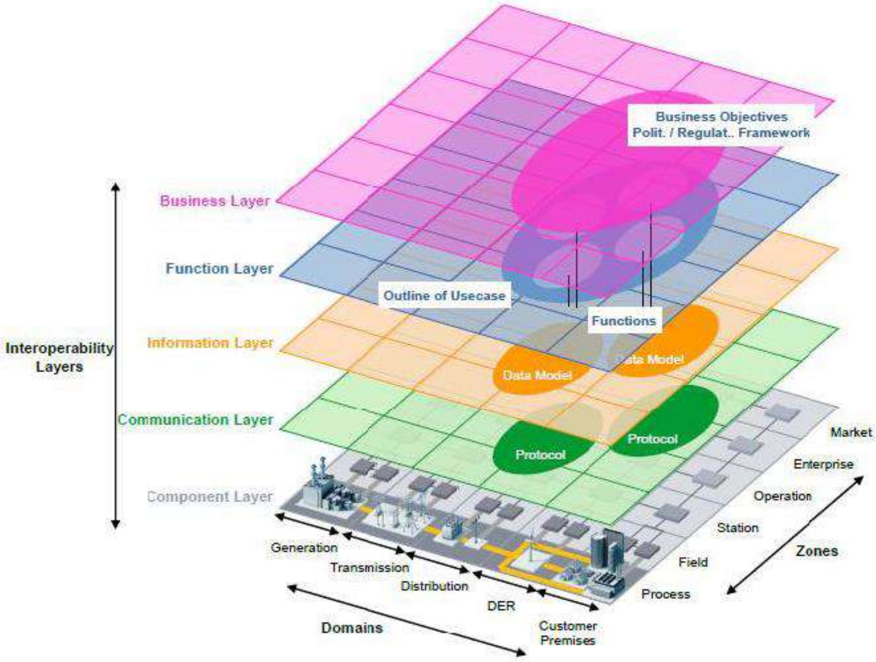

Figure 5. SGAM Framework [4]

3.2 SGAM Methodology

The SGAM framework is based on a specific methodology, which intends to provide users an understanding on its principles and introduce guidelines for its proper use [4].

The definition of the principles of the SGAM is essential in order to leverage its capabilities for the universal representation of smart grid architectures. In Table 3 the SGAM principles universality, localization, consistency, flexibility, scalability, extensibility and interoperability are described.

Table 3. SGAM principles

Principles	Description
Universality	The SGAM is intended as a model to represent smart grid architectures in a common and neutral view.
Localization	The fundamental idea of the SGAM is to place entities to the appropriate location in the smart grid plane and layer respectively. With this principle an entity and its relation to other entities can be clearly represented in a comprehensive and systematic view.
Consistency	A consistent mapping of a given use case or function means that all SGAM layers are covered with an appropriate entity. If a layer remains open, this implies that there is no specification (data model, protocol) or component available to support the use case or function. This inconsistency shows that there is the need for specification or standard in order to realize the given use case or function. When all five layers are consistently covered, the use case or function can be implemented with the given specifications / standards and components.
Flexibility	This principle is essential to enable future mappings as smart grid use cases, functions and services evolve. Furthermore the principle of flexibility allows to map extensibility, scalability and upgradability of a given smart grid architecture.
Scalability	The SGAM encompasses the entire smart grid from a top level view. An enlargement to specific domains and zones is possible in order to detail given use cases, functions and services.
Extensibility	The SGAM reflects domains and zones of organizations which are seen from the current state. In the evolution of the smart grid there might be a need to extend the SGAM by adding new domains and zones.
Interoperability	The consistency of an interoperable interaction can be represented by a consistent chain of entities, interfaces and connections in the SGAM layers.

3.3 Model-Driven Architecture Specification using the SGAM Toolbox

The abstract architectural concepts presented in the previous sections provide the general as well as theoretical concept of the SGAM framework. Moving onto the more practical aspect of the modelling process, the incorporation of a UC into the SGAM framework is performed through the SGAM Toolbox [5]. This useful tool provides a simple and structured way of combining the available information to extract a unified model, distributed to the different parts of the framework. The hierarchical structure of the toolbox is presented below.

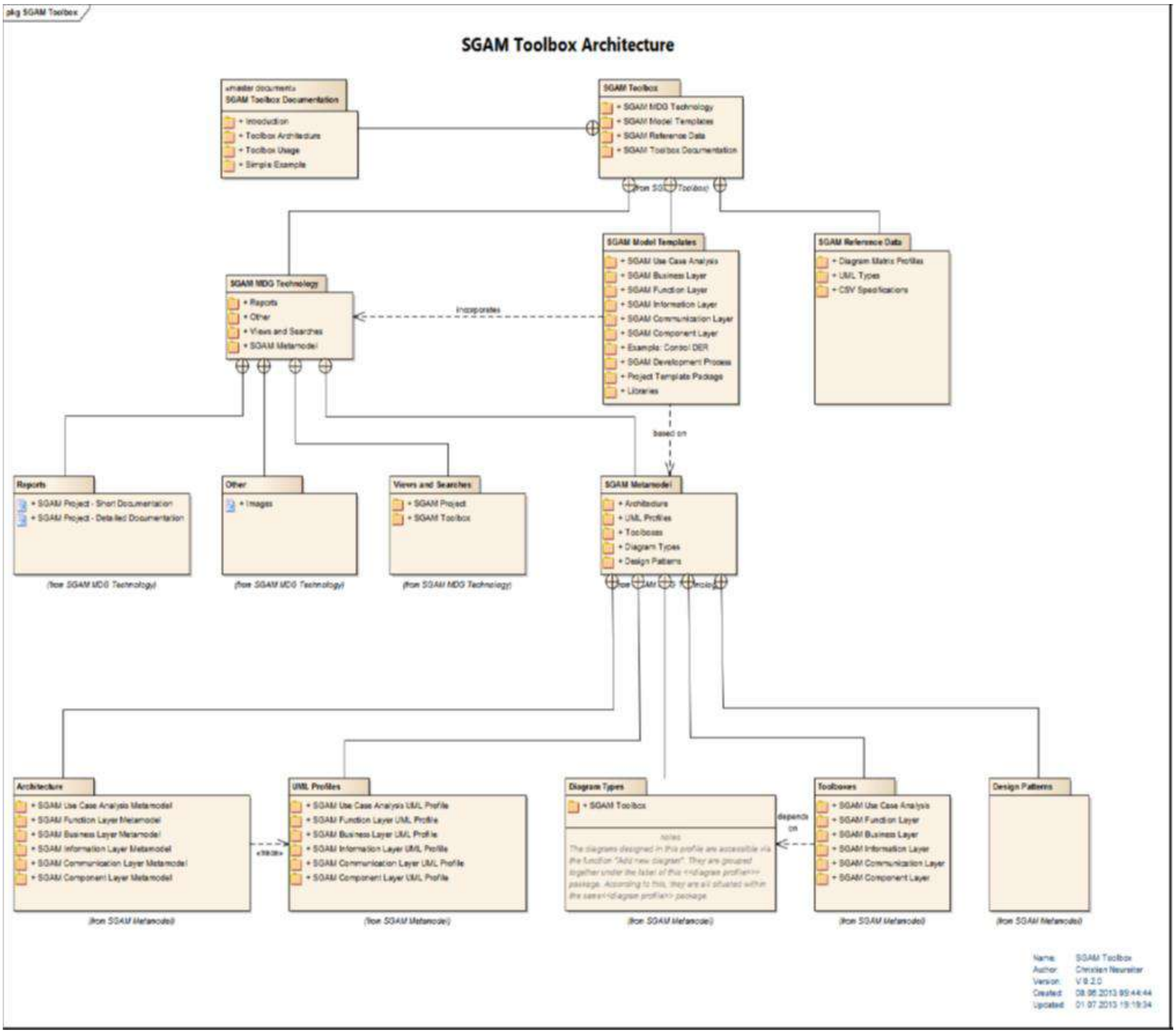

Figure 6. SGAM Toolbox architecture

As presented in the above diagram, three basic components are aggregated into the SGAM Toolbox: the SGAM MDG Technology (plugged into Enterprise Architect software to provide additional toolboxes, Unified Modelling Language profiles and other modelling resources), the SGAM Model Templates (UC analysis and SGAM Layers) and the SGAM Reference Data (providing information regarding the Model Import/Export, as well as other important elements). The core component of the framework, the SGAM Metamodel is aggregated to the MDG Technologies, and constitutes the base of the Model Templates. A brief picture of the Metamodel is presented below.

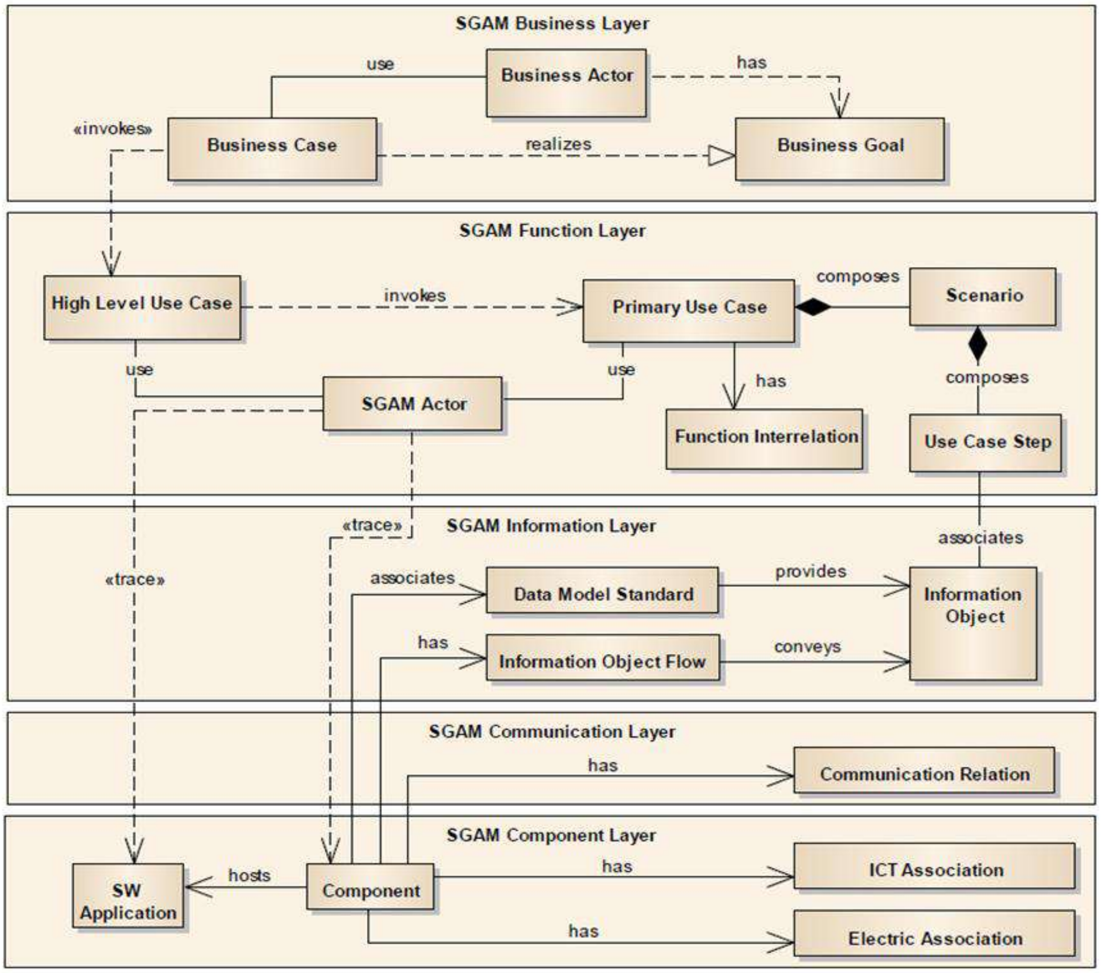

Figure 7. The SGAM Metamodel

The various components (protection devices, cable lines, etc.) associated with the ICT and electrical sector, are presented in the Component layer. These components need to interoperate with each other while complying with the standards and specific protocols of the market. The Communication layer takes care of these procedures, providing an intermediate stage where the components' behaviour is transformed into the communication protocols, the actors and functions can use. In the Information layer, the objects are defined through the data model standards providing information to the above level. The objects designed at this stage, are used to compose the Primary Use Case (PUC) scenarios, which are in turn invoked by the High-Level Use Case (HLUC), in the Function layer. A general description of the actors and the roles involved is also provided at this stage. While not depicted in the diagram above, a PUC is composed by a number of different Secondary Use Cases (SUC). Finally, in the Business layer, the HLUC is invoked by the business case, involving the actors necessary to realize the business goals that have been defined.

3.4 SGAM Blockchain extension

The Energy Web Chain (EWC), part of the Energy Web's Digital Operating System (EW-DOS), is proposed as a foundational "trust layer" in the Smart Grid Architecture Model (SGAM) framework.

EWC has been established as an open-source, Proof-of-Authority public blockchain derived from Ethereum technology, serving as a trust and persistence layer within EW-DOS.

As per EWC proposal, the layer performs the following key functions:

1. **Smart Contract Mechanism**: Stores decentralized identities (DIDs) through smart contracts, providing a secure way to manage identities in a decentralized manner.
2. **On-chain Verification and Transactions**: Facilitates on-chain verification and transactions between parties, ensuring secure and trustworthy interactions within the network.
3. **Execution of Smart Contracts**: Executes smart contracts used by (EW-DOS) decentralized applications, SDKs, and utility packages, enabling automated and efficient operations within the ecosystem.

The trust provided by the implementation, is achieved through:

- **Immutability of Data**: The data in each block is immutable and linked to the previous block by a cryptographically created hash. This design ensures that any tampering with a block would be detectable and rejected by the network validators.
- **Automated Logic of Smart Contracts**: Smart contracts (on EWC) contain explicit logic and requirements for actions to occur. These contracts self-execute when specific conditions are met, ensuring that the logic of the contracts cannot be altered for personal gain.
- **Cryptographic Verification**: Cryptographic verification is required for all on-chain transactions, making unauthorized transactions impossible without the corresponding private key.

Additionally, web-chain stores various types of smart contracts:

- Smart contracts for decentralized identities.
- Smart contracts governing validator consensus behaviour and remuneration (system contracts).
- Smart contracts implementing Ethereum network protocols (such as permissioning).
- Smart contracts specific to applications deployed on the chain and the utility packages connecting users to the chain

In the reference proposal, blockchain is positioned in the "function layer", between the “information layer” and “business layer” of the SGAM model. In principle, the description of the Information, Function and Business layers of SGAM is proposed as described in the following Figure and Table to include blockchain technologies. Annex 2 presents UC 1.10 including the modelling of blockchain technologies.

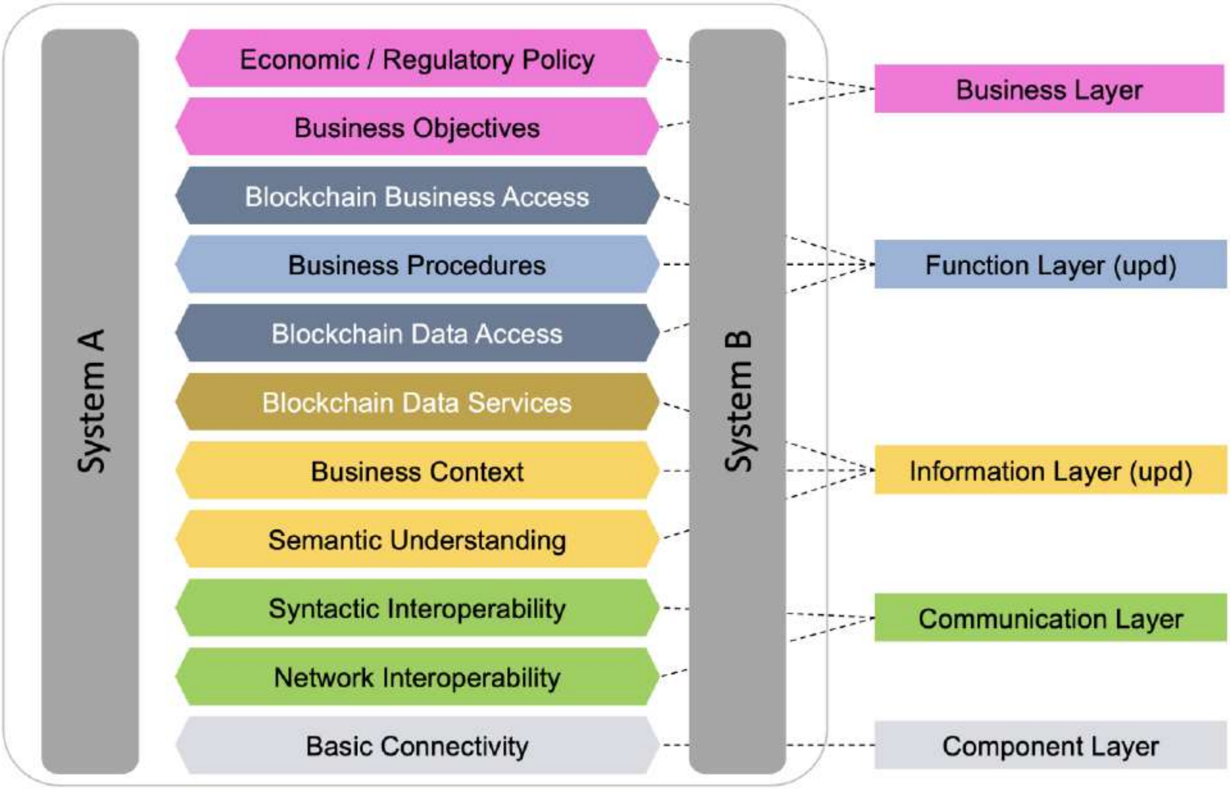

Figure 8. SGAM extensions to blockchain layers

Table 4. List of suggestions to extend SGAM function and information layer to blockchain

Layer Name	Description
Function Layer with Blockchain enhancements	To support the implementation of Blockchain architectures for Energy applications, the "function layer" provides access to services for Identity, Data Access, and Smart Contracts. Implementation may include "Oracles" or other appropriate Blockchain access mechanisms. This functionality is either transparently exposed to the "Business Layer", or via a parallel mechanism that allows the invocation of Blockchain-based logic from Business Layer objects and services.
Information Layer with Blockchain enhancements	To support the implementation of Blockchain architectures for Energy applications, the "information layer" needs to include services that prepare data objects to be offered in data structures appropriate for adding in a Blockchain. This includes the addition of structural and context metadata, DIDs, references to semantics and more. Notably, these functions are implemented after semantic transformations need have been applied.

4 Overview of Business goals, cases, use cases & actors in OPENTUNITY project

The OPENTUNITY project is driven by three core S.M.A.R.T. (Specific, Measurable, Achievable, Realistic, and Timely) objectives, designed to assess impactful change within the EU society. Those three objectives are, **Decarbonization of EU Society**, **Citizen and Stakeholder Empowerment** and **Ensuring Quality of Supply in the Context of Increased RES**

To realize these objectives, a series of innovative solutions will be developed within the project. These innovations are presented in the following table.

Table 5. List of OPENTUNITY Innovations.

OPENTUNITY innovations
HEMS and BEMS Flexibility and DR optimization including initial settings algorithms.
AI non-intrusive load monitoring algorithms as a low-cost technology for sensorless prosumers.
Optimal selection of available flexibility.
Flexibility market design and management.
Topology identification and state estimation via machine learning.
Low-cost real-time thermal rating.
Advanced asset management.
Grid planning methodologies.

4.1 Actors

In OPENTUNITY, different actors from the energy sector will share the innovations and find synergies among them in order to meet the common aforementioned business goals. The list of OPENTUNITY actors, as agreed by the different stakeholders of the consortium, and their description is presented in the following table.

Table 6. OPENTUNITY Actors

Actor name	Description	Actor type
Aggregator	Entity or grouping of agents (i.e., consumers, producers or any mix of them) that aggregate flexibility of disperse DERs with the aim of providing services to the Supplier, the DSO or the TSO via bilateral agreements or by trading in the flexibility market.	Organisation
Blockchain Node	A blockchain network operator maintains a complete copy of the blockchain and broadcasts transactions throughout the network.	System

Consumer	A party that consumes energy. There is no distinction between residential end-users, small and medium-sized enterprises or industrial users. This is a Type of Party Connected to the Grid.	Person
DSO	Distribution System Operator. The entity responsible for: operating, planning, and developing the distribution network; guarantee the safe and secure operation and management of the distribution system; for data management associated with the use of the distribution system; for procurement of flexibility services.	Organisation
Energy Management System	A system that monitors, controls and optimizes the operation of the energy system under supervision. No distinction between an Energy Management System for a Distribution Grid, a Building, an EV fleet etc.	System
ESCO	An Energy Service COmpany is a company that offers energy services which may include implementing energy-efficiency projects (and also renewable energy projects). They provide their energy services to final energy users, including the supply and installations of energy efficient equipment, and/or the building refurbishment.	Organisation
EV Fleet Manager	Electric Vehicle Fleet Manager. An organization that operates and controls an EV fleet.	Organisation
EVSE Operator	Electric Vehicle Supply Equipment Operator. The entity responsible for managing and operating the EV charging infrastructure.	Organisation
FSP	Flexibility Service Provider: A party that offers flexibility services such adaption of consumption and/or production. An FSP can be an independent entity or an Aggregator	Organisation
Flexibility Market Operator	A party that operates a market platform and manages the associated services to ensure the correct market clearing of registered bids and offers as well as the validation and settlement of each transaction.	Organisation
Market Operator	A party that ensures the correct clearing of electricity sell and buy orders as well as their associated validation and settlement. In a more detailed description, the Market Operator provides a service of collecting offers to sell and bids to buy electricity and matching these offers and bids in order to determine a market price at the clearing point. This activity can be conducted in the forward, days-ahead and/or intraday timeframes, and can be combined with transmission capacity allocation in the context of market coupling. This is usually an energy/power exchange or platform.	Organisation
OEM	An Original Equipment Manufacturer is a company that manufactures and sells products. In the context of OPENTUNITY, those products may be HVACs, Lighting, Batteries etc.	Organisation
Producer	A party that generates electricity.	Organisation
Prosumer	An entity that consumes and produces energy. There is no distinction between residential end-users, small and medium-sized enterprises or industrial users.	Person

Retailer	A Retailer supplies electricity to or takes electricity from a party connected to the grid at an Accounting Point. An Accounting Point can only have one retailer. It can also take the role of Energy Community responsible.	Organisation
TSO	Transmission System Operator. A party that is responsible for the stable power system operation (including the organisation of physical balance) of the transmission grid in a geographical area. Its mission is to ensure the country's electricity's transmission in an adequate, secure, efficient, and reliable manner. Additionally, TSO is responsible for the operation of the balancing market.	Organisation

4.2 Business layer description

To effectively align their innovations with project objectives and actors, an SGAM Business Layer has been developed for each innovation and several high level use cases have been created`. This layer serves as the cohesive link, intertwining the innovations, involved actors, business goals, and Use Cases (UCs) within the project framework.

4.2.1 HEMS and BEMS Flexibility and DR optimization including initial settings algorithms

This innovation aims to enhance the adaptability of BEMS/HEMS by modularizing their functions. This approach caters to diverse needs beyond simple electricity management within a building and fosters seamless interaction between different systems. Specifically, the initiative involves creating modules tailored for managing flexibility in Electric Vehicles (EVs) and charging points, storage units, Combined Heat and Power (CHP) systems, and other assets utilized across OPENTUNITY demonstration sites.

Additionally, OPENTUNITY will devise an algorithm to configure initial settings for prosumers. This algorithm will automatically generate a Demand Response (DR) profile to be implemented during DR campaigns. Consequently, the project eases concerns among prosumers regarding their response to DR signals, ensuring minimal impact on their comfort and behaviour. The business layer diagram is presented in the following figure. The actors benefited from this innovation are prosumers, ESCOs, Flexibility Market operators, Aggregators, FSPs, EVSE operators and EV Fleet managers, while seven high level UCs have been defined that are linked with this innovation.

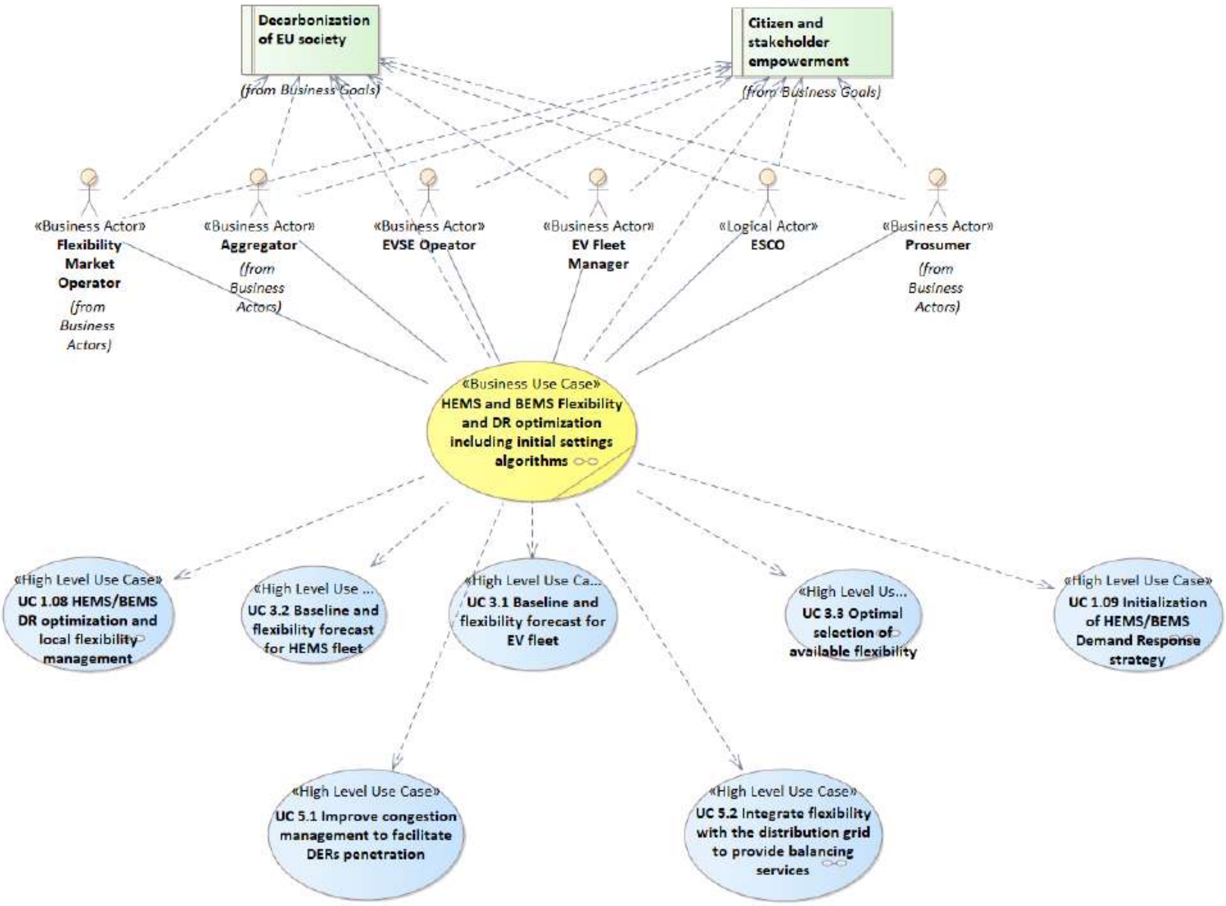

Figure 9. Business layer diagram of HEMS and BEMS Flexibility and DR optimization including initial settings algorithms

4.2.2 AI non-intrusive load monitoring algorithms as a low-cost technology for sensorless prosumers

This innovation involves advancing NILM (Non-Intrusive Load Monitoring) through optimized Neural Network models. These models will be integrated into affordable IoT smart energy meters, forming the foundation for more efficient energy monitoring and Demand Response (DR) implementation within the project. The business layer diagram is depicted in the following figure. The actors benefited from this innovation are consumers and ESCOs while a high-level UC have been defined that are linked with this innovation.

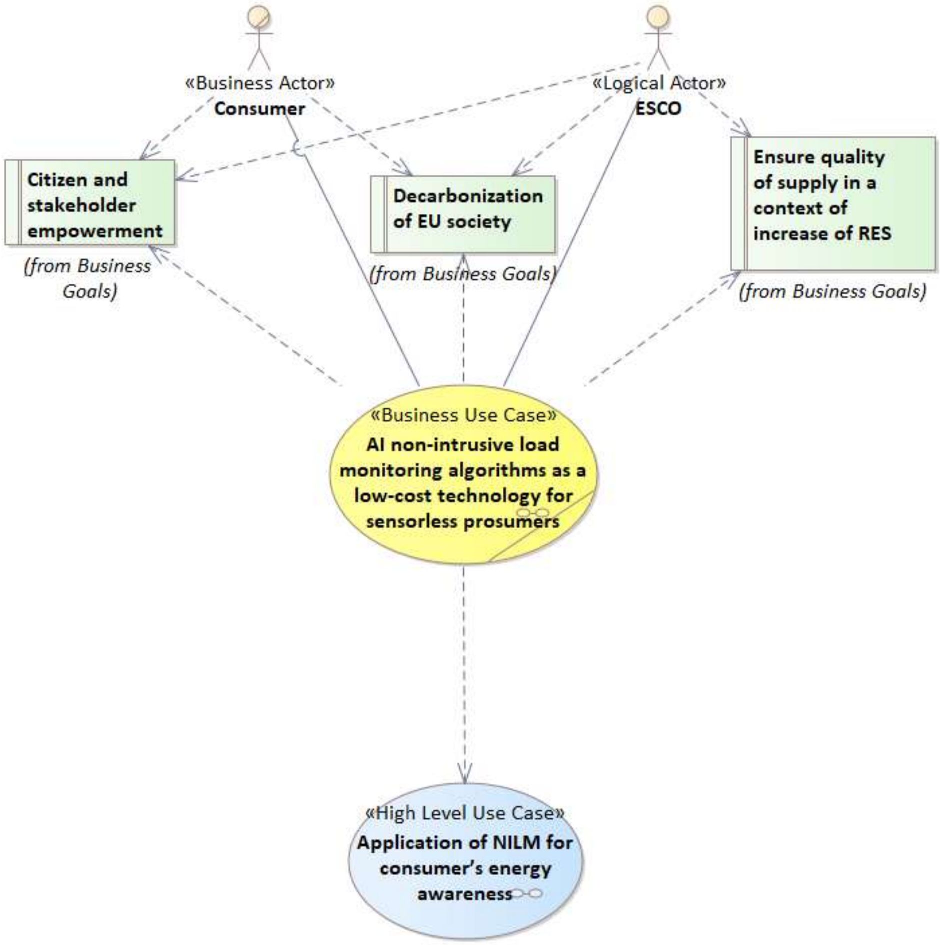

Figure 10. Business layer diagram of AI non-intrusive load monitoring algorithms as a low-cost technology for sensorless prosumers

4.2.3 Optimal selection of available flexibility

This innovation seeks to maximize the utilization of diverse demand response units. Within OPENTUNITY, a systematic framework will be introduced to evaluate the technical specifications of smaller, decentralized demand response units. A specialized tool will be created and implemented, leveraging predictive analyses and big data alongside AI to execute the optimal selection of demand response units based on their anticipated availability. This comprehensive approach considers various input parameters, such as e-vehicle details like average daily distance travelled, charging patterns, and estimated current charge status. Moreover, for households, a dedicated platform for home energy management systems will be deployed. This platform will ensure the efficient allocation of activations across multiple households. The primary goal is to augment the pool of available units, thereby enhancing profitability while mitigating any adverse impacts on the local grid. The business layer diagram is depicted in the following figure. The actors benefited from this innovation are prosumers, ESCOs, Flexibility Market operators, Aggregators/FSPs, EVSE operators and EV Fleet managers, while five high level UC have been linked with this innovation.

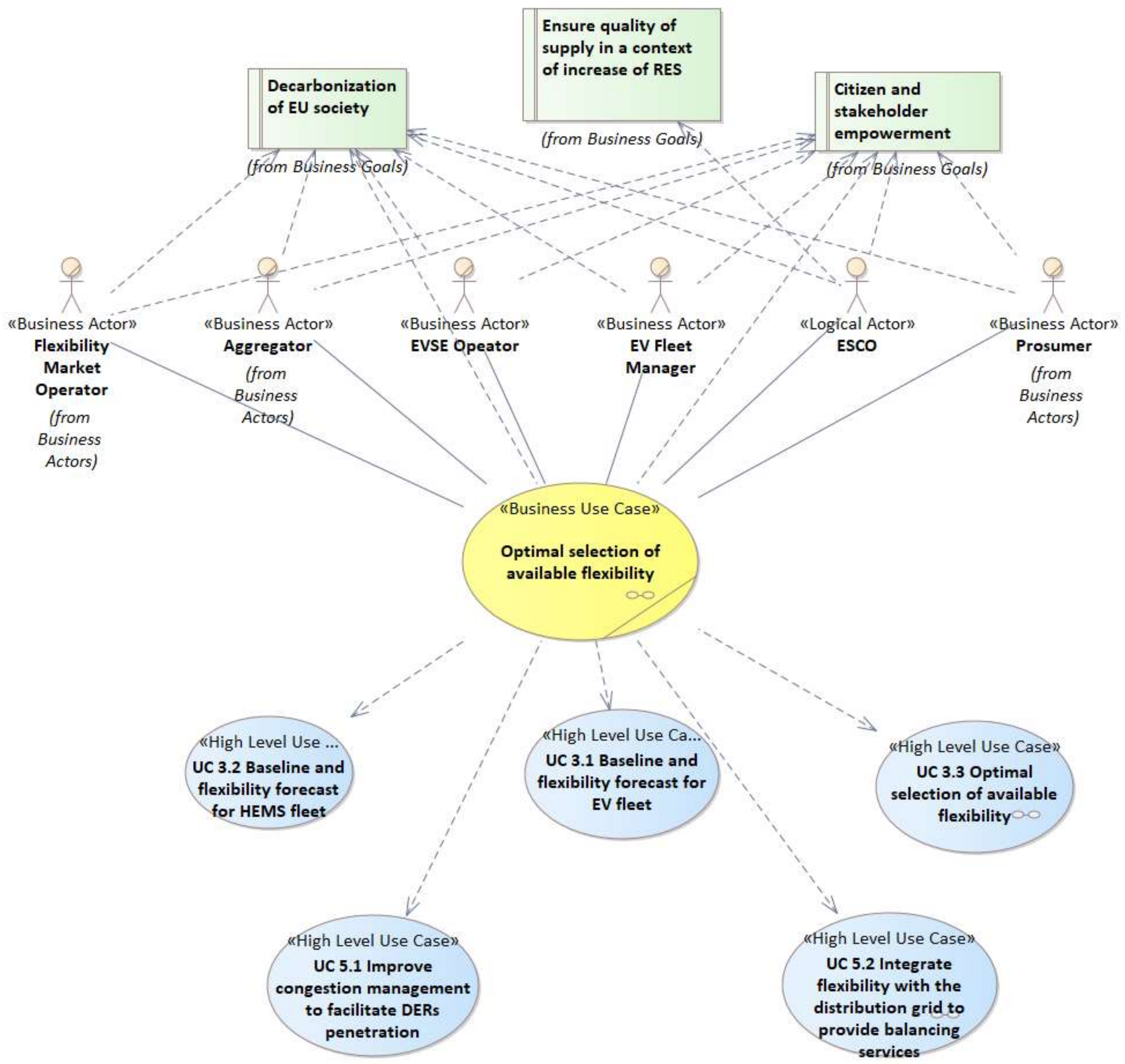

Figure 11. Business layer diagram Optimal selection of available flexibility

4.2.4 Flexibility market design and management

This innovation aims to create a clear framework and deploy a local flexibility market for the various pilot sites, serving the different requirements and operational processes of each grid. The actors that can be benefited are DSO, TSO, aggregators/FSPs as well as flexibility market operators as presented in the following figure, while one high level UC have been defined that is linked with this innovation.

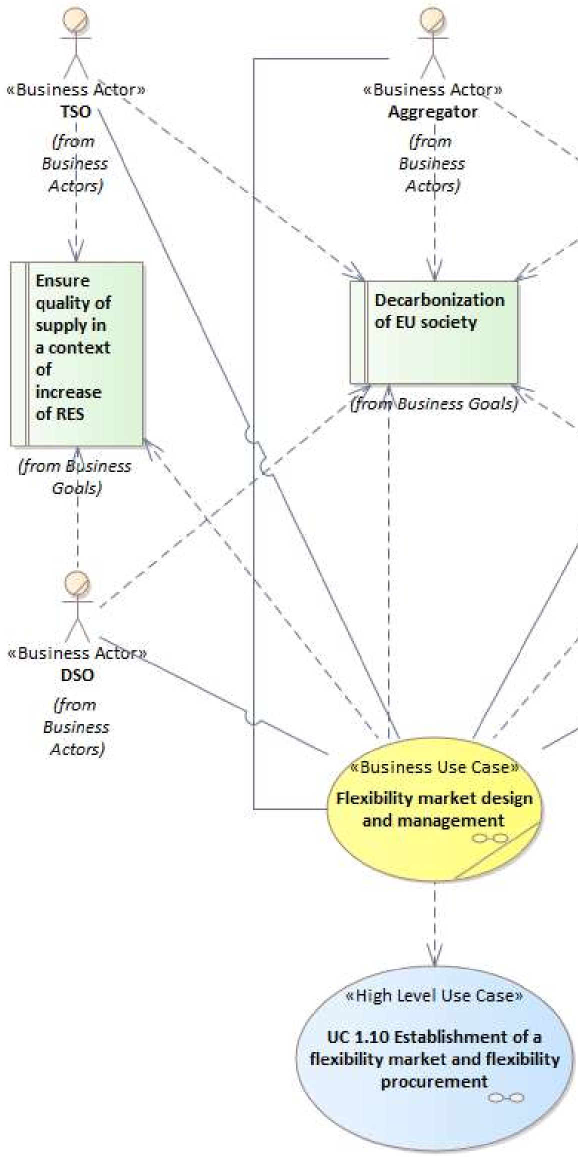

Figure 12. Business layer of Flexibility market design and management innovation

4.2.5 Topology identification and state estimation via machine learning

This innovation aims to create a Machine Learning-powered software module designed for distribution networks. This module will accurately estimate both the system states and grid configuration topology simultaneously. Once implemented, this module will function without the need for sensors or measurement devices to analyse and determine the DSO grid's topology.

The technology developed by OPENTUNITY will monitor the behaviour of voltage and current profiles in each feeder through a sophisticated Deep Learning algorithm. Consequently, the project will have the capability to detect the status of switching devices and identify various distribution system topologies and connected loads without reliance on additional hardware. The business layer diagram is depicted in the following figure, where DSO is obviously the actor benefited from this UC, while six high level UC have been defined that are linked with this innovation.

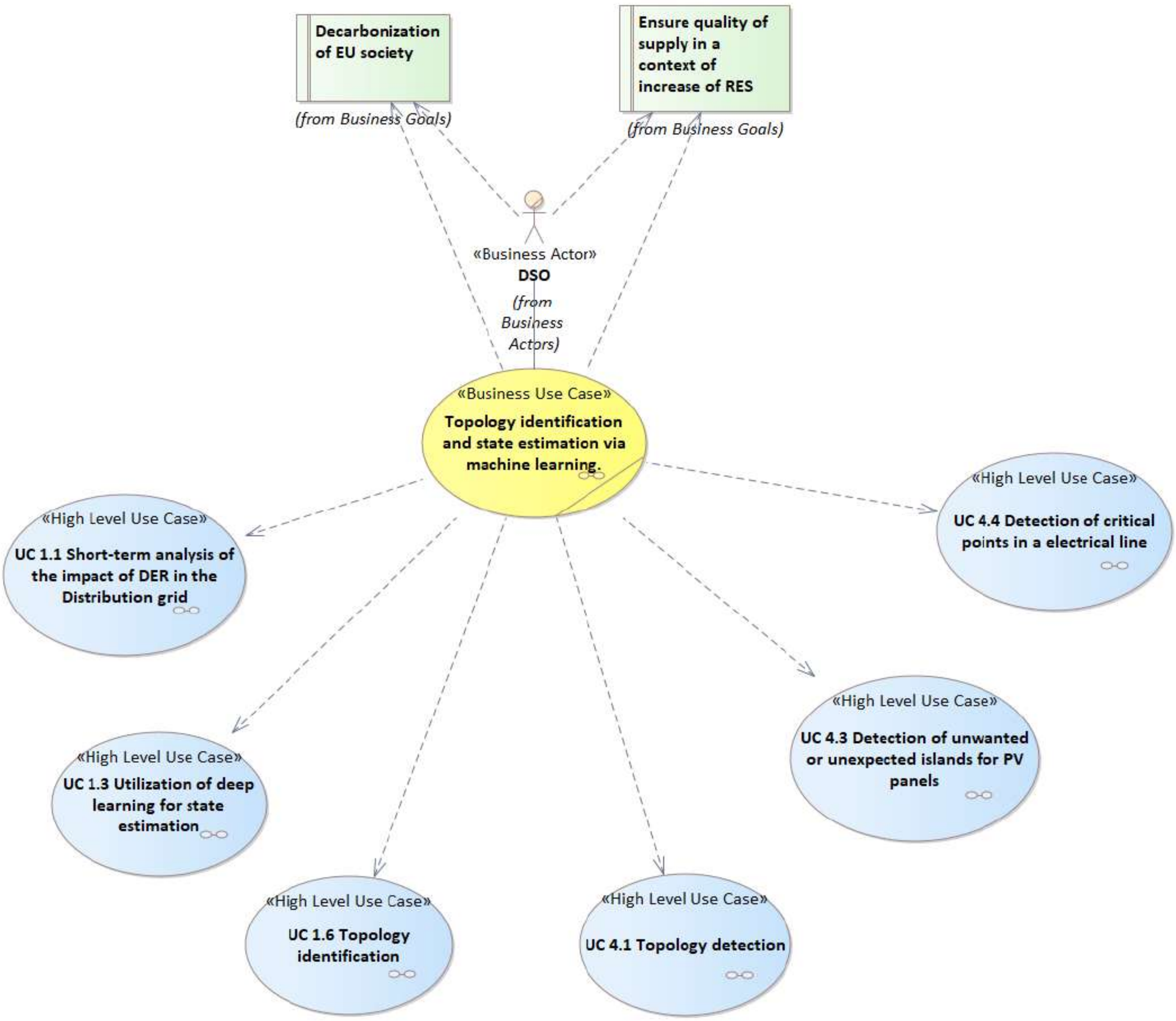

Figure 13. Business layer of Topology identification and state estimation via machine learning innovation

4.2.6 Low-cost real-time thermal rating

This innovation introduces a novel approach for achieving cost-effective real-time thermal rating. This methodology begins with precise numerical weather forecasting, leveraging established models like GFS and ECMWF. Enhancing the accuracy of these models will involve utilizing measurements from sensors within the OPENTUNITY ecosystem. These measurements could originate from various sources like Home Automation Systems, BMS, RES plants, and other nearby infrastructure related to the transmission lines, depending on the specific case. The business layer diagram is depicted in the following figure, where DSO and TSO are the actors benefited from this UC, while a high level UC have been defined that is linked with this innovation.

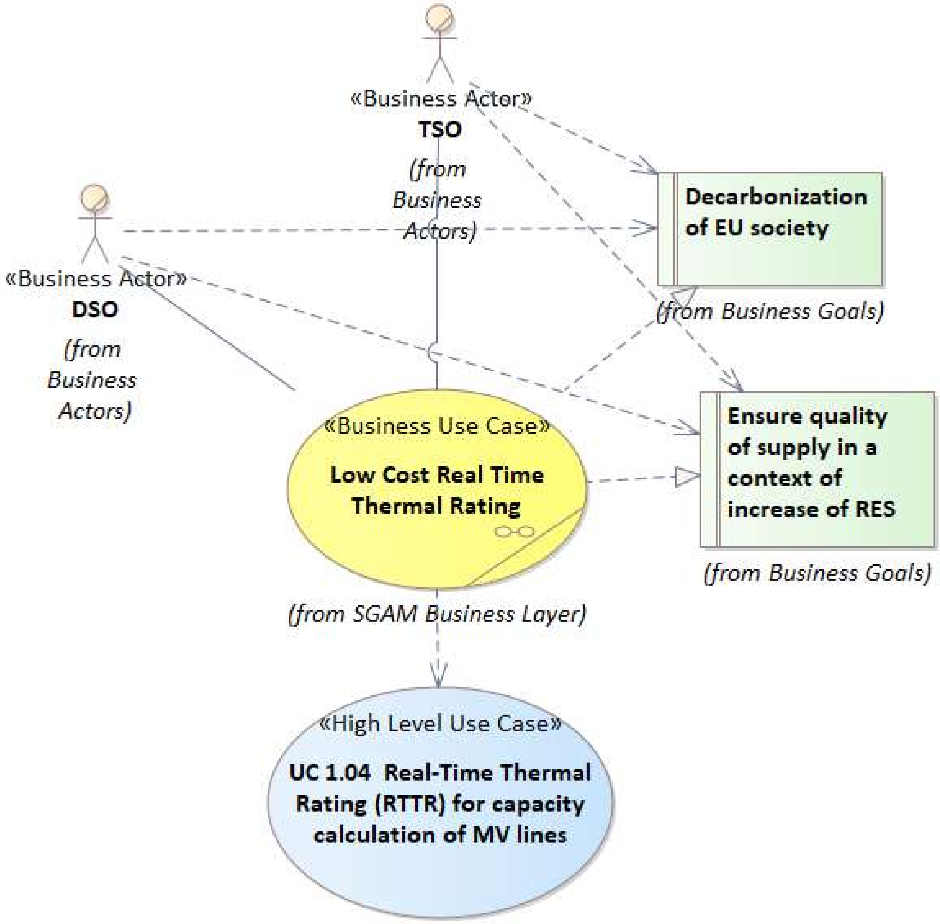

Figure 14. Business layer of Low-cost real-time thermal rating innovation

4.2.7 Advanced asset management

This innovation uses data obtained from diverse sensors, including electronic meters and smart appliances, aiming is to develop novel methodologies for both risk assessment and asset condition assessment. The modern distribution grids accumulate a vast array of measurements from varied sensors and measuring devices. Extracting meaningful insights from this extensive dataset necessitates employing advanced techniques. The incorporation of sophisticated analytics and machine learning algorithms, such as support vector machines, will enable the creation of precise aging models. Additional models will be generated focusing on the identification of non-technical losses. These developments will encompass both electronic equipment within distribution grids (such as power electronics, charging stations, substation automation, communication systems, etc.) and traditional equipment like transformers and lines. The business layer diagram is depicted in the following figure, where DSO and TSO are the actors benefited from this UC, while two high level UCs have been defined that are linked with this innovation.

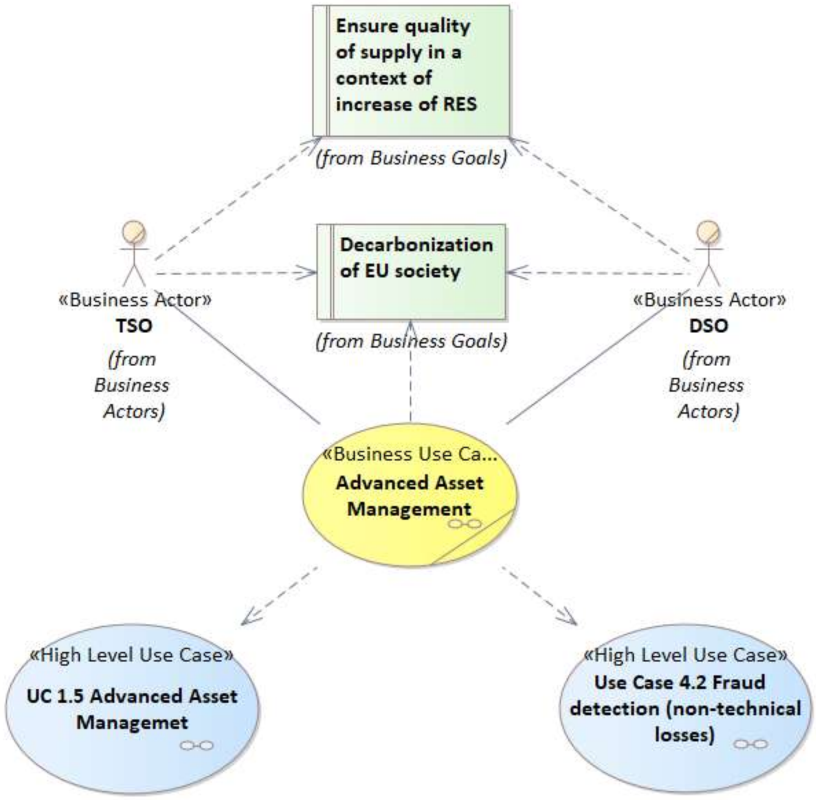

Figure 15. Business layer of Advanced Asset Management innovation

4.2.8 Grid Planning methodologies

This innovation aims to develop a grid planning tool that uses advanced optimization techniques will be used to provide solution for the new formulation of the planning problem, considering the use of flexibility assets. The business layer diagram is depicted in the following figure, where DSO is obviously the actor benefited from this UC, while three high level UCs have been defined that are linked with this innovation.

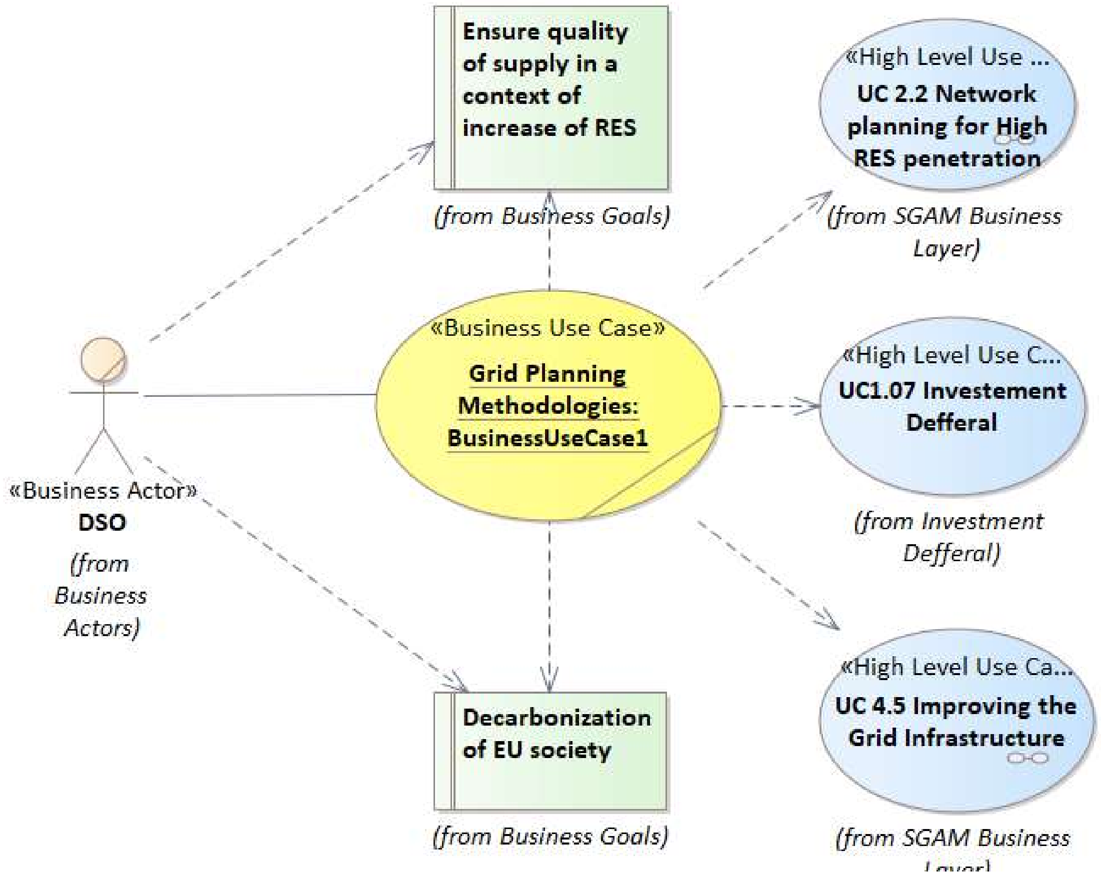

Figure 16. Business layer of Grid Planning methodologies

4.3 Use Cases

As described in the previous section, to fulfil the aforementioned business cases linked with the project's innovations, several high level UC have been defined. The description of the Use Cases (UCs) of the project is an important step towards the achievement of OPENTUNITY objectives. In Task 2.1, the Use Cases and the Scenarios associated to the integration of the OPENTUNITY solutions into the Pilot Sites' systems have been specified and described and they will be the basis for the definition of the demonstration activities of WP6. The UCs have been divided, based on the different pilot sites, into 5 categories. In the table below. The horizontal UC will be applied to more than one pilot site.

Table 7. List of the Use Cases

Horizontal	
Use Case 1.1	Short-term analysis of the impact of DER in the Distribution grid
Use Case 1.2	Application of NILM for consumer's energy awareness
Use Case 1.3	Utilization of deep learning for state estimation
Use Case 1.4	Real-Time Thermal Rating (RTTR) for capacity calculation of MV lines

Use Case 1.5	Advanced Asset Management
Use Case 1.6	Topology identification
Use Case 1.7	Investment Deferral considering flexibility
Use Case 1.8	HEMS/BEMS DR optimization and local flexibility management
Use Case 1.9	Initialization of HEMS/BEMS Demand Response strategy
Use Case 1.10	Establishment of a flexibility market and flexibility procurement
Greek Pilot	
Use Case 2.2	Network planning for High RES penetration
Slovenian Pilot	
Use Case 3.1	Baseline and flexibility forecast for EV fleet
Use Case 3.2	Baseline and flexibility forecast for HEMS fleet
Use Case 3.3	Optimal selection of available flexibility
Spanish Pilot	
Use Case 4.1	Topology detection
Use Case 4.2	Fraud detection (non-technical losses)
Use Case 4.3	Detection of unwanted or unexpected islands for PV panels
Use Case 4.4	Detection of critical points in a electrical line
Use Case 4.5	Improving the Grid Infrastructure
Swiss Pilot	
Use Case 5.1	Improve congestion management to facilitate DERs penetration
Use Case 5.2	Integrate flexibility with the distribution grid to provide balancing services

5 USE CASE MODELLING

5.1 UC 1.1: Short-term analysis of the impact of DER in the Distribution grid

5.1.1 Use Case Description

The penetration of DER (mainly PV on roof) installed by energy communities may cause impact (congestions) in the Distribution Grid due to bidirectional electricity flows. This Use Case will tackle this issue and will provide a technology path to:

- Forecast the power flows (taking into account demand and generation) of the grid (24 hours in advance).
- Predict when the distributed PV will feed the grid (24 hours in advance)..
- Calculate which is the impact in the grid of this bidirectional flow (mainly to study the voltage variations in the affected line in the transient state).

With the analysis performed, the DSO will be able to define the best strategy to solve the congestion according to their resources and capabilities.

5.1.2 Function Layer

The functional layer of UC 1.1 is presented in the following graph highlighting the key actors of the use case.

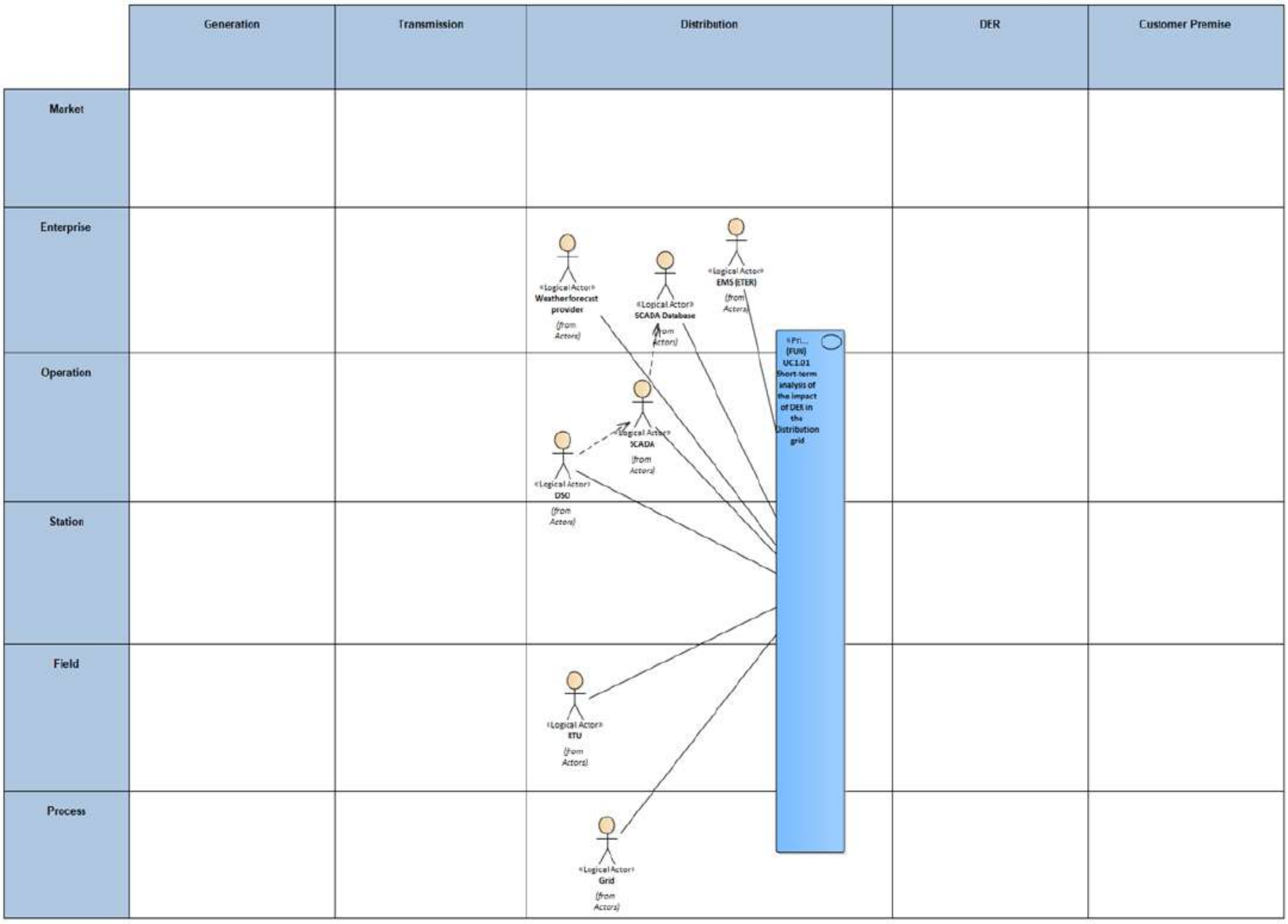

Figure 17. UC 1.1 Function Layer

Table 8. List of actors involved in UC 1.1

Actor Name	Actor Type
Weather forecast provider	Organization
SCADA	System
SCADA Database	Device
EMS (ETER)	System
DSO	Organization
RTU	Device
Grid	Device

5.1.3 Information layer

Details about information layer of UC1.1 are presented in the following figure, highlighting the key information objects.

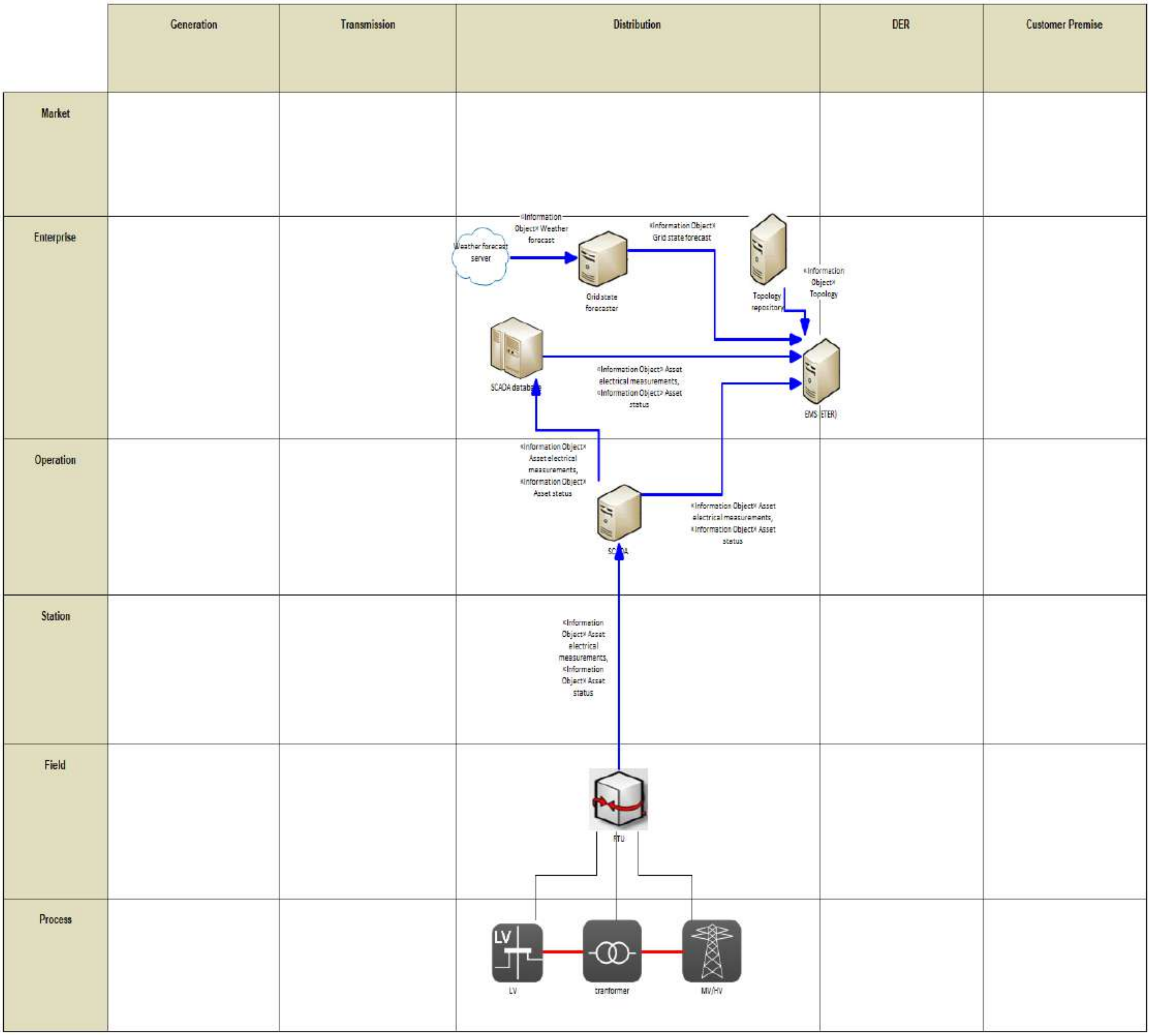

Figure 18. UC 1.1 Information layer

5.1.4 Canonical Data Model

The identified canonical data models for UC1.1 are described below.

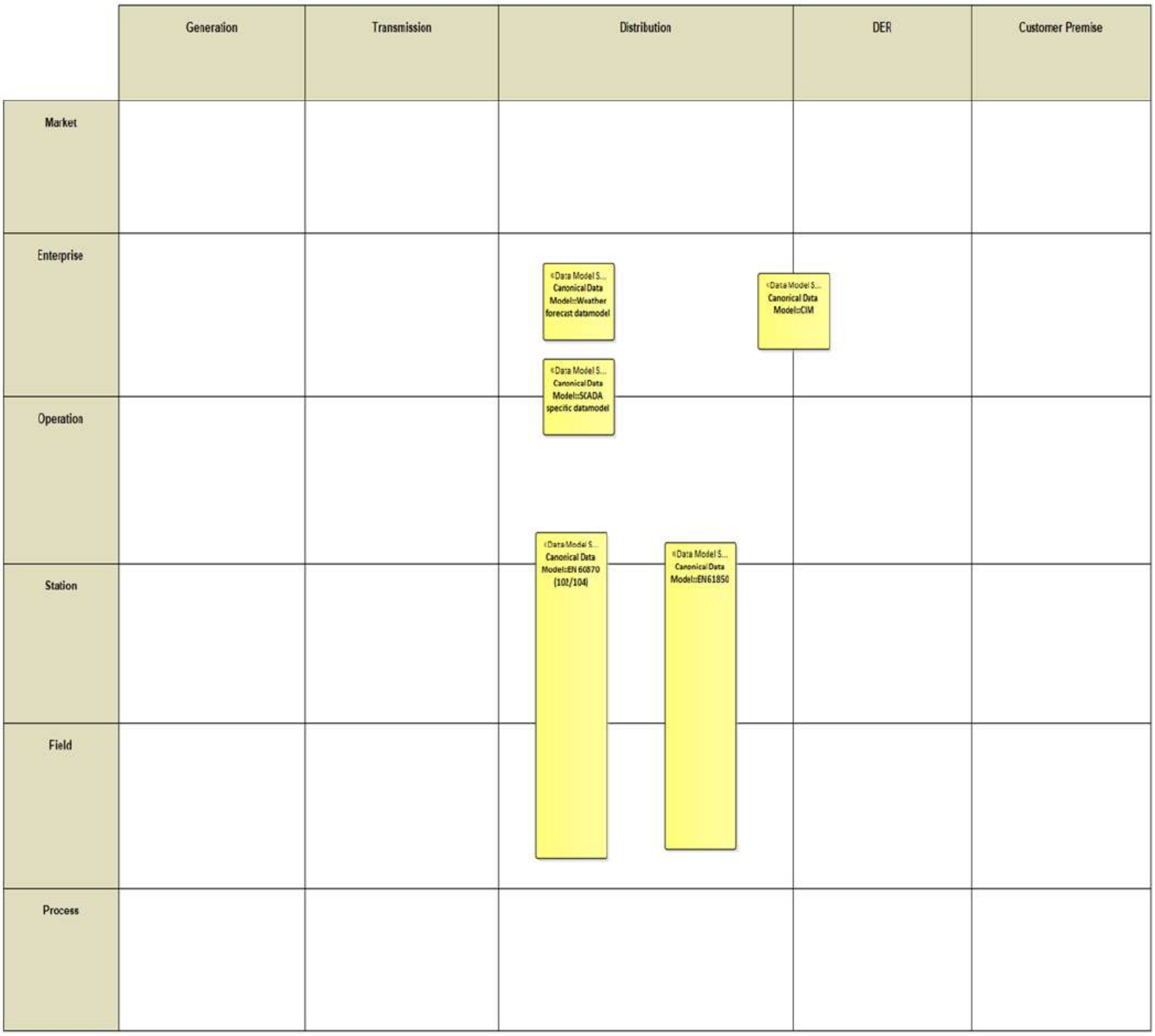

Figure 19. UC 1.1 Canonical data model

Table 9. UC 1.1 Data models

Data Models
Weather forecast data model
CIM
Scada specific data model
En 60870 (102/104)
EN 61850

5.1.5 Standards and Information Object Mapping

Data Standards and Information Objects Mapping for UC1.1 are presented in the following figure.

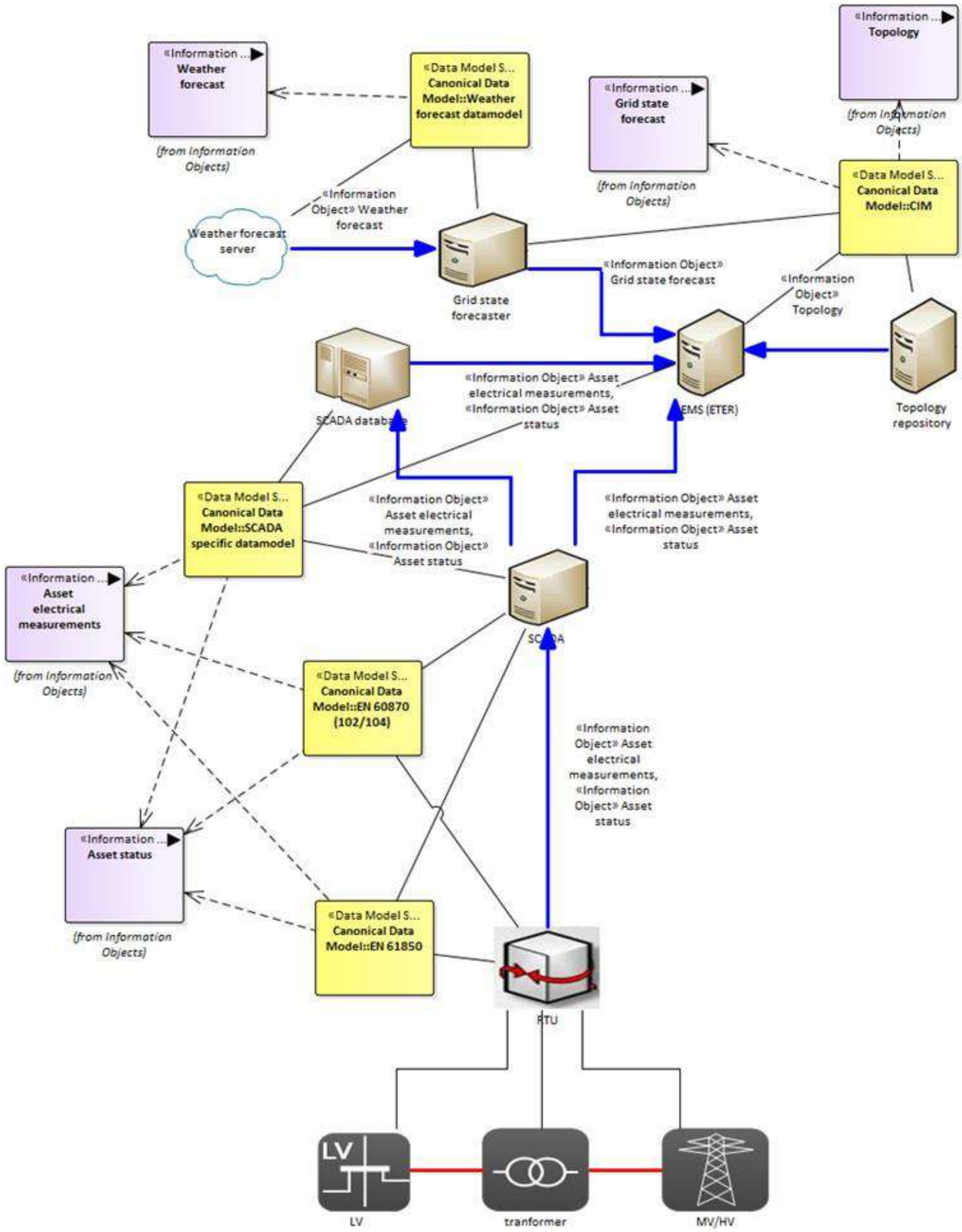

Figure 20. UC 1.1 Standards and Information Objects Mapping

Table 10. List of Information Objects, link with Data Standards in UC 1.1

Information Object	DATA Models	Information
Asset Status	Scada specific data model, EN 61850, En 60870 (102/104)	Condition of an asset (on/off)
Assets electrical measurements	Scada specific data model, EN 61850, En 60870 (102/104)	Active power, reactive power, voltage, current, etc
Weather forecasts	Weather forecast data model	Weather data like temperature, irradiation, wind speed and direction.
Grid state forecast	CIM	Forecast of grid state in terms of nodes voltages, lines loading
Topology	CIM	Electrical grid topology

5.1.6 Activity Diagram

The detailed activity diagram for UC 1.1 is presented in the following figure.

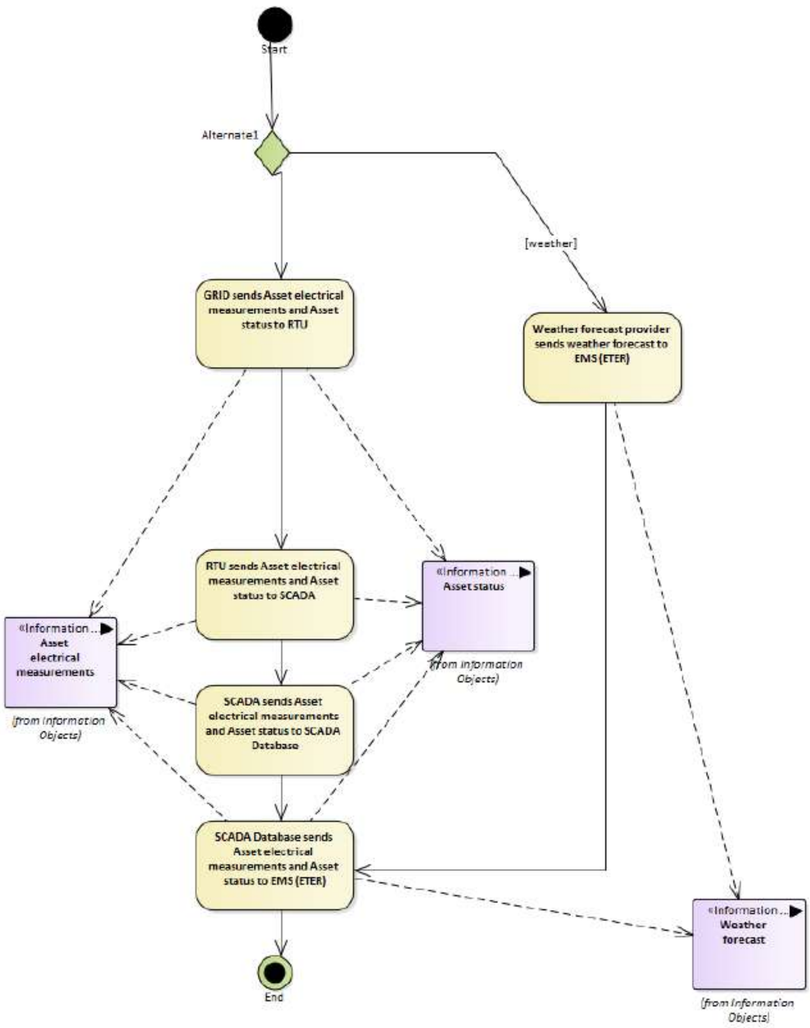

Figure 21. UC 1.1 Activity Diagram

5.1.7 Sequence Diagram

The detailed sequence diagram for UC 1.1 is presented in the following figure.

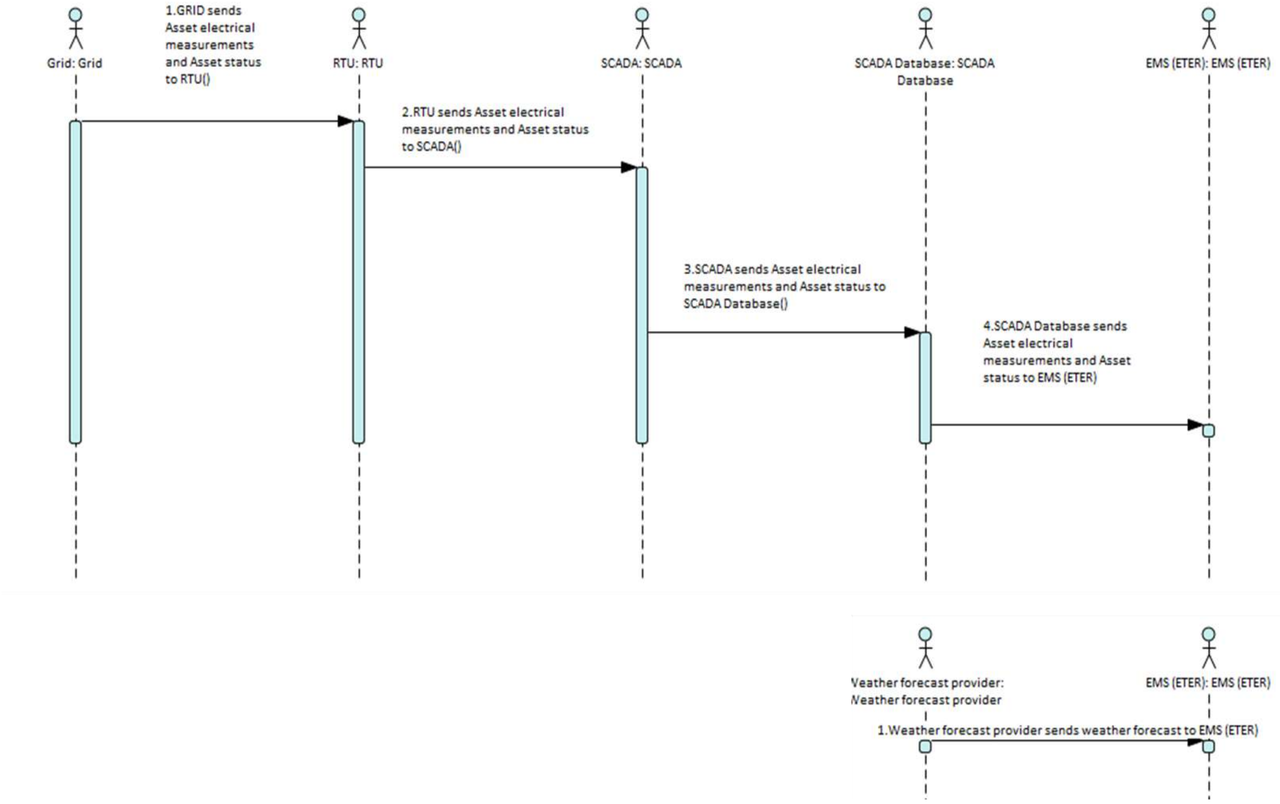

Figure 22. UC 1.1 Sequence Diagram

5.1.8 Communication Layer

The communication layer of UC 1.1 is presented in the following figure, highlighting the key communication protocols among the different modules.

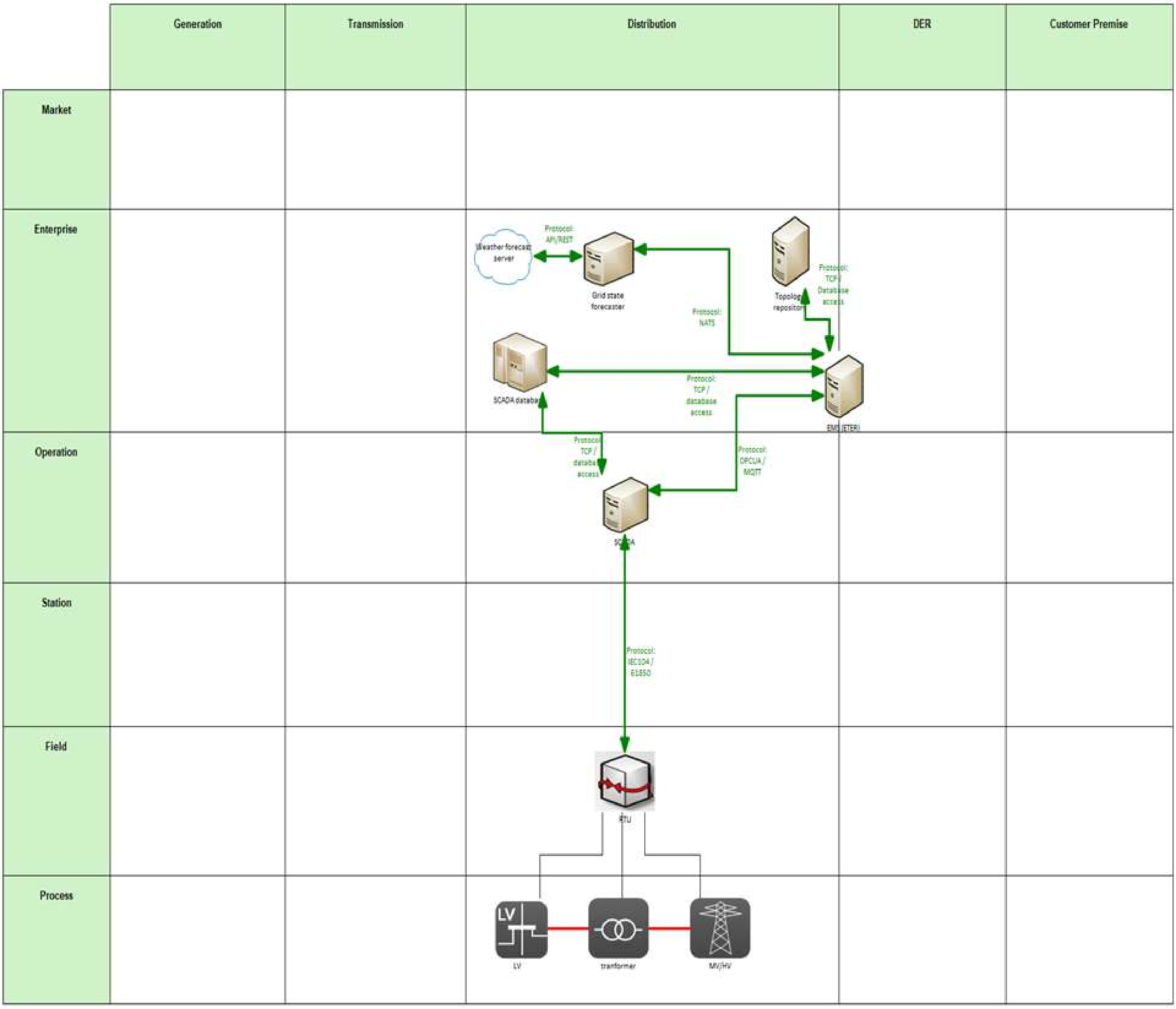

Figure 23. UC 1.1 Communication Layer

Table 11. List of Communication technologies linked with UC 1.1

Communication Technology	Description
REST	Representational State Transfer. Set of software constraints for web services, to provide interoperability between computer systems on the Internet. A RESTful web service defines a uniform and predefined set of stateless operations that accept requests through a URI.
NATS	Neural Autonomic Transport System (NATS) is an open-source messaging system. NATS features a simple, plaintext-based protocol designed for fast and reliable data exchange, segmented in the form of messages.
MQTT	Message Queuing Telemetry Transport. Publish-subscribe message protocol over TCP/IP defined in ISO/IEC PRF 20922 standard. It is designed for connections where network bandwidth is limited and a lightweight messaging mechanism is required.
TCP/IP	Transmission Control Protocol/Internet Protocol. Conceptual model and set of communication protocols used on the Internet. They provide end-to-end data communication, specifying how data should be packetized, addressed, transmitted, routed, and received, through four abstraction layers (link, internet, transport, and application).
IEC 104 / 61850	IEC 104 is a standard telecontrol protocol used for remote control and monitoring of substations, while IEC 61850 is a comprehensive standard for substation automation, covering various aspects such as data modeling, communication services, and system configuration.

5.1.9 Component Layer

The components included in the use case are depicted below, including the technology used for connecting each other.

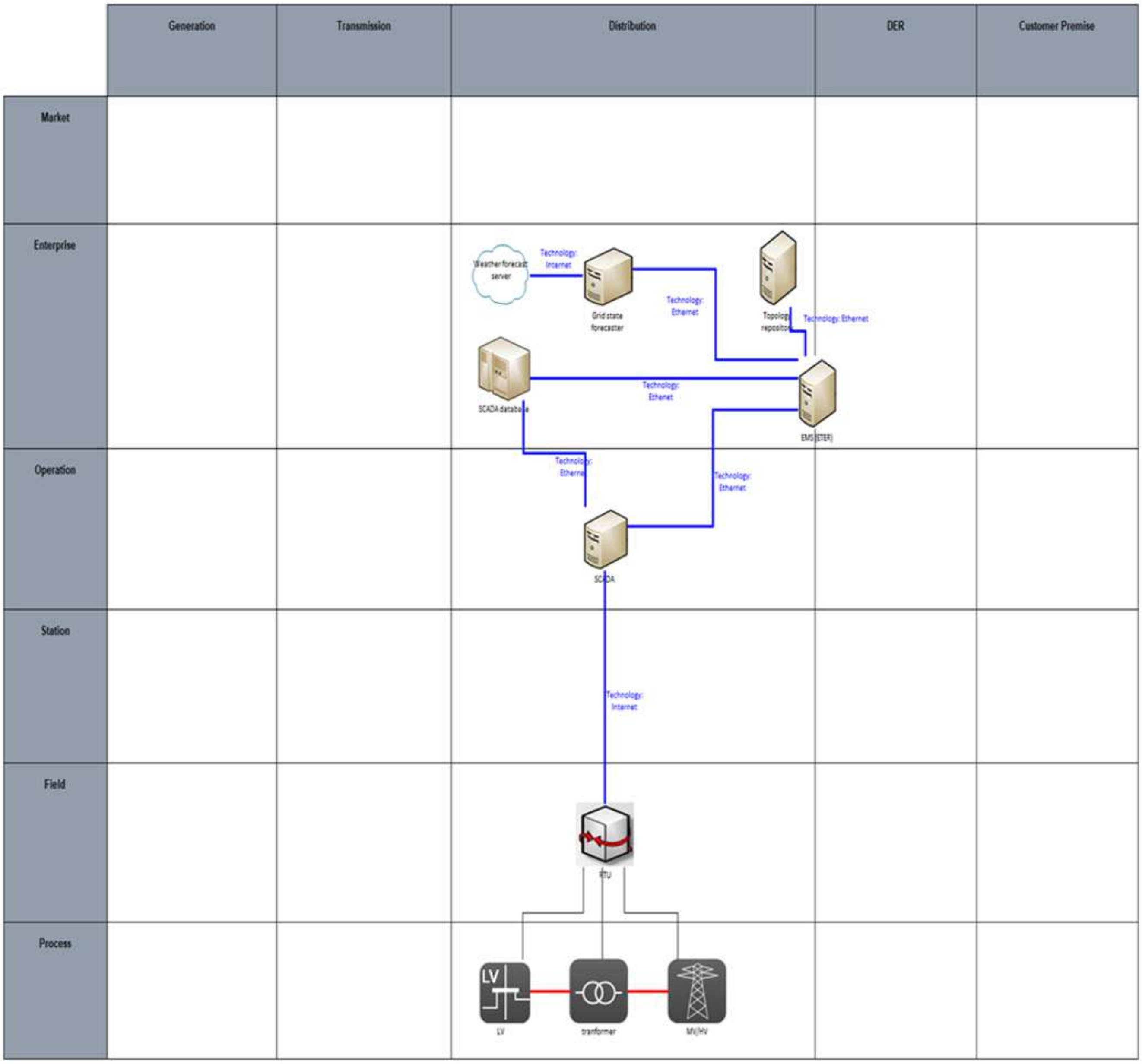

Figure 24. UC 1.1 Component Layer

Table 12. List of Components linked with UC 1.1

Component	Component Type
LV assets, transformer, MV/HV grid, RTU, SCADA database, Topology repository	device
SCADA, EMS (ETER), Weather Forecast Server	system
Grid state forecaster	Software application

5.2 UC 1.2: Application of NILM for consumer's energy awareness

5.2.1 Use Case Description

Capturing the data from smart meters, the NILM will analyse the consumption of the linked meter and will disaggregate the consumption into the main consumption devices. The focus will be put on the main appliances like HVAC, lighting, refrigerator, TV, washing machine, dishwasher, dryer and electric boiler. The NILM algorithms may be embedded into IoT smart devices (mainly smart meters) or deployed in the cloud in order to run.

The goal is to identify and analyse the energy consumption patterns of customers to facilitate the reduction of their energy consumption and detect anomalies that may mean an incorrect functioning of an asset. Linked to this, this NILM functionalities will also be the basis for estimating the actual Energy Efficiency Label of the asset based on EU regulation 2021/340 of 17 December 2020.

5.2.2 Function Layer

The functional layer of UC 1.2 is presented in the following graph highlighting the key actors of the use case.

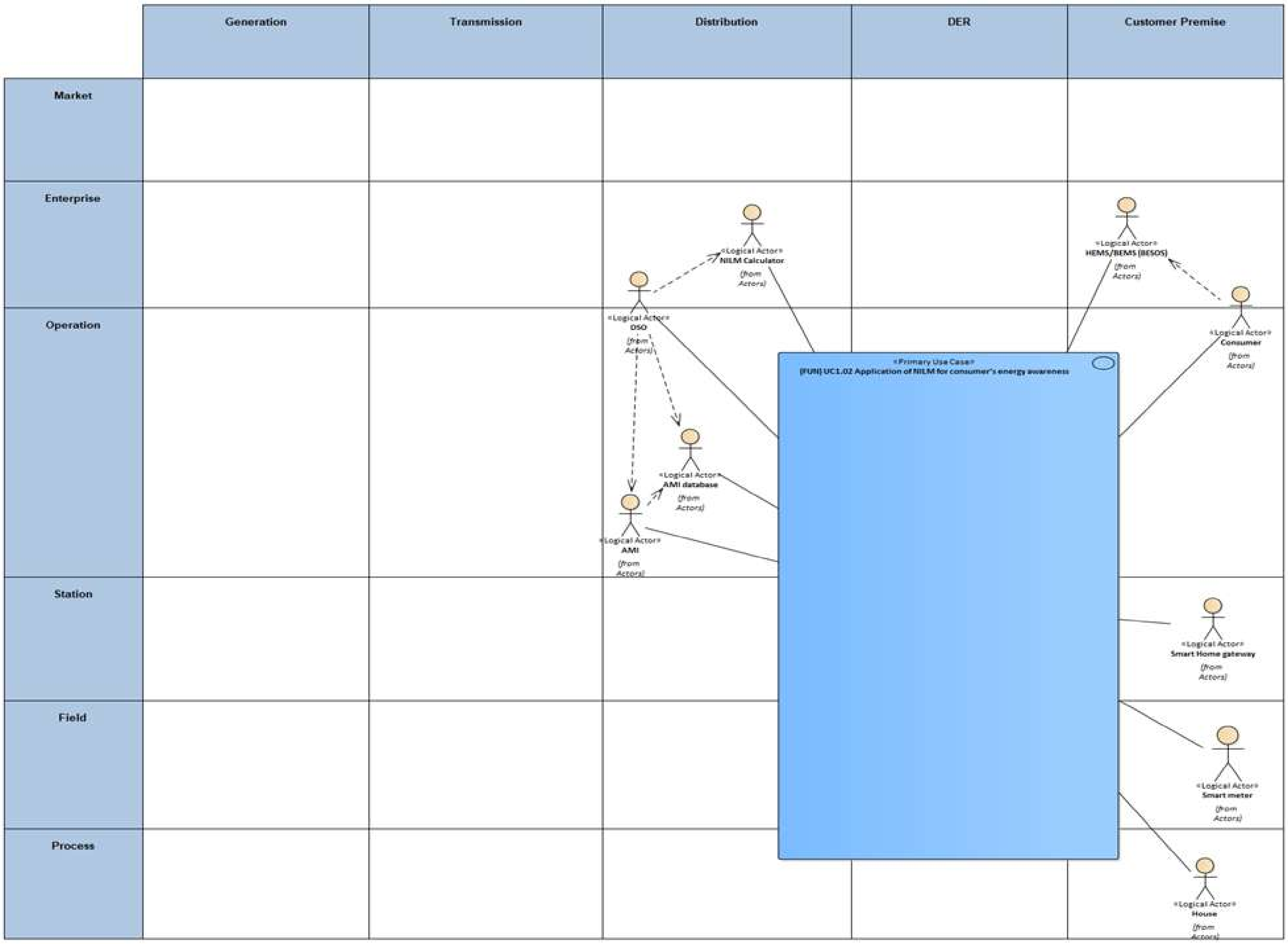

Figure 25. UC 1.2 Function layer

Table 13. List of actors involved in UC 1.2

Actor Name	Actor Type
DSO	Organization
NILM Calculator	Software Application
AMI database	Device
AMI	System
HEMS/BEMS (BESOS)	System
Consumer	Person
Smart Home gateway	Device
Smart meter	Device
House	Device

5.2.3 Information layer

Details about information layer of UC1.2 are presented in the following figure, highlighting the key information objects.

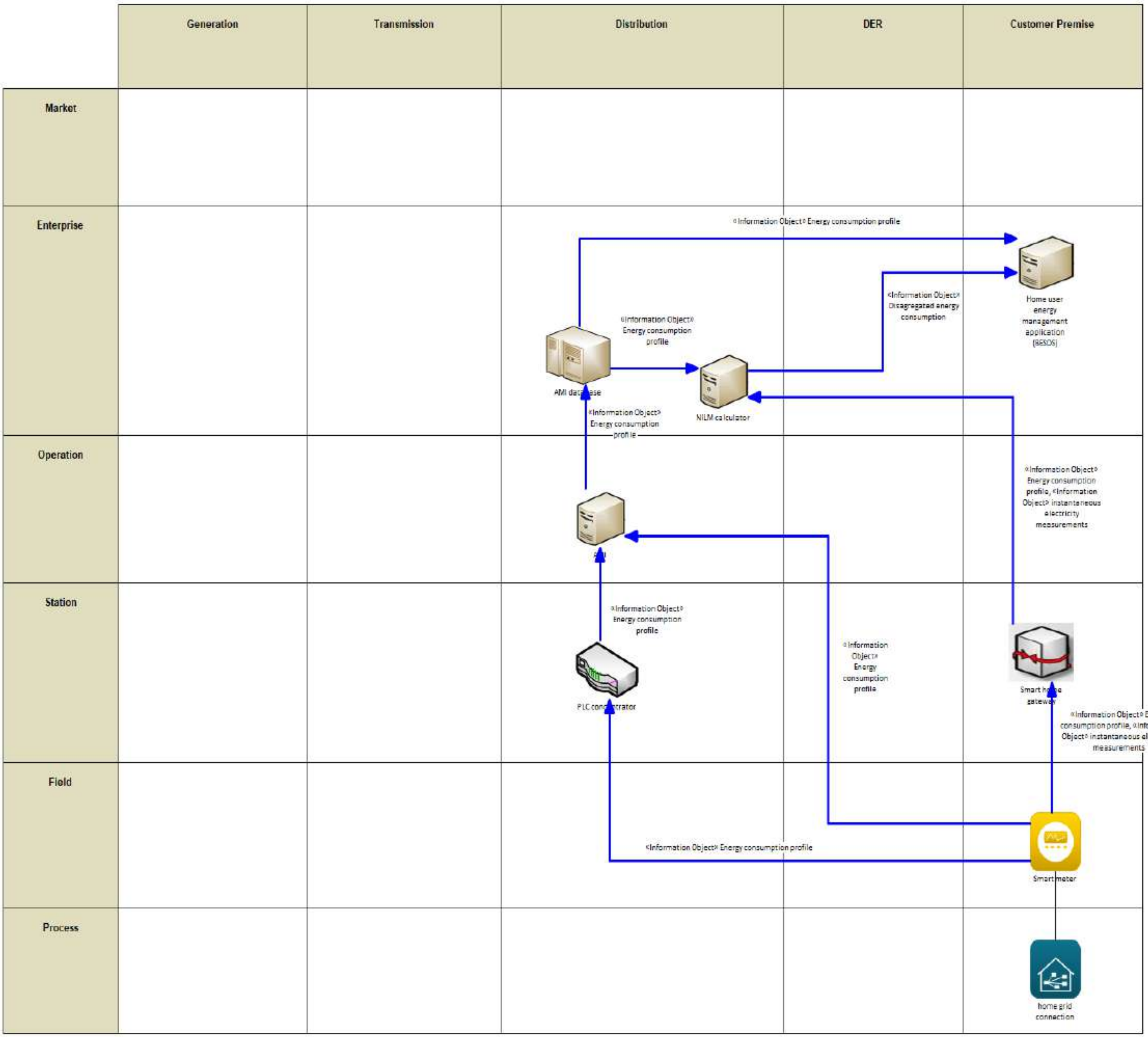

Figure 26. UC 1.2 Information layer

5.2.4 Canonical Data Model

The identified canonical data models for UC1.2 are described below.

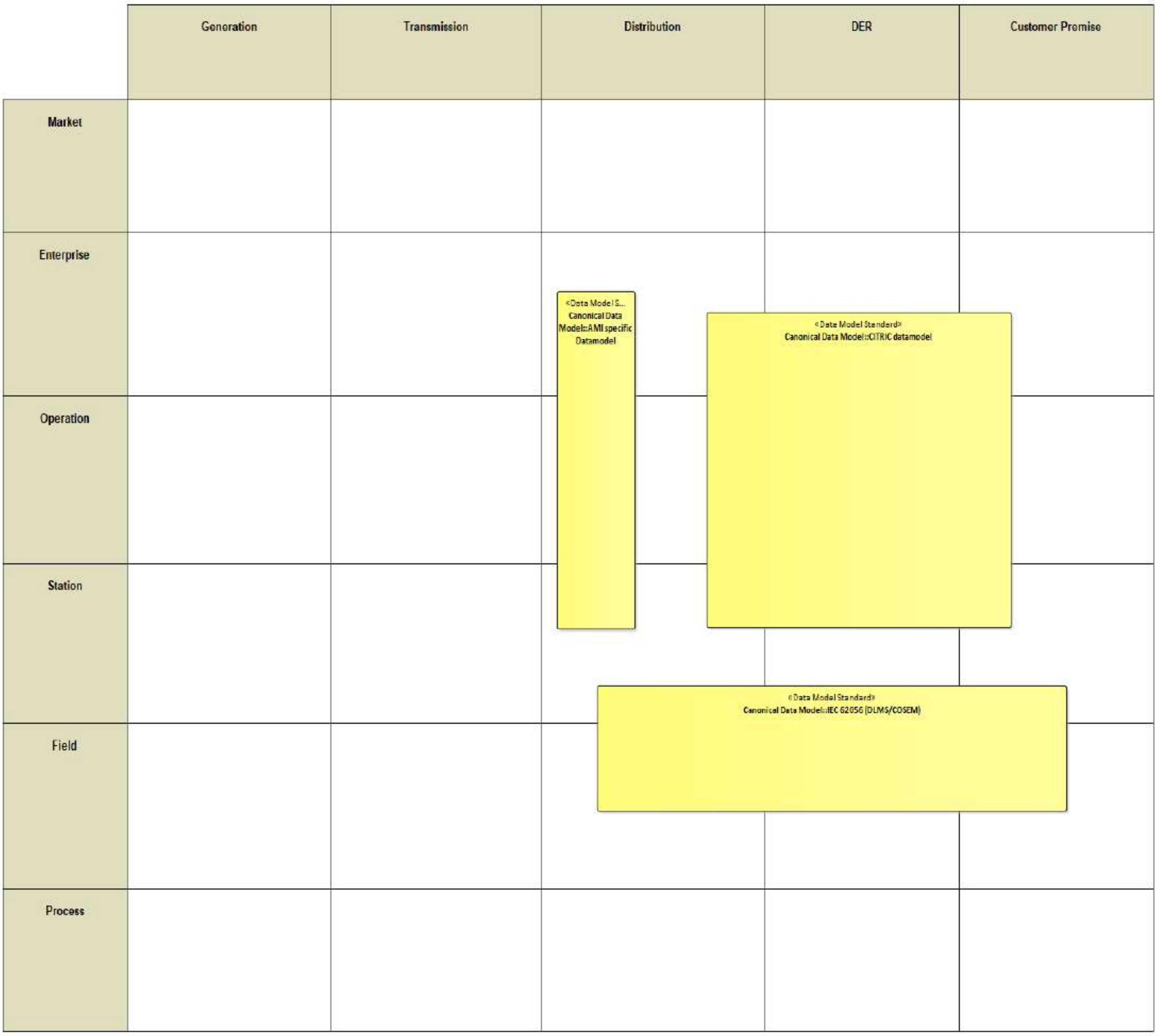

Figure 27. UC 1.2 Canonical data model

Table 14. UC 1.2 Data Models

Data Models
AMI specific data model
CITRIC data model
EC 62056 (DLMS/COSEM)

5.2.5 Standards and Information Object Mapping

SGAM Standards and Information Objects Mapping for UC1.2 is presented in the following figure.

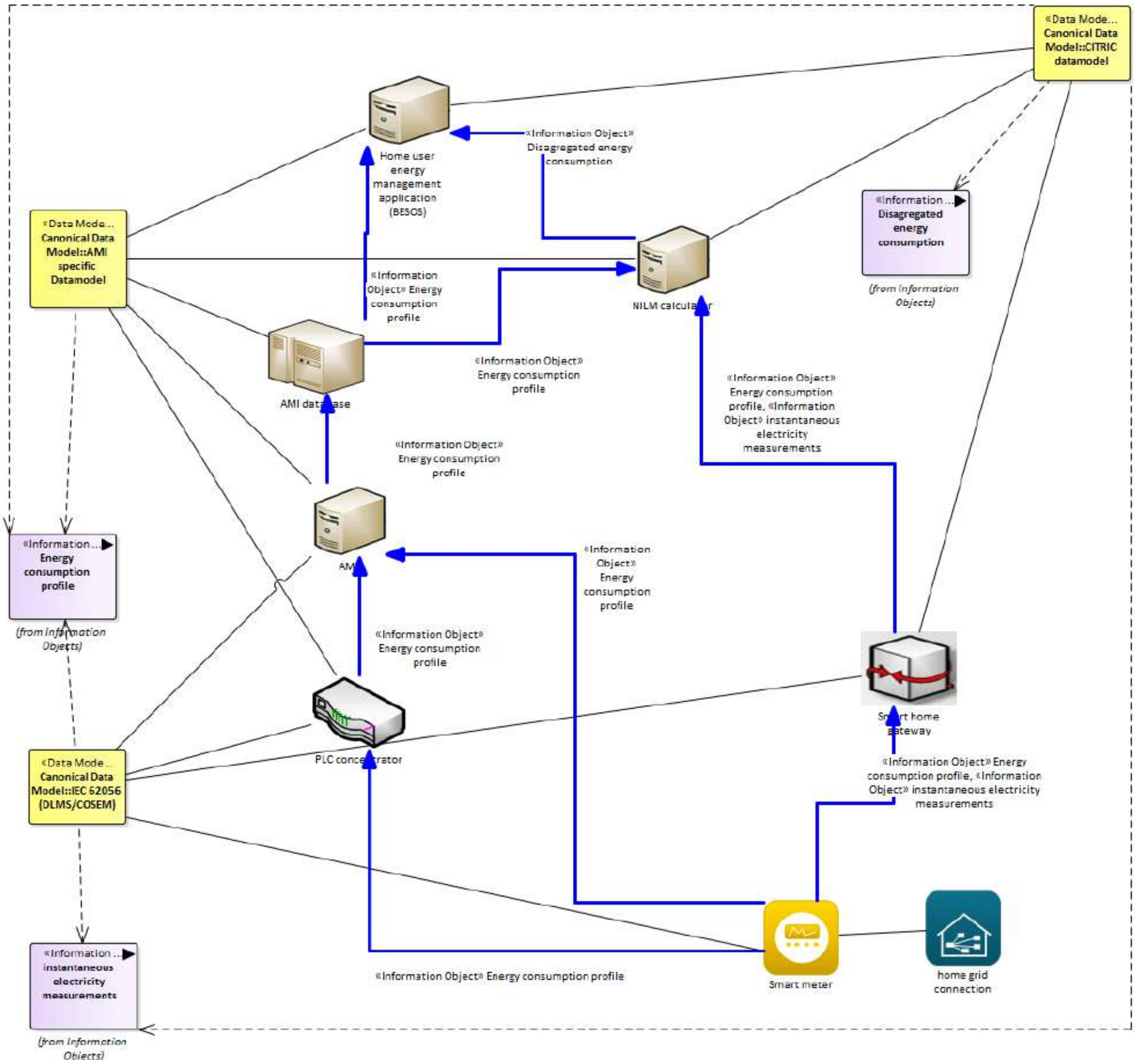

Figure 28. UC 1.2 Standards and Information Object Mapping

Table 15. List of Information Objects, link with Data Standards in UC 1.2

Information Object	DATA Models	Information
Instantaneous electricity measurements	EC 62056 (DLMS/COSEM), CITRIC data model	Electricity consumption measurements sampled with high resolution
Energy consumption profiles	EC 62056 (DLMS/COSEM), AMI specific data model, CITRIC data model	Energy consumption of household.
Disaggregated energy consumption	CITRIC data model	Energy consumption disaggregated per appliance.

5.2.3 SGAM Activity Diagram

The detailed activity diagram for UC 1.2 is presented in the following figure.

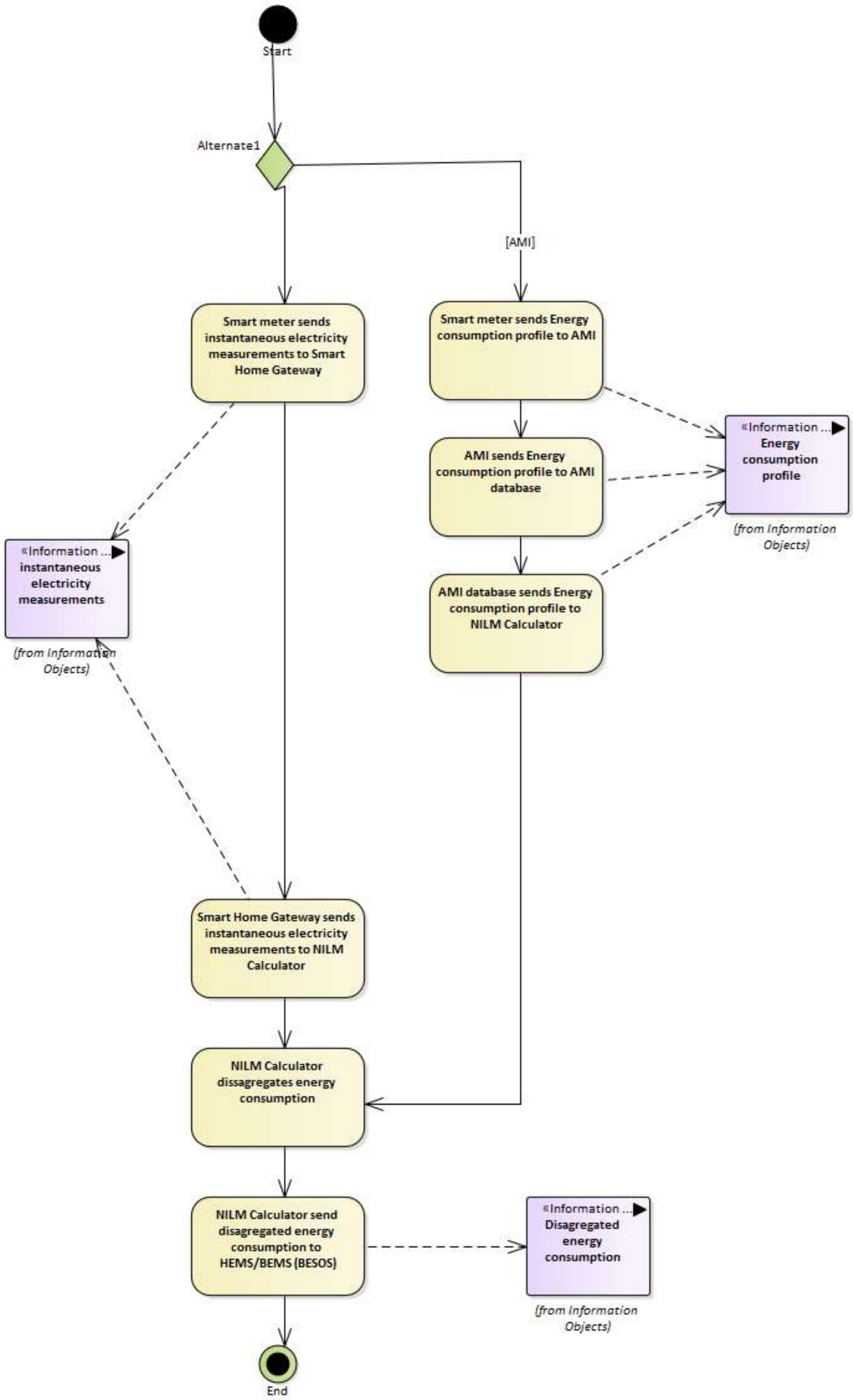

Figure 29. UC 1.2 Activity Diagram

5.2.6 Sequence Diagram

The detailed sequence diagram for UC 1.2 is presented in the following figure.

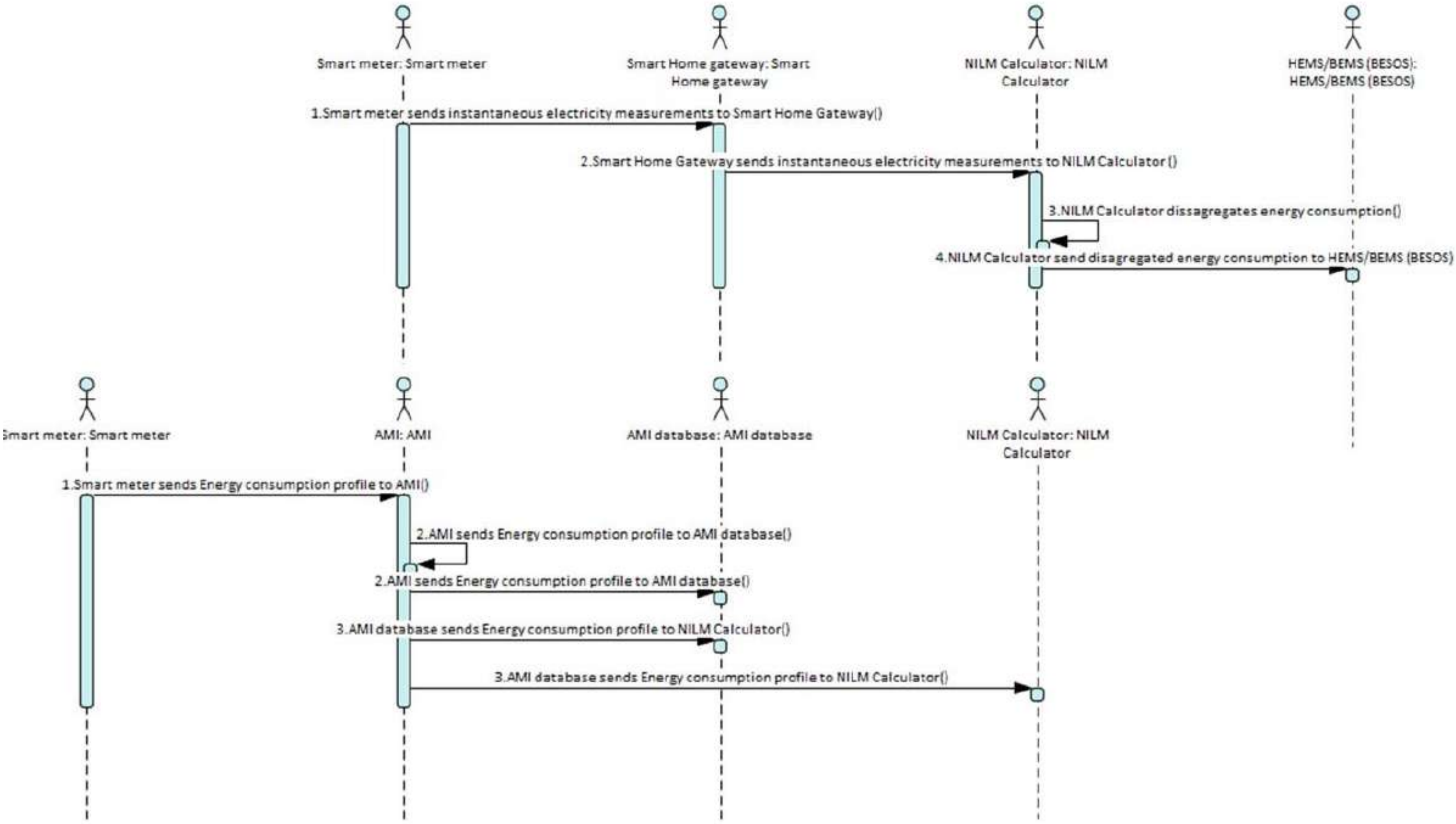

Figure 30. UC 1.2 Sequence Diagram

5.2.7 Communication Layer

The communication layer of UC 1.2 is presented in the following figure, highlighting the key communication protocols among the different modules.

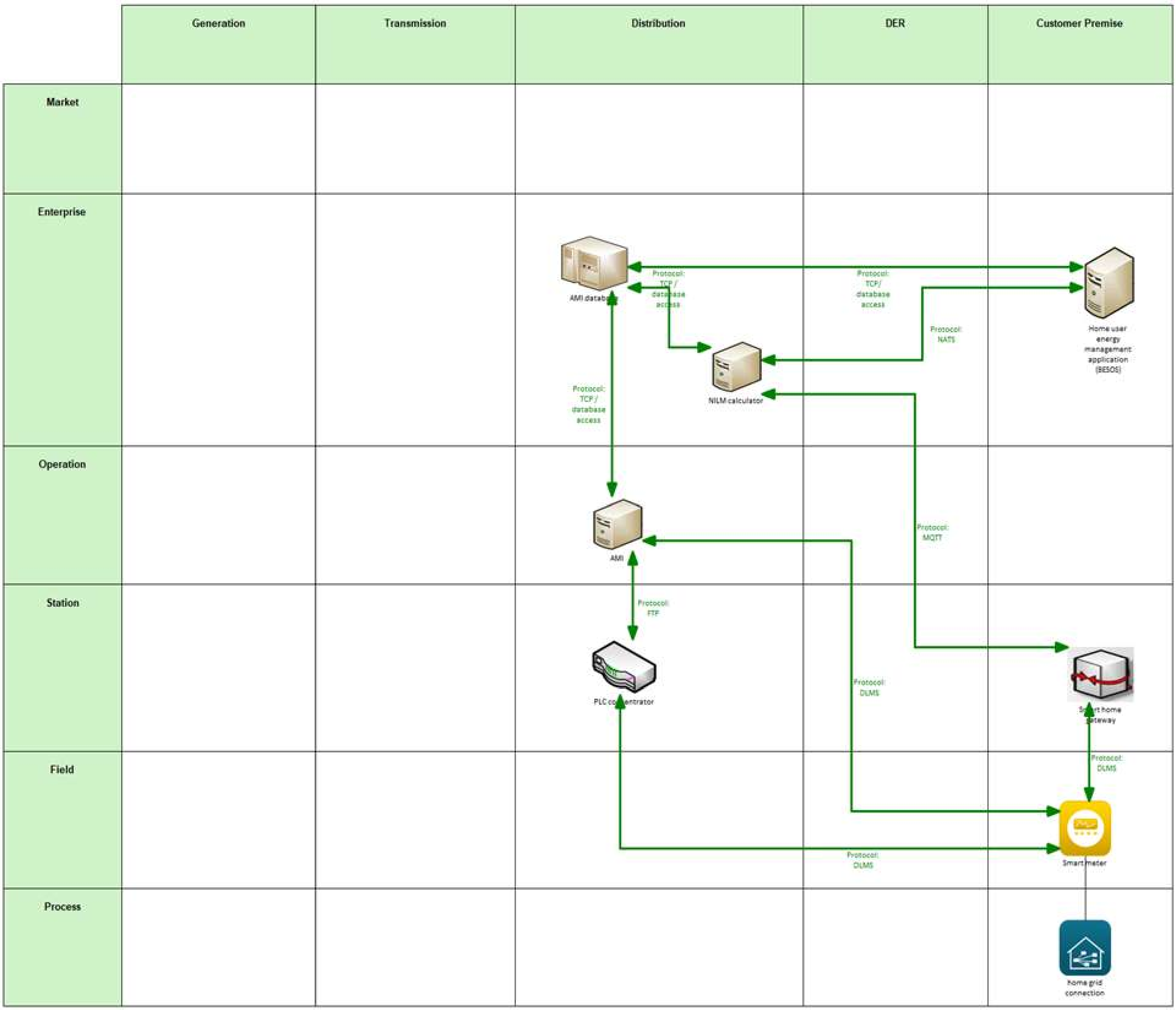

Figure 31. UC1.2 Communication Layer

Table 16. List of Communication technologies linked with UC 1.2

Communication Technology	Description
FTP	The File Transfer Protocol (FTP) is a standard communication protocol used for the transfer of computer files from a server to a client on a computer network. FTP is built on a client–server model architecture using separate control and data connections between the client and the server.
NATS	Neural Autonomic Transport System (NATS) is an open-source messaging system. NATS features a simple, plaintext-based protocol designed for fast and reliable data exchange, segmented in the form of messages.
MQTT	Message Queuing Telemetry Transport. Publish-subscribe message protocol over TCP/IP defined in ISO/IEC PRF 20922 standard. It is designed for connections where network bandwidth is limited and a lightweight messaging mechanism is required.
TCP/IP	Transmission Control Protocol/Internet Protocol. Conceptual model and set of communication protocols used on the Internet. They provide end-to-end data communication, specifying how data should be packetized, addressed, transmitted, routed, and received, through four abstraction layers (link, internet, transport, and application).
DLMS/COSEM	Device Language Message specification/Companion Specification for Energy Metering. Standards for electricity metering data exchanged defined in IEC 62056. DLMS defines the data model specification of the messages, while COSEM includes directives that define the transport and application layers of the DLMS protocol. It is the main global standard for smart energy metering, control and management. It includes specifications for media-specific communication profiles, an object-oriented data model and an application layer protocol.

5.2.8 Component Layer

The components included in the use case are depicted below, including the technology used for connecting each other.

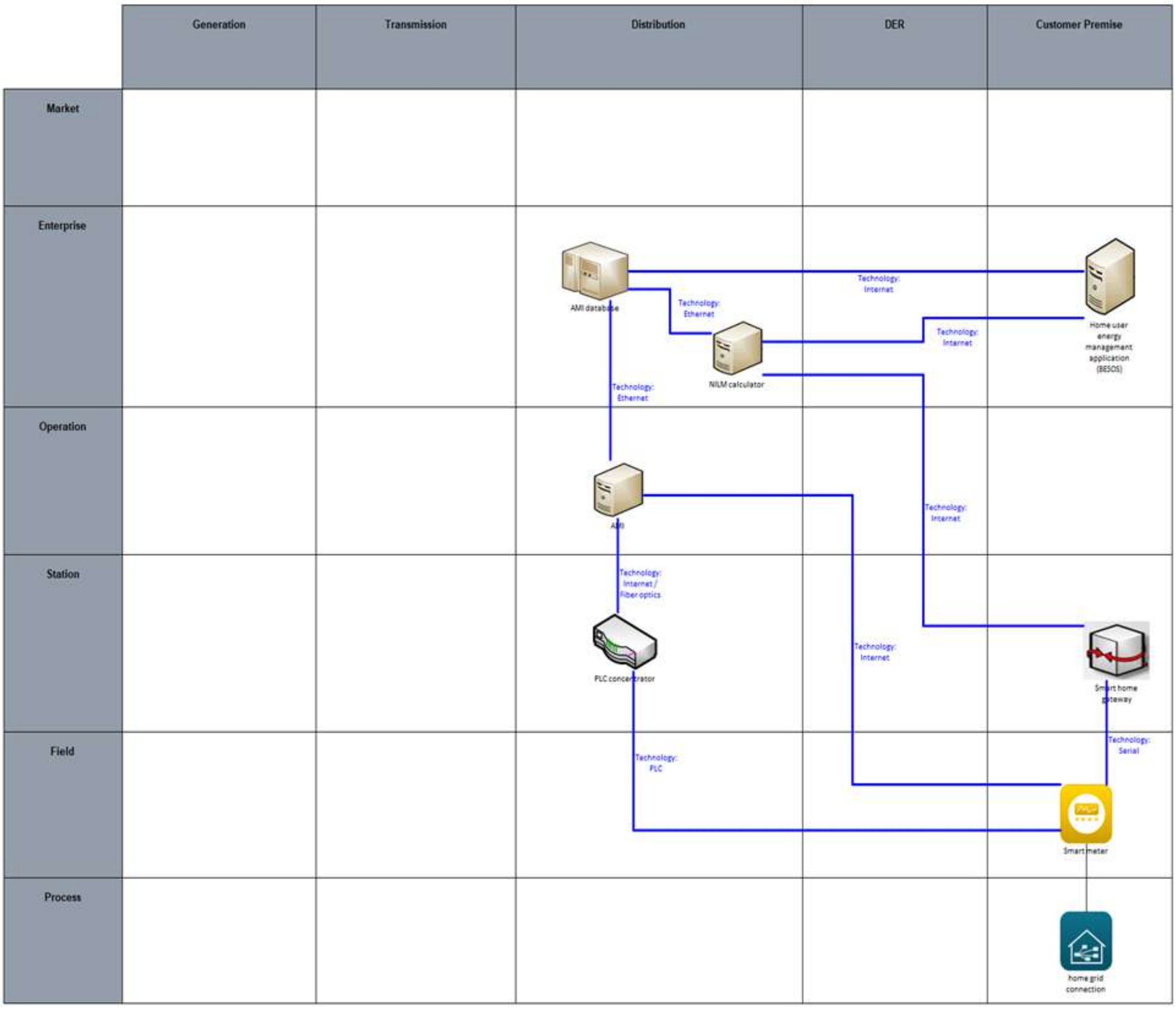

Figure 32. UC1.2 Component Layer

Table 17. List of Components linked with UC 1.2

Component	Component Type
Smart Meter, Smart Home gateway, PLC concentrator, AMI database, home grid connection	Device
AMI	System
HEMS (BESOS)	System
NILM calculator	Software application

5.3 UC 1.3: Utilization of deep learning for state estimation

5.3.1 Use case description

State estimation in OPENTUNITY will consist in solving an optimization problem that processes the available reliable measurements of the network together with the network topology in order to determine the most accurate estimation of the system state. This Use Case is relevant in a scenario where there are measurement losses or measurement errors.

The output of state estimation is typically the voltage magnitude and phase (phase-to-ground voltage phasors) at all the network buses. If the voltage phasors are computed, then - for a given network topology, it is possible to compute all other parameters of interest, such as the power injections and power flows, the current injections and flows, the power losses, etc.

Going beyond traditional mechanisms, this OPENTUNITY's state estimation will use deep learning to model complex relations among the measurements, also including time-series analysis and exogenous variables like calendar, weather prediction, etc.

5.3.2 Function layer

The functional layer of UC 1.3 is presented in the following graph highlighting the key actors of the use case.

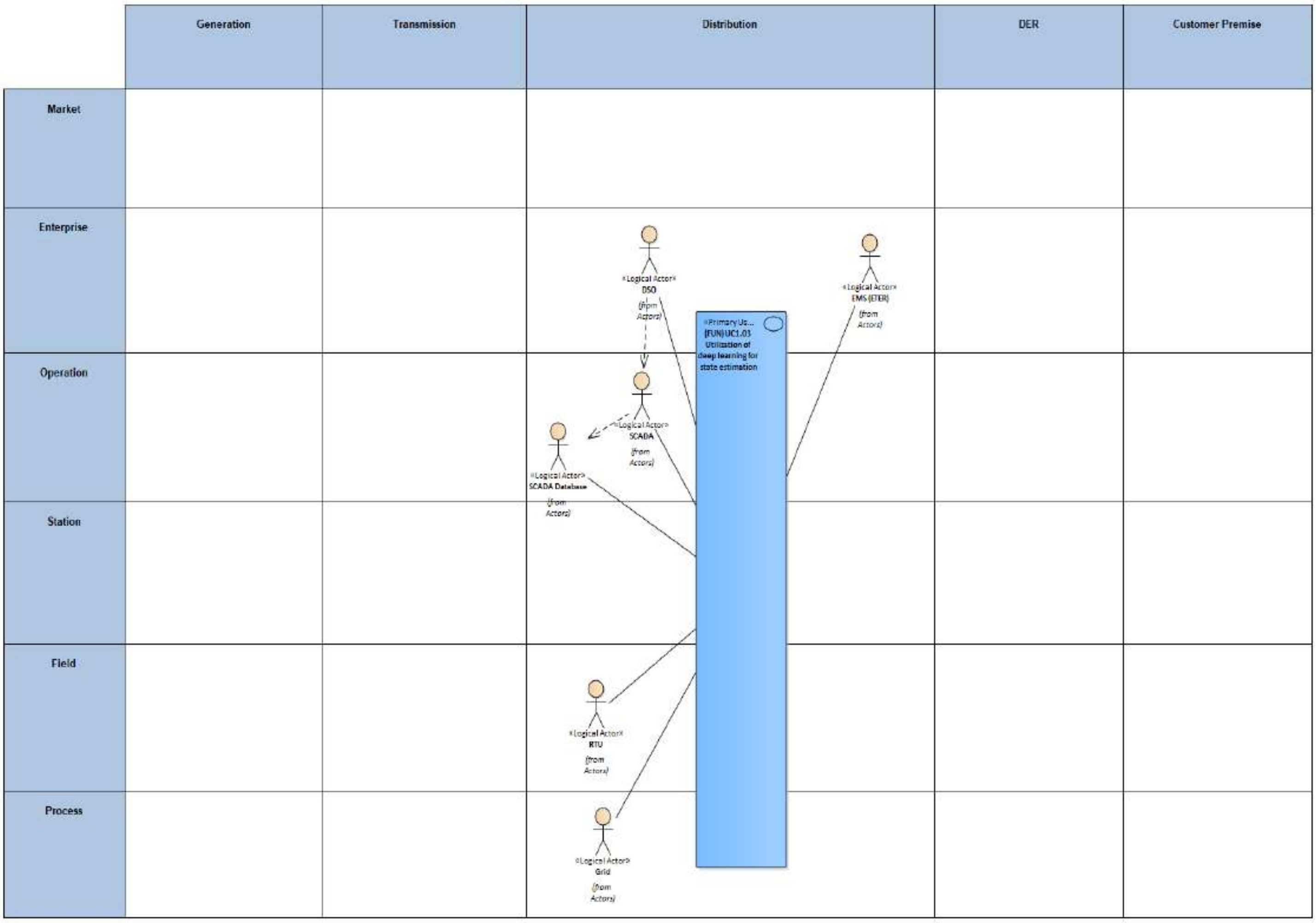

Figure 33 UC 1.3 Function layer

Table 18. List of actors involved in UC 1.3

Actor Name	Actor Type
DSO	Organization
SCADA	System
SCADA Database	Device
EMS (ETER)	System
RTU	Device
Grid	Device

5.3.3 SGAM Information layer

Details about information layer of UC1.3 are presented in the following figure, highlighting the key information objects.

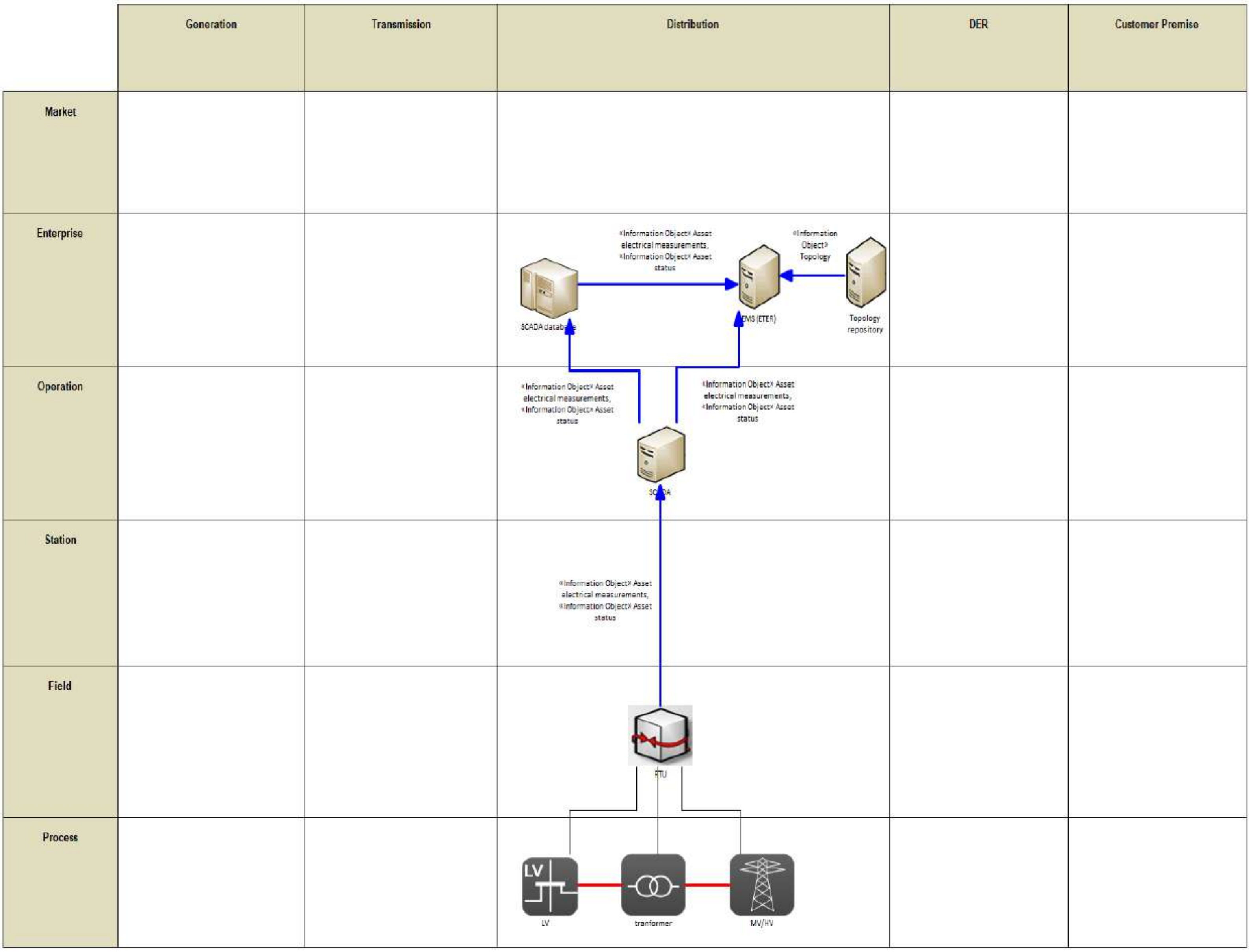

Figure 34. UC 1.3 Information Layer

5.3.4 Canonical Data Model

The identified canonical data models for UC1.3 are described below.

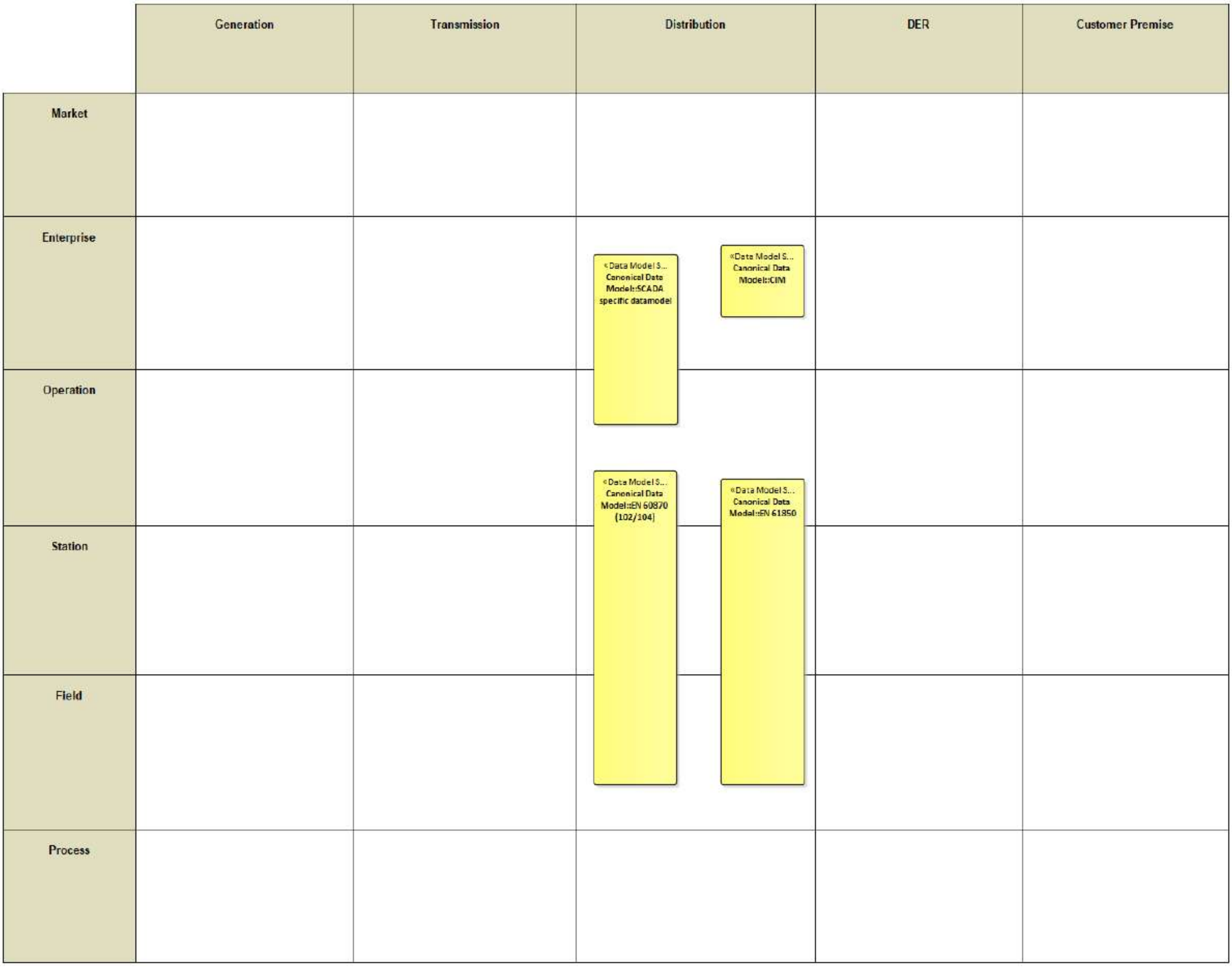

Figure 35 UC 1.3 Canonical data model

Table 19. List of Data models involved in UC 1.3

Data Models
CIM
Scada specific data model
En 60870 (102/104)
EN 61850

5.3.5 Standards and Information Object Mapping

SGAM Standards and Information Objects Mapping for UC1.3 is presented in the following figure.

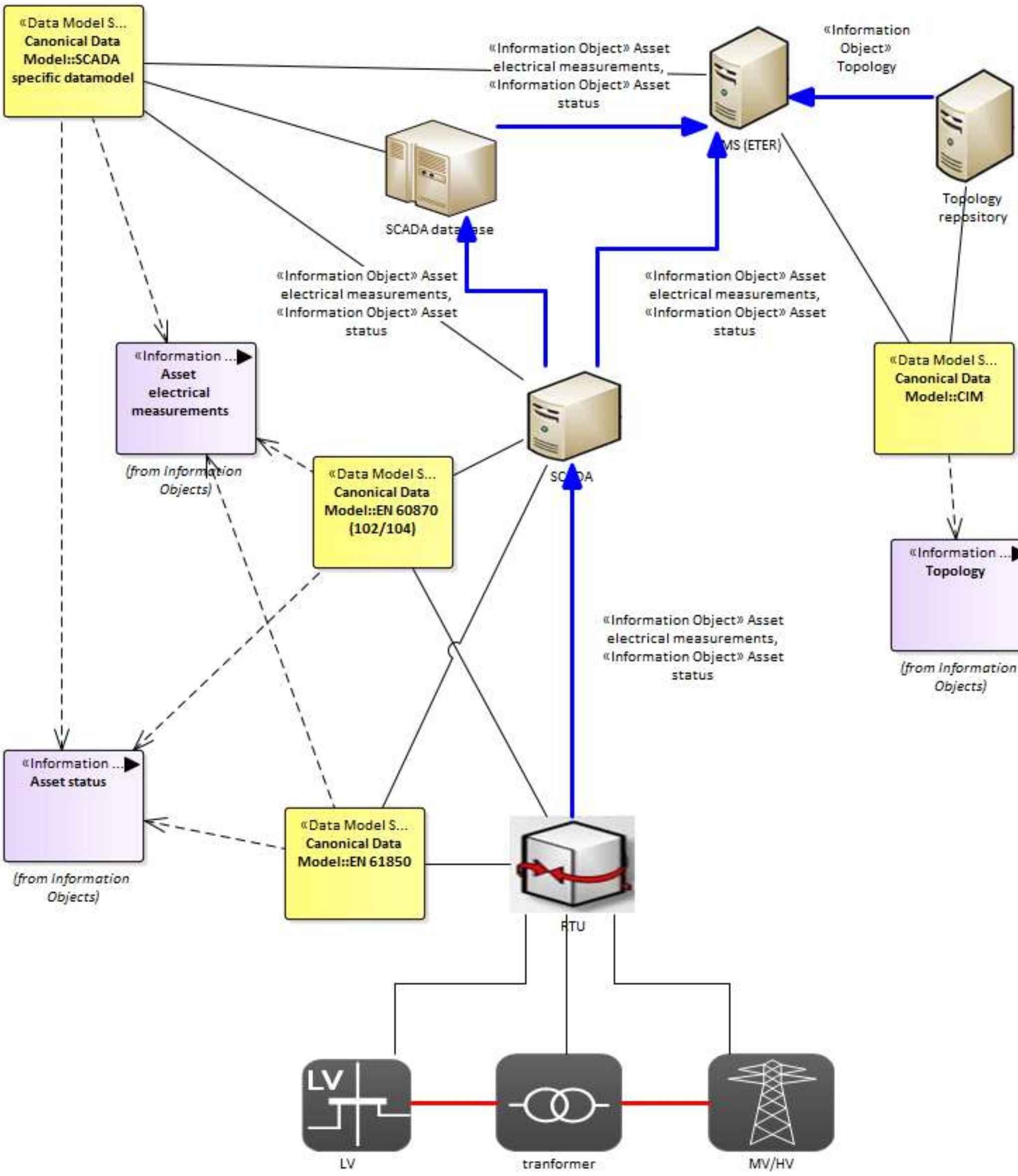

Figure 36. UC 1.3 Standards and Information Object Mapping

Table 20. List of Information Objects, link with Data Standards in UC 1.3

Information Object	DATA Models	Information
Asset Status	Scada specific data model, EN 61850, En 60870 (102/104)	Condition of an asset (on/off)
Assets electrical measurements	Scada specific data model, EN 61850, En 60870 (102/104)	Active power, reactive power, voltage, current, etc
Topology	CIM	Electrical grid topology

5.3.6 Activity Diagram

The detailed activity diagram for UC 1.3 is presented in the following figure.

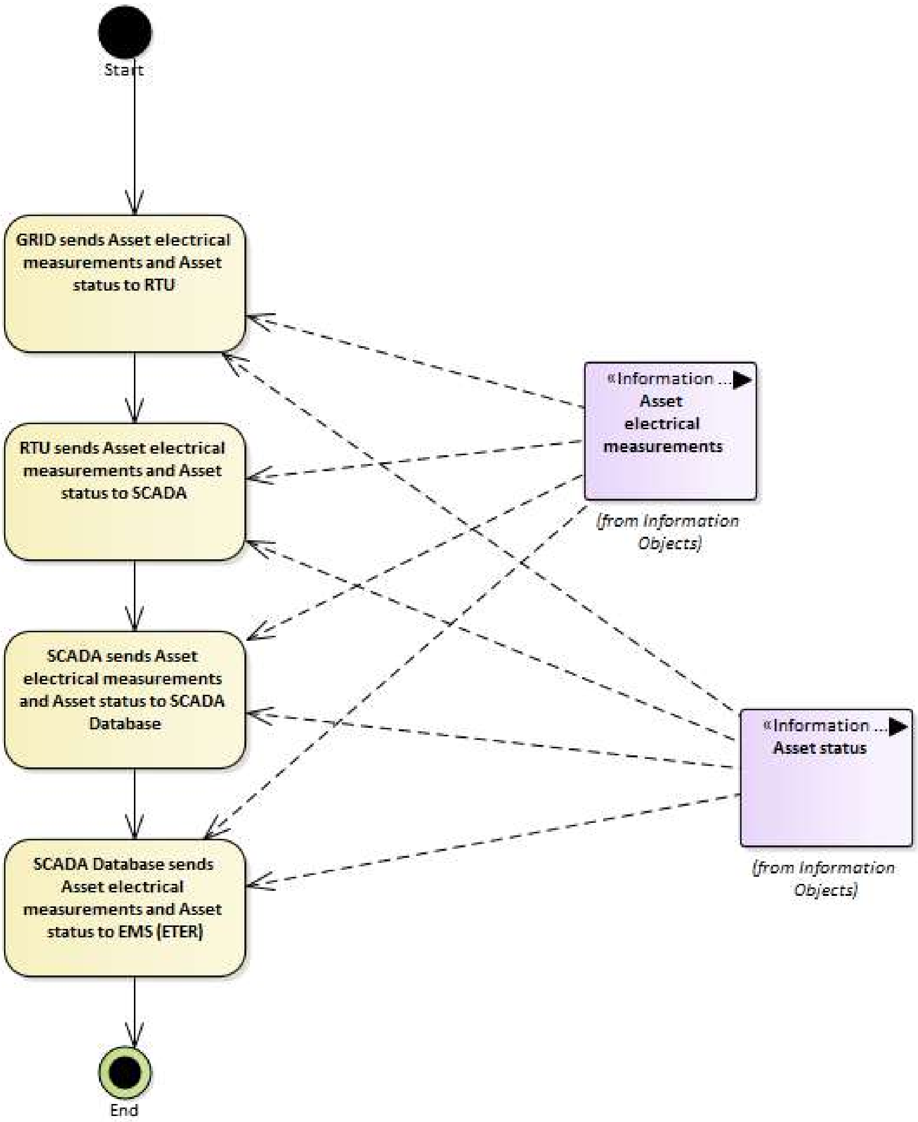

Figure 37. UC 1.3 Activity Diagram

5.3.7 Sequence Diagram

The detailed sequence diagram for UC 1.3 is presented in the following figure.

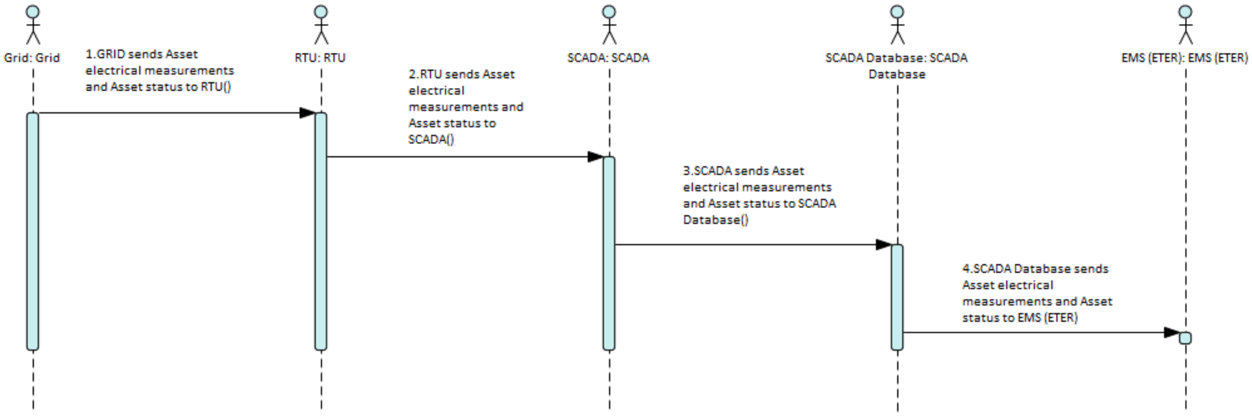

Figure 38. UC 1.3 Sequence Diagram

5.3.8 Communication Layer

The communication layer of UC 1.3 is presented in the following figure, highlighting the key communication protocols among the different modules.

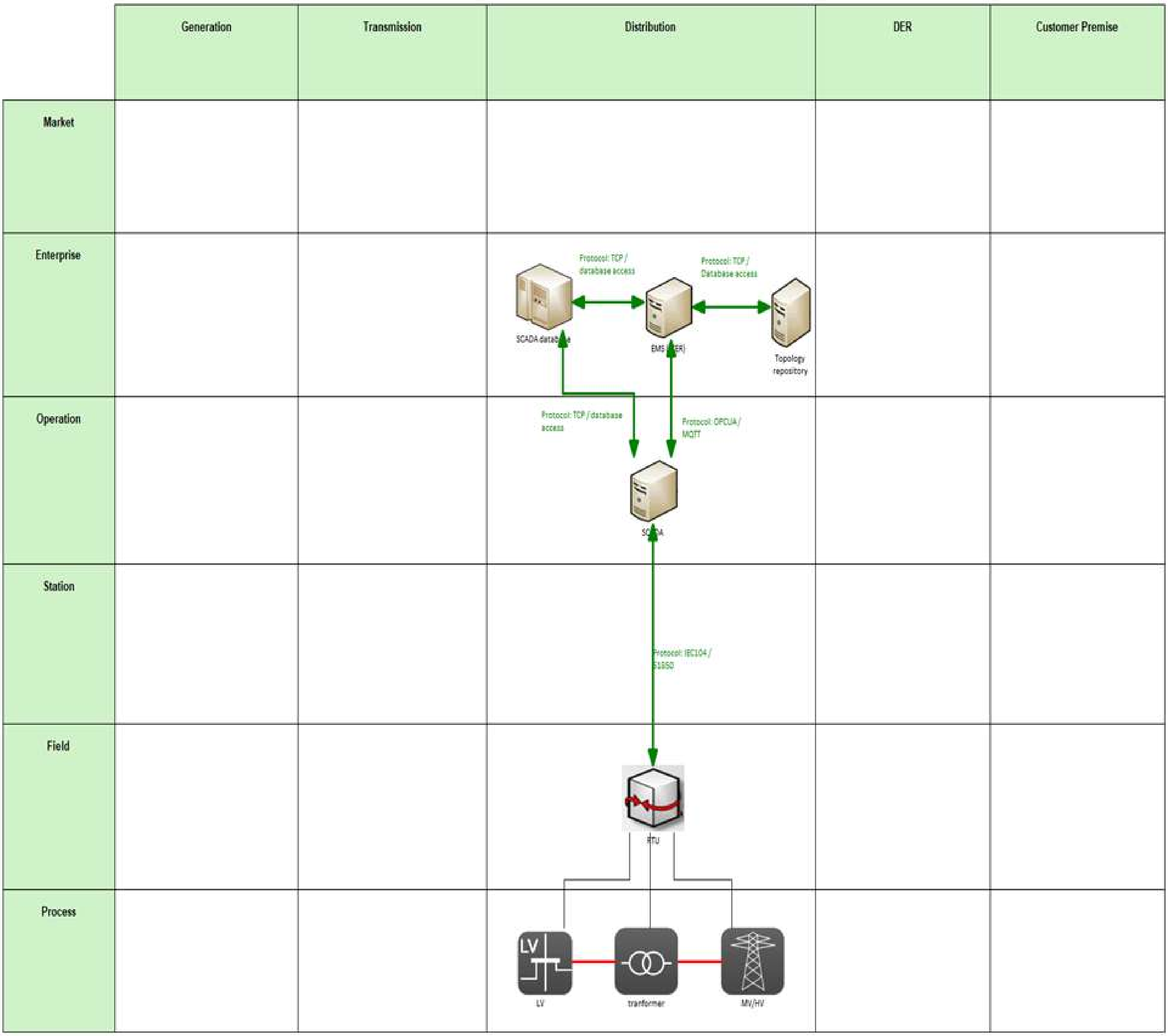

Figure 39. UC1.3 Communication Layer

Table 21 List of Communication technologies linked with UC 1.3

Communication Technology	Description
MQTT	Message Queuing Telemetry Transport. Publish-subscribe message protocol over TCP/IP defined in ISO/IEC PRF 20922 standard. It is designed for connections where network bandwidth is limited and a lightweight messaging mechanism is required.
TCP/IP	Transmission Control Protocol/Internet Protocol. Conceptual model and set of communication protocols used on the Internet. They provide end-to-end data communication, specifying how data should be packetized, addressed, transmitted, routed, and received, through four abstraction layers (link, internet, transport, and application).
IEC104/61850	IEC 104 is a standard telecontrol protocol used for remote control and monitoring of substations, while IEC 61850 is a comprehensive standard for substation automation, covering various aspects such as data modelling, communication services, and system configuration.

5.3.9 Component Layer

The components included in the use case are depicted below, including the technology used for connecting each other.

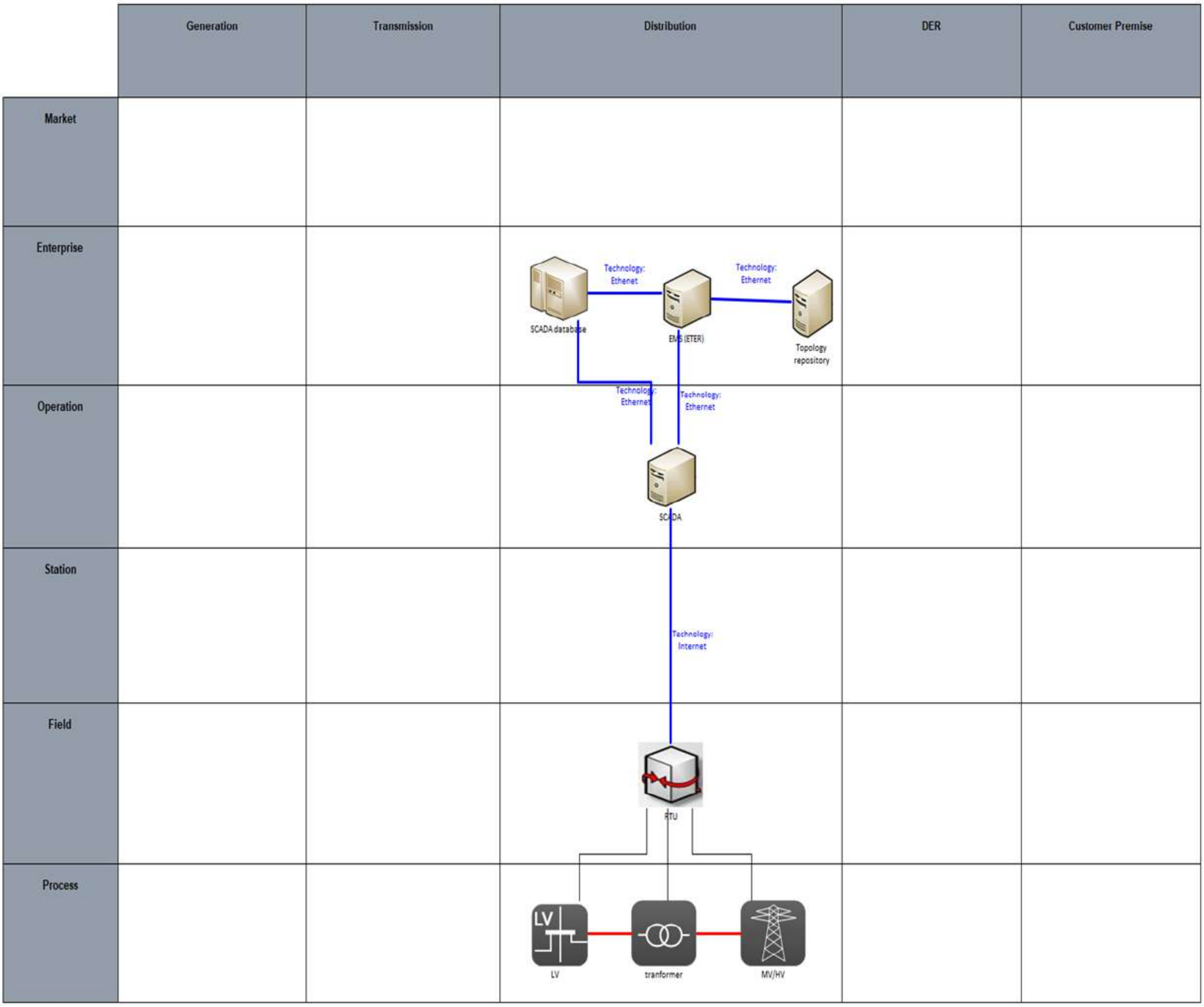

Figure 40. UC1.3 Component Layer

Table 22. List of Components linked with UC 1.3

Component	Component Type
LV assets, transformer, MV/HV grid, RTU, SCADA database, Topology repository	device
SCADA	system
EMS (ETER)	system

5.4 UC 1.4: Real-Time Thermal Rating (RTTR) for capacity calculation of MV lines

5.4.1 Use Case Description

Real-Time Thermal Rating (RTTR) or Dynamic Line Rating (DLR) of overhead lines uses the fact that the capacity of these lines depends on ambient conditions and the lines are designed for high summer weather conditions. As less severe weather conditions exist for most of the year, the capacity of the existing lines can be significantly increased. Therefore, the capacity of a conductor is constantly changing and depends on various factors (mainly related to weather ones such as wind speed, wind direction, solar radiation and ambient temperature).

RTTR offers many applications and benefits to the power system. It reduces congestion in the power system, avoid RES curtailment, improves cost efficiency of the lines and avoids investment in new lines. RTTR proposed in OPENTUNITY will use an indirect approach (non-contact technology) so the major task is to analyse the present conditions and forecast the future weather conditions using available ambient measurements and data coming from other distributed devices.

5.4.2 Function Layer

The functional layer of UC 1.4 is presented in the following graph highlighting the key actors of the use case.

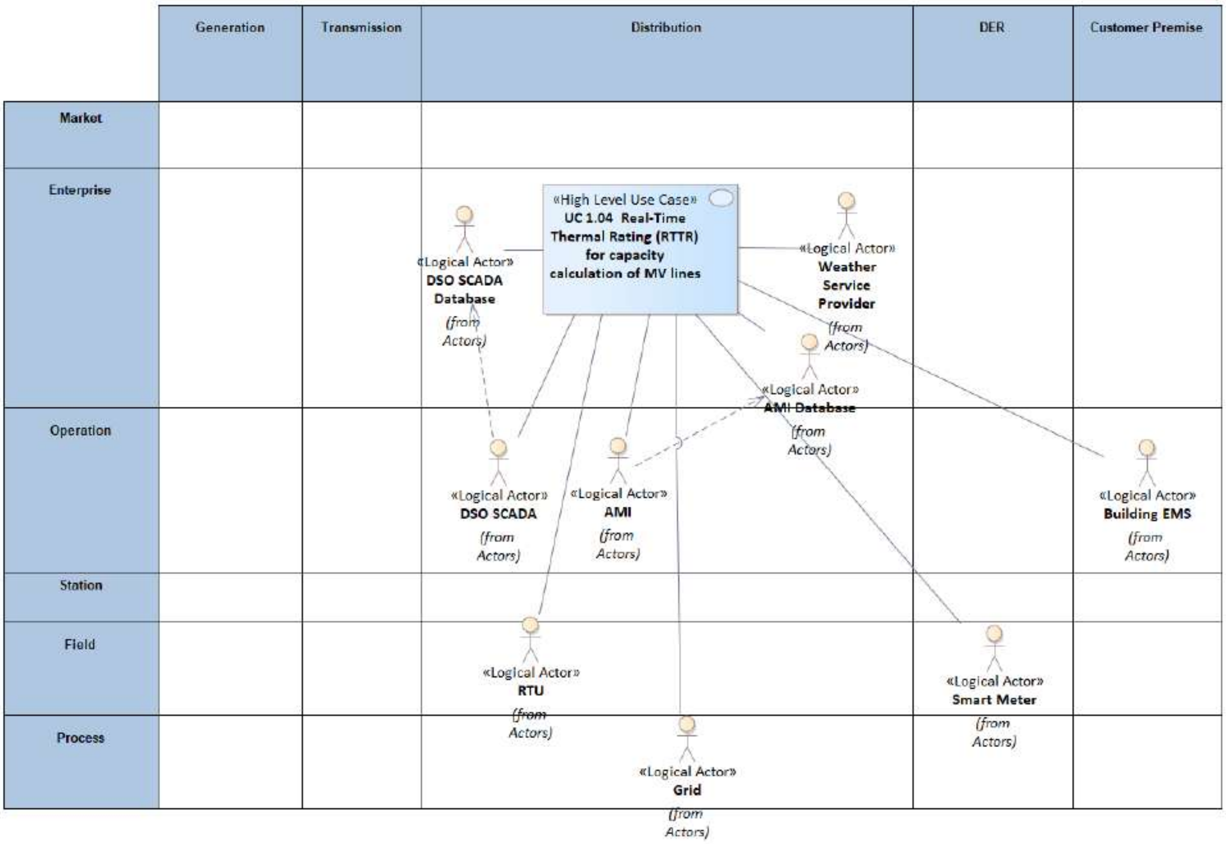

Figure 41. UC 1.4 Function layer

Table 23. List of actors involved in UC 1.4

Actor Name	Actor Type
Weather forecast provider	Organization
SCADA	System
DSO SCADA Database	Device
AMI	System
AMI Database	Device
RTTR software	Software application
DSO	Organization
RTU	Device
Grid	Device
Smart Meter	Device
Building EMS	System

5.4.3 Information Layer

Details about information layer of UC1.4 are presented in the following figure, highlighting the key information objects.

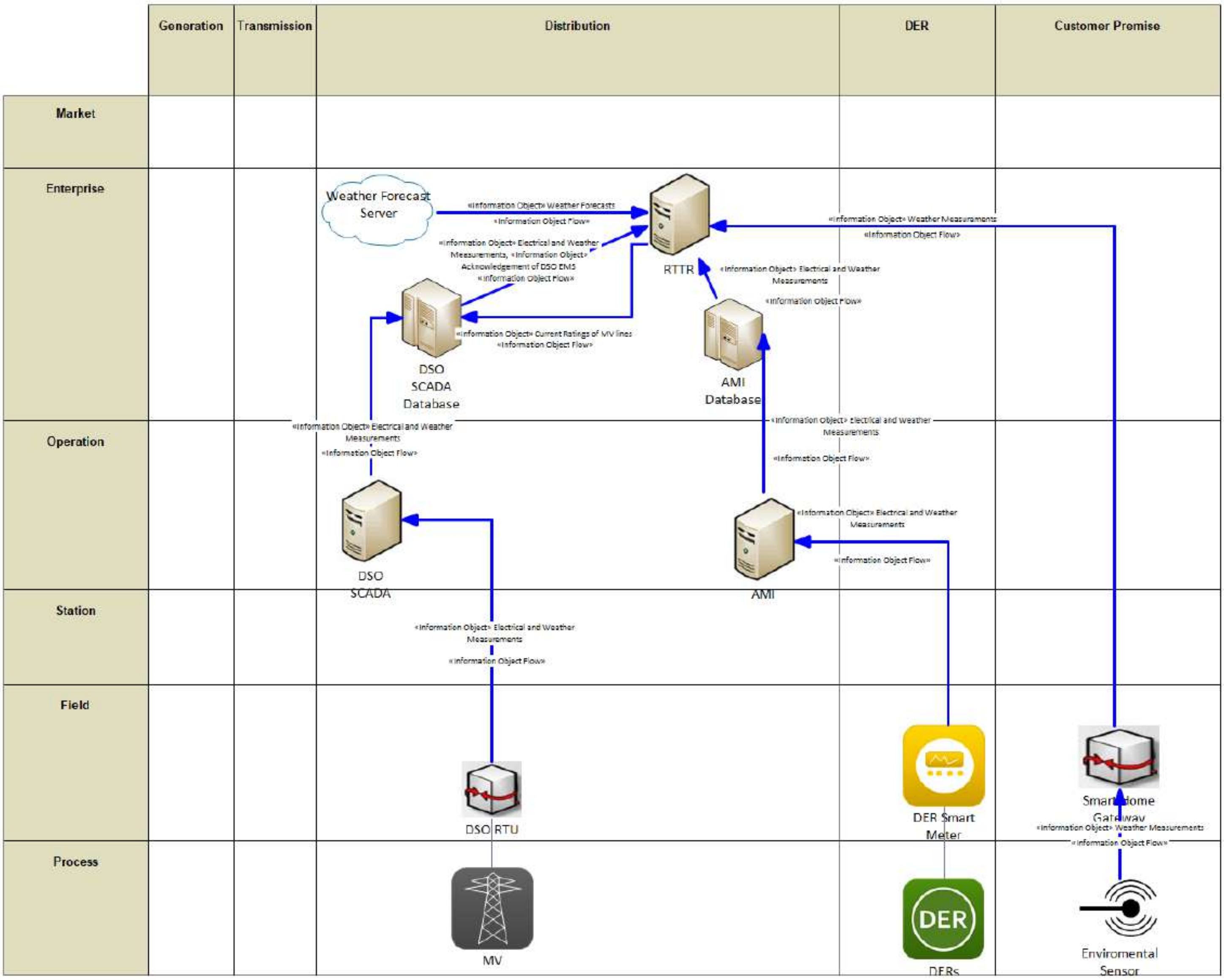

Figure 42. UC 1.4 Information layer

5.4.4 Canonical Data Model

The identified canonical data models for UC1.4 are described below.

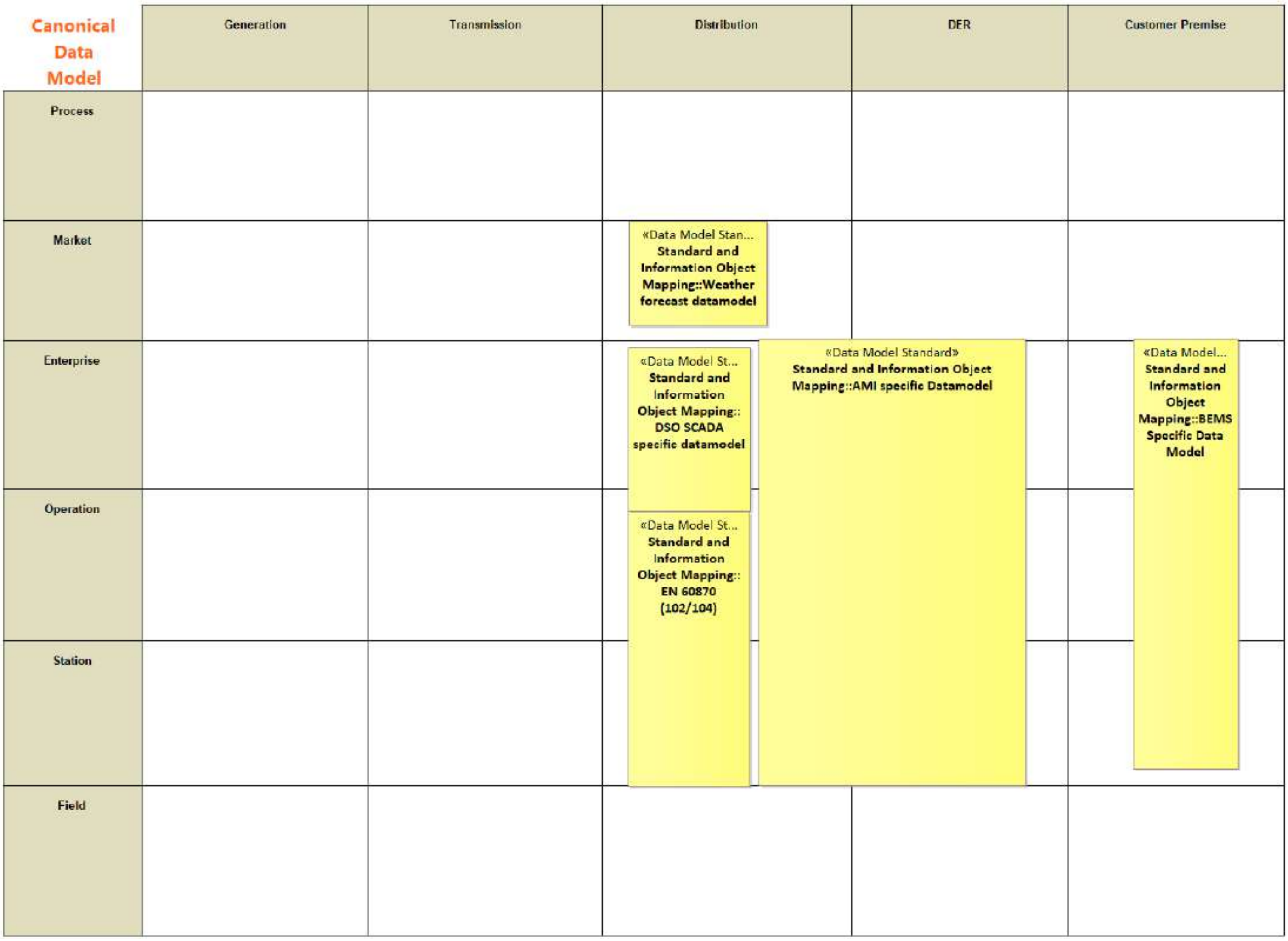

Figure 43. UC 1.4 Canonical data model

Table 24. UC 1.4 Data models

Data Models
Weather forecast data model
CIM
Scada specific data model
En 60870 (102/104)
AMI Specific data model
BEMS specific data model

5.4.5 Standard and Information objects mapping

Data Standards and Information Objects Mapping for UC1.4 are presented in the following figure.

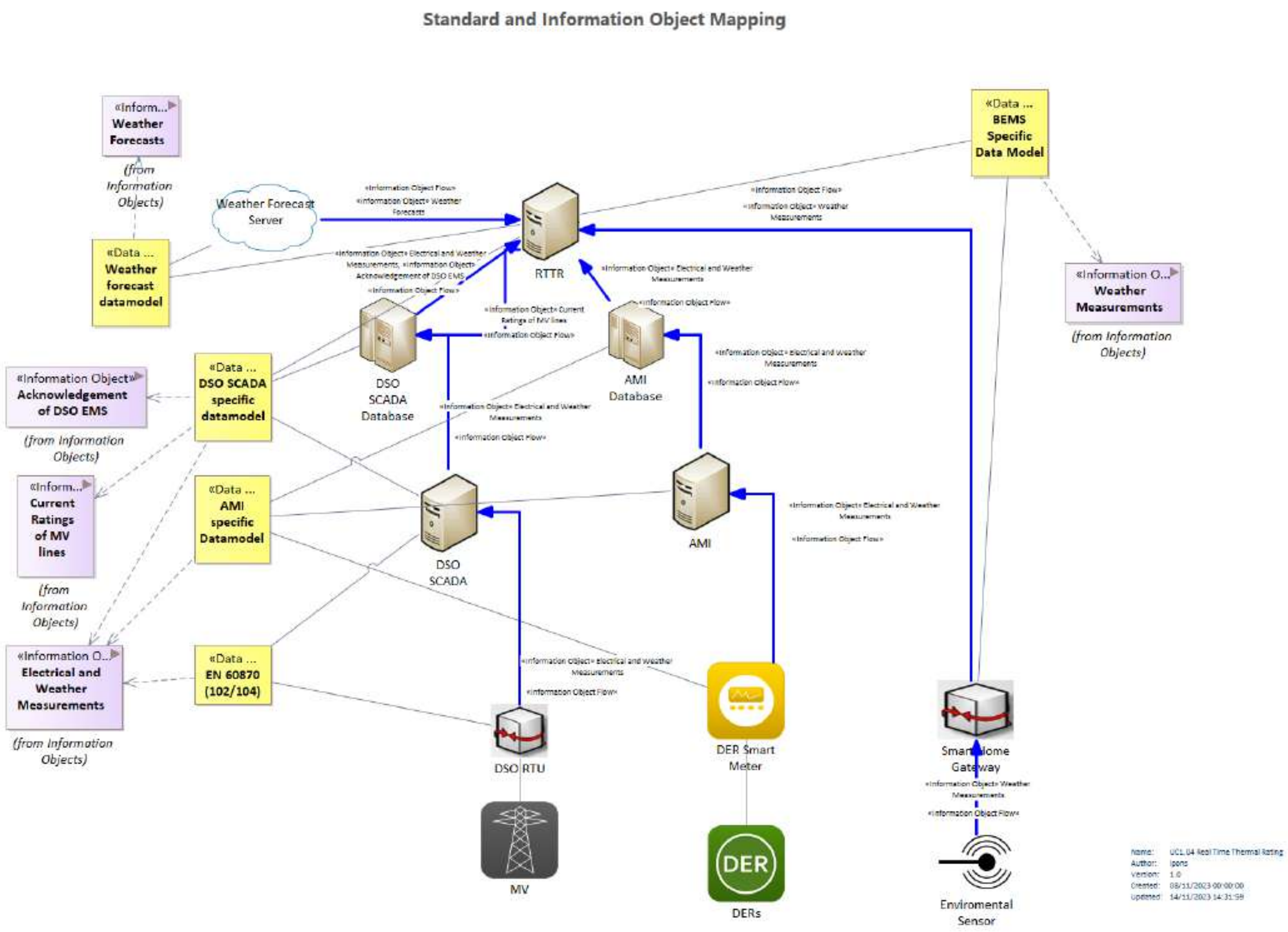

Figure 44. UC 1.4 Standards and Information Objects Mapping

Table 25. List of Information Objects, link with Data Standards in UC 1.4

Information Object	DATA Models	Information
Electrical and weather measurements	DSO Scada specific data model, AMI specific data model, En 60870 (102/104)	voltage, current, active power weather data of sensors on DSO infrastructure
Weather measurements	BEMS specific data model	Weather measurements like ambient temperature, irradiation, wind speed/measured by home automation sensors.
Weather forecasts	Weather forecast data model	Weather data like temperature, irradiation, wind speed and direction.
Acknowledgement of DSO EMS	DSO Scada specific data model	Forecast of grid state in terms of nodes voltages, lines loading
Current Ratings of MV lines	DSO Scada specific data model	Current ratings of MV lines with hourly resolution.

5.4.6 Activity Diagram

The detailed activity diagram for UC 1.4 is presented in the following figure.

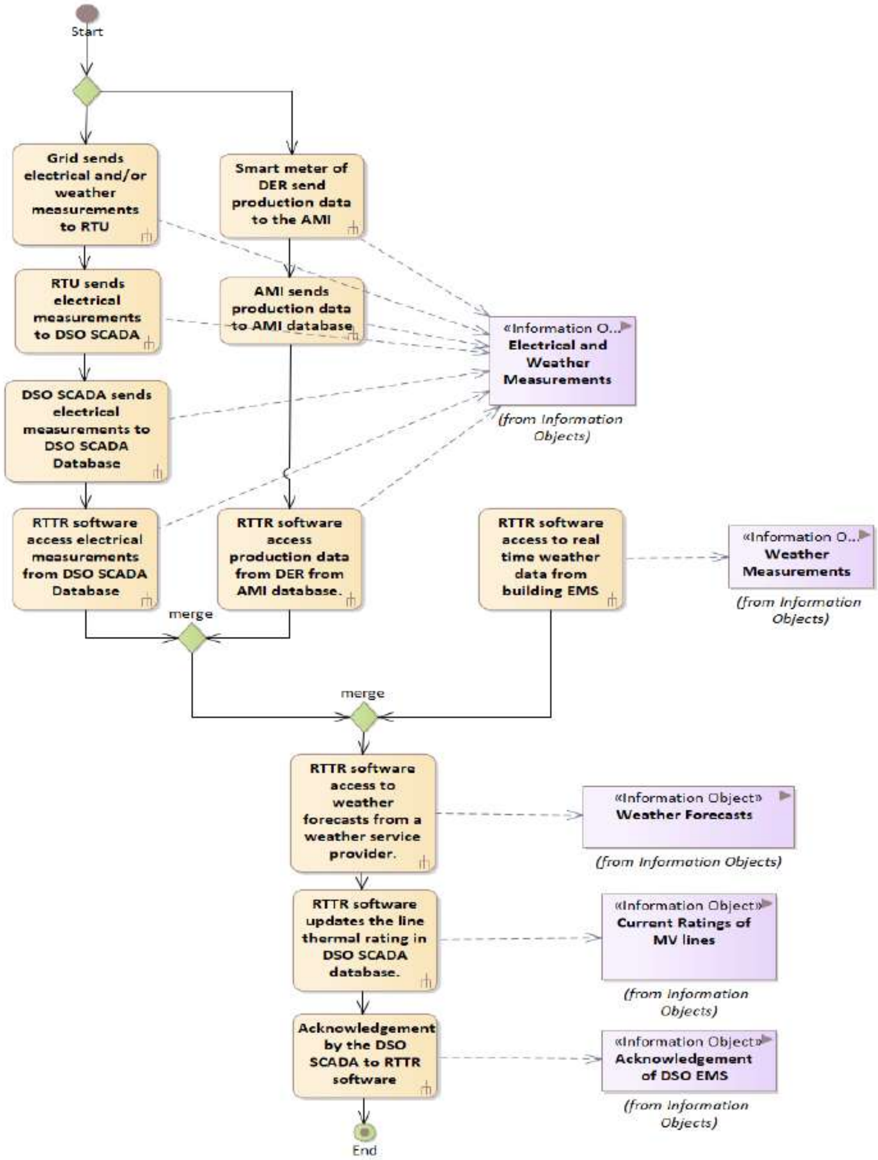

Figure 45. UC 1.4 Activity Diagram

5.4.7 Sequence Diagram

The detailed sequence diagram for UC 1.4 is presented in the following figure.

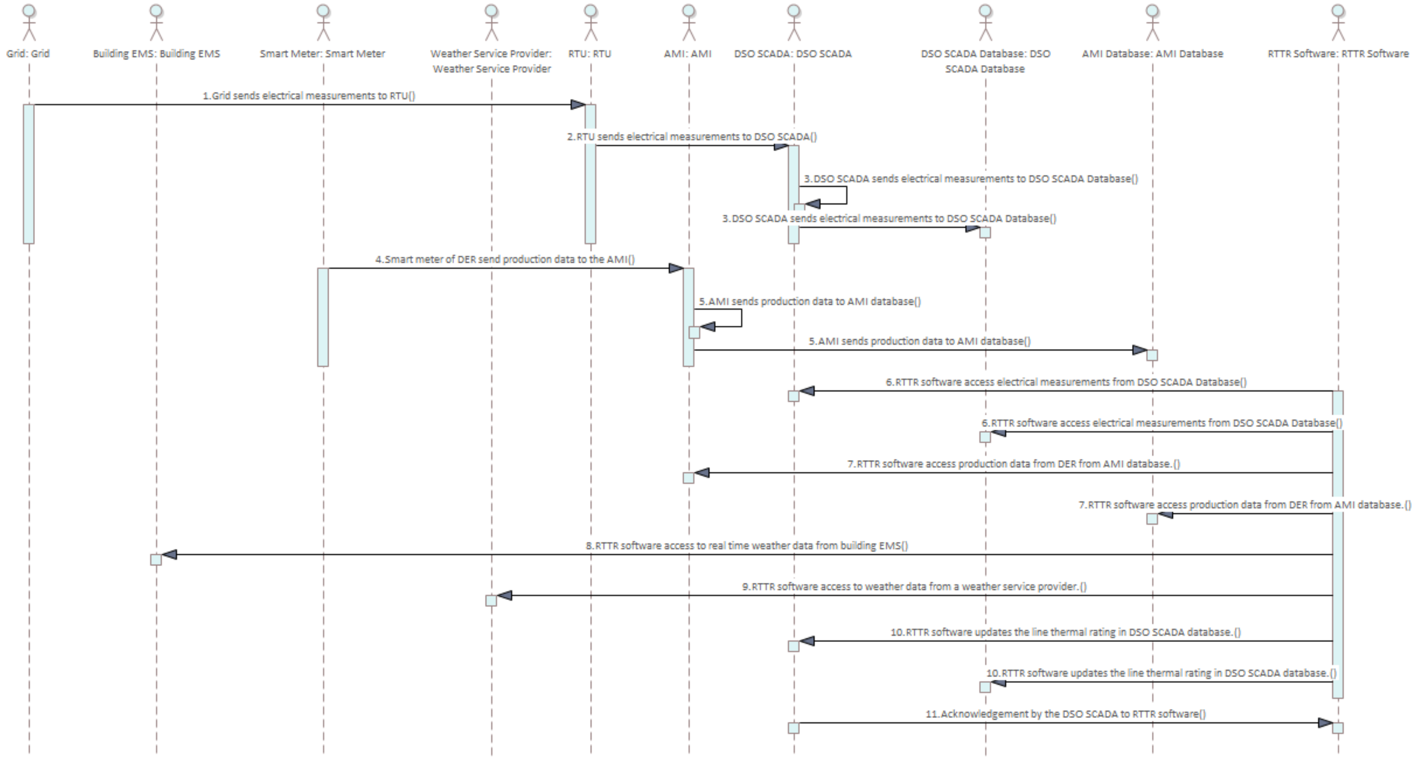

Figure 46. UC 1.4 Sequence Diagram

5.4.8 Communication Layer

The communication layer of UC 1.4 is presented in the following figure, highlighting the key communication protocols among the different modules.

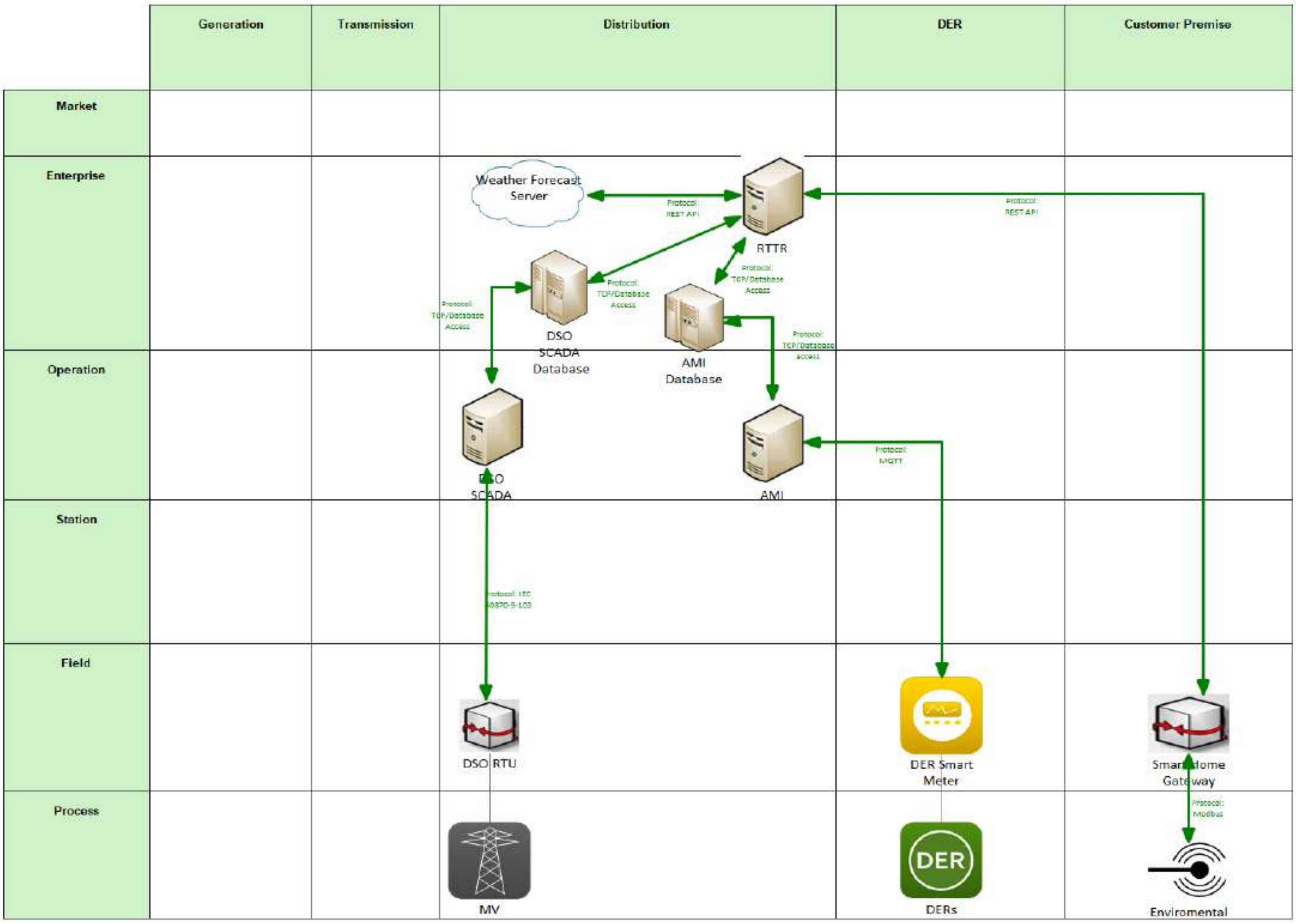

Figure 47. UC1.4 Communication Layer

Table 26. List of Communication technologies linked with UC 1.4

Communication Technology	Description
REST	Representational State Transfer. Set of software constraints for web services, to provide interoperability between computer systems on the Internet. A RESTful web service defines a uniform and predefined set of stateless operations that accept requests through a URI.
MQTT	Message Queuing Telemetry Transport. Publish-subscribe message protocol over TCP/IP defined in ISO/IEC PRF 20922 standard. It is designed for connections where network bandwidth is limited and a lightweight messaging mechanism is required.
TCP/IP (Database Access)	Group of protocols enabling communication between devices in a network up to the transport layer.
IEC 104 / 61850	IEC 104 is a standard telecontrol protocol used for remote control and monitoring of substations.

5.4.9 Component Layer

The components included in the use case are depicted below, including the technology used for connecting each other.

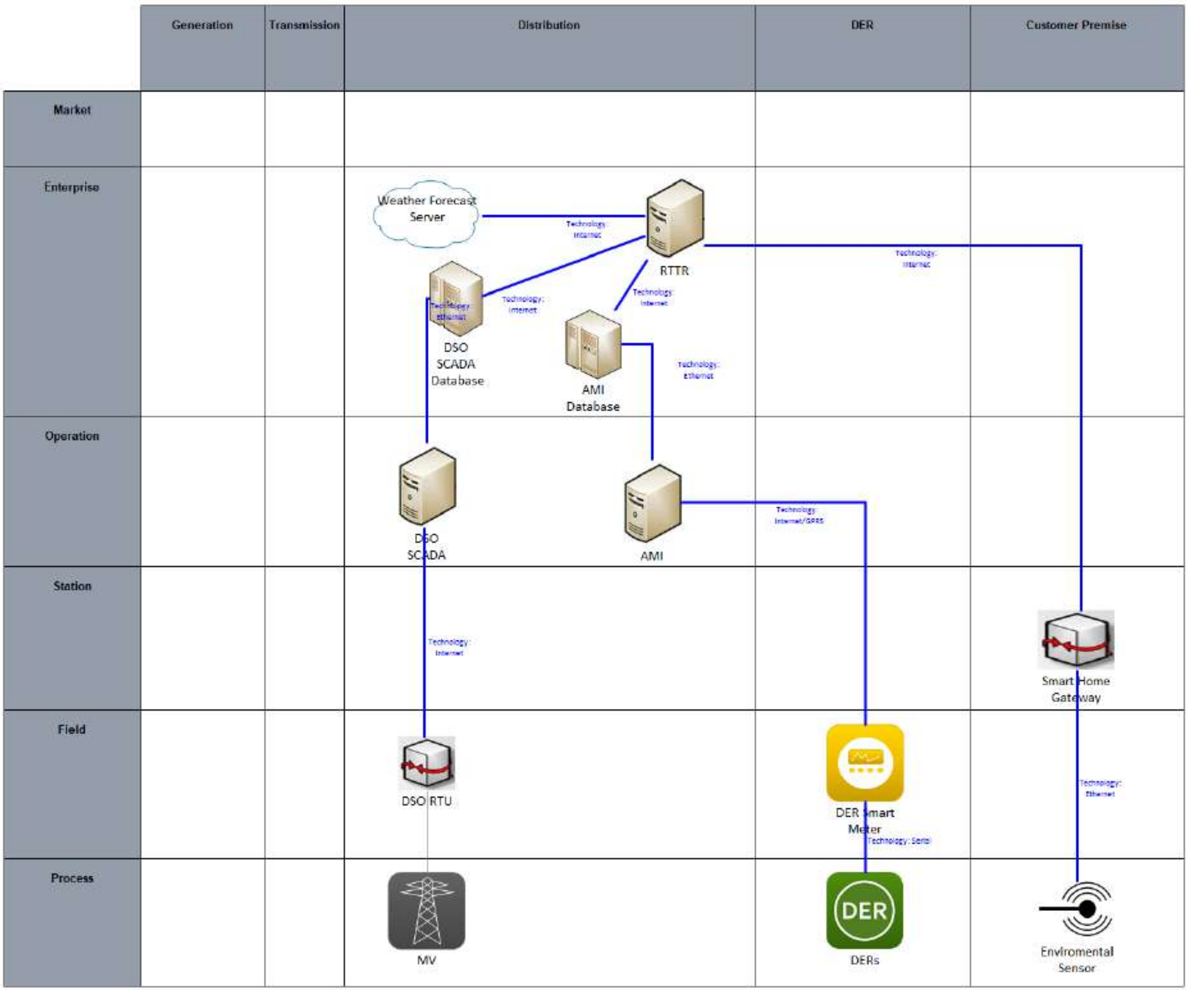

Figure 48. UC1.4 Component Layer

Table 27. List of Components linked with UC 1.4

Component	Component Type
MV lines, DSO RTU, DSO SCADA database, DER smart meter, AMI database, Environmental sensor, DERs, Smart Home Gateway	device
DSO SCADA	system
AMI	system
Weather Forecast Server	System
Real Time Thermal Rating (RTTR)	Software application

5.5 UC 1.5 Advanced Asset Management

5.5.1 Use Case Description

The objective of Advanced Asset Management will start with the identification of critical components and the associated risk index, namely the type of failure each component may have. This initial assessment of the critical components will also focus on the necessary data availability. Next, the task will focus on the development of ageing and failure models for different time scales (operation or planning). The core of these algorithms will be based on advanced machine learning and big data analytics algorithms.

The advanced asset management software will use (nearly) real-time data acquired from SCADA and AMI platforms, historical data and logs (events) records for pretraining and fine-tuning tasks, in order to predict potential failures at different time horizon. The next step involves training the machine learning models using the available data.

When executed, the software of Advanced Asset Management will be used to predict potential failures in critical components of the power system at different time horizons, from short-term to long-term

5.5.2 Function Layer

The functional layer of UC 1.5 is presented in the following graph highlighting the key actors of the use case.

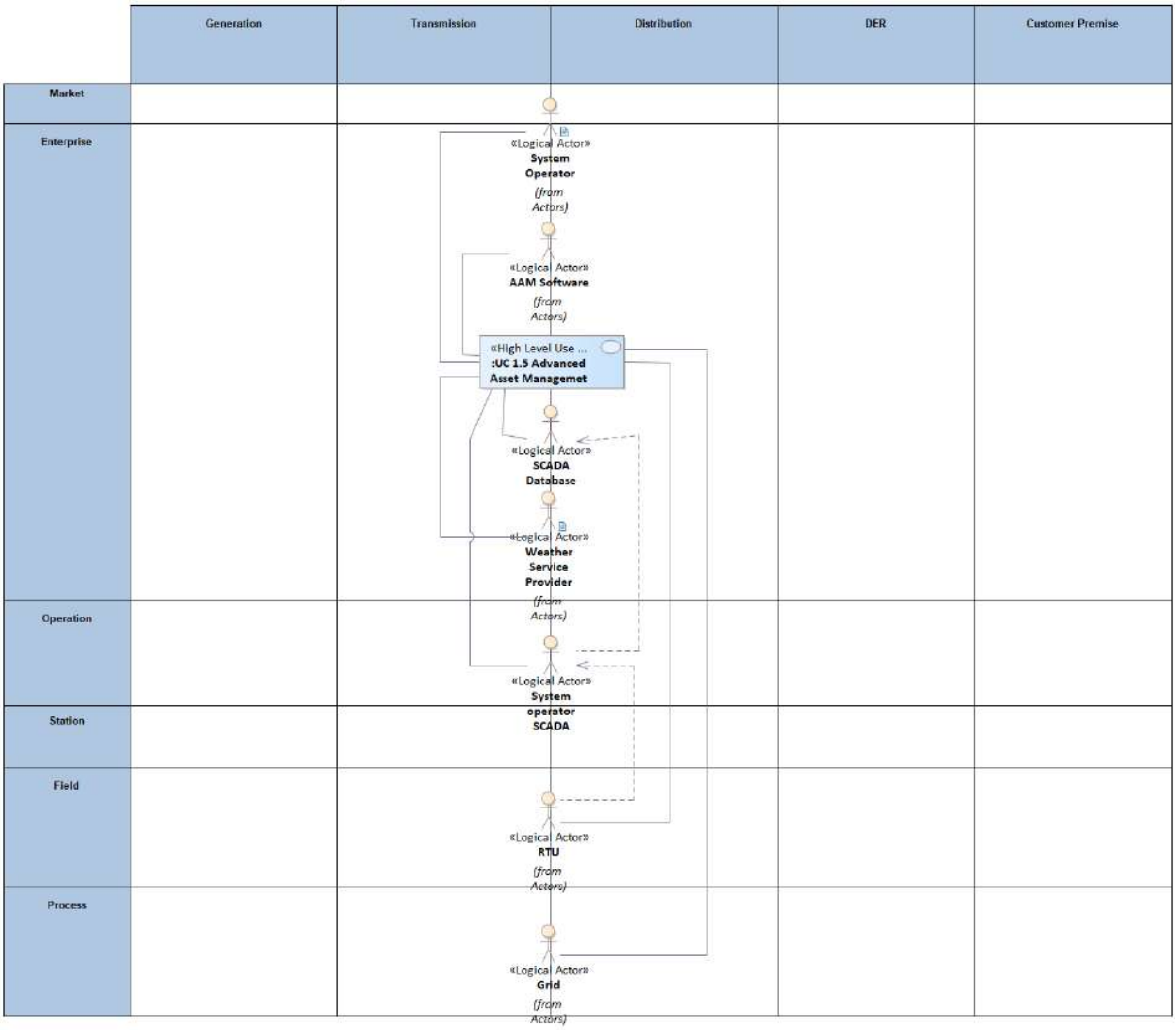

Figure 49. UC 1.5 Function layer

Table 28. List of actors involved in UC 1.5

Actor Name	Actor Type
Weather service provider	Organization
SCADA	System
SCADA Database	Device
AAM software server	Software Application
System Operator (DSO/TSO)	Organization
RTU	Device
Grid	Device

5.5.3 Information Layer

Details about information layer of UC1.5 are presented in the following figure, highlighting the key information objects.

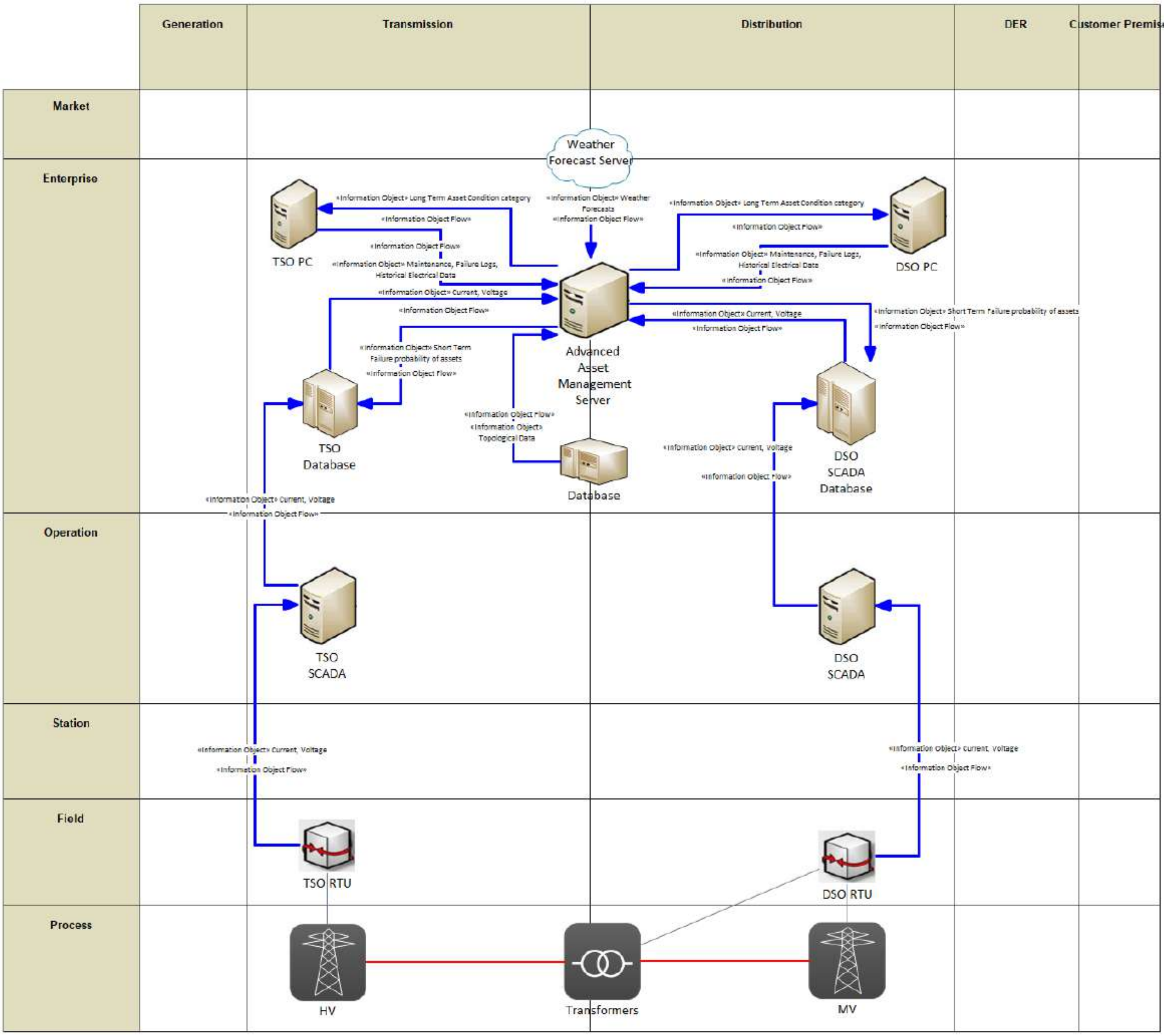

Figure 50. UC 1.5 Information layer

5.5.4 Canonical Data model

The identified canonical data models for UC1.5 are described below.

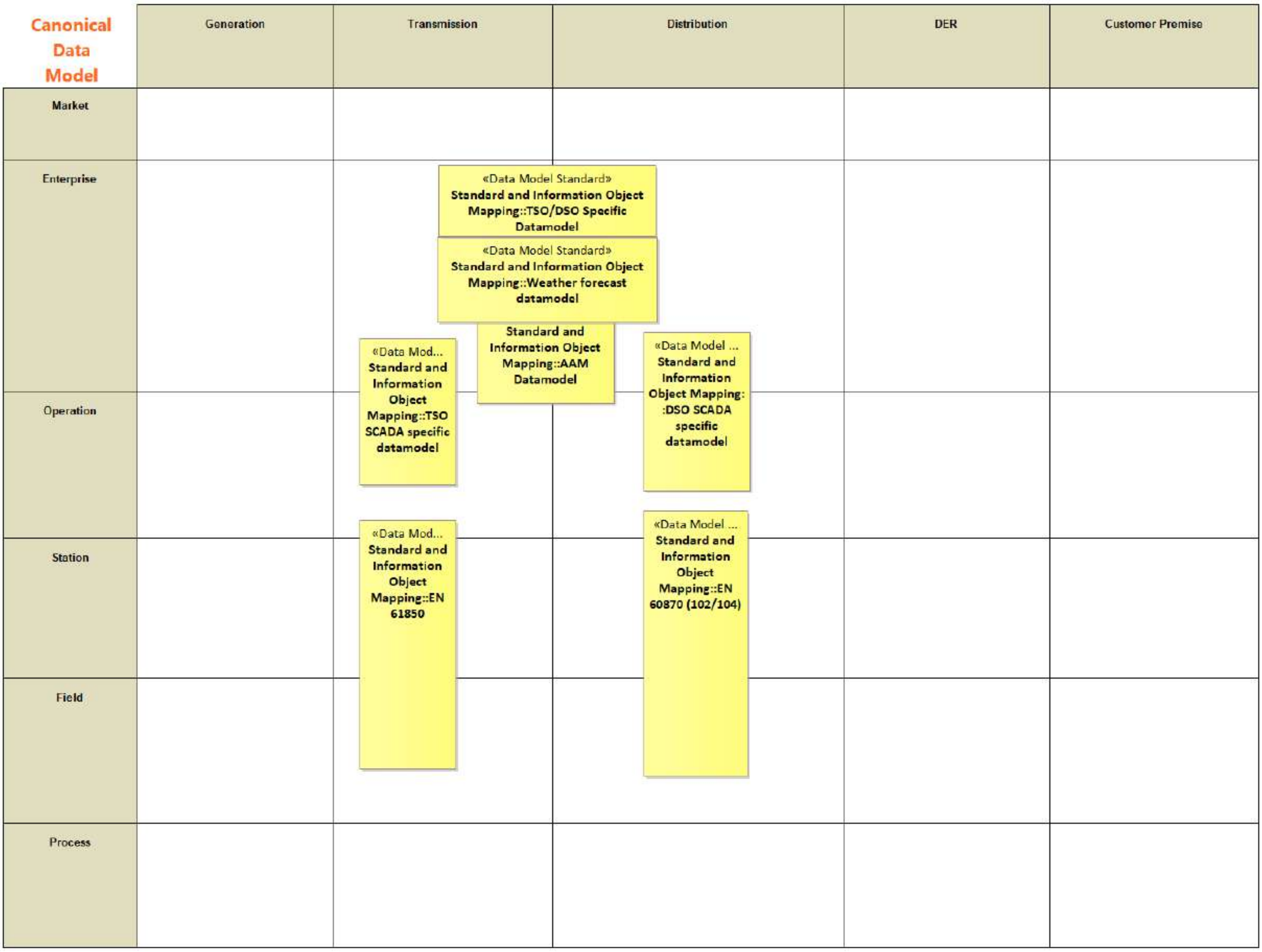

Figure 51. UC 1.5 Canonical data model

Table 29. UC 1.5 Data models

Data Models
Weather forecast data model
AAM Data model
DSO/TSO Specific Data model
En 60870 (102/104)
EN 61850

5.5.5 Standard and Information Object mapping

Data Standards and Information Objects Mapping for UC1.5 are presented in the following figure.

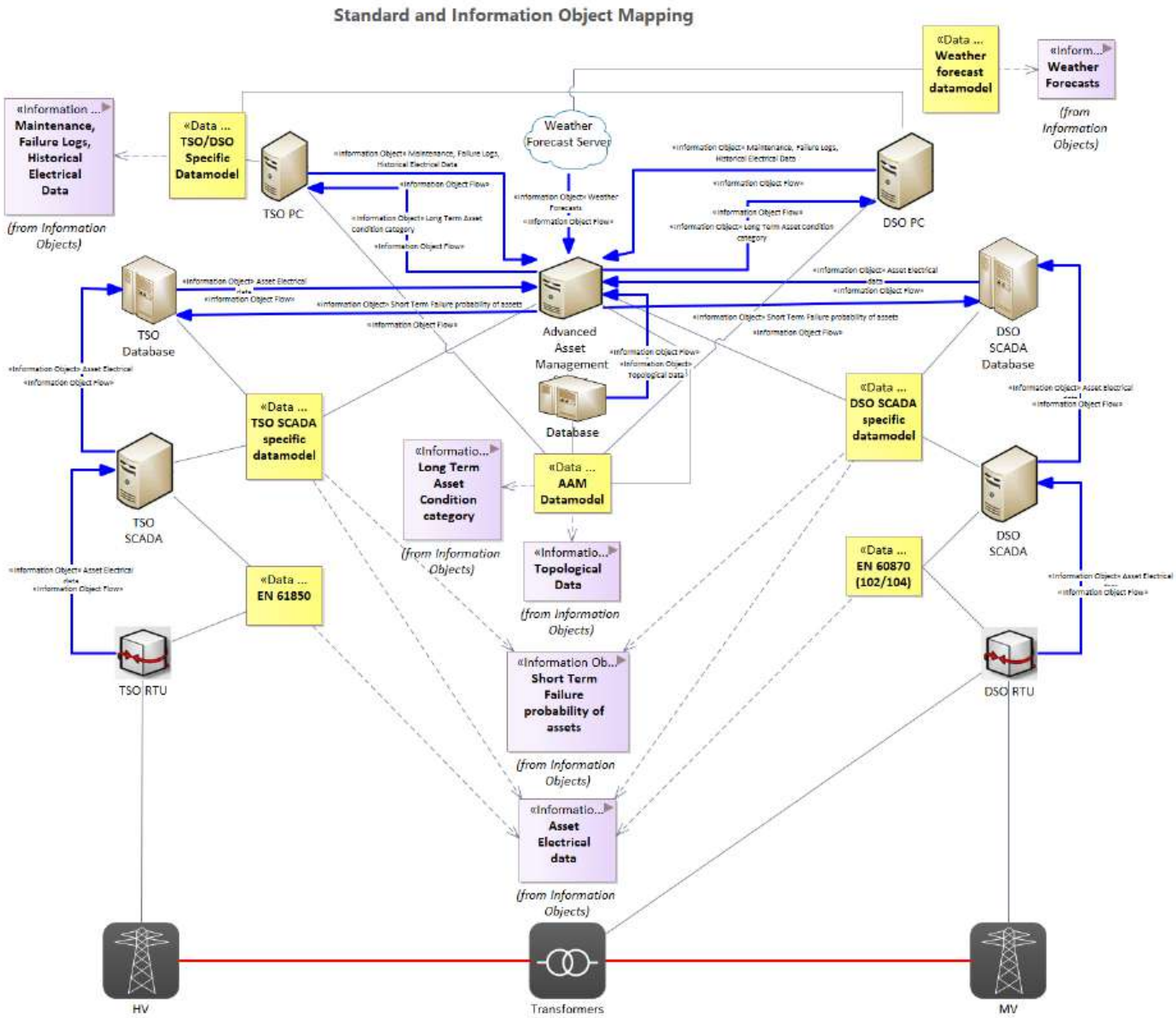

Figure 52.UC 1.5 Standards and Information Objects Mapping

Table 30. List of Information Objects, link with Data Standards in UC 1.5

Information Object	DATA Models	Information
Asset electrical measurements	TSO/DSO Scada specific data model, EN 61850, En 60870 (102/104)	Voltage and current measurements of grid assets
Short Term Failure probability of assets	TSO/DSO Scada specific data model	Active power, reactive power, voltage, current, etc
Topological Data	AAM data model	Pre-processed data about grid topology stored in AAM software database.
Weather Forecasts	Weather Forecast Service Data model	Weather forecasts like wind speed, direction, irradiation, temperature
Maintenance, Failure logs, Historical electrical data	TSO/DSO Scada specific data model	Failure events, recordings during maintenance and historical electrical data

5.5.6 Activity Diagram

The detailed activity diagram for UC 1.5 is presented in the following figure.

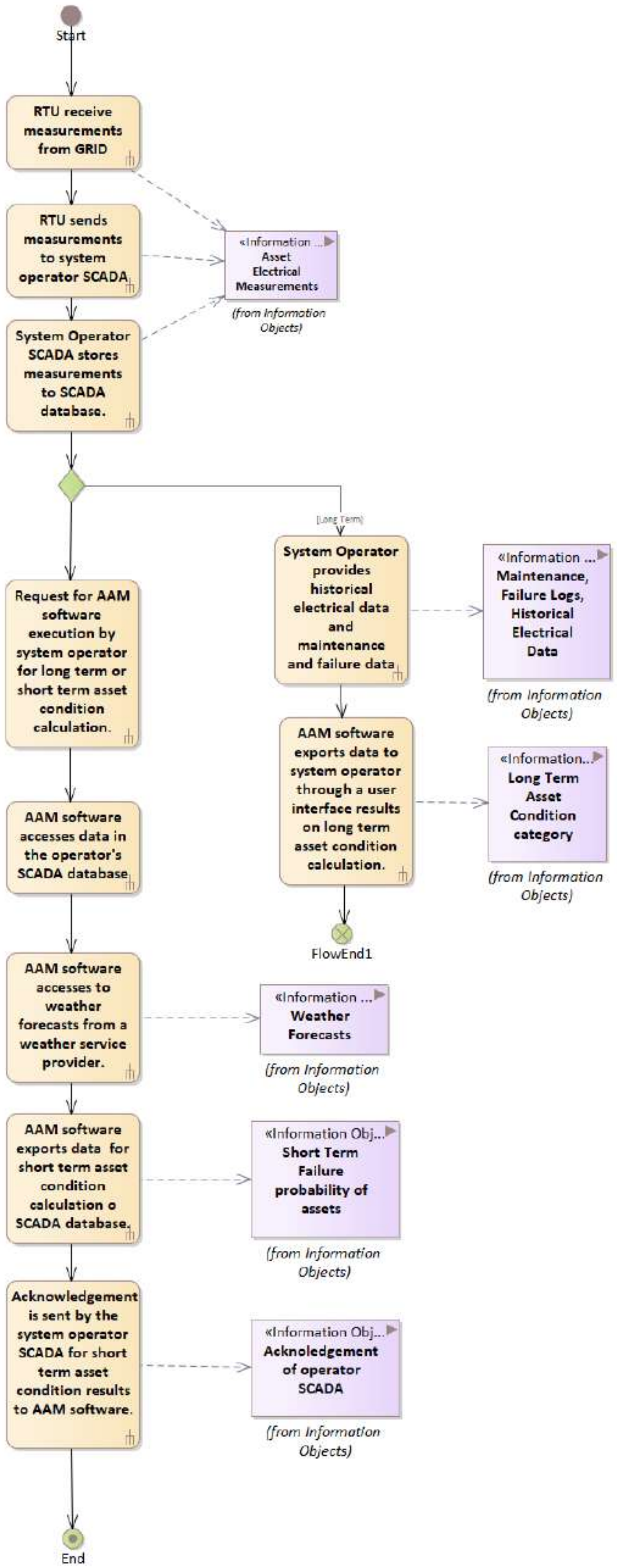

Figure 53.UC 1.5 Activity Diagram

5.5.7 Sequence Diagram

The detailed sequence diagram for UC 1.5 is presented in the following figure.

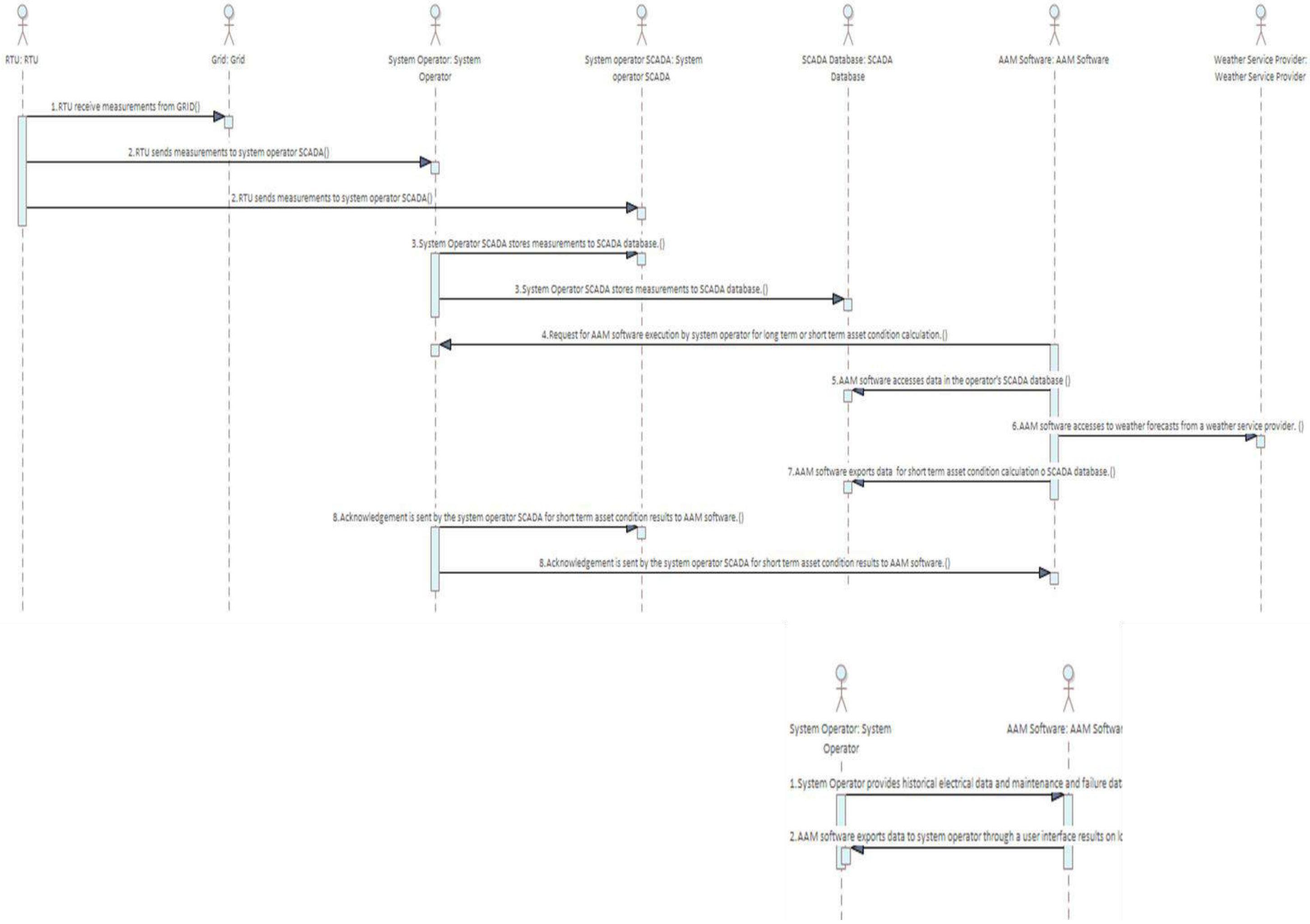

Figure 54.UC 1.5 Sequence Diagram

5.5.8 Communication Layer

The communication layer of UC 1.5 is presented in the following figure, highlighting the key communication protocols among the different modules.

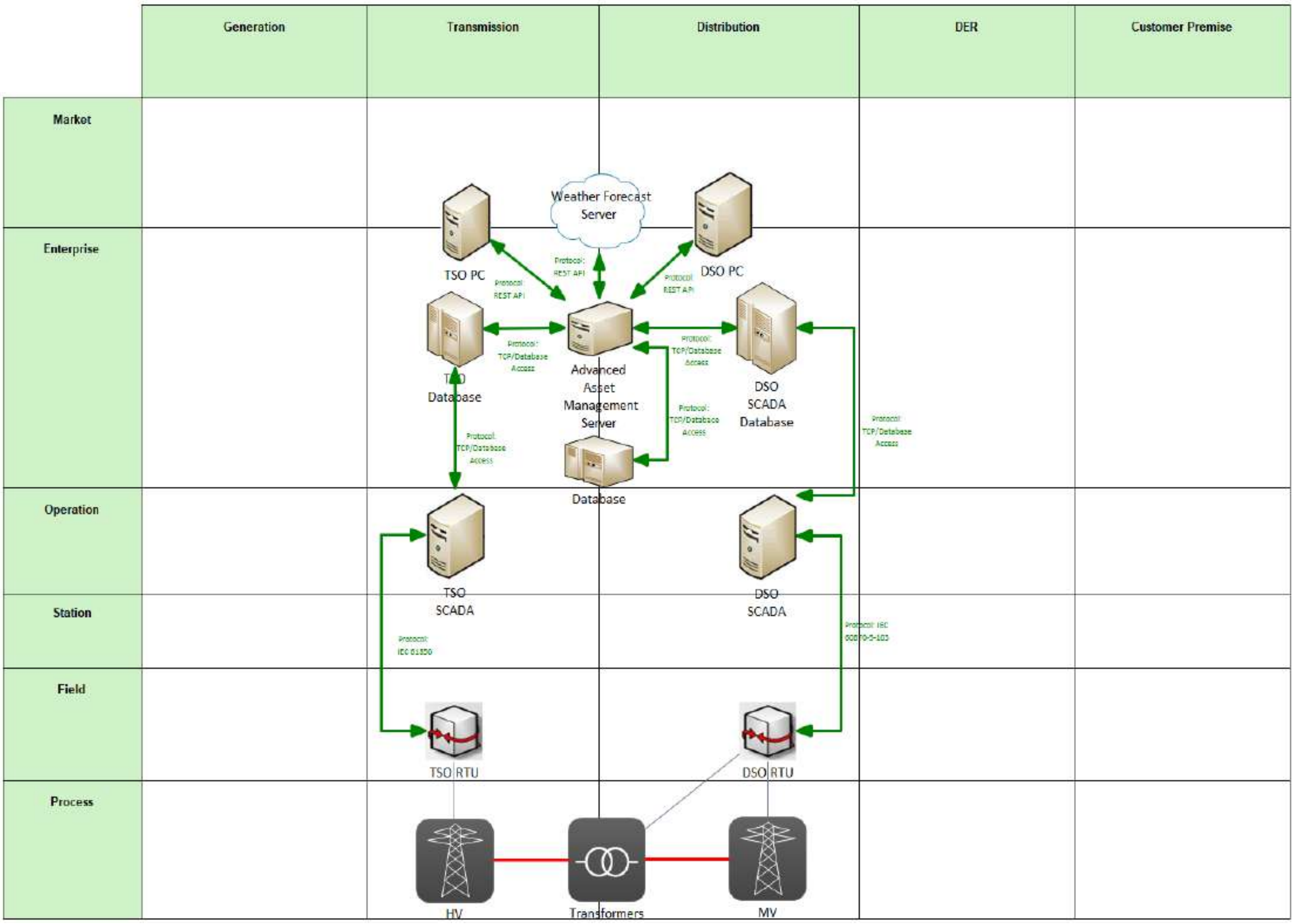

Figure 55. UC1.5 Communication Layer

Table 31. List of Communication technologies linked with UC 1.5

Communication Technology	Description
REST	Representational State Transfer. Set of software constraints for web services, to provide interoperability between computer systems on the Internet. A RESTful web service defines a uniform and predefined set of stateless operations that accept requests through a URI.
TCP/IP	Transmission Control Protocol/Internet Protocol. Conceptual model and set of communication protocols used on the Internet. They provide end-to-end data communication, specifying how data should be packetized, addressed, transmitted, routed, and received, through four abstraction layers (link, internet, transport, and application).
IEC 104 / 61850	IEC 104 is a standard telecontrol protocol used for remote control and monitoring of substations, while IEC 61850 is a comprehensive standard for substation automation, covering various aspects such as data modeling, communication services, and system configuration.

5.5.9 Component Layer

The components included in the use case are depicted below, including the technology used for connecting each other.

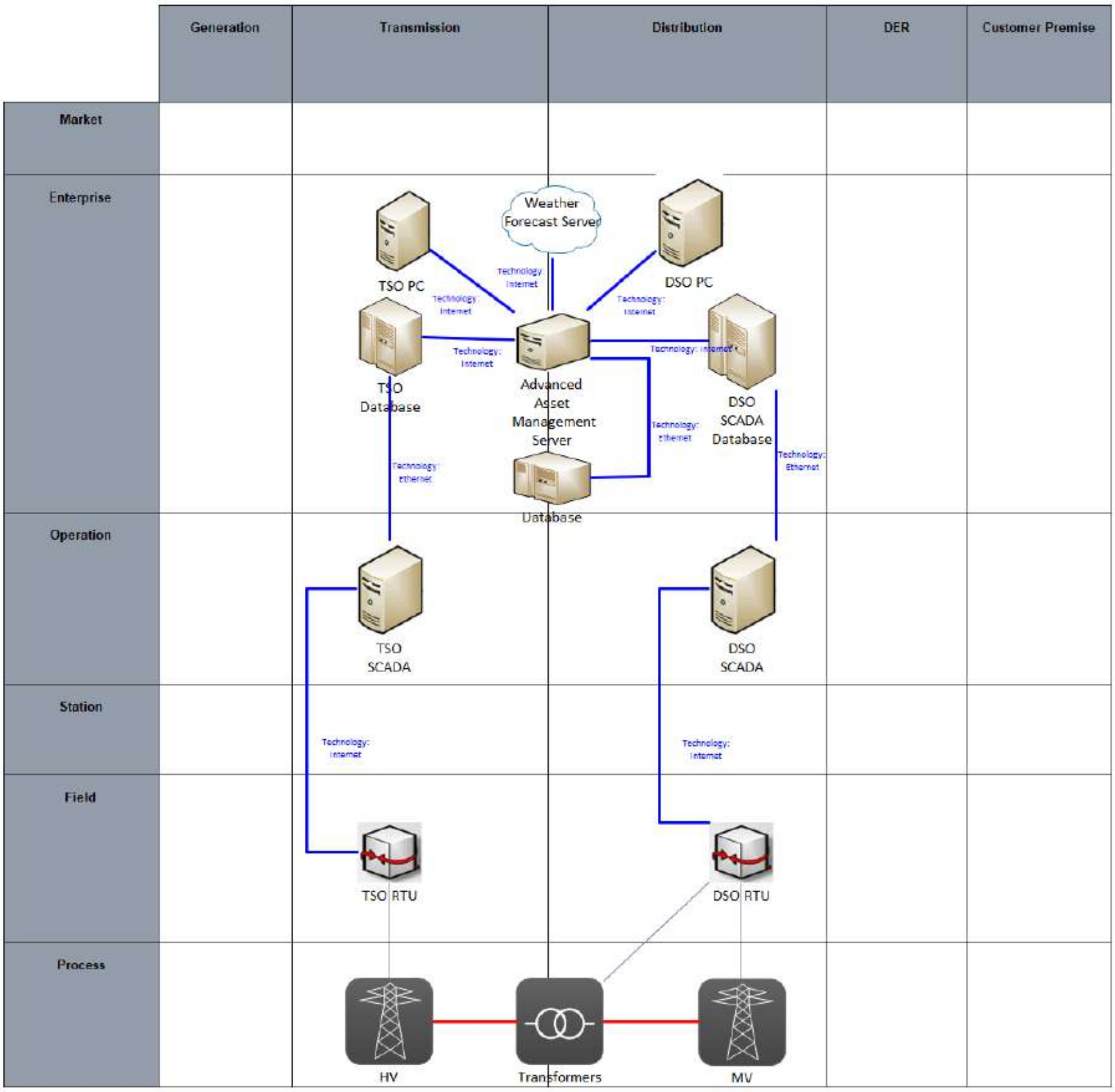

Figure 56. UC1.5 Component Layer

Table 32. List of Components linked with UC 1.5

Component	Component Type
transformer, MV/HV grid, TSO/DSO RTU, TSO/DSO SCADA database, database, TSO/DSO PC	device
TSO/DSO SCADA	system
EMS (ETER)	system
Weather Forecast Server	System
Advanced Asset Management server	Software application

5.6 UC 1.6: Topology identification

5.6.1 Use Case Description

This Use Case focuses on performing a topology analysis for distribution networks. In this Use Case, the network operator does not have a complete knowledge about the line infrastructure and needs to understand how the components of the network are interconnected.

The aim is to determine both the connections and line impedances. This will allow to Identify power supply interruptions so that operators can quickly and efficiently address them.

5.6.2 Function layer

The functional layer of UC 1.6 is presented in the following graph highlighting the key actors of the use case.

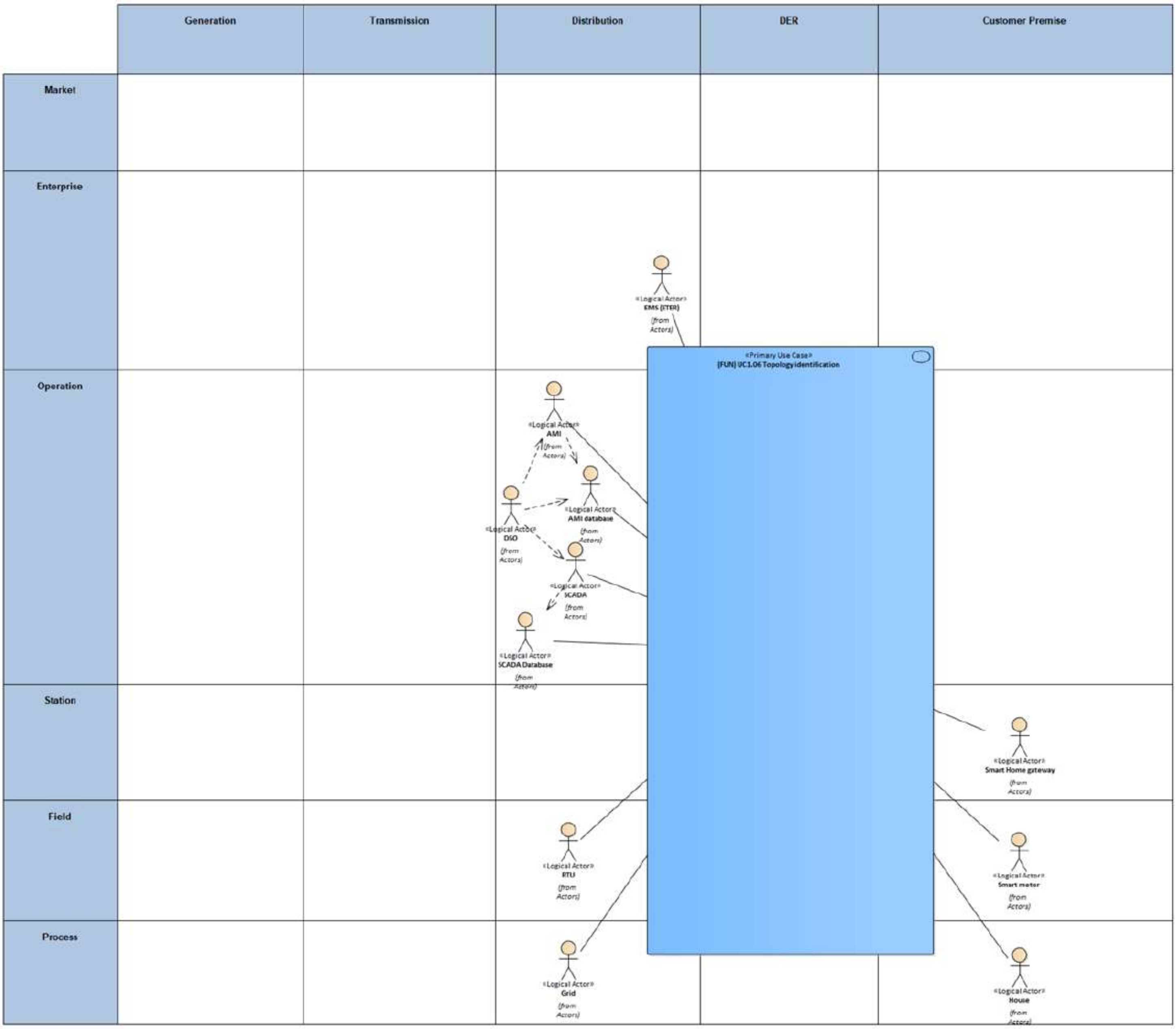

Figure 57. UC 1.6 Function layer

Table 33. List of actors involved in UC 1.6

Actor Name	Actor Type
DSO	Organization
AMI	System
AMI Database	Device
SCADA	System
SCADA Database	Device
EMS (ETER)	System
Smart home gateway	Device
Smart meter	Device
House	Device
RTU	Device
Grid	Device

5.6.3 Information layer

Details about information layer of UC1.6 are presented in the following figure, highlighting the key information objects.

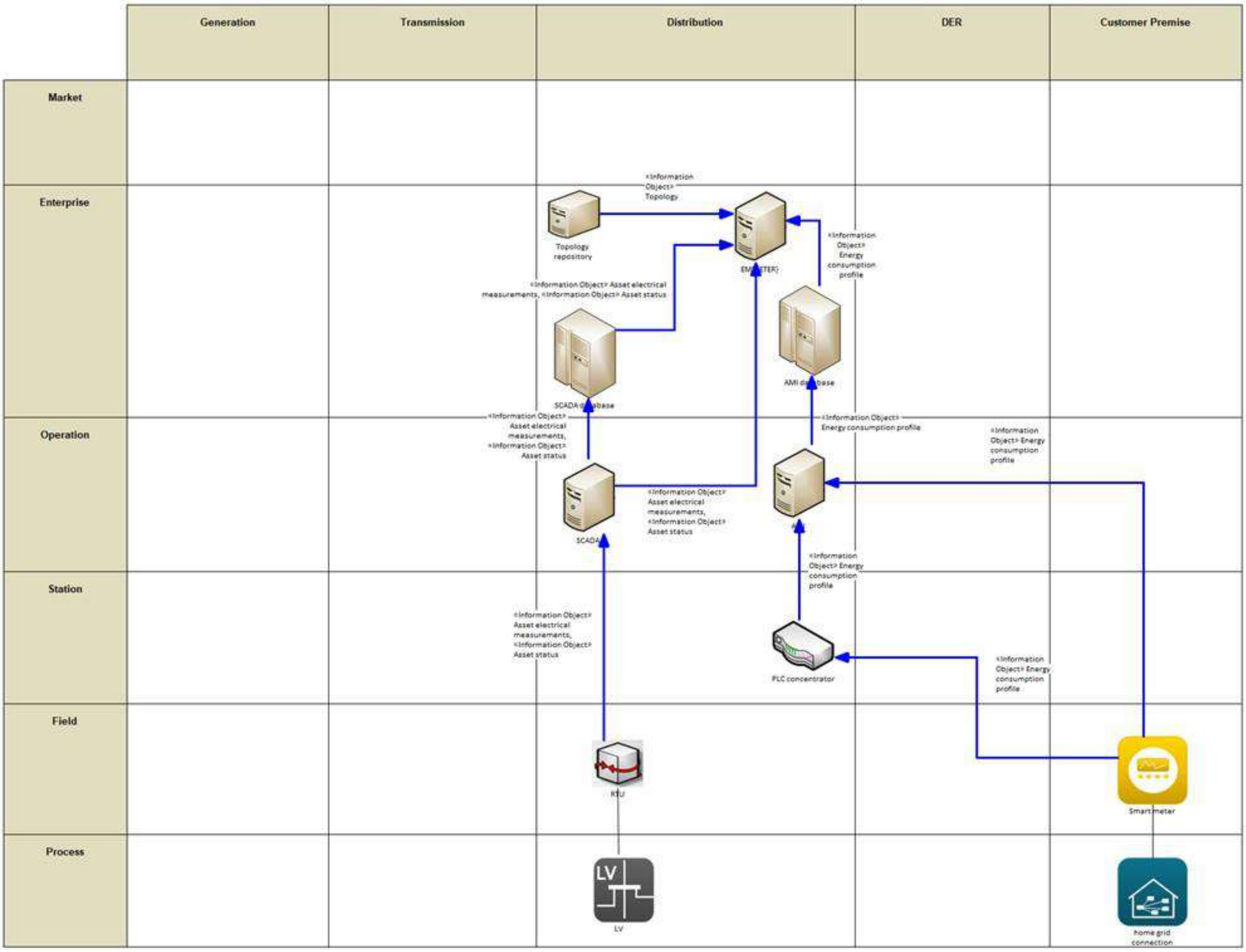

Figure 58. UC 1.6 Information Layer

5.6.4 Canonical Data Model

The identified canonical data models for UC1.6 are described below.

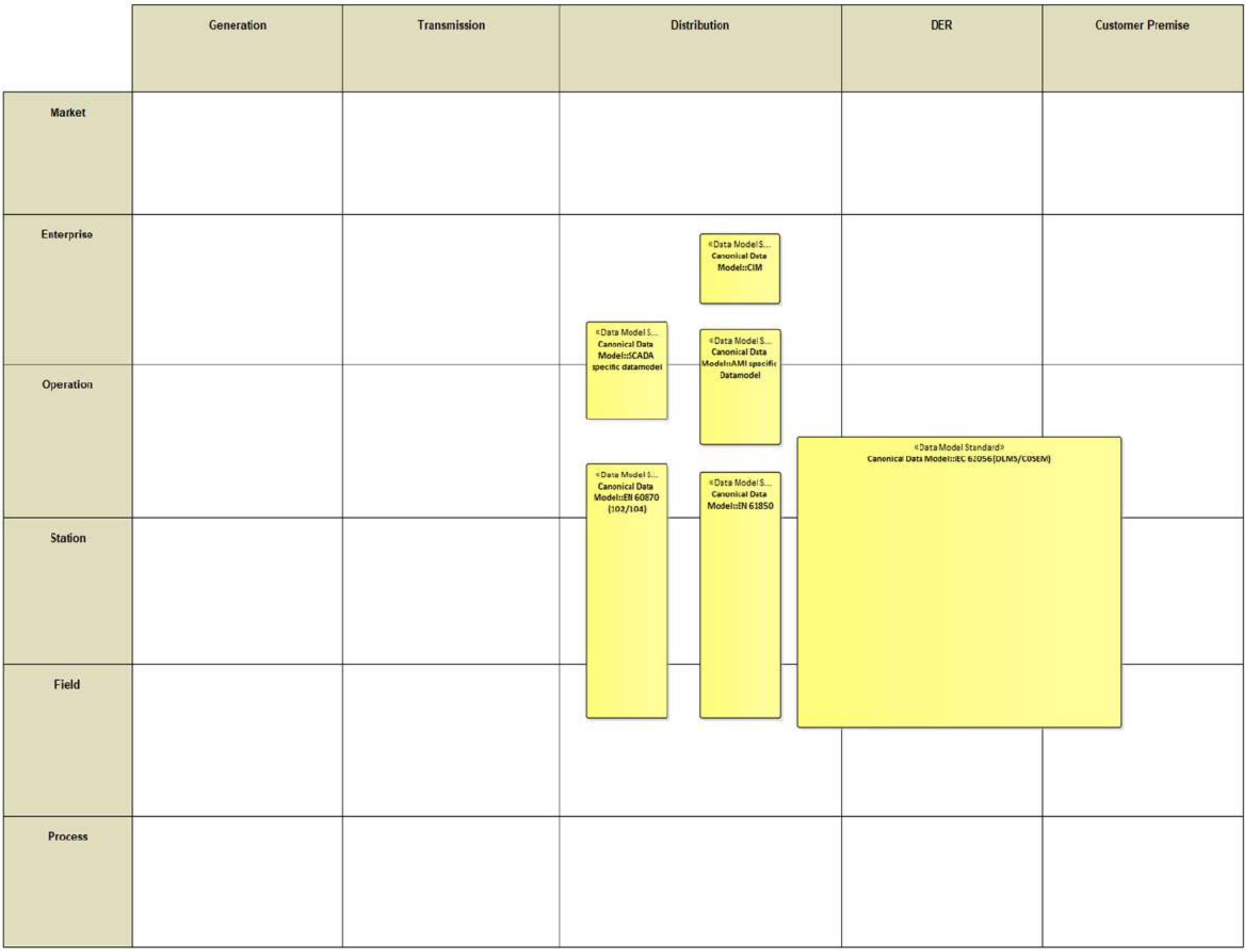

Figure 59. UC 1.6 Canonical data model

Table 34. List of Data models involved in UC 1.6

Data Models
CIM
AMI specific data model
Scada specific data model
En 60870 (102/104)
EN 61850
IEC 62056 (DLMS/COSEM)

5.6.5 Standards and Information Object Mapping

Data Standards and Information Objects Mapping for UC1.6 are presented in the following figure.

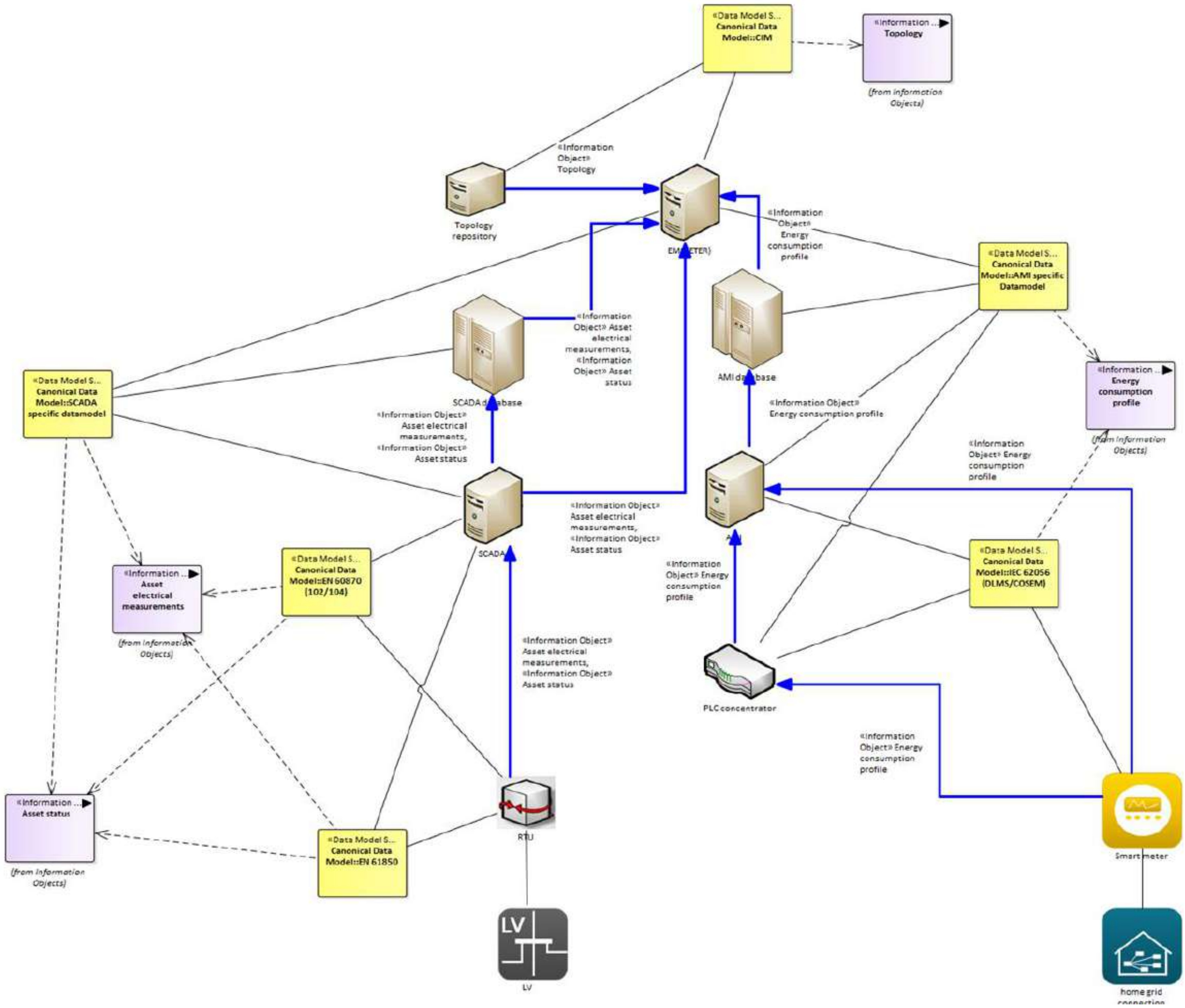

Figure 60. UC 1.6 Standards and Information Object Mapping

Table 35. List of Information Objects, link with Data Standards in UC 1.6

Information Object	DATA Models	Information
Asset Status	Scada specific data model, EN 61850, En 60870 (102/104)	Condition of an asset (on/off)
Assets electrical measurements	Scada specific data model, EN 61850, En 60870 (102/104)	Active power, reactive power, voltage, current, etc
Topology	CIM	Electrical grid topology
Energy Consumption data	IEC 62056 (DLMS/COSEM), AMI specific data model	Consumption data of consumers

5.6.6 Activity Diagram

The detailed activity diagram for UC 1.6 is presented in the following figure.

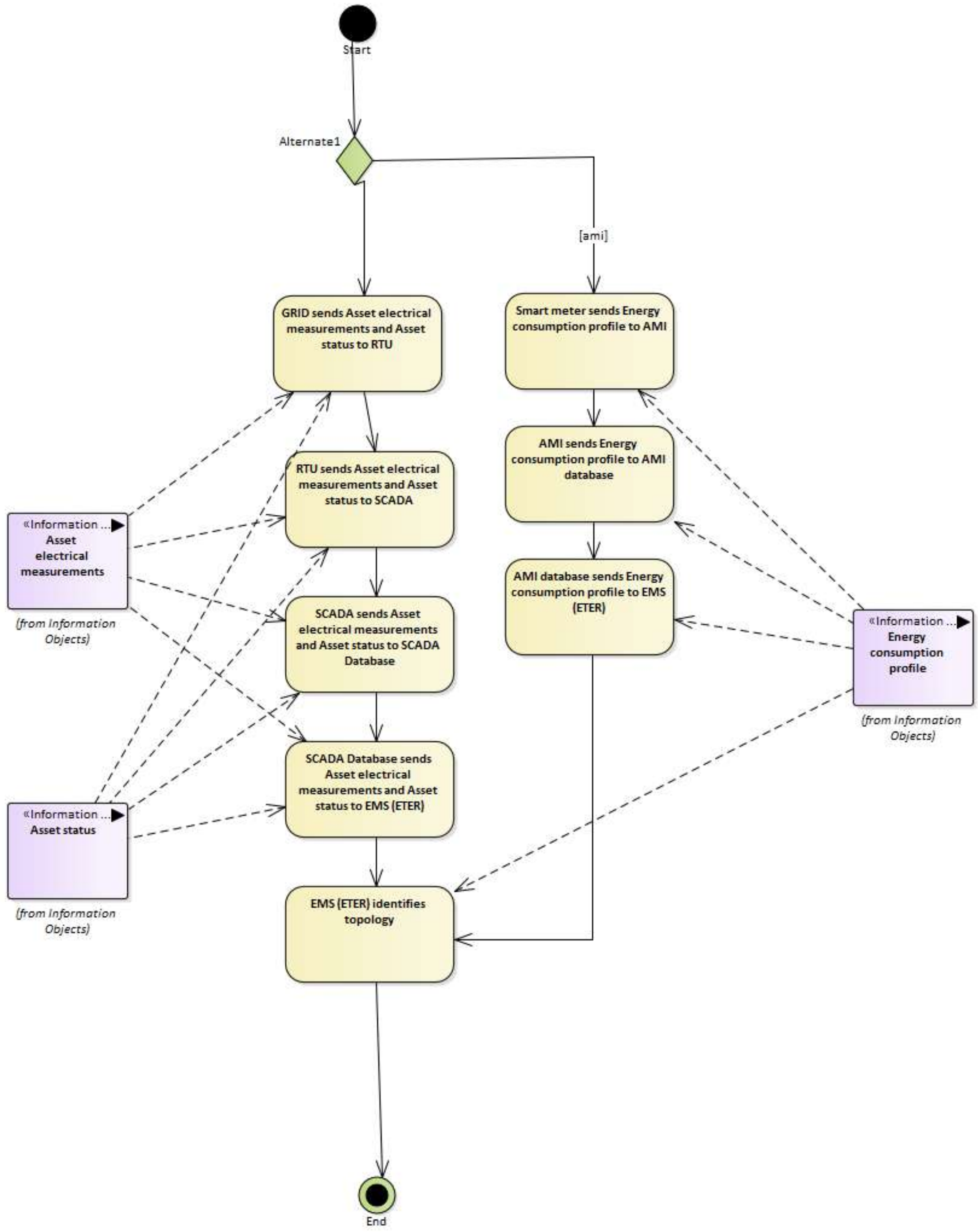

Figure 61.UC 1.6 Activity Diagram

5.6.7 Sequence Diagram

The detailed sequence diagram for UC 1.6 is presented in the following figure.

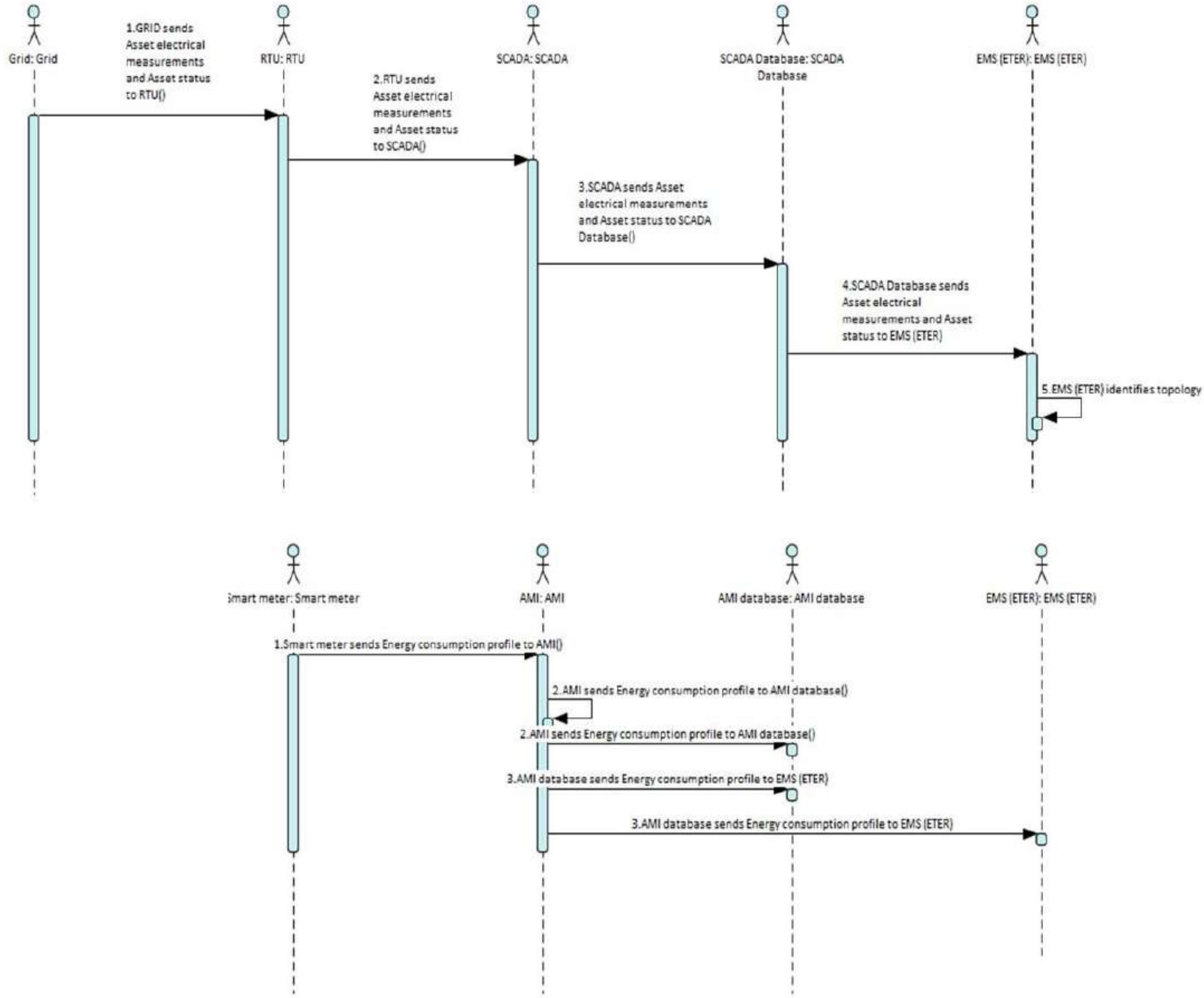

Figure 62.UC 1.6 Sequence Diagram

5.6.8 Communication Layer

The communication layer of UC 1.6 is presented in the following figure, highlighting the key communication protocols among the different modules.

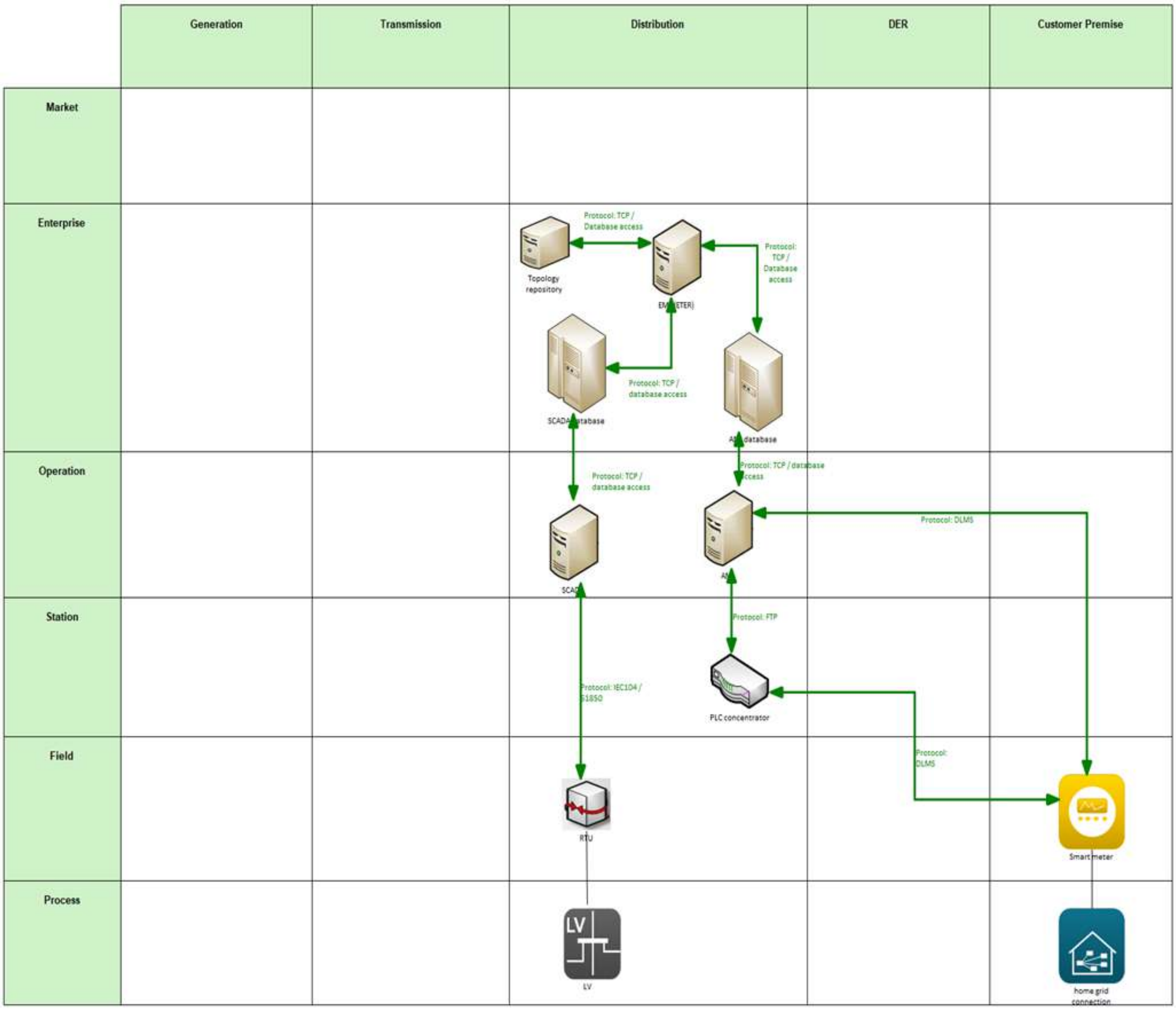

Figure 63. UC1.6 Communication Layer

Table 36. List of Communication technologies linked with UC 1.6

Communication Technology	Description
FTP	The File Transfer Protocol (FTP) is a standard communication protocol used for the transfer of computer files from a server to a client on a computer network. FTP is built on a client–server model architecture using separate control and data connections between the client and the server.
TCP/IP	Transmission Control Protocol/Internet Protocol. Conceptual model and set of communication protocols used on the Internet. They provide end-to-end data communication, specifying how data should be packetized, addressed, transmitted, routed, and received, through four abstraction layers (link, internet, transport, and application).
IEC104/61850	IEC 104 is a standard telecontrol protocol used for remote control and monitoring of substations, while IEC 61850 is a comprehensive standard for substation automation, covering various aspects such as data modeling, communication services, and system configuration.
DLMS	Device Language Message specification/Companion Specification for Energy Metering. Standards for electricity metering data exchanged defined in IEC 62056. DLMS defines the data model specification of the messages, while COSEM includes directives that define the transport and application layers of the DLMS protocol. It is the main global standard for smart energy metering, control and management. It includes specifications for media-specific communication profiles, an object-oriented data model and an application layer protocol.

5.6.9 Component Layer

The components included in the use case are depicted below, including the technology used for connecting each other.

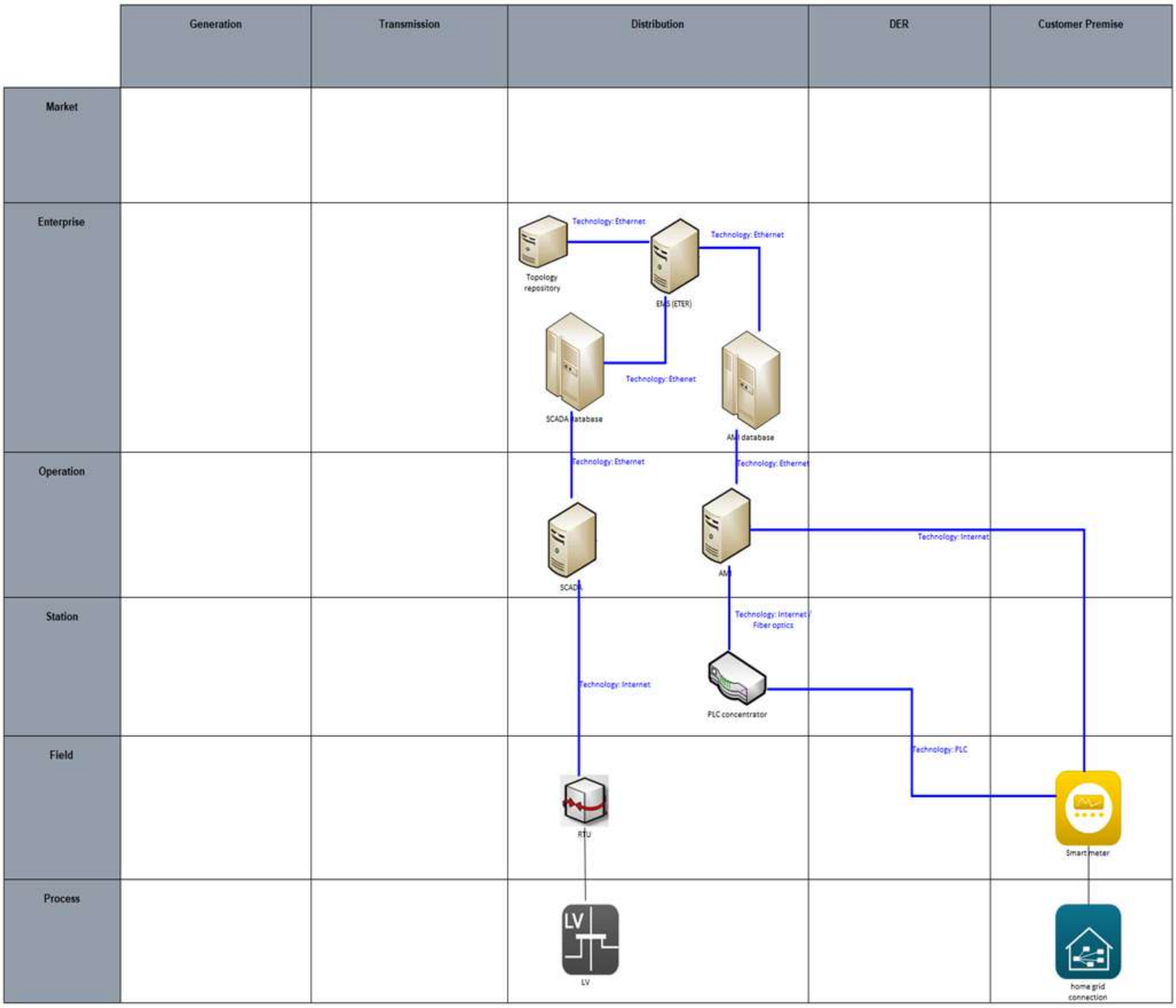

Figure 64. UC1.6 Component Layer

Table 37. List of Components linked with UC 1.6

Component	Component Type
LV grid, home grid connection, PLC concentrator, SCADA database, AMI database, Topology repository, Smart meter	device
SCADA, AMI, EMS (ETER)	system

5.7 UC 1.7: Investment Deferral considering flexibility

5.7.1 Use Case Description

The goal of the algorithm is to defer distribution network investments by identifying the most cost-effective mix and location of flexibility such as RES and energy storage and demand response. By optimizing the size and location of these options, the algorithm aims to achieve the best investment deferral outcomes while maintaining the reliability and stability of the power system.

The steps of the UC are:

- Collection of data: Collect data from various sources such as historical usage data, load forecasts, and energy market data. Furthermore, topology data from the specific MV lines are needed as well as the long-term failure indications of assets from UC 1.5.
- Develop models for investment deferral: Develop models using advanced optimization techniques to identify the most cost-effective mix and location of flexibility to defer network investments.
- Incorporate uncertainty and risk analysis: In order to evaluate the impact of different scenarios, such as changes in load forecasts, energy prices, or policy decisions.

5.7.2 Function Layer

The functional layer of UC 1.7 is presented in the following graph highlighting the key actors of the use case.

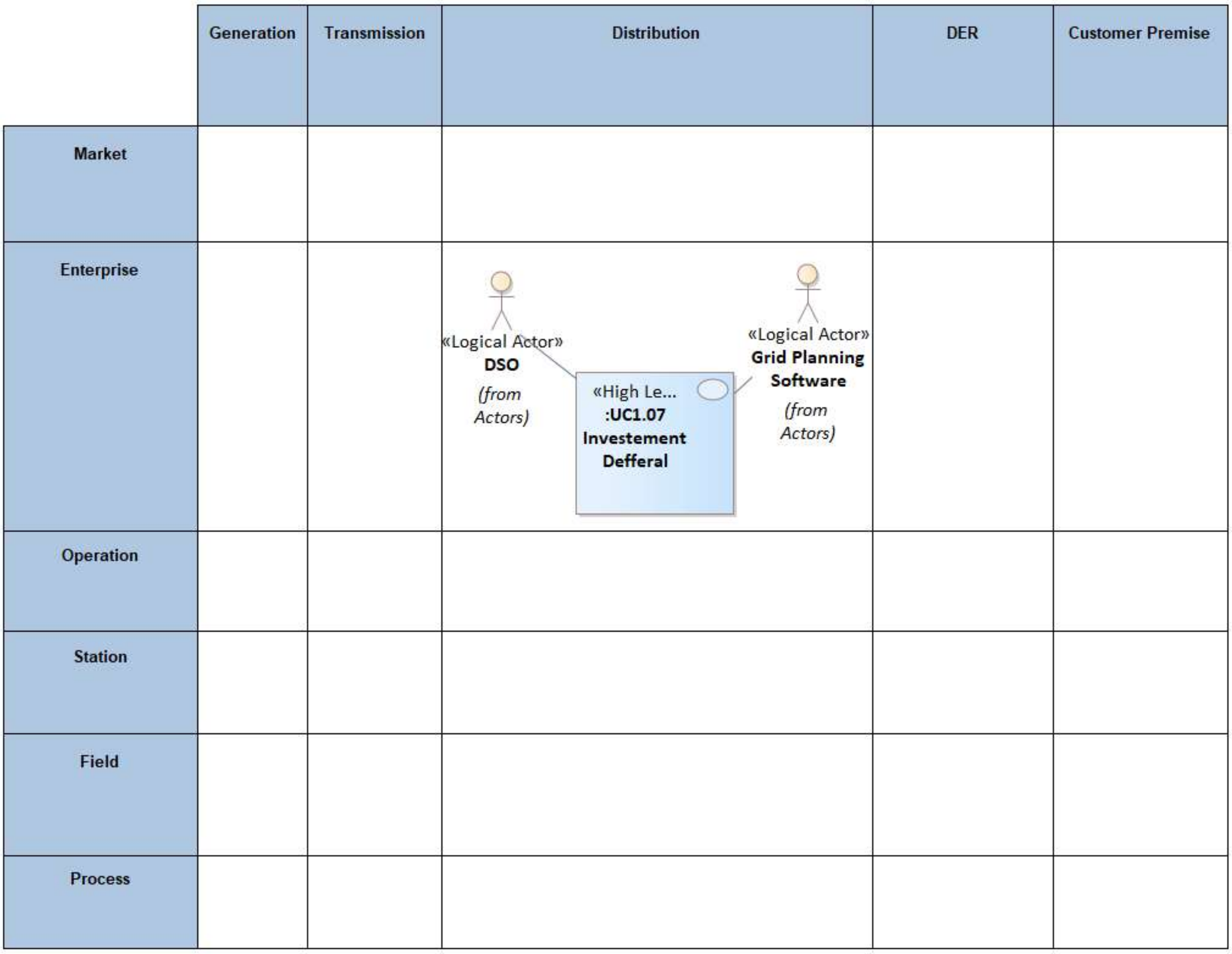

Figure 65. UC 1.7 Function layer

Table 38. List of actors involved in UC 1.7

Actor Name	Actor Type
DSO	Organization
Grid Planning software	Software Application

5.7.3 Information Layer

Details about information layer of UC1.7 are presented in the following figure, highlighting the key information objects.

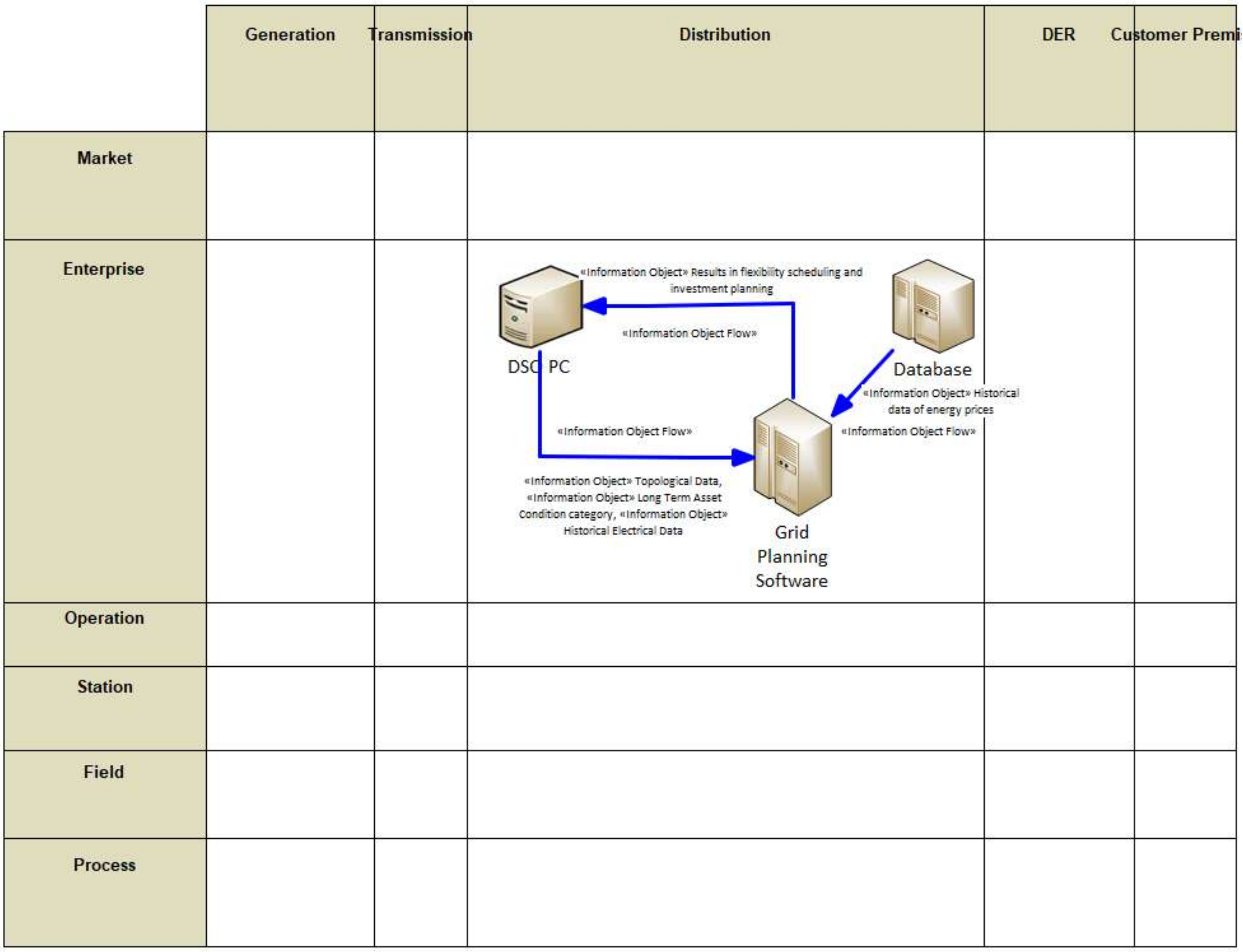

Figure 66. UC 1.7 Information layer

5.7.4 Canonical Data model

The identified canonical data models for UC1.7 are described below.

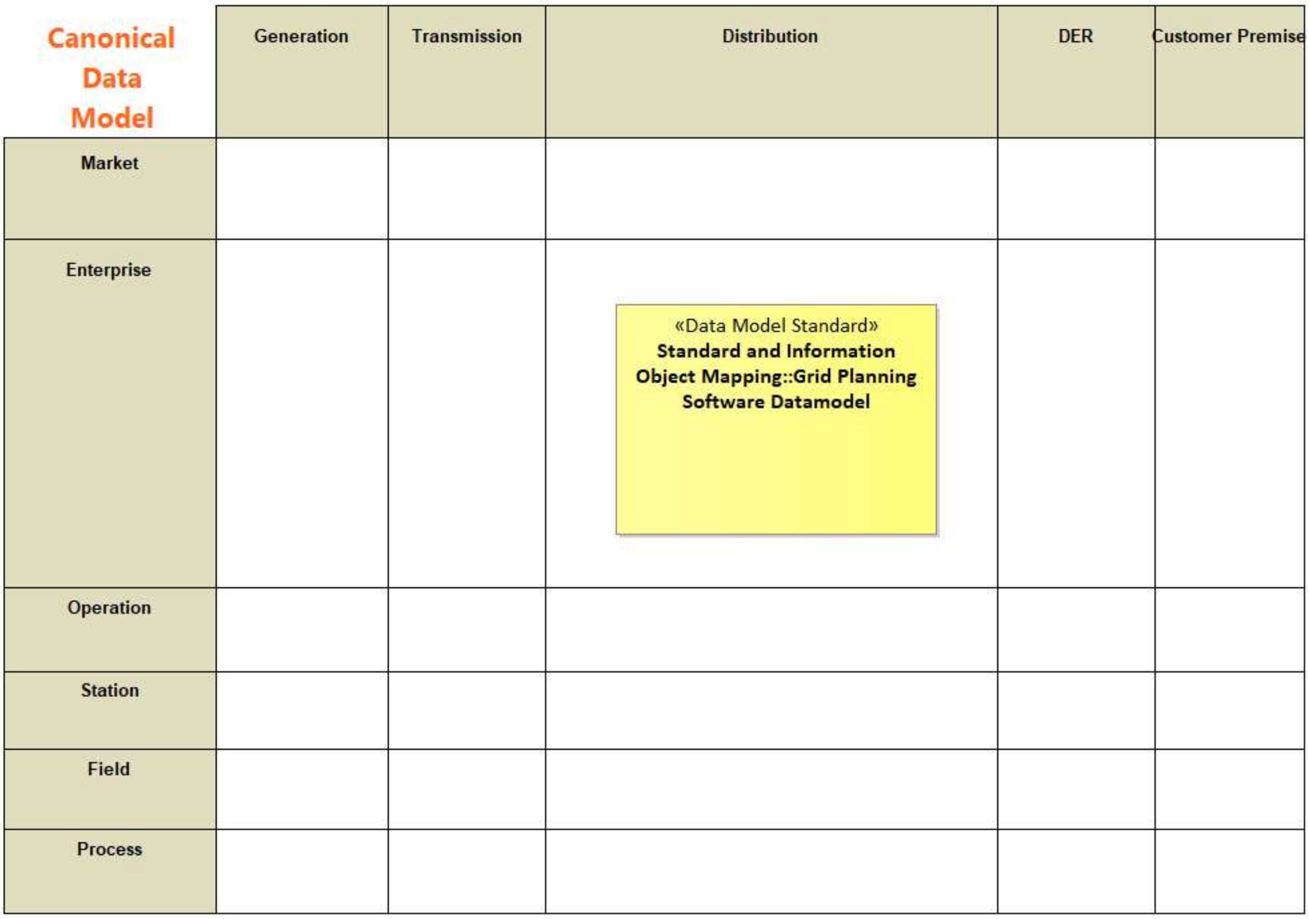

Figure 67. UC 1.7 Canonical Data model

Table 39. UC 1.7 Data models

Data Models
Grid Planning Software Data model

5.7.5 Standards and information object mapping

SGAM Standards and Information Objects Mapping for UC1.6 is presented in the following figure.

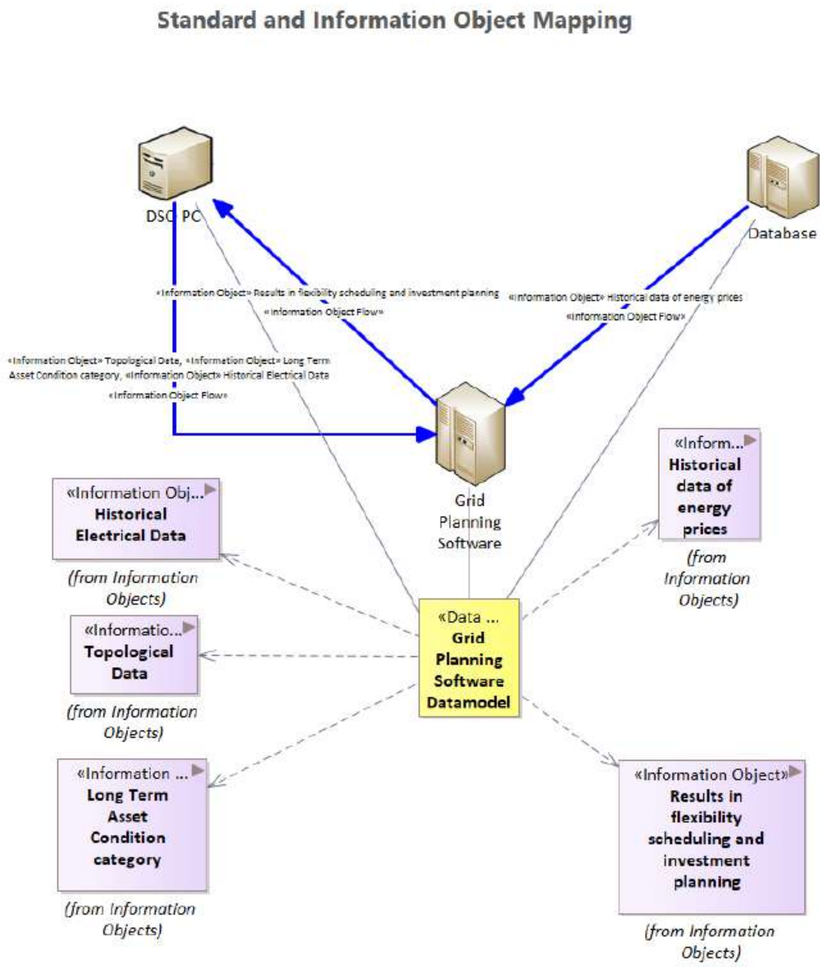

Figure 68. UC 1.7 Standards and information object mapping

Table 40. List of Information Objects, link with Data Standards in UC 1.7

Information Object	DATA Models	Information
Topological Data	Grid Planning Software Data model	Grid topology, future RES installations,
Long term asset condition category	Grid Planning Software Data model	Information up to which year an asset should be replaced
Historical electrical data	Grid Planning Software Data model	Annual load curve(s) available for the distribution system considered for RES and demand.
Historical data of energy prices	Grid Planning Software Data model	Historical data on energy price with hourly resolution.
Results in flexibility scheduling and investment planning	Grid Planning Software Data model	Yearly output of flexibility schedule and asset investment periods. Comparison with base case model

5.7.6 Activity Diagram

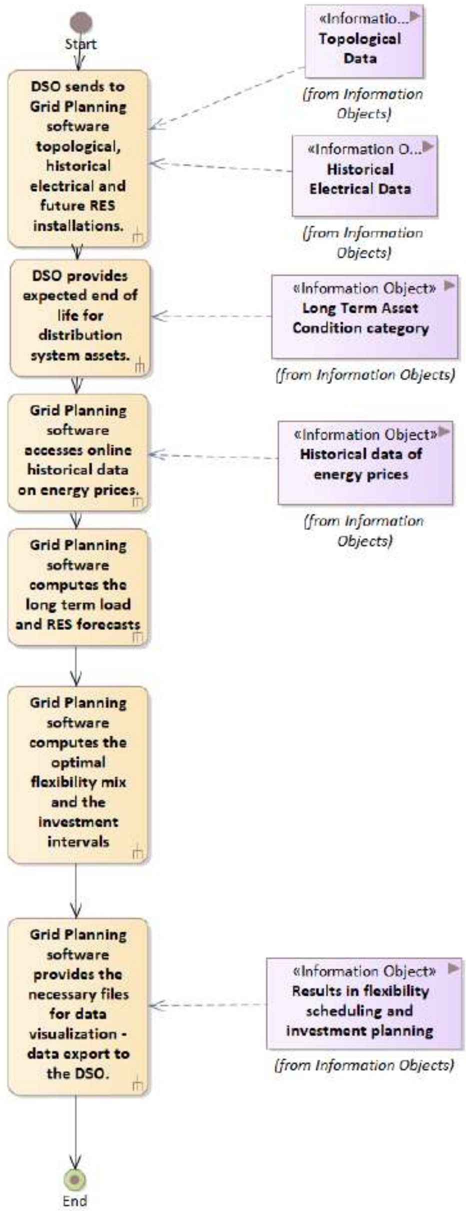

Figure 69. UC 1.7 Activity Diagram

5.7.7 Sequence Diagram

The detailed sequence diagram for UC 1.7 is presented in the following figure

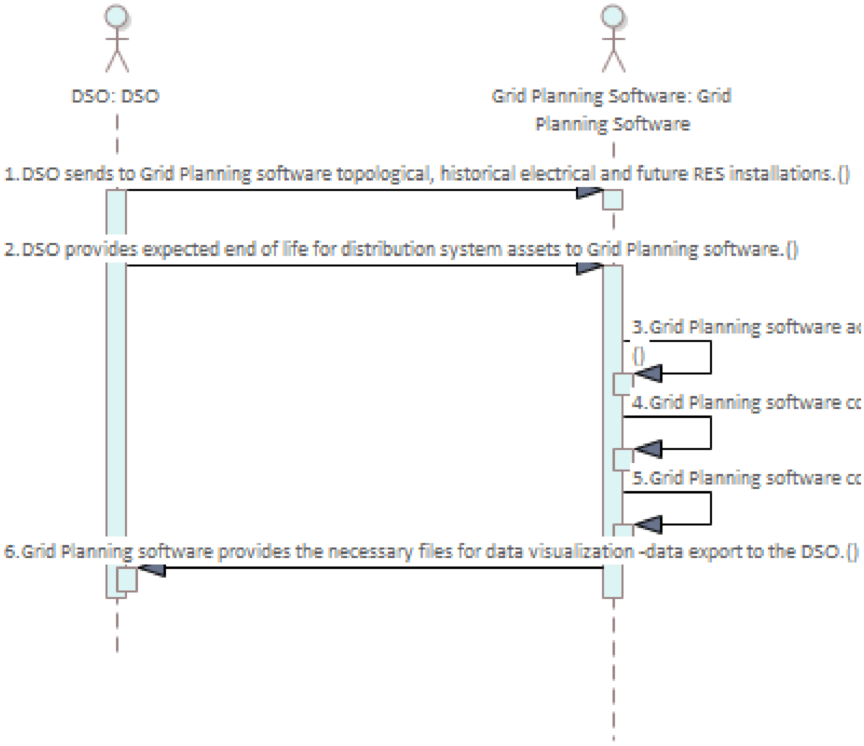

Figure 70. UC 1.7 Sequence Diagram

5.7.8 Communication Layer

The communication layer of UC 1.6 is presented in the following figure, highlighting the key communication protocols among the different modules.

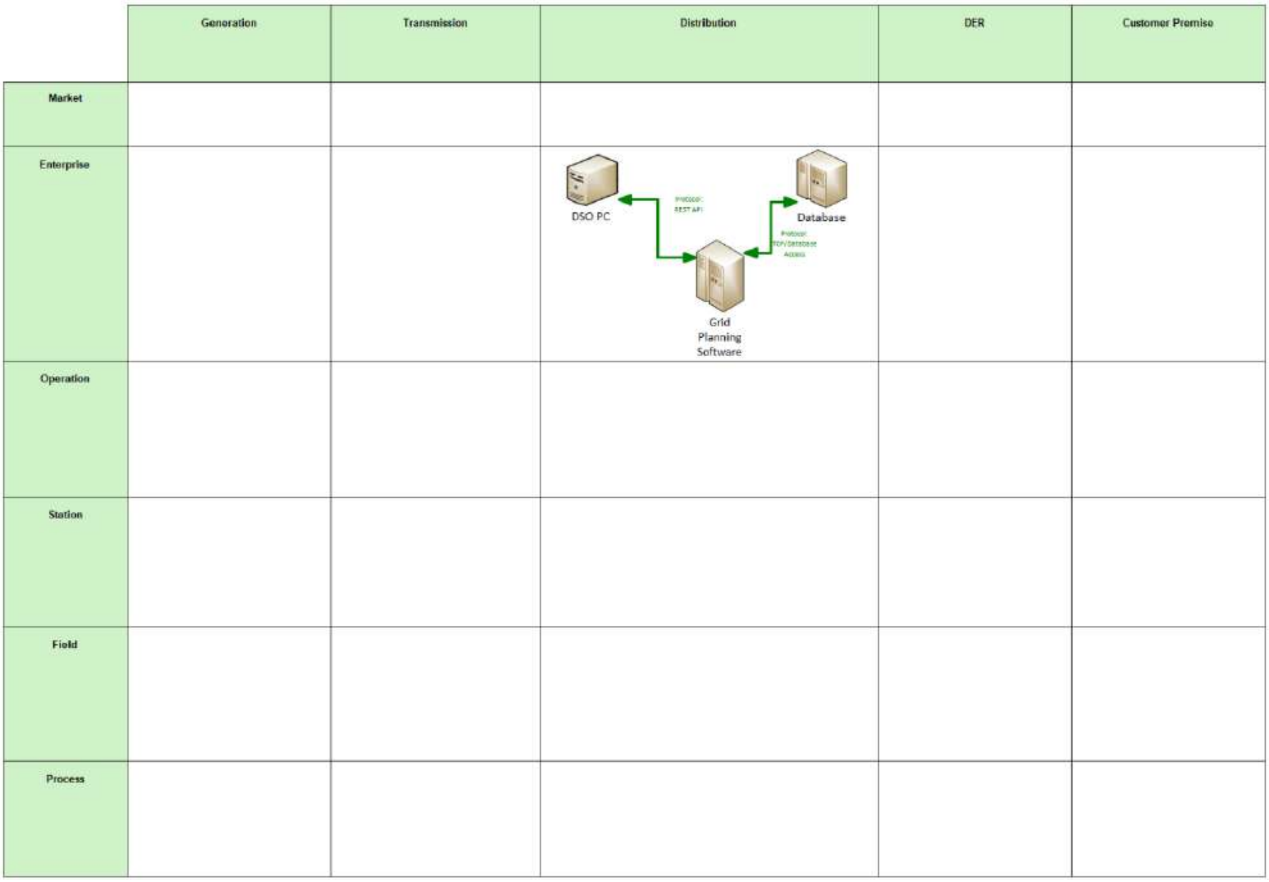

Figure 71. UC1.7 Communication layer

Table 41. List of Communication technologies linked with UC 1.7

Communication Technology	Description
REST	Representational State Transfer. Set of software constraints for web services, to provide interoperability between computer systems on the Internet. A RESTful web service defines a uniform and predefined set of stateless operations that accept requests through a URI.
TCP/IP	Transmission Control Protocol/Internet Protocol. Conceptual model and set of communication protocols used on the Internet. They provide end-to-end data communication, specifying how data should be packetized, addressed, transmitted, routed, and received, through four abstraction layers (link, internet, transport, and application).

5.7.9 Component Layer

The components included in the use case are depicted below, including the technology used for connecting each other.

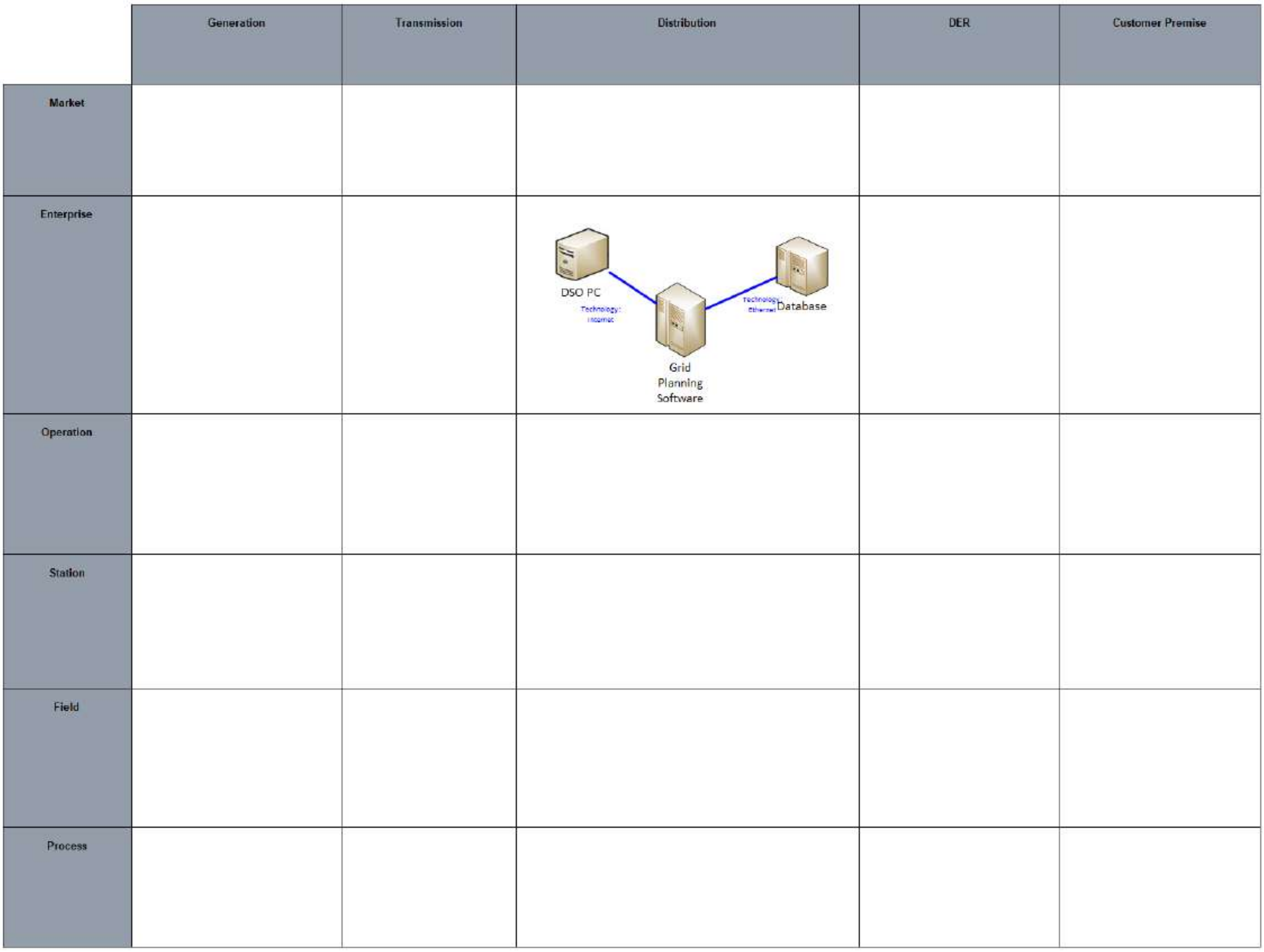

Figure 72. UC 1.7 Component layer

Table 42. List of Components linked with UC 1.7

Component	Component Type
DSO PC, Database	device
Grid Planning Software	Software application

5.8 UC 1.8: HEMS/BEMS DR optimization and local flexibility management

5.8.1 Use Case Description

OPENTUNITY HEMS/BEMS are responsible for the local flexibility management and the participation of the demo sites in Demand Response services. They are software backend systems developed in a modular approach to provide specific functionalities and flexibility management over various building assets (i.e., HVACs, DHWs, EVs including charging points, storage and other assets) for effectively unlocking and exploiting the distributed small-scale flexibility potential behind every residential/building connection point.

HEMS/BEMS provide day-ahead (24h) flexibility forecasts - possibility for upwards or downwards regulation of a building/asset consumption - based on the existing energy resources inside the pilot premises and will co-optimize the operation of several appliances to deliver maximum flexibility without violating end-users' comfort boundaries. To achieve this goal, several optimization engines are embedded in the core functionalities of the HEMS. Extracted flexibility forecasts will be provided to the main market actors including aggregators and the NODES' local flexibility markets through the proper interfaces and according to predefined or standardized flexibility semantics.

Upon a flexibility request from the DR market actors, the HEMS/BEMS integrated control system will respond by generating optimal control actions in order to deliver the requested load dispatching while monitoring the assets' consumption and the overall performance of the dispatched control signals. The final activation of the building assets will be performed through the local controllers within the pilot buildings.

5.8.2 Function Layer

The functional layer of UC 1.8 is presented in the following graph highlighting the key actors of the use case

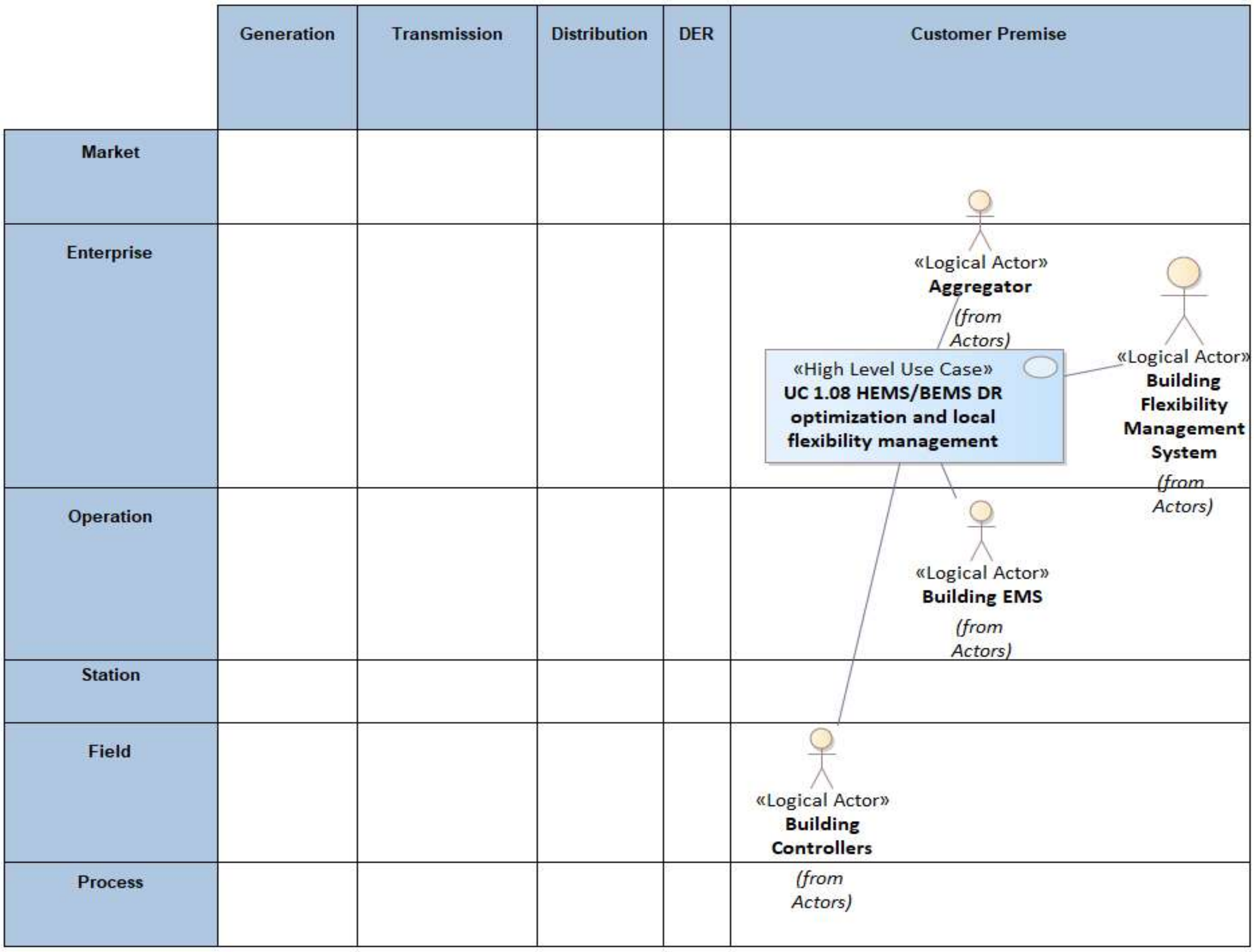

Figure 73. UC 1.8 Function layer

Table 43. List of actors involved in UC 1.8

Actor Name	Actor Type
Aggregators/FSPs	Organization
BFMS	System
Building EMS	System
Building Controllers	Devices

5.8.3 Information Layer

Details about information layer of UC1.8 are presented in the following figure, highlighting the key information objects

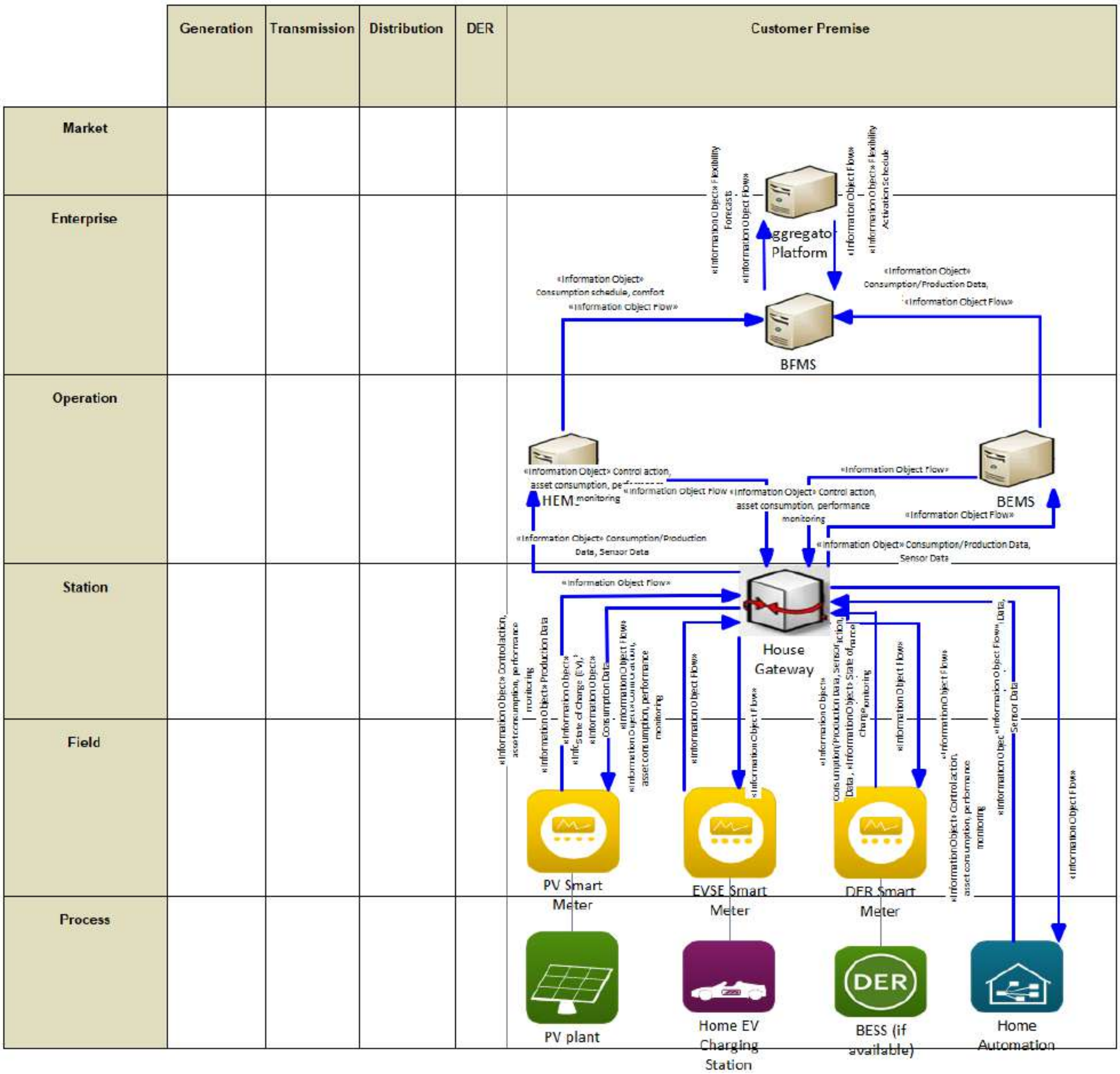

Figure 74. UC 1.8 Information Layer

5.8.4 Canonical Data model

The identified canonical data models for UC1.8 are described below.

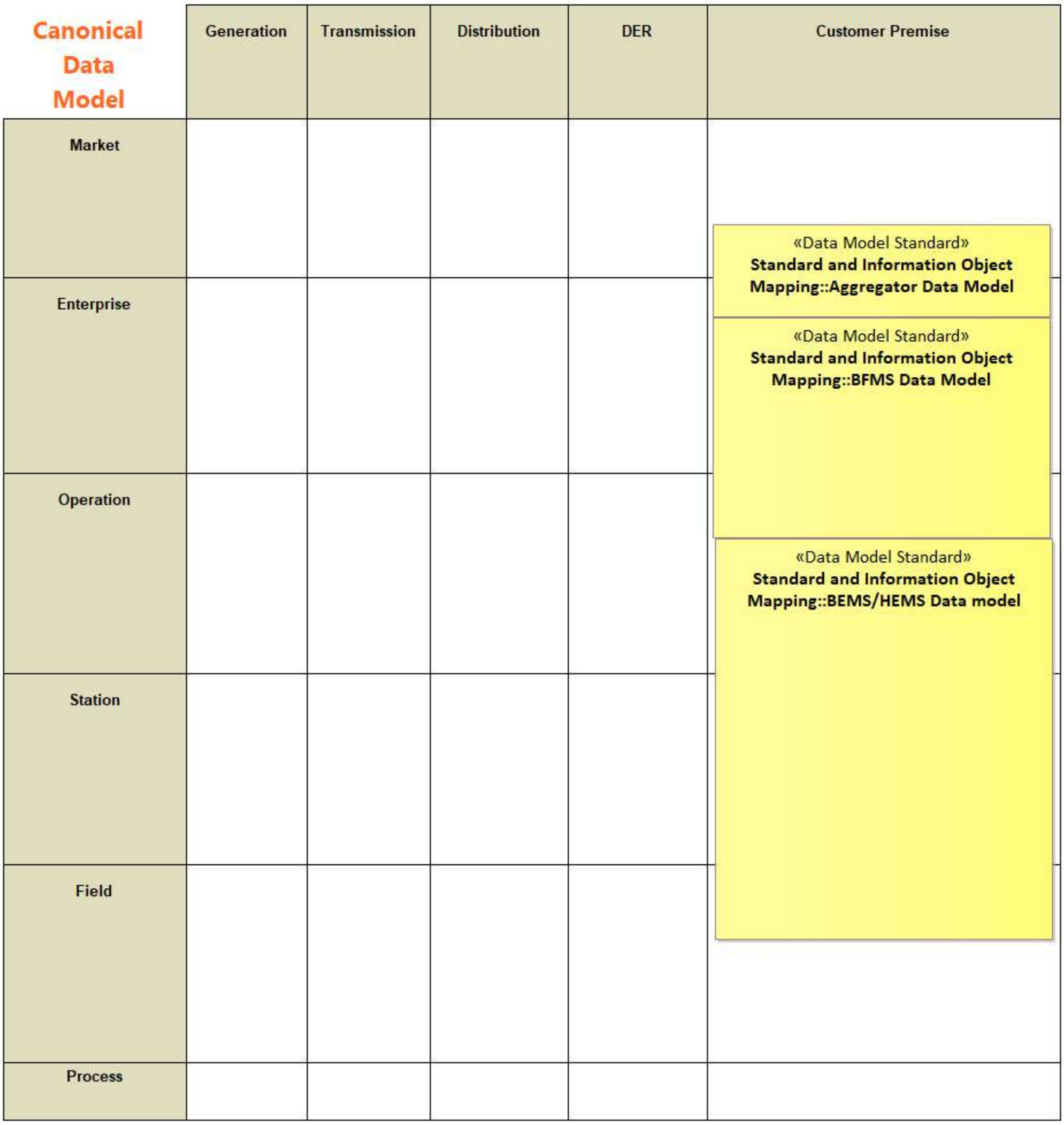

Figure 75. UC 1.8 Canonical data model

Table 44. List of Data models involved in UC 1.8

Data Models
Aggregator data model
BFMS data model
BEMS/HEMS Data model

5.8.5 Standards and information object mapping

SGAM Standards and Information Objects Mapping for UC 1.8 is presented in the following figure.

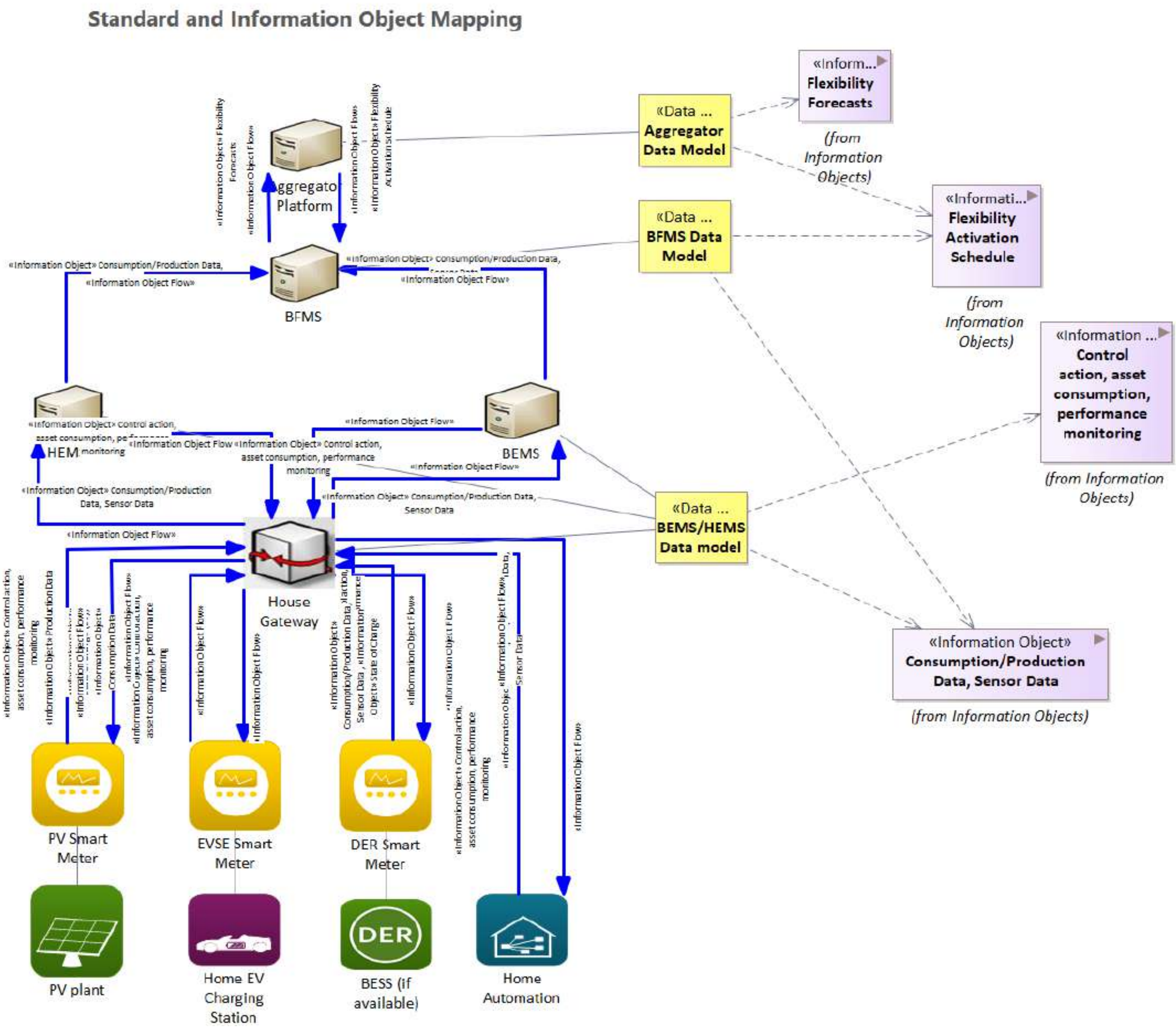

Figure 76. UC 1.8 Standards and Information Object Mapping

Table 45. List of Information Objects, link with Data Standards in UC 1.8

Information Object	DATA Models	Information
Flexibility Forecasts	Aggregator platform model	Schedule of available flexibility that can be offered.
Consumption Schedule, comfort preferences	BFMS model, BEMS/HEMS model	Building consumption schedule and comfort preferences of residents.
Consumption/Production Data, Sensor Data	BFMS model, BEMS/HEMS model, Building Data model	Data generated by the building assets and pushed through BEMS/HEMS to BFMS for the calculation of flexibility forecasts.

5.8.6 Activity Diagram

The detailed activity diagram for UC 1.8 is presented in the following figure.

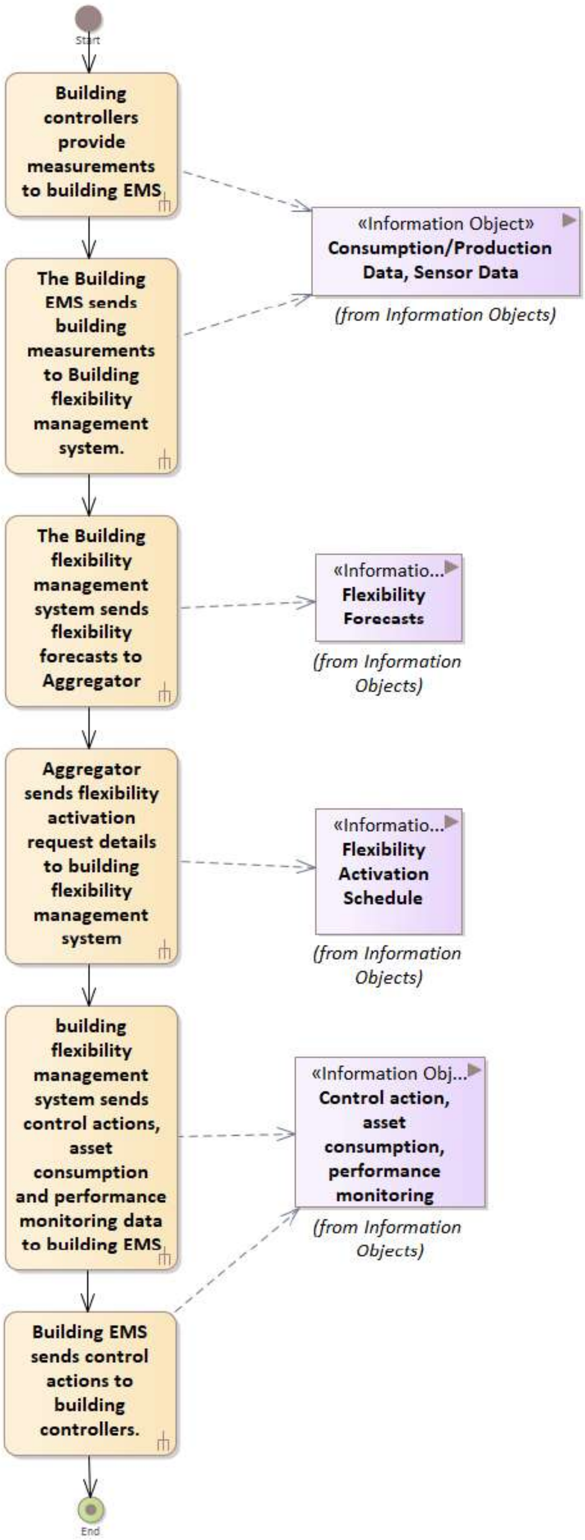

Figure 77. UC1.8 Activity Diagram

5.8.7 Sequence Diagram

The detailed sequence diagram for UC 1.8 is presented in the following figure

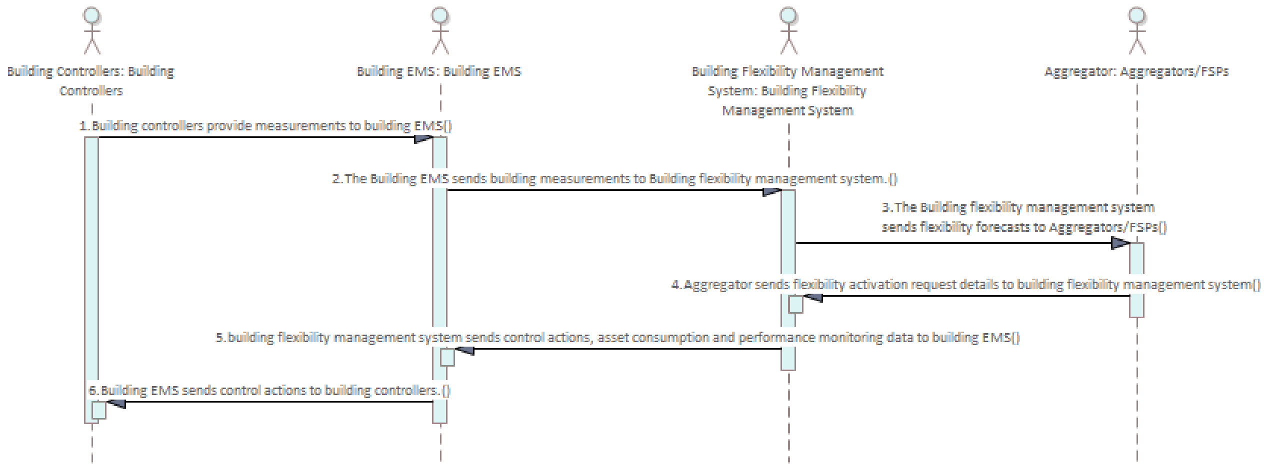

Figure 78. UC 1.8 Sequence Diagram

5.8.8 Communication Layer

The communication layer of UC 1.8 is presented in the following figure, highlighting the key communication protocols among the different modules.

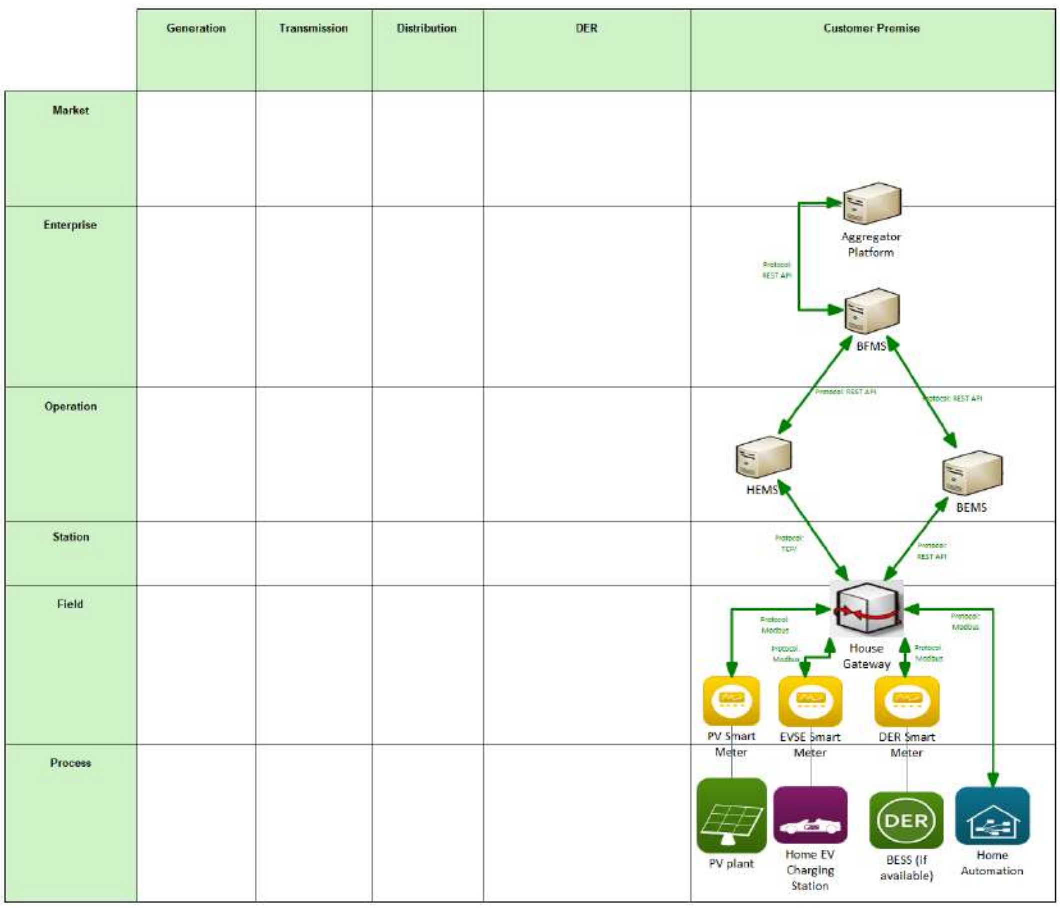

Figure 79. UC 1.8 Communication layer

Table 46. List of Communication technologies linked with UC 1.8

Communication Technology	Communication Technology Description
Modbus	Communication protocol for programmable logic controllers (PLCs). It is openly published, easy to deploy and maintain, and does not present many restrictions on integration with different vendors. Modbus TCP covers the use of Modbus messaging using the TCP/IP protocols .
REST API	A REST API is an application programming interface (API or web API) that conforms to the constraints of REST architectural style and allows for interaction with RESTful web services.
WSS	WSS (Web WebSocket Secure) is a computer communications protocol, providing simultaneous two-way communication channels over a single TCP connection.

5.8.9 Component Layer

The components included in the use case are depicted below, including the technology used for connecting each other.

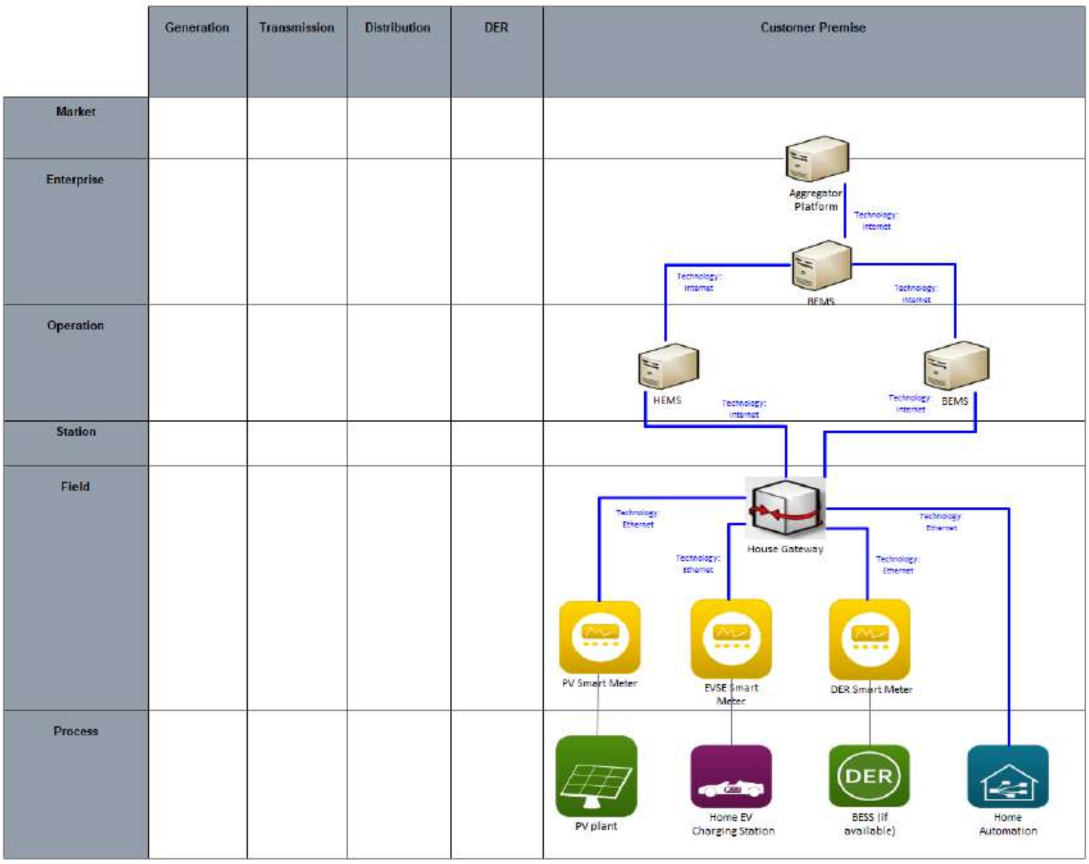

Figure 80. UC 1.8 Component Layer

Table 47. List of Components linked with UC 1.8

Component	Component Type
PV plant, BESS, Home Automation, PV Smart Meter, DER Smart Meter, House Gateway, Home EV charging station	Devices
HEMS, BEMS, BFMS, Aggregator Platform	System

5.9 UC 1.9 Initialization of HEMS/BEMS Demand Response strategy

5.9.1 Use Case Description

End-users' comfort constraints must not be violated during the operation of the HEMS/BEMS systems while their participation in Demand Response campaigns should not interfere with their preferences and affect their daily routine. Therefore, the end-users are in the center of the solution by actively participating in the system configuration during the initial phase of the demonstration activities. On the other hand, they can also bypass any control actuation on their own assets during the demand response campaigns.

During HEMS/BEMS initialization the end-users will scan the QR codes of their meters and energy assets for including their desired flexibility assets and also answer some simple questions through a user-friendly way for indicating their comfort preferences and daily schedules. All their inputs will be evaluated for understanding their DR capabilities and the degree of involvement in the DR campaigns. In addition, the initial settings algorithms will be triggered for fine-tuning the system and introducing the proper constraints in the HEMS/BEMS optimization framework so that it can automatically generate demand response profiles and set the control optimization strategy without affecting the end-users. Many stakeholders will benefit from this innovation since they will have access to low volumes of flexibility usually occurring during peak hours but with high potential for large-scale aggregation.

5.9.2 Function Layer

The functional layer of UC 1.9 is presented in the following graph highlighting the key actors of the use case.

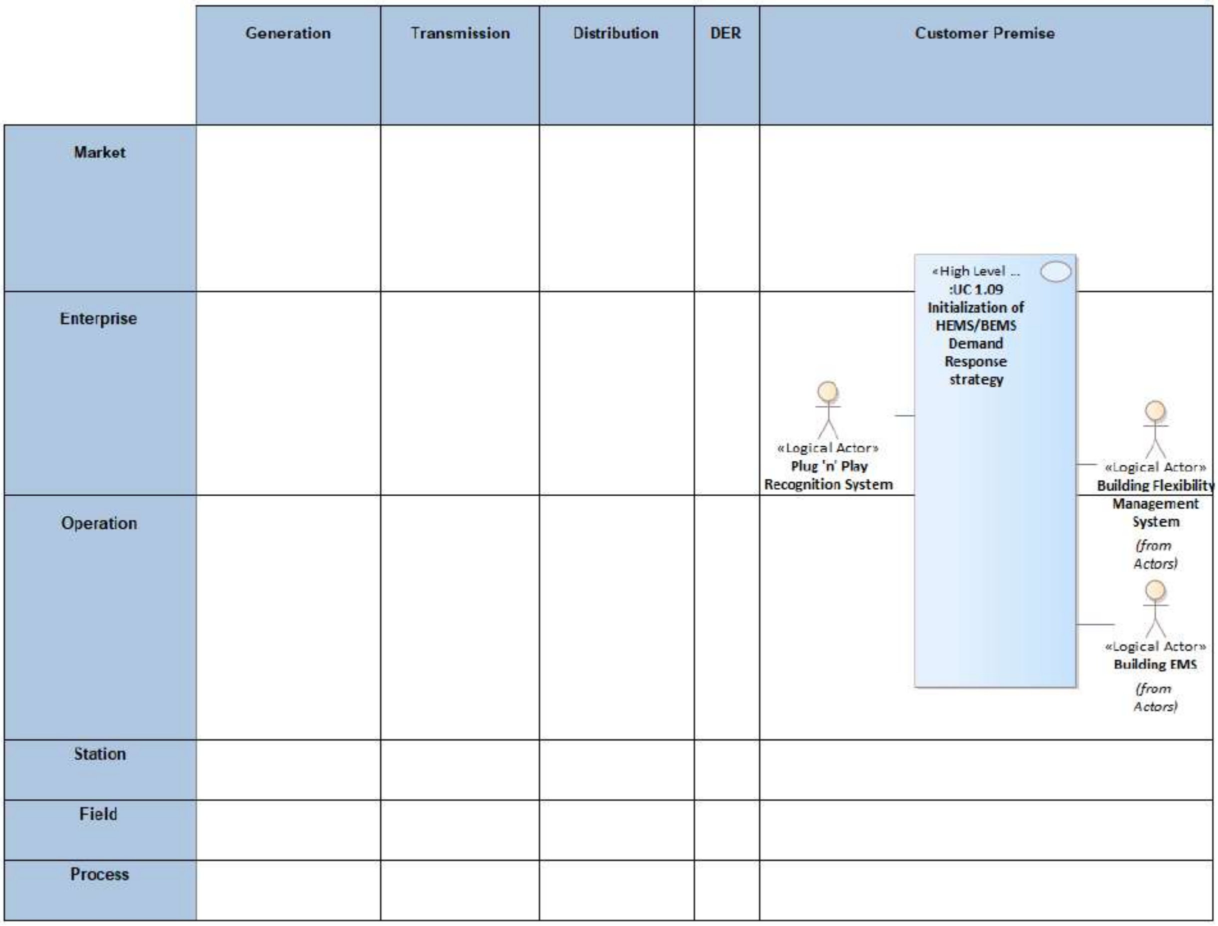

Figure 81. UC 1.9 Function Layer

Table 48. List of actors involved in UC 1.9

Actor Name	Actor Type
Plug'n'Play recognition system	System
BFMS	System
Building EMS	System

5.9.3 Information Layer

Details about information layer of UC1.9 are presented in the following figure, highlighting the key information objects.

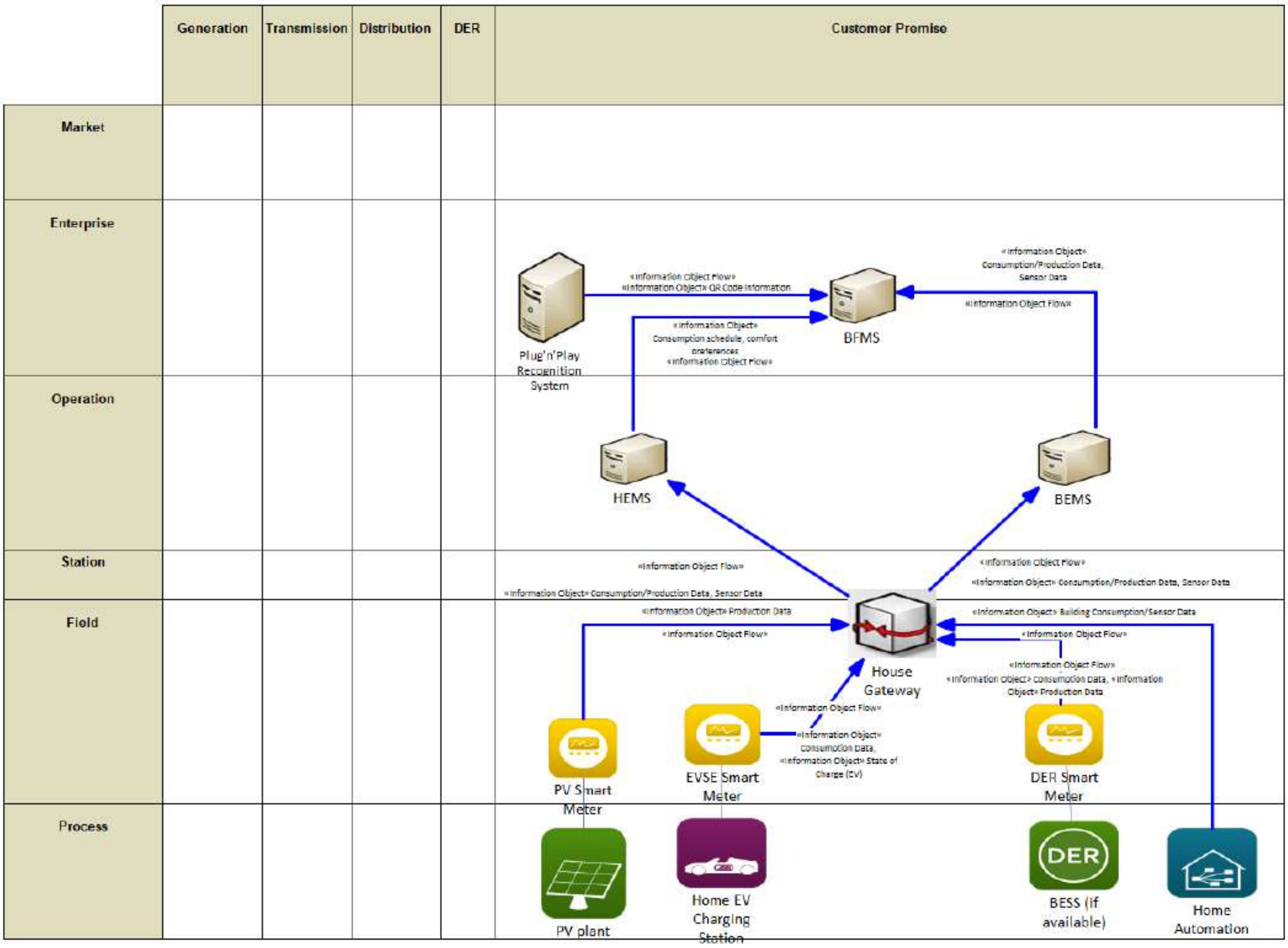

Figure 82. UC 1.9 Information Layer Diagram

5.9.4 Canonical Data Model

The identified canonical data models for UC1.9 are described below.

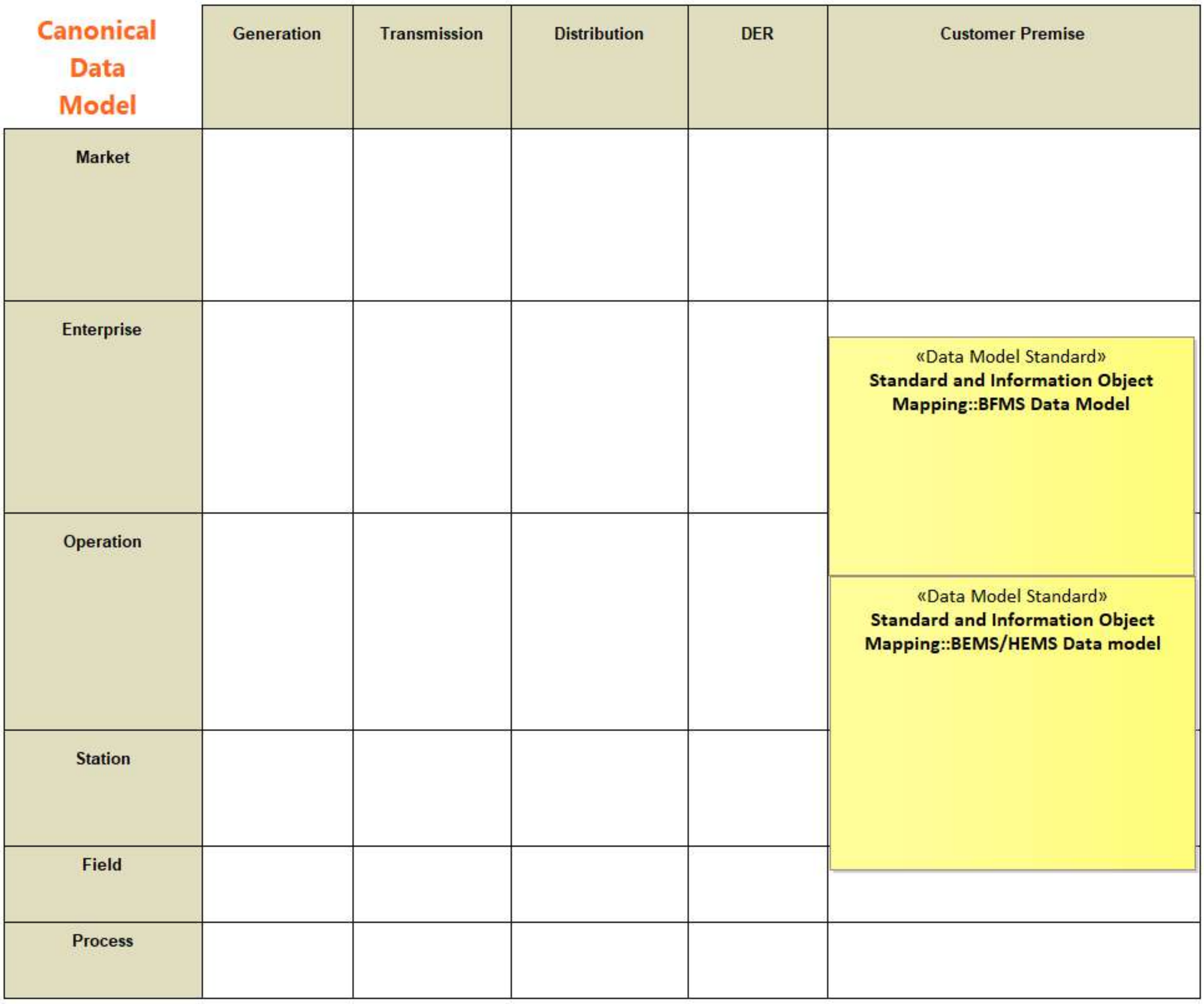

Figure 83. UC 1.9 Canonical data model

Table 49. List of Data models involved in UC 1.9

Data Models
BFMS data model
BEMS/HEMS Data model

5.9.5 Standards and Information Object Mapping

SGAM Standards and Information Objects Mapping for UC 1.9 is presented in the following figure.

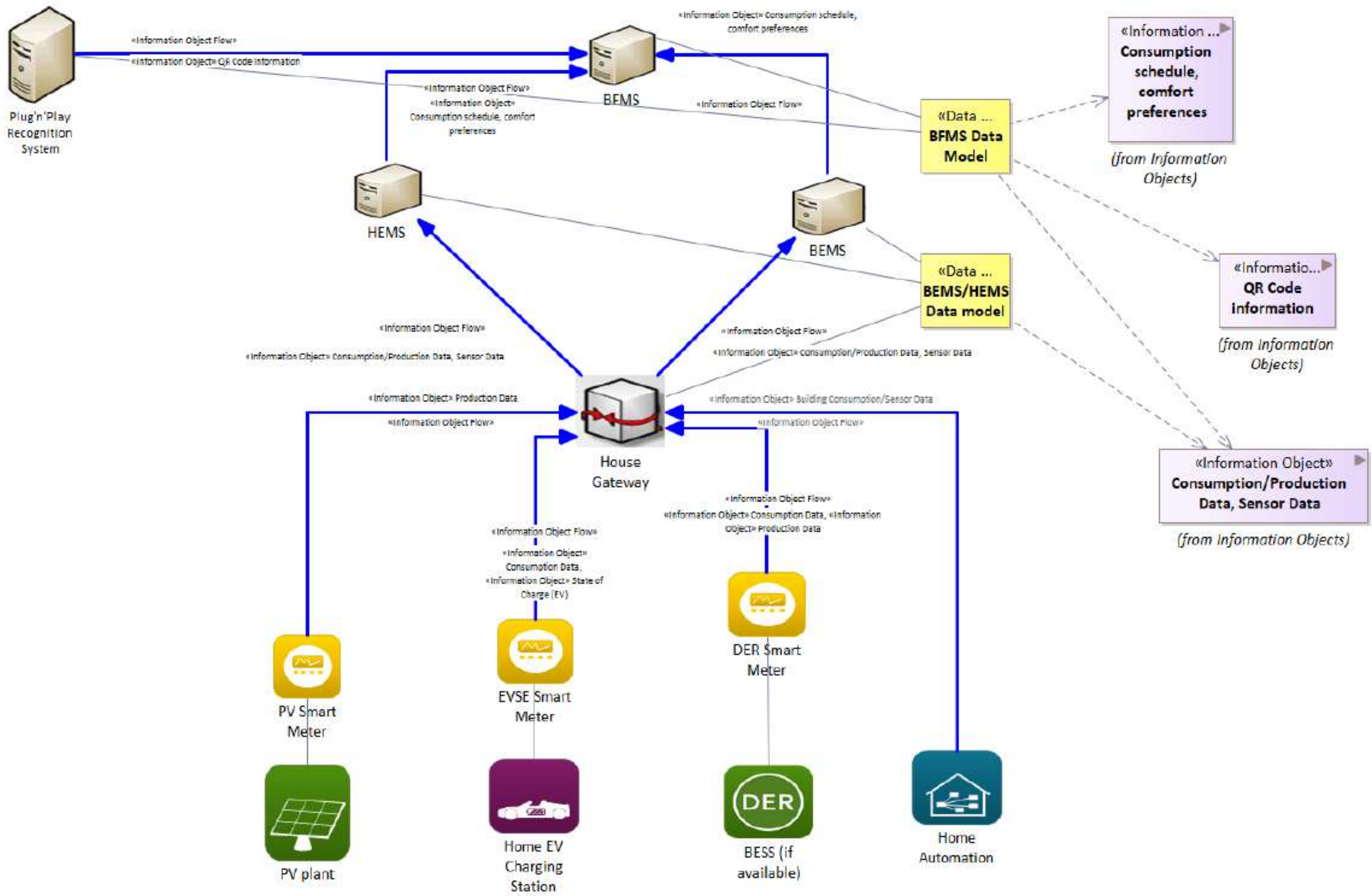

Figure 84. UC 1.9 Standards and Information Object Mapping

Table 50. List of Information Objects, link with Data Standards in UC 1.9

Information Object	DATA Models	Information
QR code information	BFMS, data model	Information on new flexibility assets, e.g. nominal power.
Consumption Schedule, comfort preferences	BFMS model, BEMS/HEMS model	Building consumption schedule and comfort preferences of residents.
Consumption/Production Data, Sensor Data	BFMS model, BEMS/HEMS model	Data generated by the building assets and pushed through BEMS/HEMS to BFMS for the calculation of flexibility forecasts.

5.9.6 Activity Diagram Layer

The detailed activity diagram for UC 1.9 is presented in the following figure.

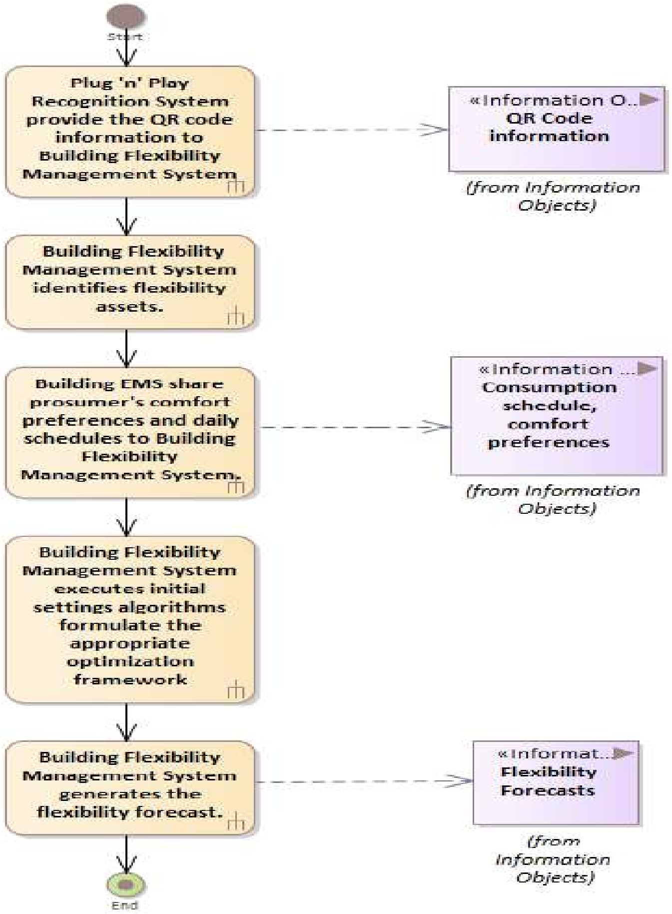

Figure 85. UC 1.9 Activity Diagram

5.9.7 Sequence Diagram

The detailed sequence diagram for UC 1.9 is presented in the following figure.

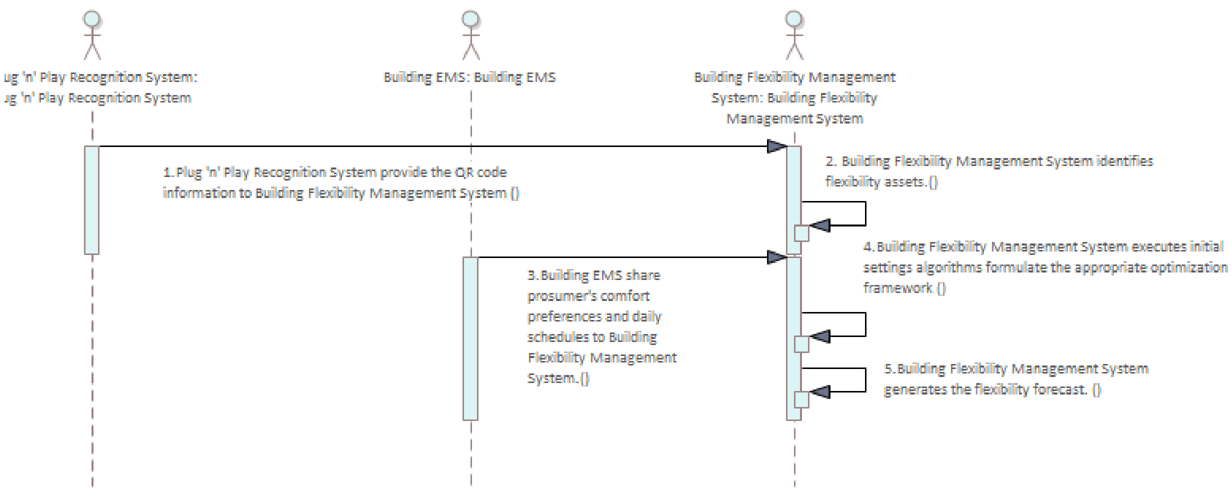

Figure 86. UC 1.9 Sequence Diagram

5.9.8 Communication Layer

The communication layer of UC 1.9 is presented in the following figure, highlighting the key communication protocols among the different modules.

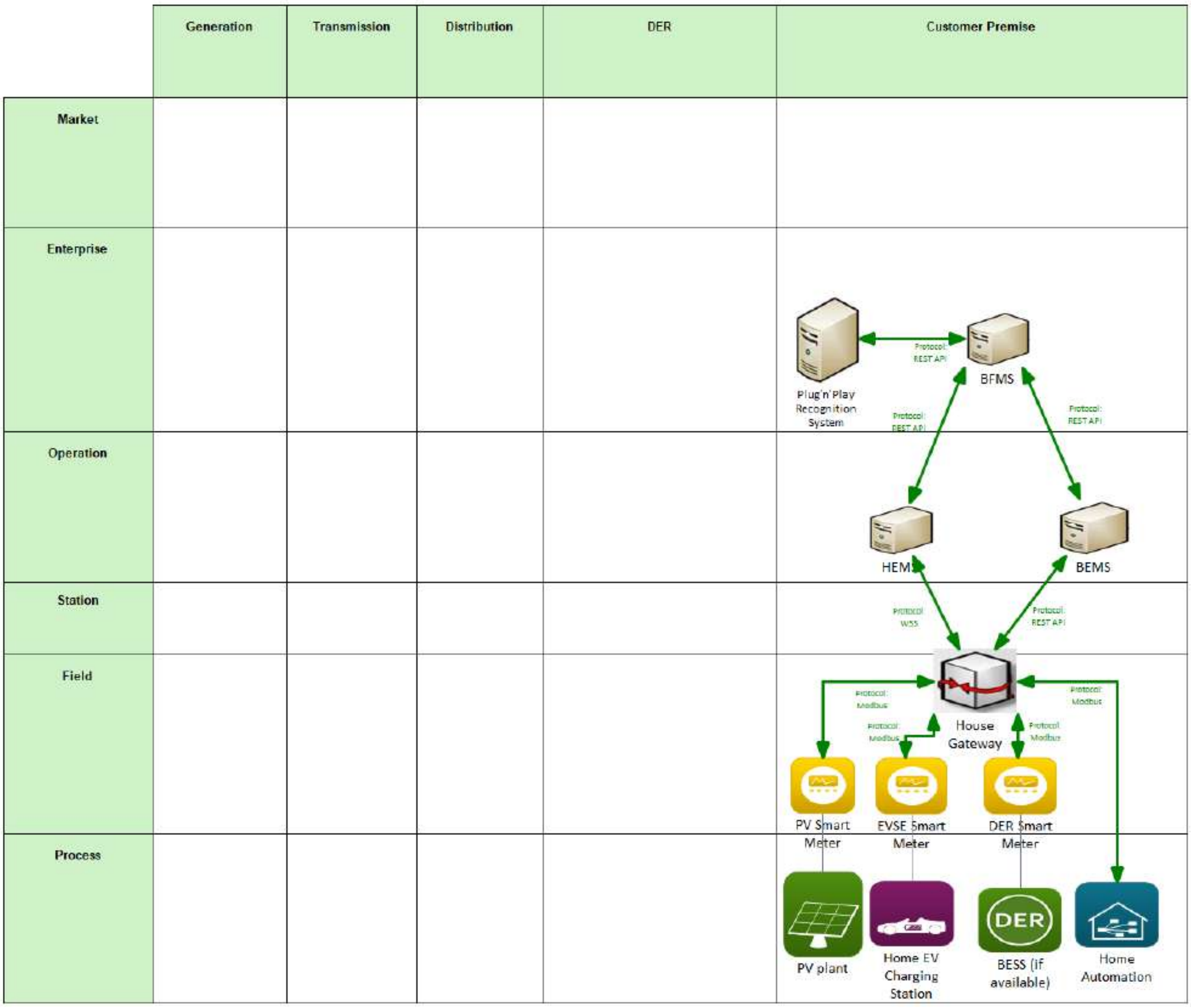

Figure 87. UC 1.9 Communication Layer

Table 51. List of Communication technologies linked with UC 1.9

Communication Technology	Description
Modbus	Communication protocol for programmable logic controllers (PLCs). It is openly published, easy to deploy and maintain, and does not present many restrictions on integration with different vendors. Modbus TCP covers the use of Modbus messaging using the TCP/IP protocols .
REST API	A REST API is an application programming interface (API or web API) that conforms to the constraints of REST architectural style and allows for interaction with RESTful web services.

WSS	WSS (Web WebSocket Secure) is a computer communications protocol, providing simultaneous two-way communication channels over a single TCP connection.

5.9.9 Component Layer

The components included in the use case are depicted below, including the technology used for connecting each other.

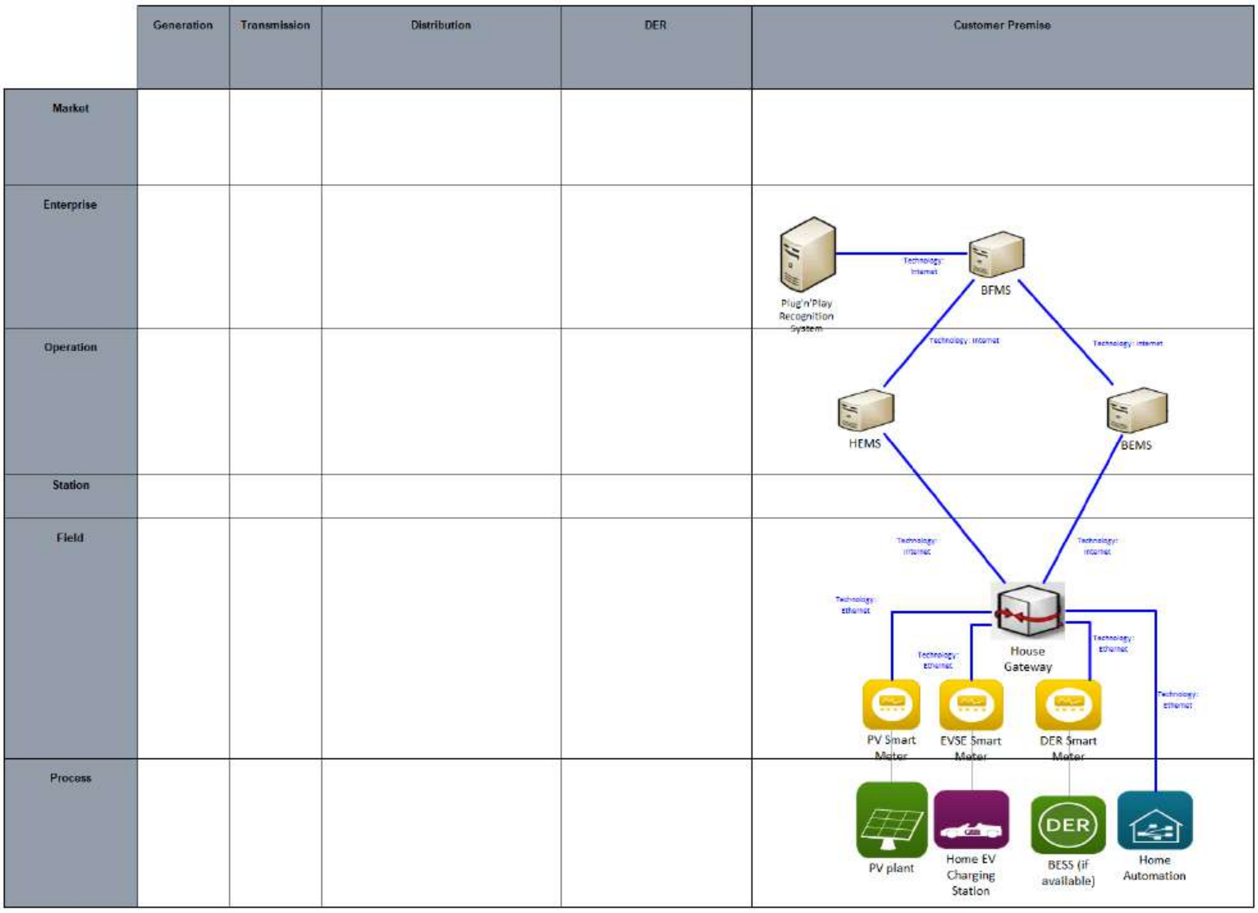

Figure 88. UC 1.9 Component Layer

Table 52. List of Components linked with UC 1.9

Component	Component Type
PV plant, BESS, Home Automation, PV Smart Meter, DER Smart Meter, House Gateway, Home EV charging station	Devices
HEMS, BEMS, BFMS, Plug'n'Play recognition systems	Applications

5.10 UC 1.10: Establishment of a flexibility market and flexibility procurement

5.10.1 Use Case Description

A flexibility market provides access to distributed flexibility assets across all grid levels. The implementation of a flexibility market can be site-specific considering national and regional characteristics in terms of TSO-DSO coordination, type of assets and asset availability, the prevailing grid problem and available devices and data. The flexibility provided may serve for the purpose of congestion management, grid balancing or voltage control and may be traded over short-term and long-term periods. The basic set up requires the presence of buyers (system operators) and sellers (Flexibility Service Providers/Aggregators). The market enables the exchange of the relevant information for each specific grid problem via buy/sell orders and associated baselines and metering data for validation and settlement.

5.10.2 Function Layer

The functional layer of UC 1.10 is presented in the following graph highlighting the key actors of the use case.

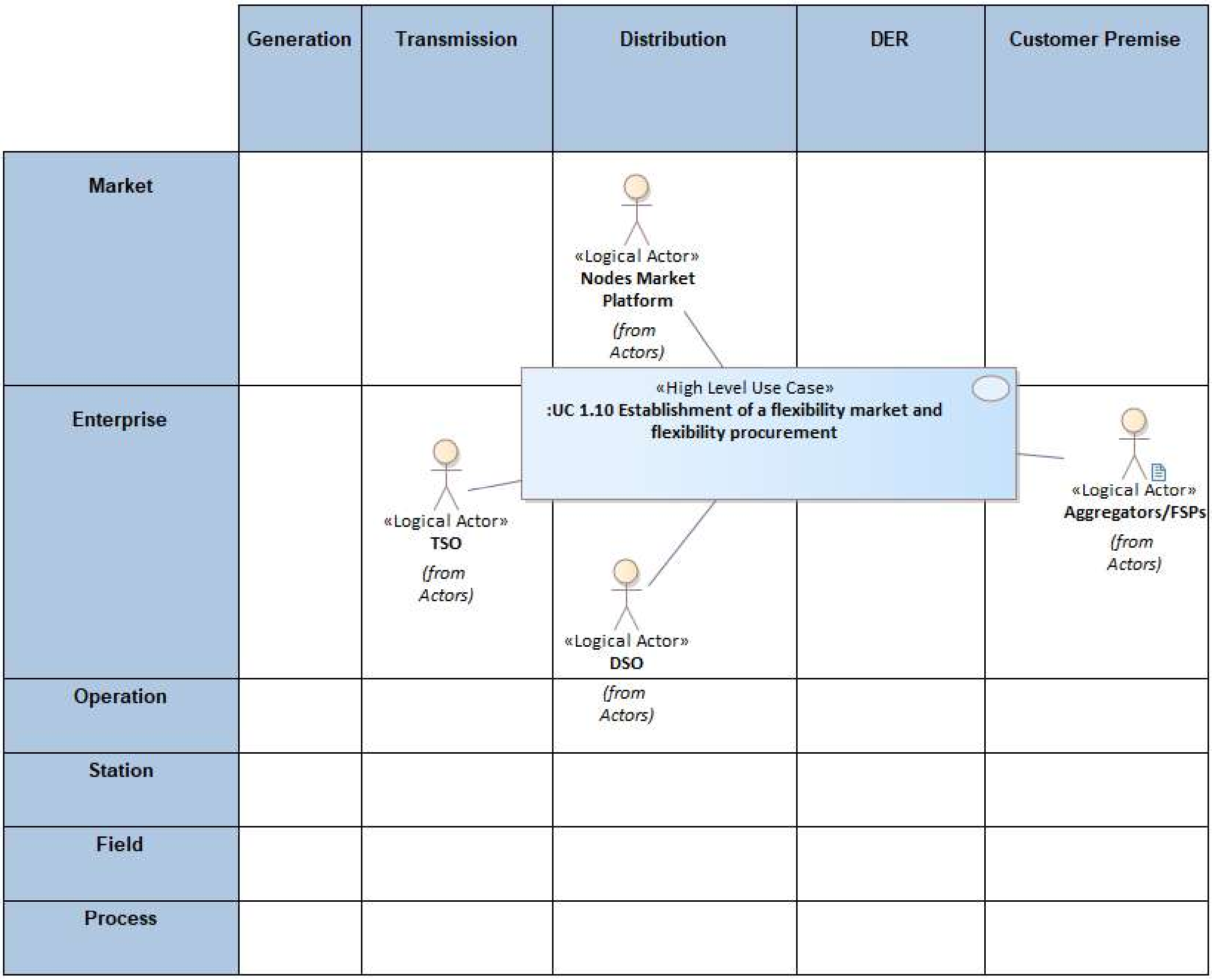

Figure 89. UC 1.10 Function layer

Table 53. List of actors involved in UC 1.10

Actor Name	Actor Type
Nodes Market Platform	System
TSO	Organization
DSO	Organization
Aggregators/FSP	Organization

5.10.3 Information Layer

Details about information layer of UC1.10 are presented in the following figure, highlighting the key information objects.

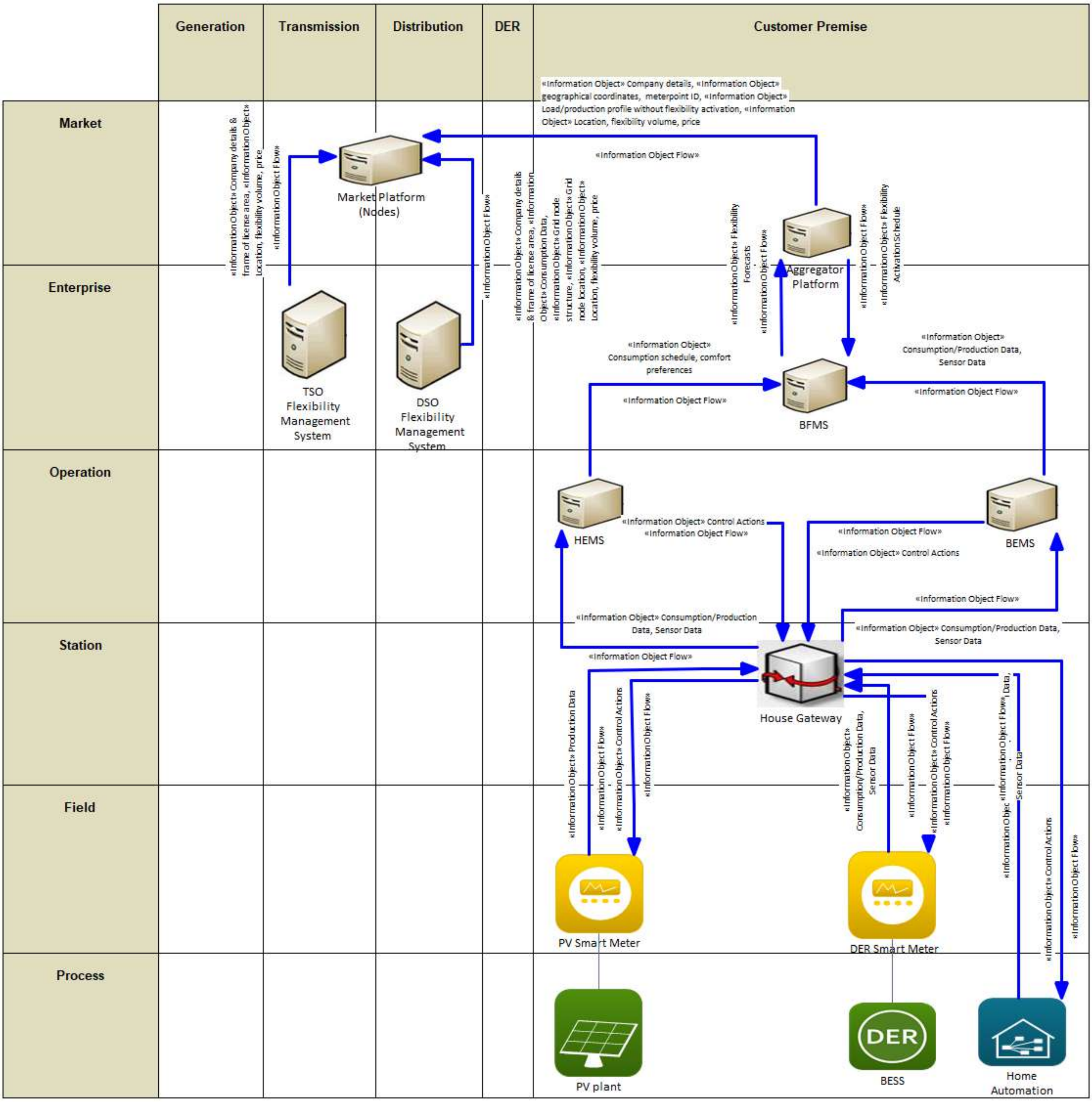

Figure 90. UC 1.10 Information Layer

5.10.4 Canonical Data Model

The identified canonical data models for UC1.10 are described below.

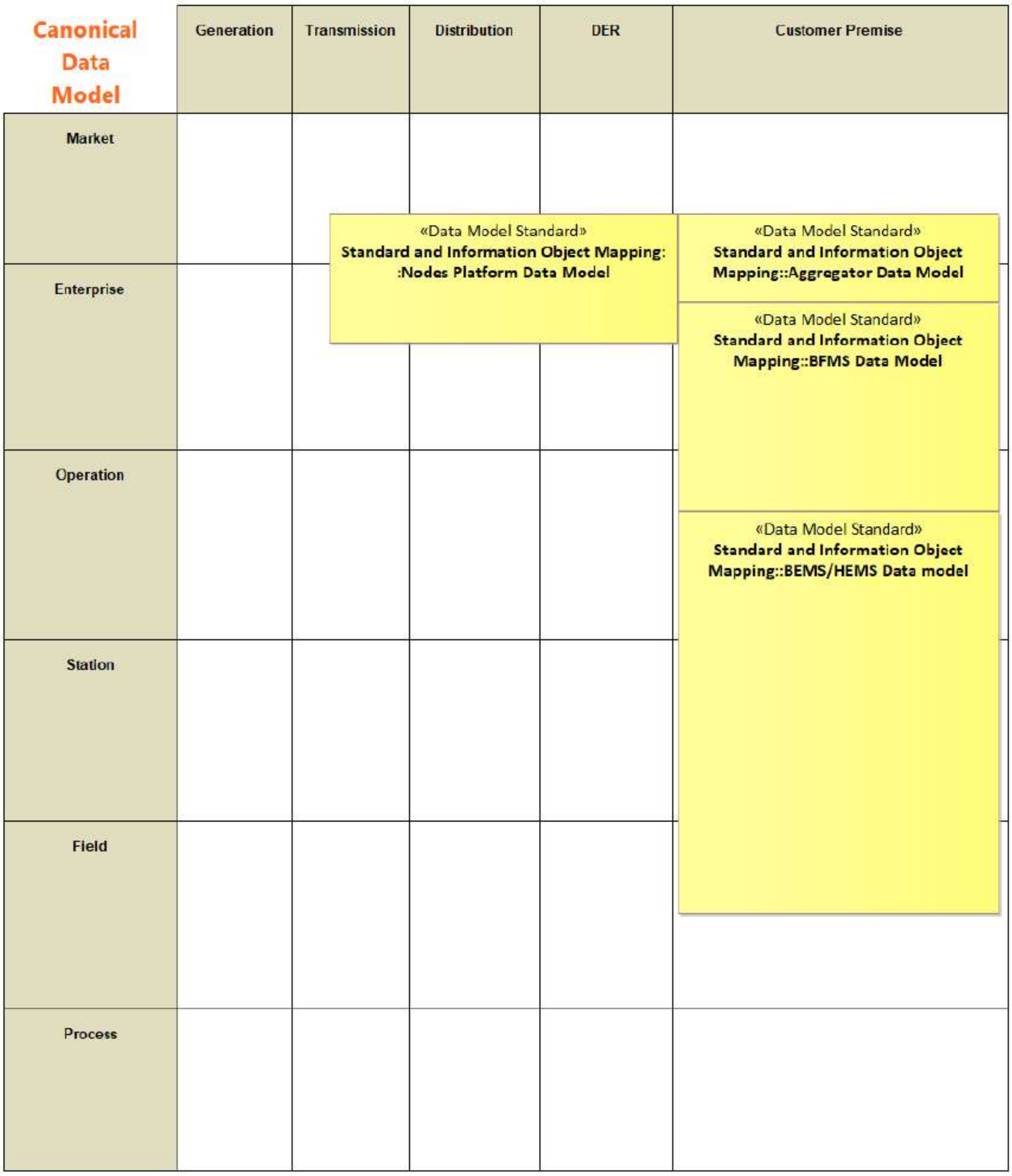

Figure 91. UC 1.10 Canonical data model

Table 54. List of Data models involved in UC 1.10

Data Models
Nodes Platform data model
Aggregator data model
BFMS data model
BEMS/HEMS Data model

5.10.5 Standards and Information Object Mapping

SGAM Standards and Information Objects Mapping for UC1.10 is presented in the following figure.

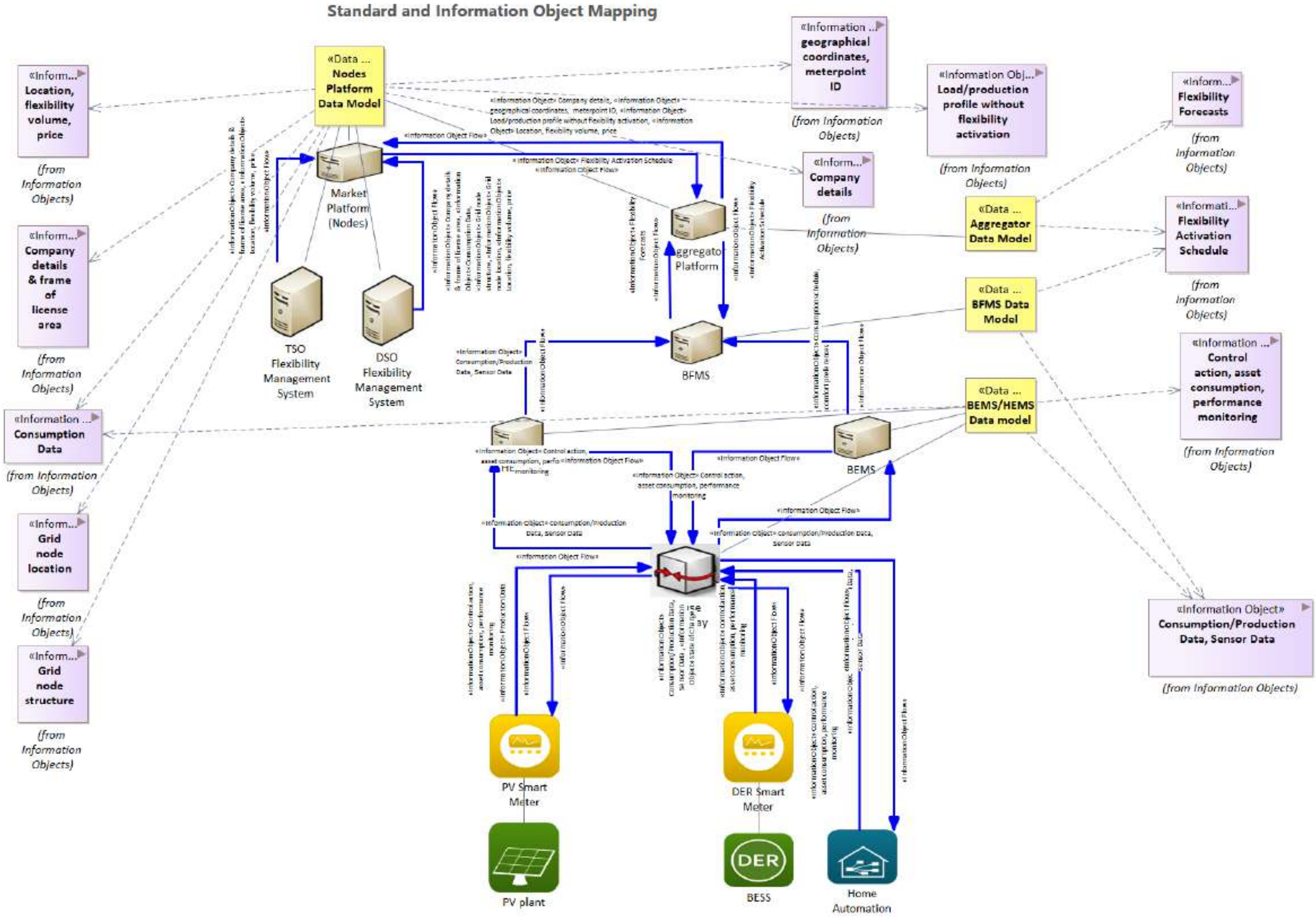

Figure 92. UC 1.10 Standards and Information Object Mapping

Table 55. List of Information Objects, link with Data Standards in UC 1.10

Information Object	DATA Models	Information
Location, Flexibility, volume, price	Nodes Platform data model	The sell or buy bid placed in nodes platform by FSP or DSO/TSO that responds to specific location (node or asset) volume in terms of energy and price
Company Details & Frame licence area	Nodes Platform data model	Data requested by Nodes platform for the registration of a DSO/TSO
Company Details	Nodes Platform data model	Data requested by Nodes platform for the registration of a FSP/Aggregator
Grid Node structure	Nodes Platform data model	Data requested by Nodes platform from DSO to generate the grid structure.
Geographical Coordinates, Meterpoint ID	Nodes Platform data model	Data requested by Nodes platform from a FSP/Aggregator for the registration of a flexibility asset.
Grid Node Location	Nodes Platform data model	Data requested by Nodes platform from DSO when a new flexibility asset is registered for its mapping to a specific node.
Load/Production profile without flexibility activation	Nodes Platform data model	Data requested by Nodes platform from a FSP/Aggregator per asset to evaluate the activation of flexibility.
Consumption Data	Nodes Platform data model	Data requested by Nodes platform from DSO to validate the activation of flexibility
Flexibility Forecasts	Aggregator platform model	Schedule of available flexibility that can be offered.
Flexibility Activation Schedule	Aggregator platform model/BFMS model	Schedule of available flexibility that has been purchased and has to be activated.
Control action, asset consumption, performance monitoring	BEMS/HEMS model	Data generated by the BEMS/HEMS for the activation and monitoring of flexibility when the flexibility activation schedule is received.
Consumption/Production Data, Sensor Data	BFMS model, BEMS/HEMS model, Building Data model	Data generated by the building assets and pushed through BEMS/HEMS to BFMS for the calculation of flexibility forecasts.

5.10.6 Activity Diagram

The detailed activity diagram for UC 1.10 is presented in the following figure.

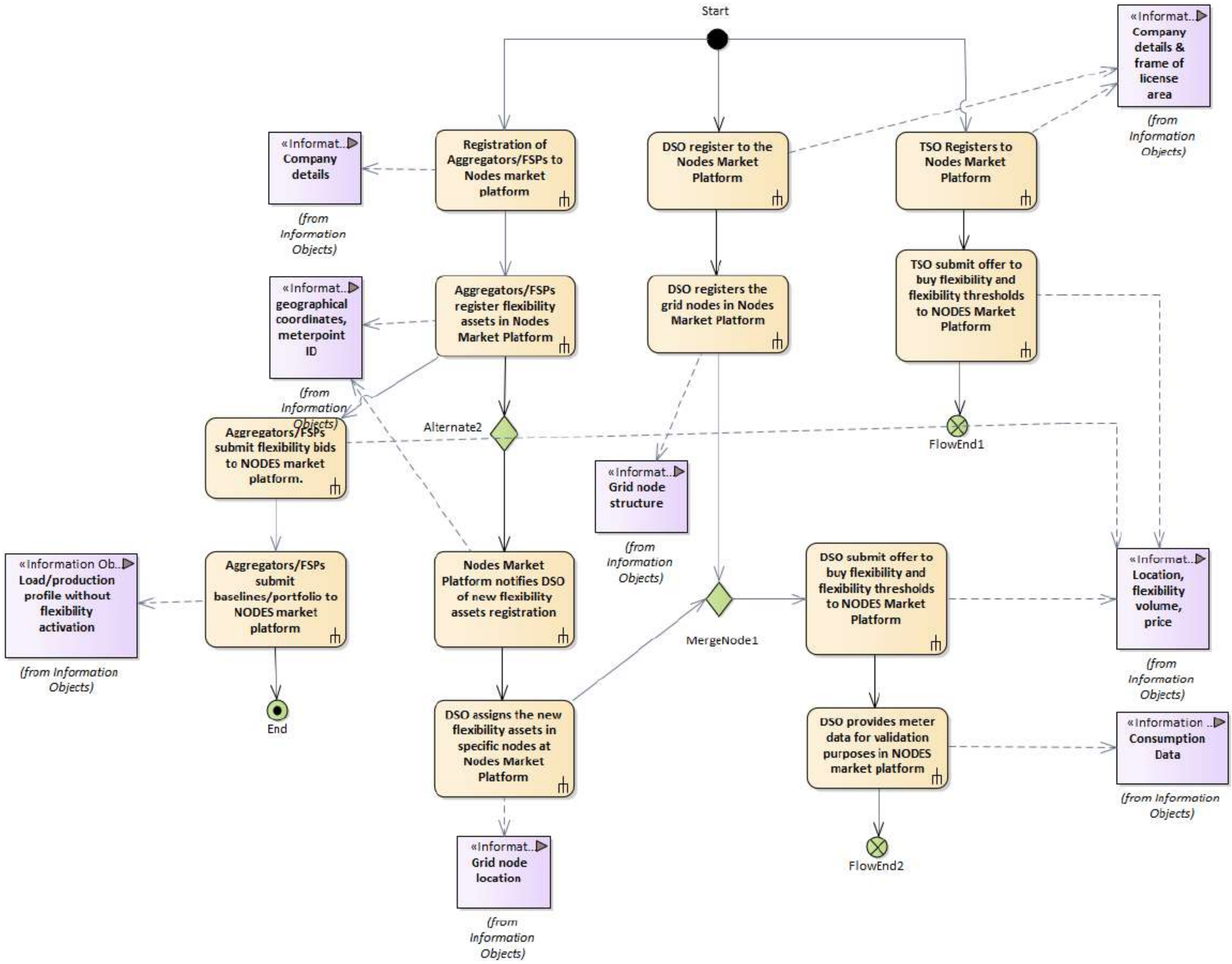

Figure 93. UC 1.10 Activity Diagram

5.10.7 Sequence Diagram

The detailed sequence diagram for UC 1.10 is presented in the following figure.

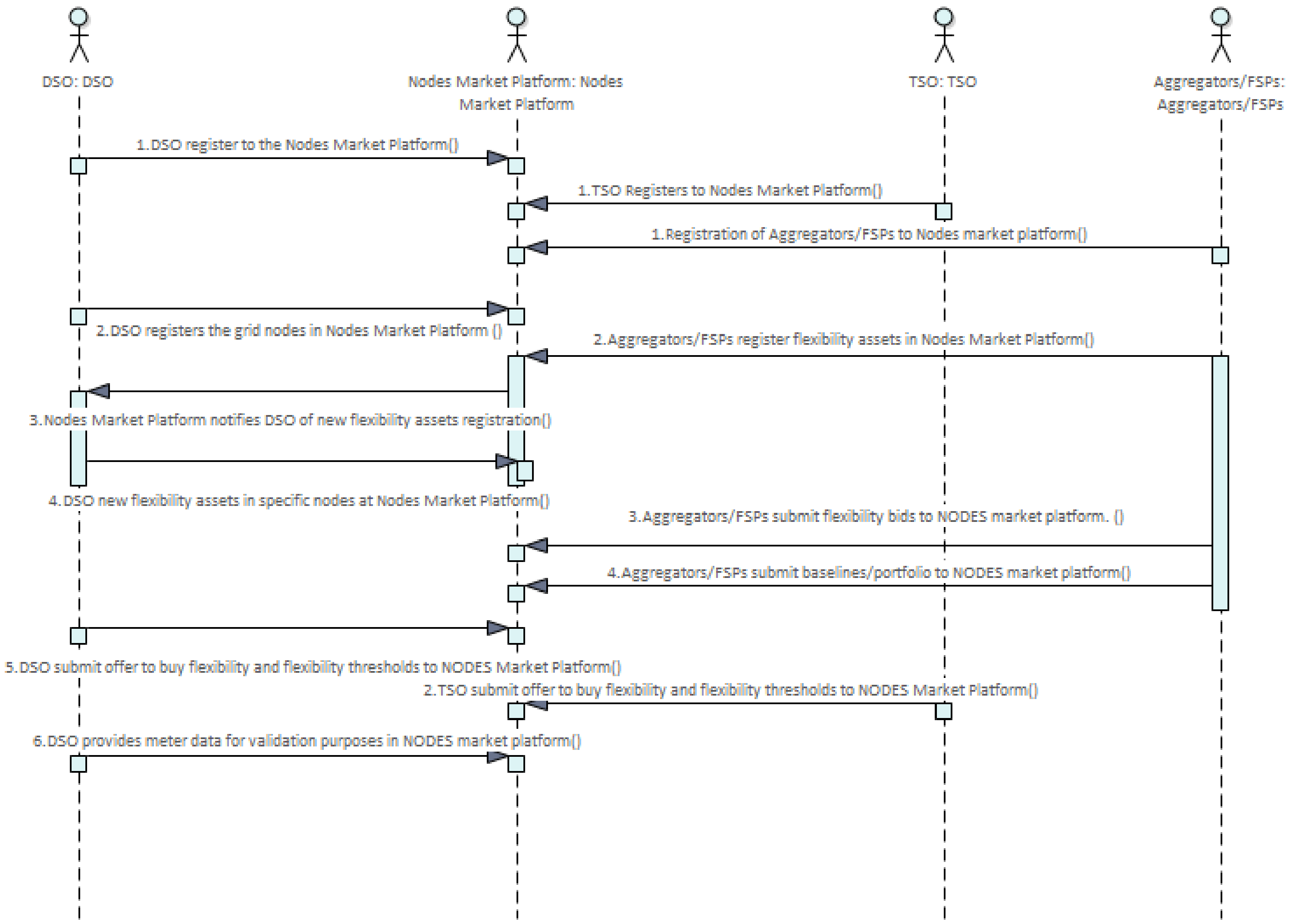

Figure 94. UC 1.10 Sequence diagram

5.10.8 Communication Layer

The communication layer of UC 1.10 is presented in the following figure, highlighting the key communication protocols among the different modules.

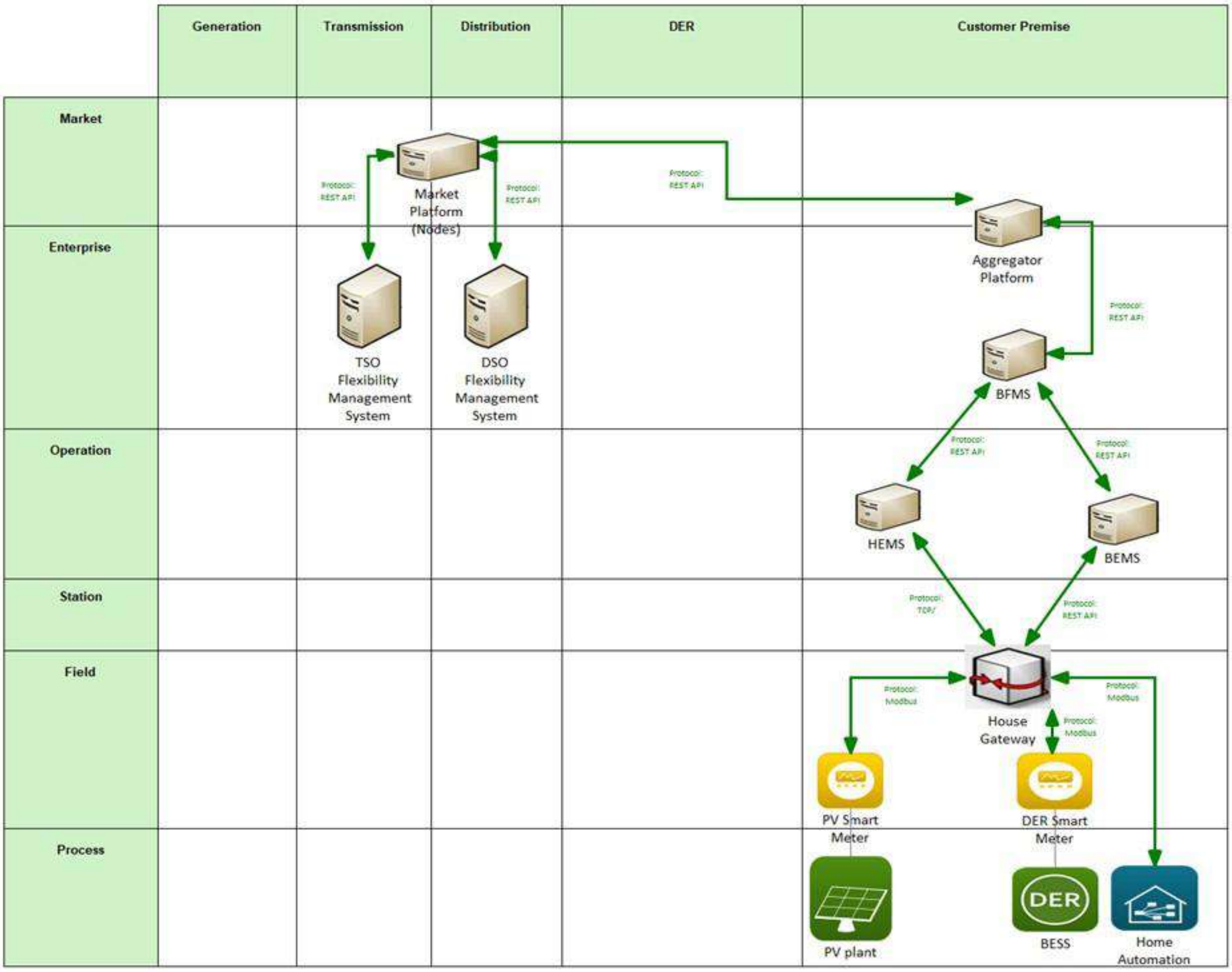

Figure 95. UC 1.10 Communication Layer

Table 56. List of Communication technologies linked with UC 1.10

Communication Technology	Communication Technology Description
Modbus	Communication protocol for programmable logic controllers (PLCs). It is openly published, easy to deploy and maintain, and does not present many restrictions on integration with different vendors. Modbus TCP covers the use of Modbus messaging using the TCP/IP protocols .
REST API	A REST API is an application programming interface (API or web API) that conforms to the constraints of REST architectural style and allows for interaction with RESTful web services.
TCP	Transmission Control Protocol/Internet Protocol. Conceptual model and set of communication protocols used on the Internet. They provide end-to-end data communication, specifying how data should be packetized, addressed, transmitted, routed, and received, through four abstraction layers (link, internet, transport, and application)

5.10.9 Component Layer

The components included in the use case are depicted below, including the technology used for connecting each other.

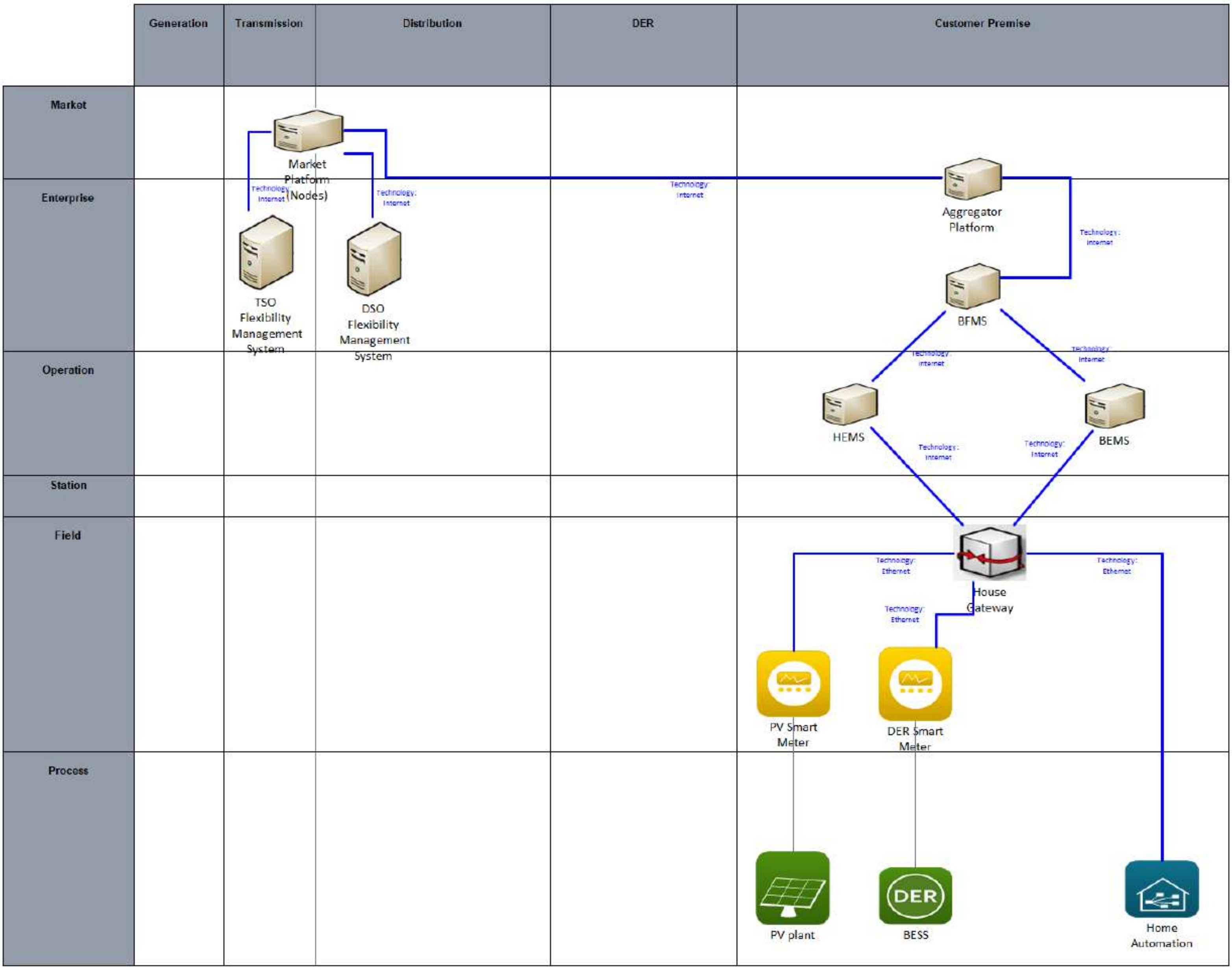

Figure 96. UC 1.10 Component Layer

Table 57. List of Components linked with UC 1.10

Component	Component Type
PV plant, BESS, Home Automation, PV Smart Meter, DER Smart Meter, House Gateway	Devices
HEMS, BEMS, BFMS, Aggregator Platform, Market Platform (Nodes)	Applications

5.11 UC 2.1: Network planning for High RES penetration

5.11.1 Use Case Description

The objective of this UC is to determine the most suitable upgrades in the MV network to enhance the penetration RES. The analysis will encompass the existing network topology, the current RES, and the potential for further RES deployment. Additionally, the proposed solutions' economic feasibility will be evaluated. Lastly, the availability of flexibility from RES and distributed generators (DGs) will also be taken into account.

5.11.2 Function Layer

The functional layer of UC 2.1 is presented in the following graph highlighting the key actors of the use case.

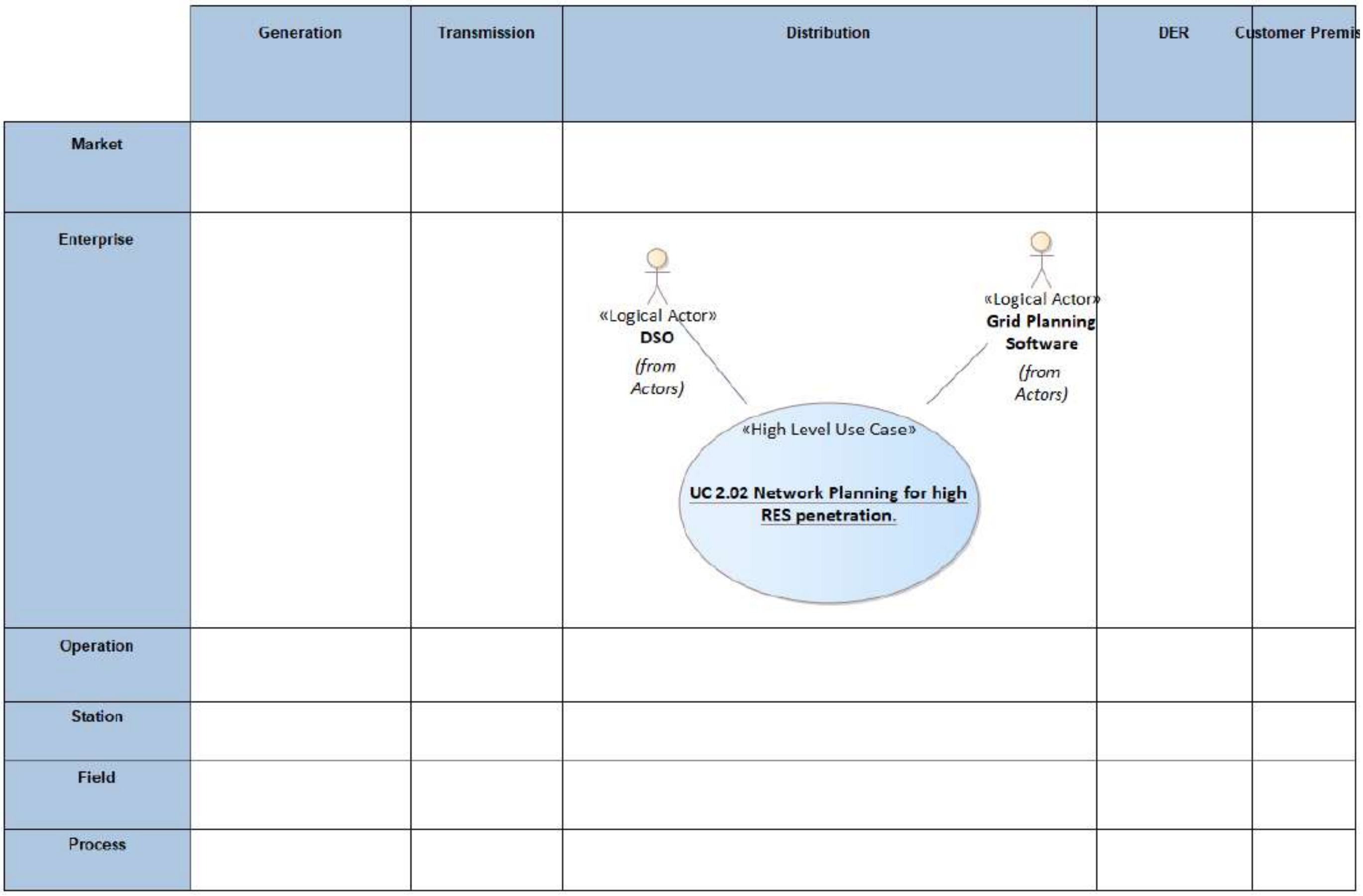

Figure 97. UC 2.1 Function Layer

Table 58. List of actors involved in UC 2.1

Actor Name	Actor Type
DSO	Organization
Grid Planning software	Software Application

5.11.3 Information Layer

Details about information layer of UC2.1 are presented in the following figure, highlighting the key information objects.

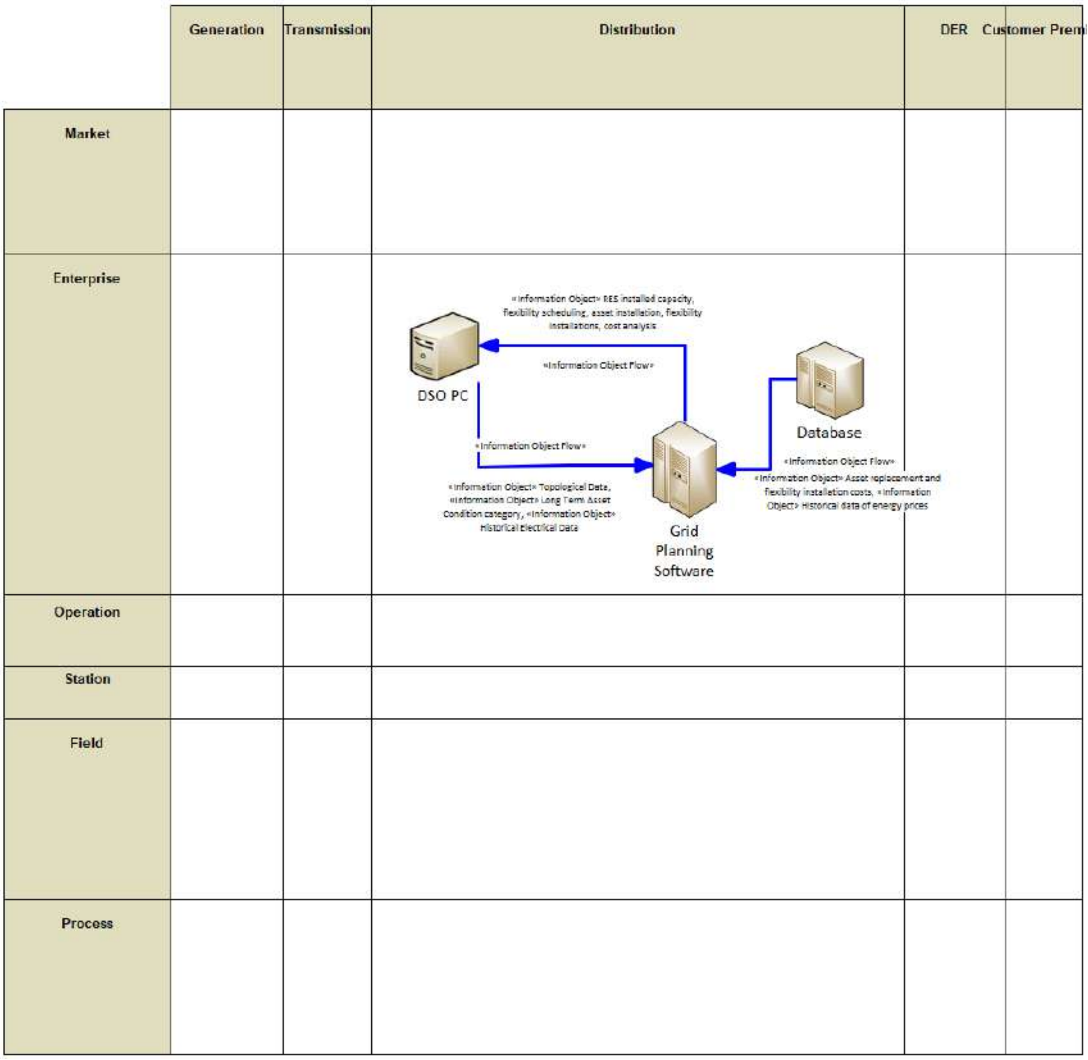

Figure 98. UC 2.1 Information Layer

5.11.4 Canonical Data model

The identified canonical data models for UC 2.1 are described below.

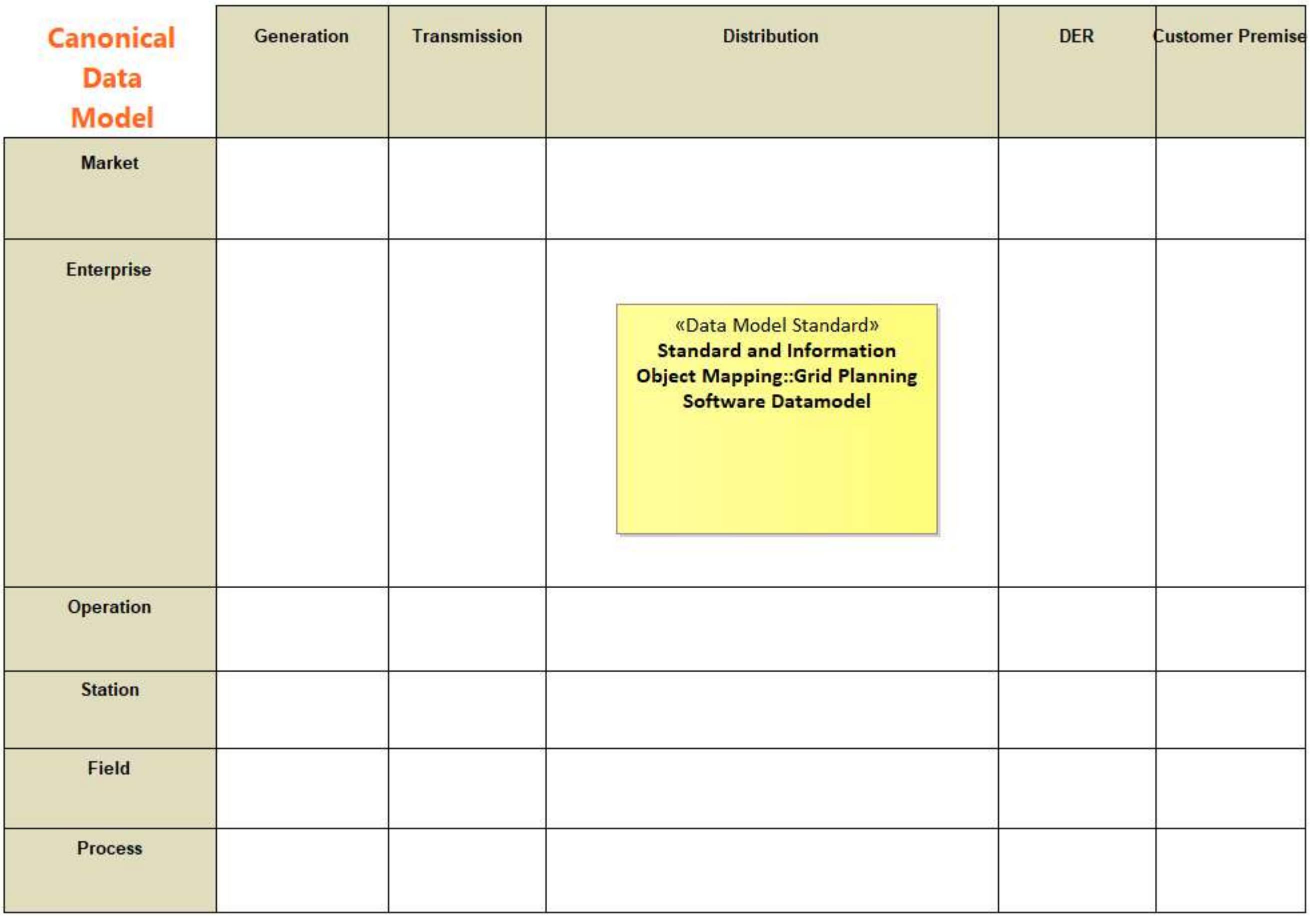

Figure 99. UC 2.1 Canonical data model

Table 59. UC 2.1 Data models

Data Models
Grid Planning Software Data model

5.11.5 Standards and information object mapping

SGAM Standards and Information Objects Mapping for UC2.1 is presented in the following figure.

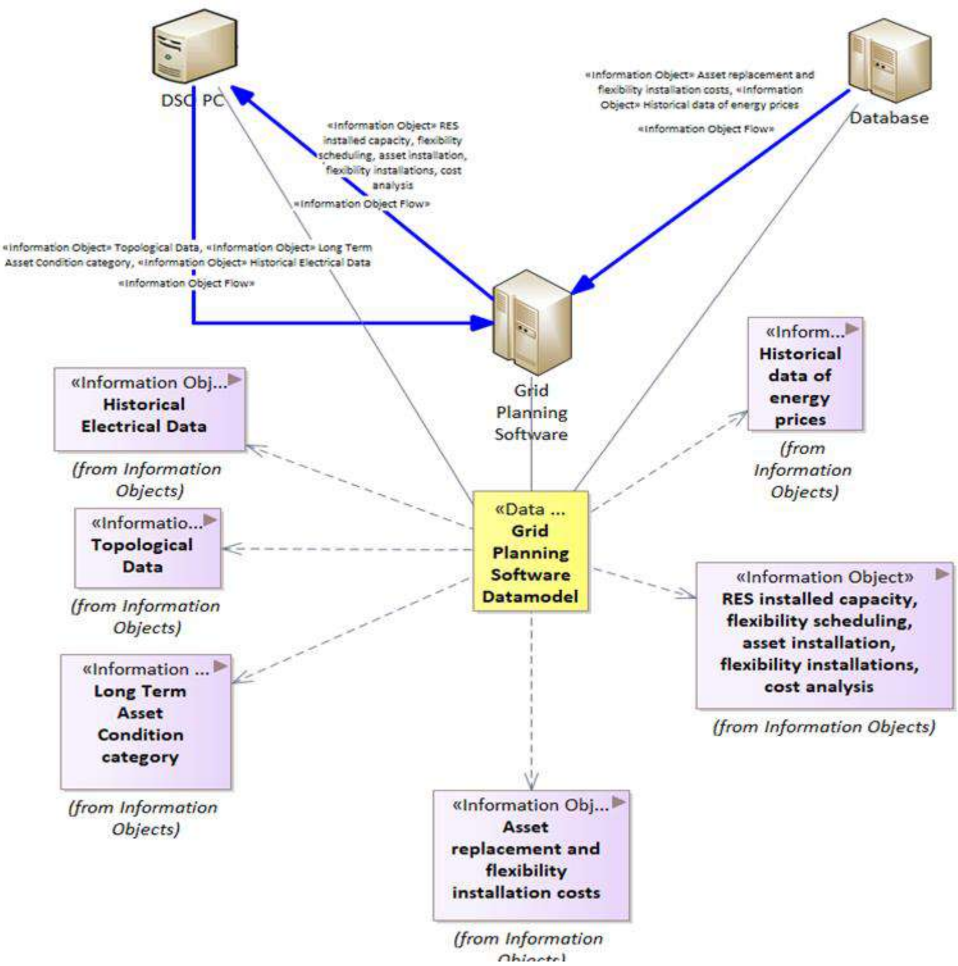

Figure 100. UC 2.1 Standards and Information Object Mapping

Table 60. List of Information Objects, link with Data Standards in UC 2.1

Information Object	DATA Models	Information
Topological Data	Grid Planning Software Data model	Grid topology, future RES installations,
Long term asset condition category	Grid Planning Software Data model	Information up to which year an asset should be replaced
Historical electrical data	Grid Planning Software Data model	Annual load curve(s) available for the distribution system considered for RES and demand.
Historical data of energy prices	Grid Planning Software Data model	Historical data on energy price with hourly resolution.
Results in flexibility scheduling and investment planning	Grid Planning Software Data model	Yearly output of flexibility schedule and investment in assets and at which periods. Comparison with base case model

5.11.6 Activity Diagram

The detailed activity diagram for UC 2.1 is presented in the following figure.

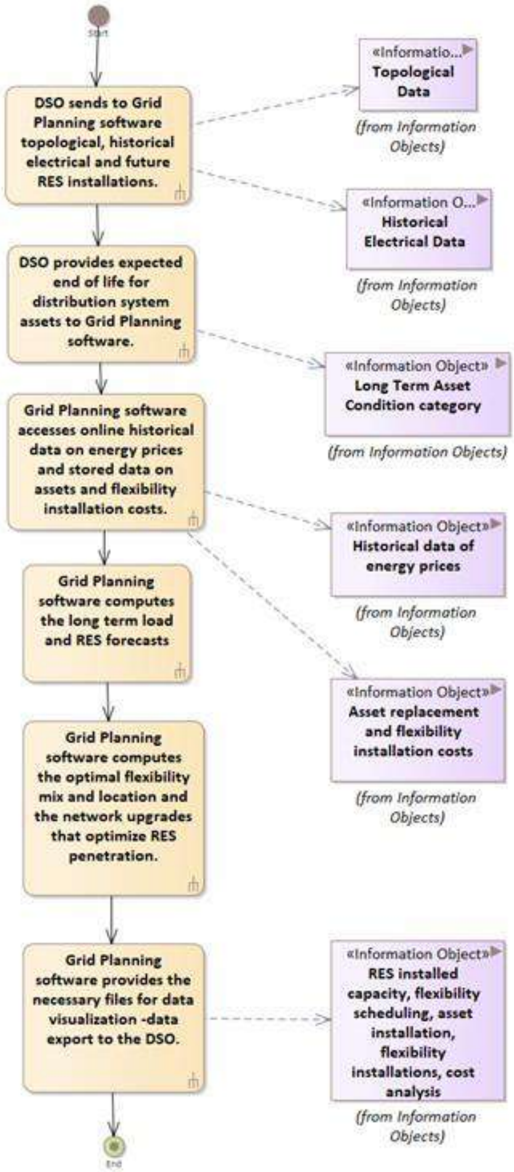

Figure 101. UC 2.1 Activity Diagram

5.11.7 Sequence Diagram

The detailed sequence diagram for UC 2.1 is presented in the following figure.

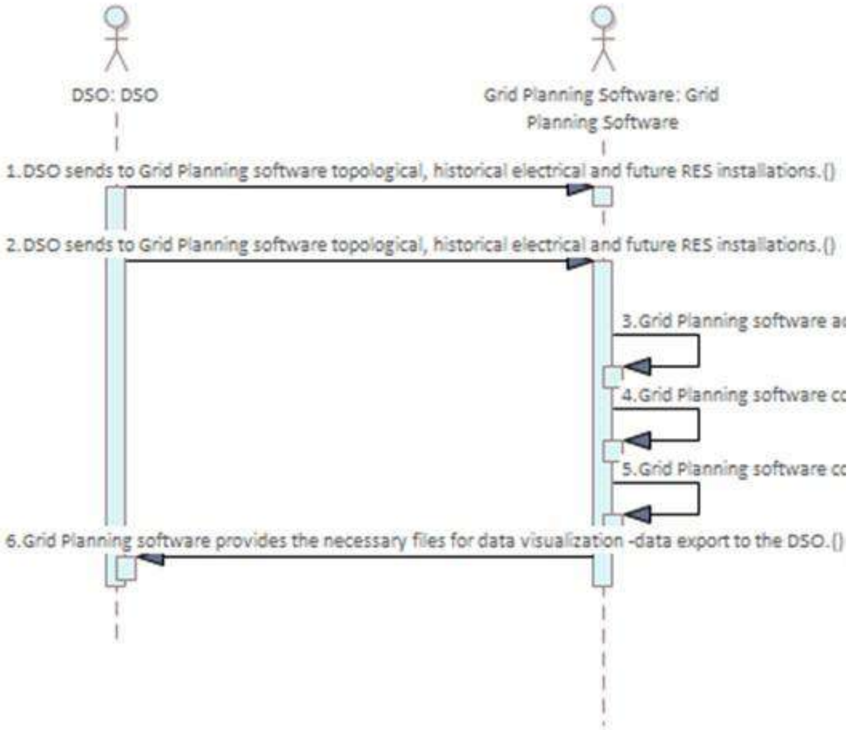

Figure 102. UC 2.1 Sequence diagram

5.11.8 Communication Layer

The communication layer of UC 2.1 is presented in the following figure, highlighting the key communication protocols among the different modules.

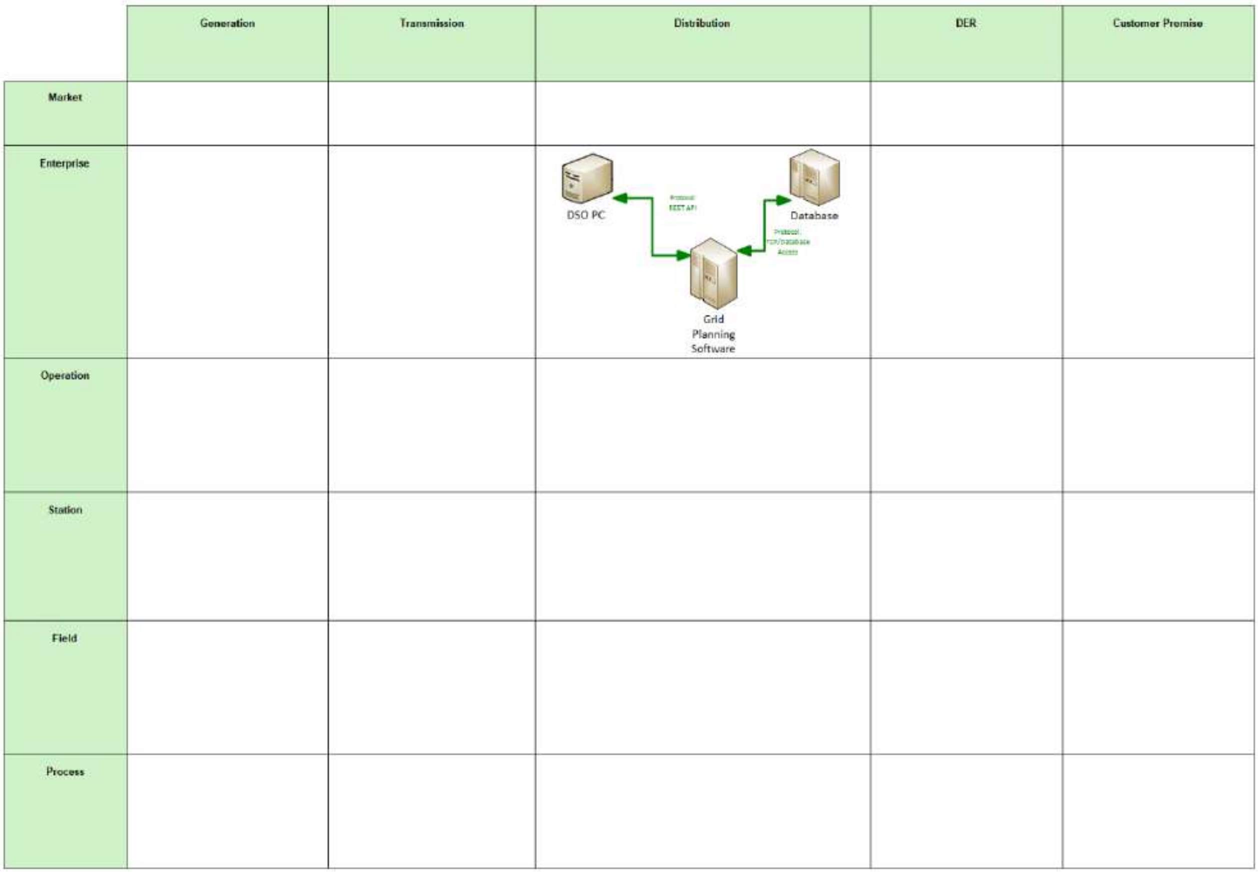

Figure 103. UC. 2.1 Communication Layer

Table 61. List of Communication technologies linked with UC 2.1

Communication Technology	Description
REST	Representational State Transfer. Set of software constraints for web services, to provide interoperability between computer systems on the Internet. A RESTful web service defines a uniform and predefined set of stateless operations that accept requests through a URI.
TCP/IP	Transmission Control Protocol/Internet Protocol. Conceptual model and set of communication protocols used on the Internet. They provide end-to-end data communication, specifying how data should be packetized, addressed, transmitted, routed, and received, through four abstraction layers (link, internet, transport, and application).

5.11.9 Component Layer

The components included in the use case are depicted below, including the technology used for connecting each other.

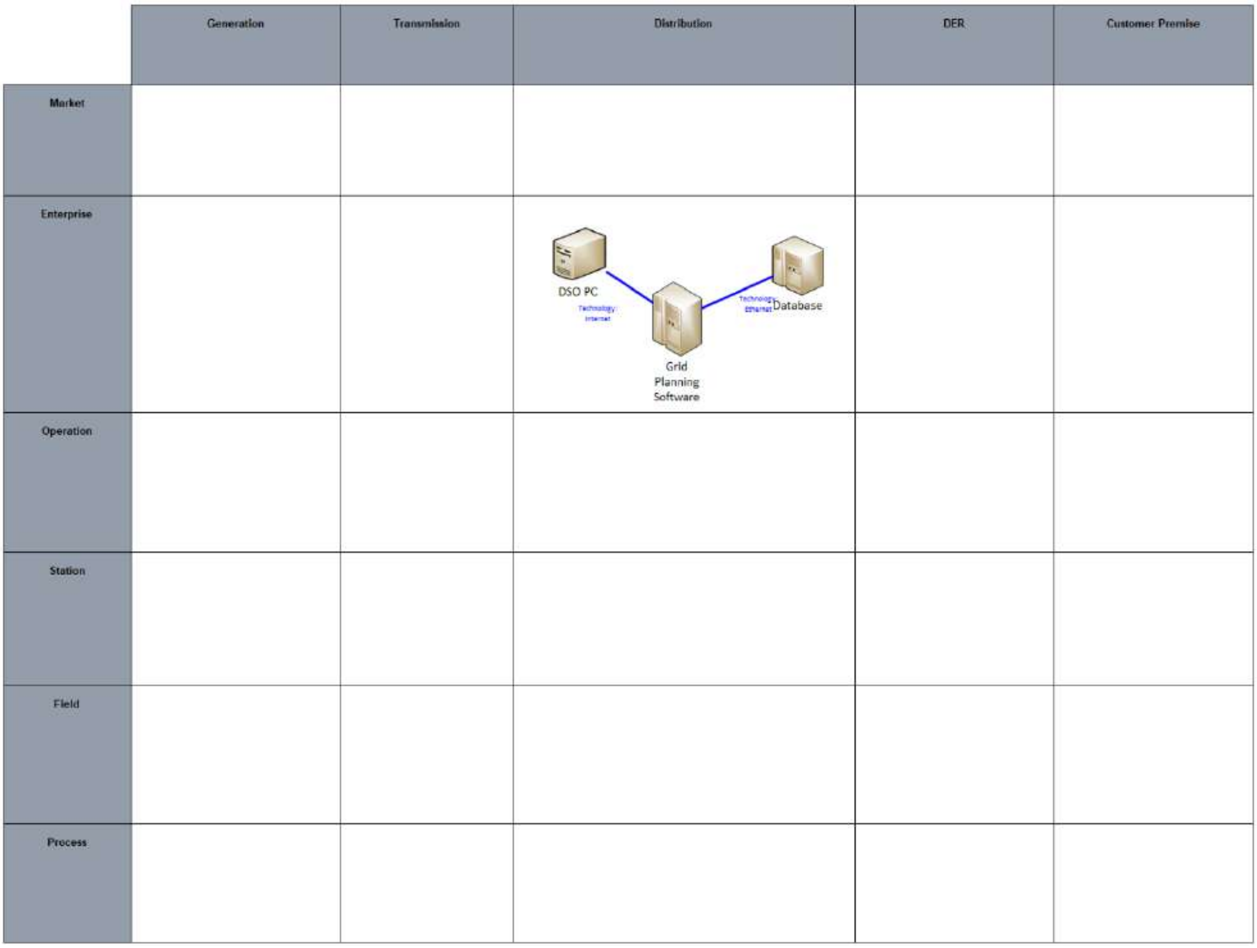

Figure 104. UC 2.1 Component Layer Diagram

Table 62. List of Components linked with UC 2.1

Component	Component Type
DSO PC, Database	device
Grid Planning Software	Software application

5.12 UC 3.1: Baseline and flexibility forecast for EV fleet

5.12.1 Use Case Description

The objective of this Use Case is to provide baseline and flexibility forecast for the EV fleet owned by AVANTCAR. This data will be used as input for optimal selection of available flexibility algorithm (UC 3.3).

The algorithm will make use of the historical charge data, EV data, weather data (additional data sources will be defined in the scope of the implementation, if needed) and form different charging point (CP) profiles to determine the flexibility potential of the EV fleet in a given time of day. The algorithm will consider different types of CP (e.g. car-sharing CP, over-night CP).

5.12.2 Function Layer

The functional layer of UC 3.1 is presented in the following graph highlighting the key actors of the use case.

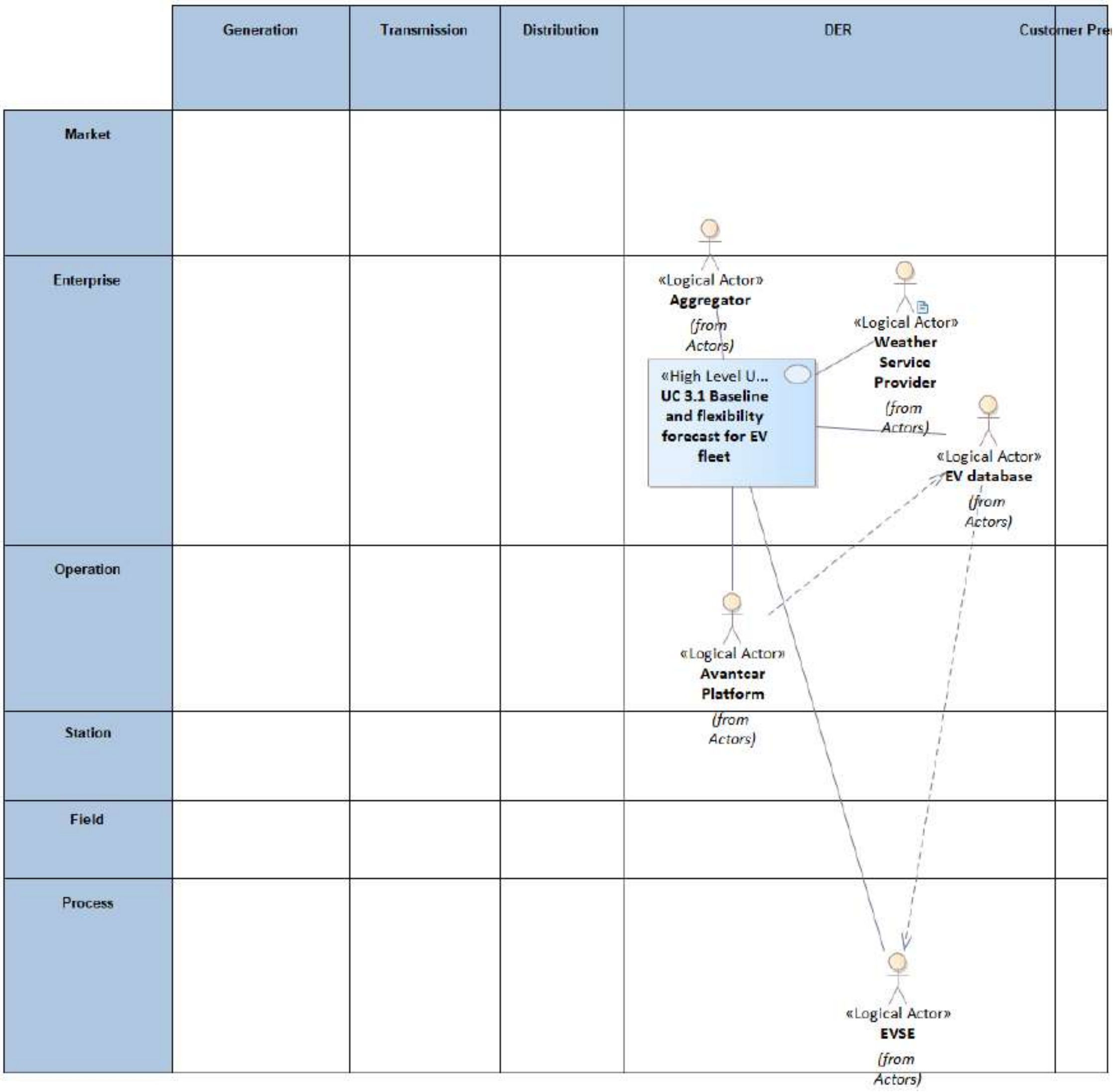

Figure 105. UC 3.1 Function diagram

Table 63. List of actors involved in UC 3.1

Actor Name	Actor Type
Weather service provider	Organization
Aggregator	Organization
Avantcar Platform	System
EV database	Device
EVSE	Device

5.12.3 Information Layer

Details about information layer of UC3.1 are presented in the following figure, highlighting the key information objects.

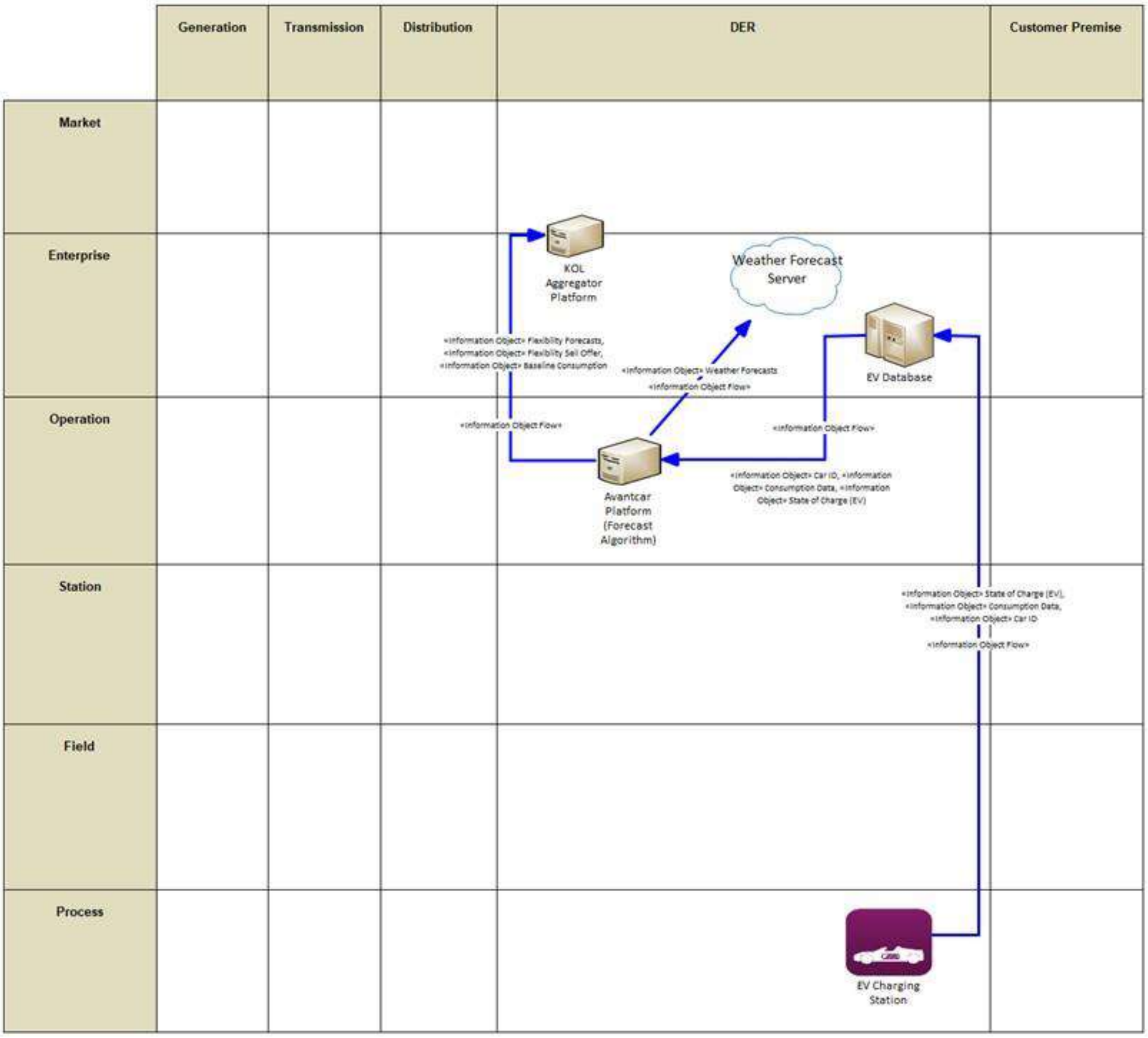

Figure 106. UC 3.1 Information Layer

5.12.4 Canonical Data model

The identified canonical data models for UC3.1 are described below.

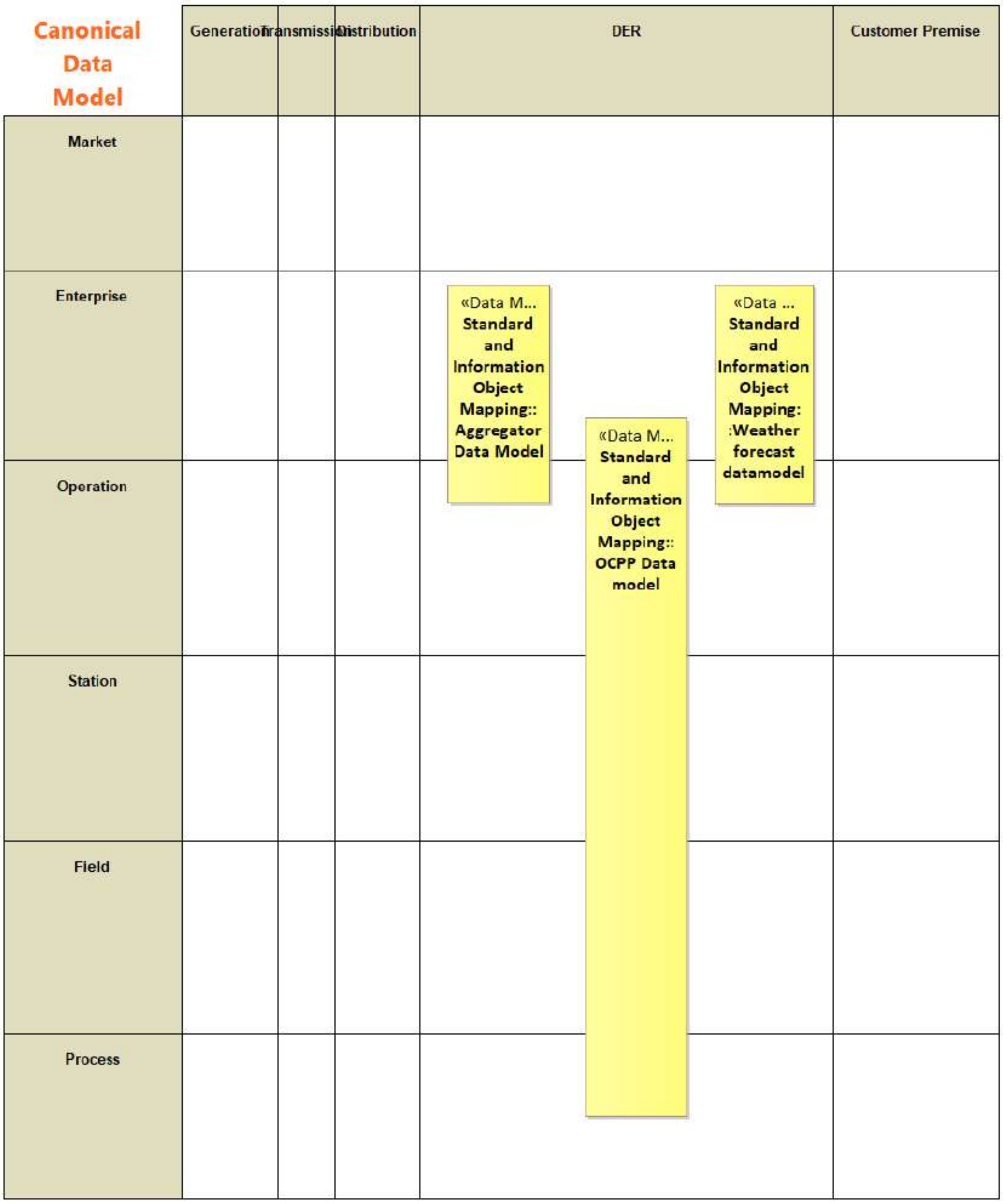

Figure 107. UC 3.1 Canonical data model

Table 64. UC 3.1 Data models

Data Models
Aggregator data model
OCPP data model
Weather forecast data model

5.12.5 Standards and information object mapping

SGAM Standards and Information Objects Mapping for UC 3.1 is presented in the following figure.

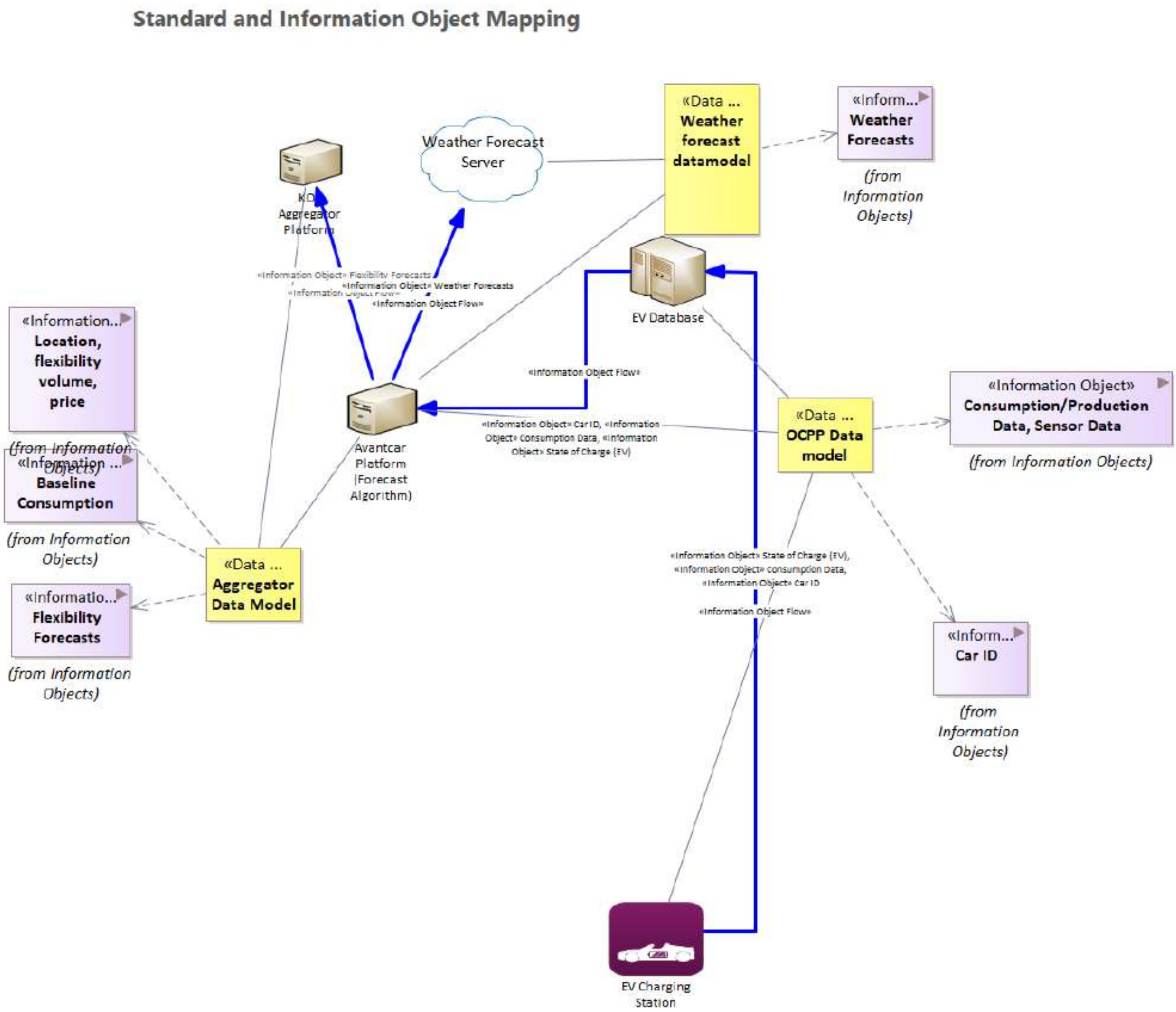

Figure 108. UC 3.1 Standards and Information Object Mapping

Table 65. List of Information Objects, link with Data Standards in UC 3.3

Information Object	DATA Models	Information
Weather Forecasts	Weather Forecast Model	Forecasts of weather data like temperature, wind speed,etc.
Consumption/Production data, Sensor data	OCPP Data model	State of Charge of Electric Vehicles, consumption of EVs
Car Id	OCPP Data model	.Identification number of cars
Location, Flexibility volume, price	Aggregator Data model	Flexibility sell offer
Baseline Consumption	Aggregator Data model	Consumption profile without flexibility activation
Flexibility Forecasts	Aggregator Data model	Schedule of available flexibility that can be offered.

5.12.6 Activity Diagram

The detailed activity diagram for UC 3.1 is presented in the following figure.

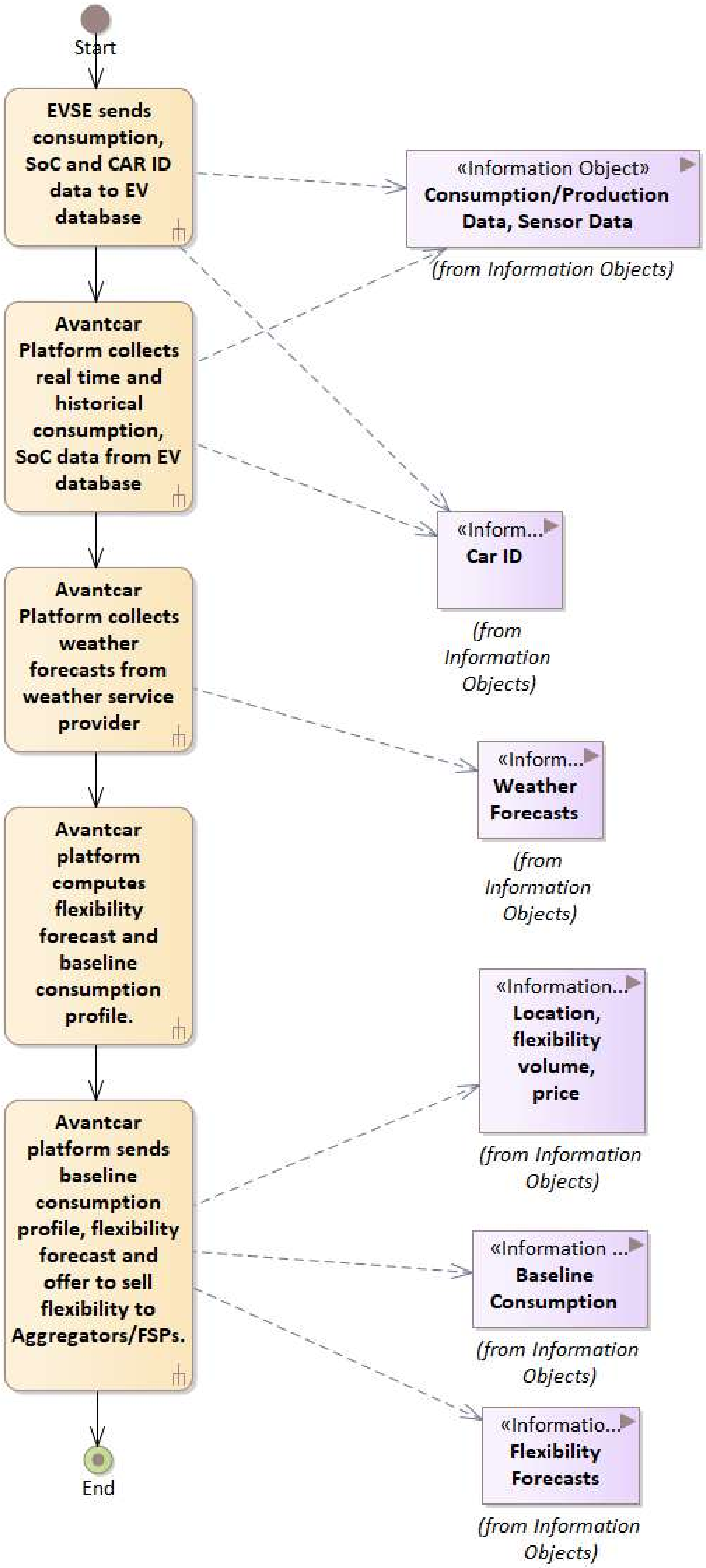

Figure 109. UC 3.1 Activity Diagram

5.12.7 Sequence Diagram

The detailed sequence diagram for UC 3.1 is presented in the following figure.

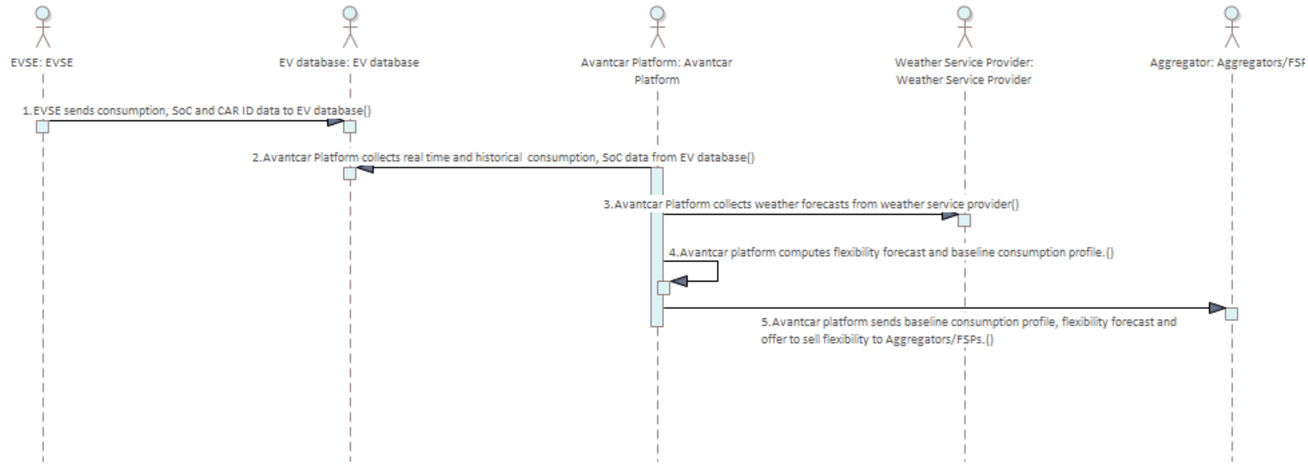

Figure 110. UC 3.1 Sequence diagram

5.12.8 Communication Layer

The communication layer of UC 2.1 is presented in the following figure, highlighting the key communication protocols among the different modules.

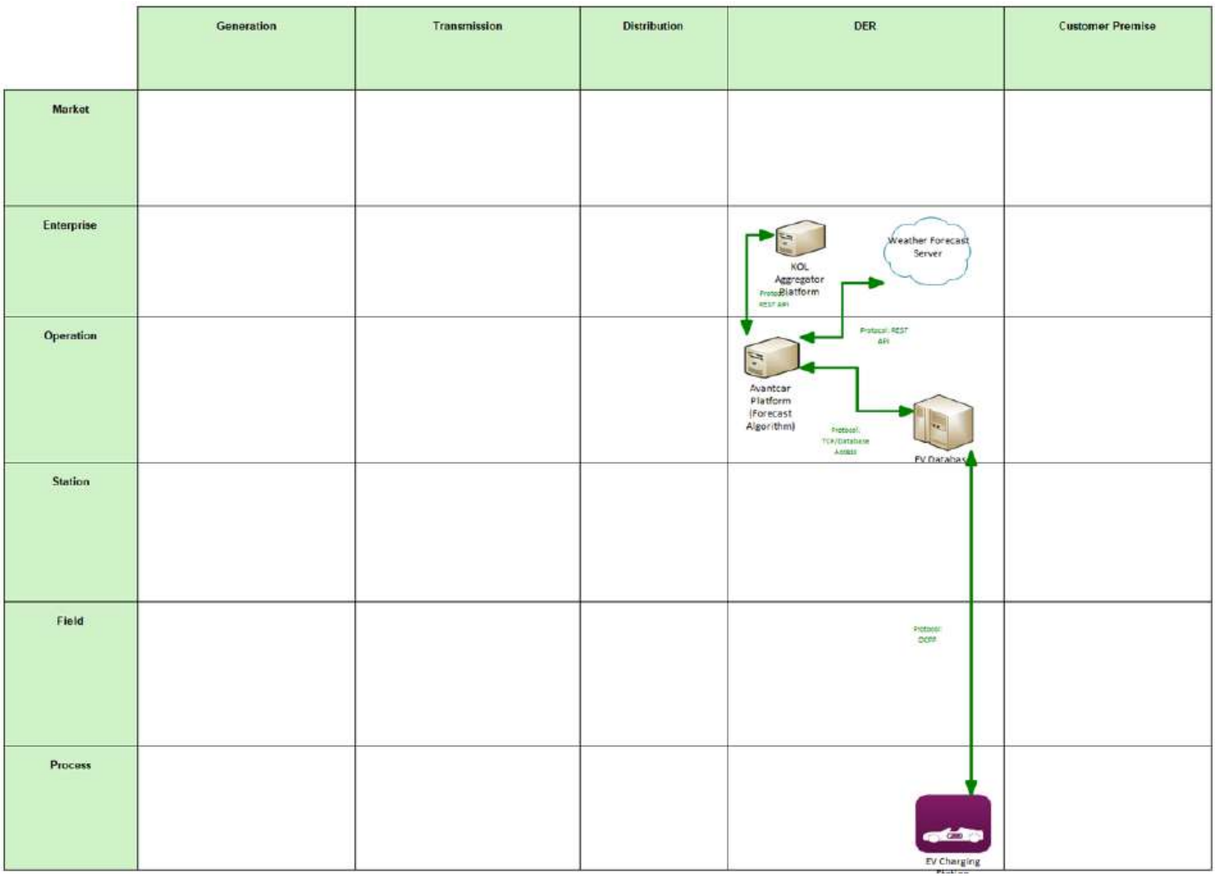

Figure 111. UC. 3.1 Communication Layer

Table 66. List of Communication technologies linked with UC 3.1

Communication Technology	Description
REST	Representational State Transfer. Set of software constraints for web services, to provide interoperability between computer systems on the Internet. A RESTful web service defines a uniform and predefined set of stateless operations that accept requests through a URI.
TCP/IP	Transmission Control Protocol/Internet Protocol. Conceptual model and set of communication protocols used on the Internet. They provide end-to-end data communication, specifying how data should be packetized, addressed, transmitted, routed, and received, through four abstraction layers (link, internet, transport, and application).
OCPP	The Open Charge Point Protocol (OCPP) is an application protocol for communication between Electric vehicle (EV) charging stations and a central management system.

5.12.9 Component Layer

The components included in the use case are depicted below, including the technology used for connecting each other.

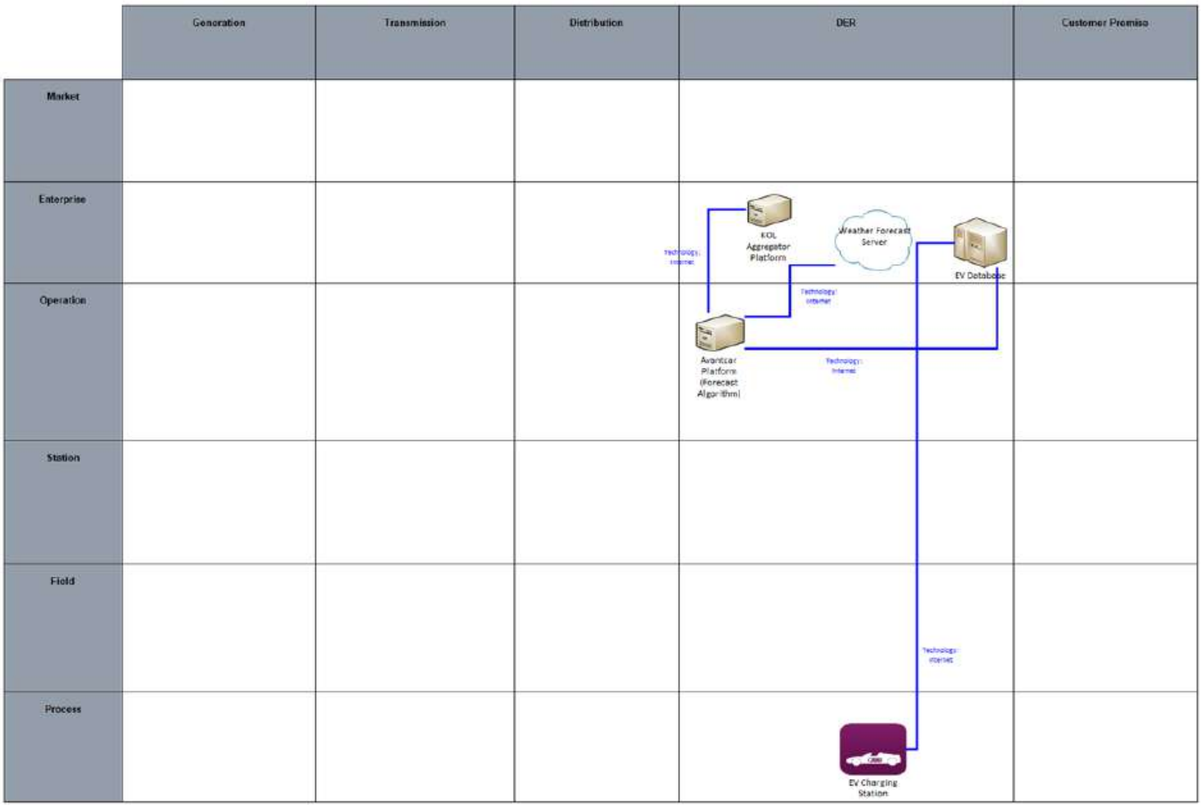

Figure 112. UC 3.1 Component Layer

Table 67. List of Components linked with UC 3.1

Component	Component Type
EV Charging station, EV database	Devices
KOL aggregation platform, AVANTCAR platform	Service

5.13 UC 3.2: Baseline and flexibility forecast for HEMS fleet

5.13.1 Use Case Description

The objective of this Use Case is to provide baseline and flexibility forecast for the HEMS fleet owned by AMIBIT. This data will be used as input for optimal selection of available flexibility algorithm (UC 3.3)

For HEMS flexibility, the forecast will take into account the types of devices, weather data and comfort of the end-user (additional data sources will be defined in the scope of the implementation, if needed), which are connected to the Reduxi unit and output the information needed for optimal selection algorithm to work (we will need the baseline for different time intervals, flexibility, price of flexibility, duration of active time of an asset and set point change). Each individual Reduxi unit will provide baseline and flexibility forecast to the KOL aggregator platform.

The forecasting algorithm will take into account both initial settings algorithm and historical measurement data.

5.13.2 Function Layer

The functional layer of UC 3.2 is presented in the following graph highlighting the key actors of the use case.

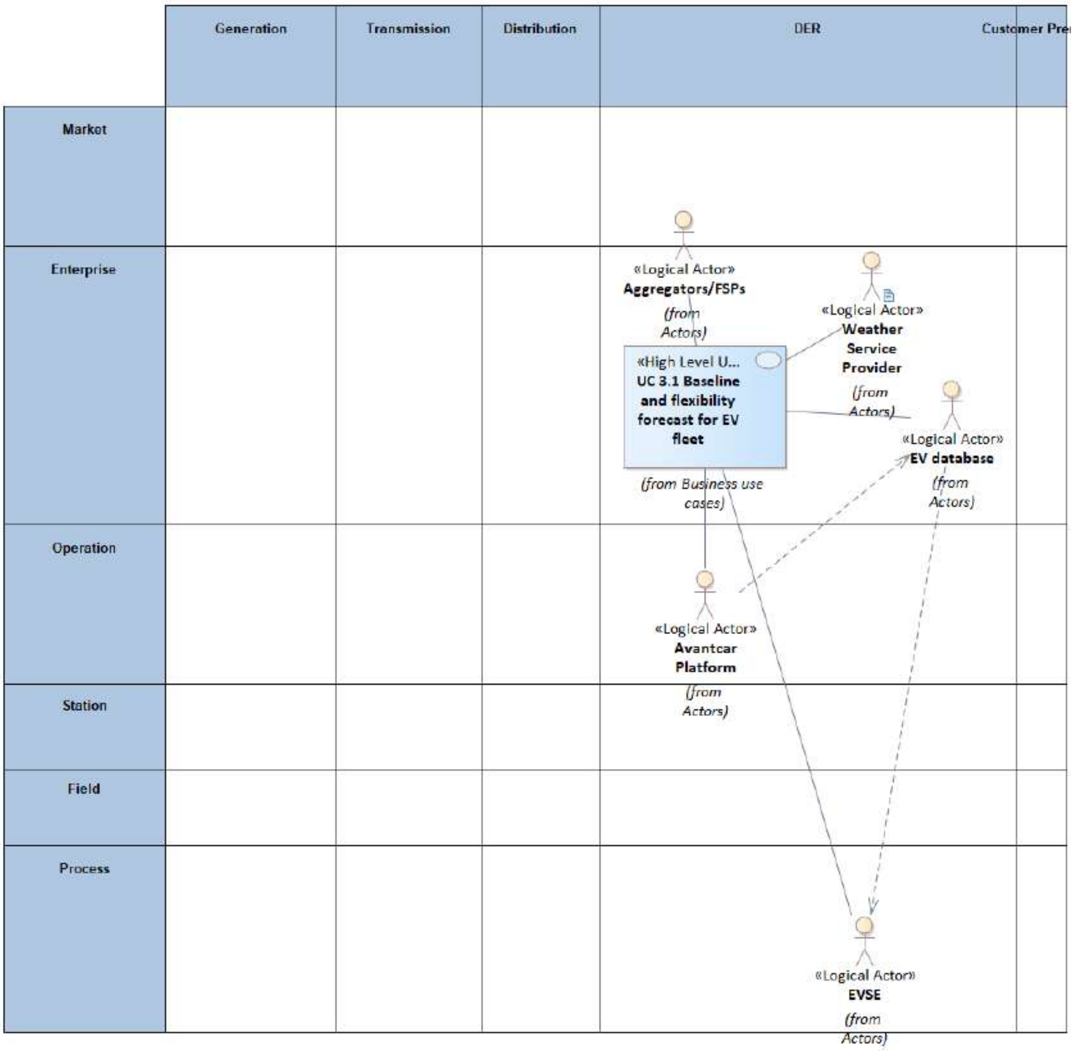

Figure 113. UC 3.2 Function diagram

Table 68.List of actors involved in UC 3.2

Actor Name	Actor Type
Weather service provider	Organization
Aggregator	Organization
HEMS	System
HEMS Database	Device
Amibit Platform	System
House Gateway	Device
House controller/meter	Device

5.13.3 Information Layer

Details about information layer of UC3.2 are presented in the following figure, highlighting the key information objects.

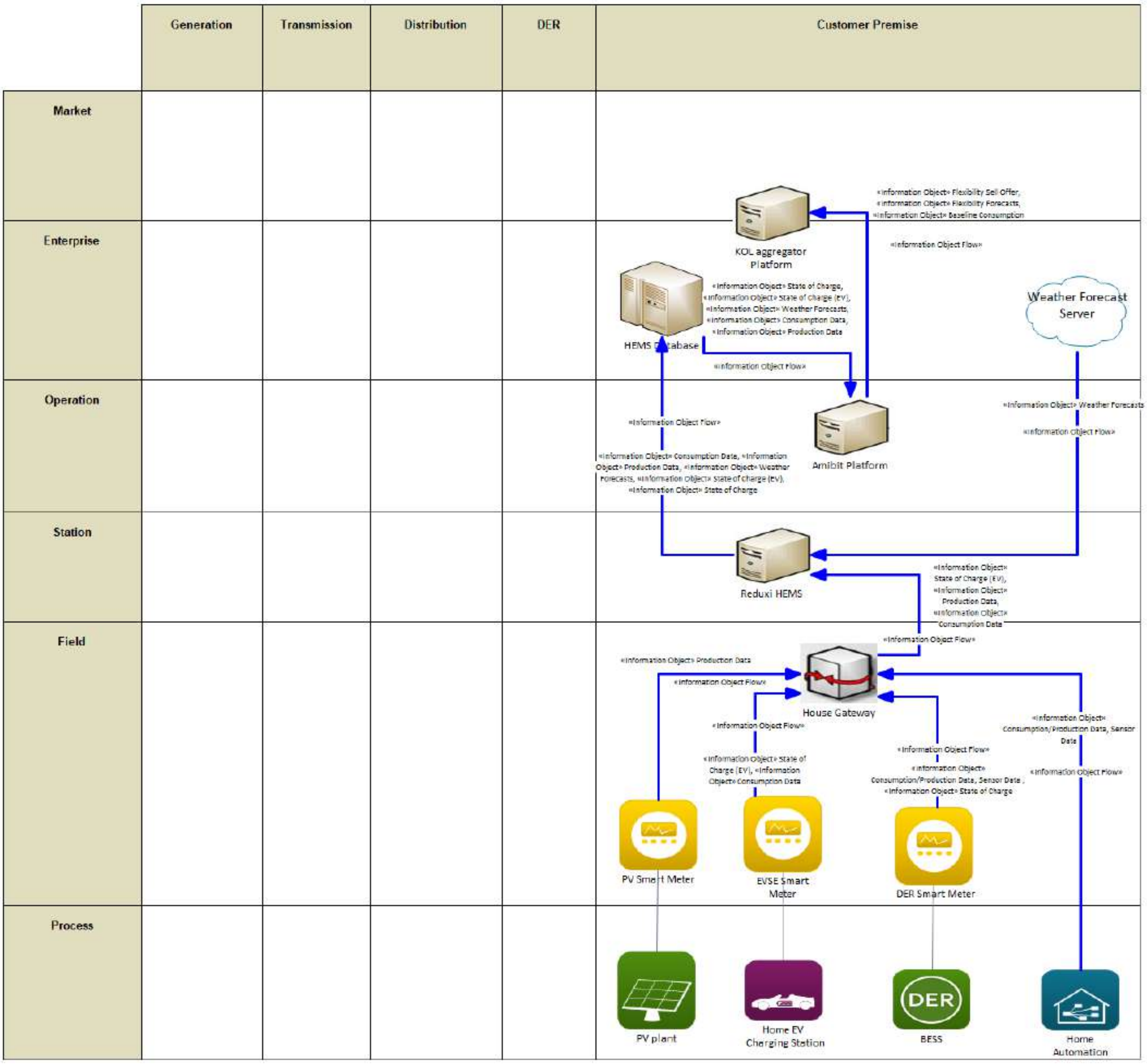

Figure 114. UC 3.2 Information Layer

5.13.4 Canonical Data model

The identified canonical data models for UC3.2 are described below.

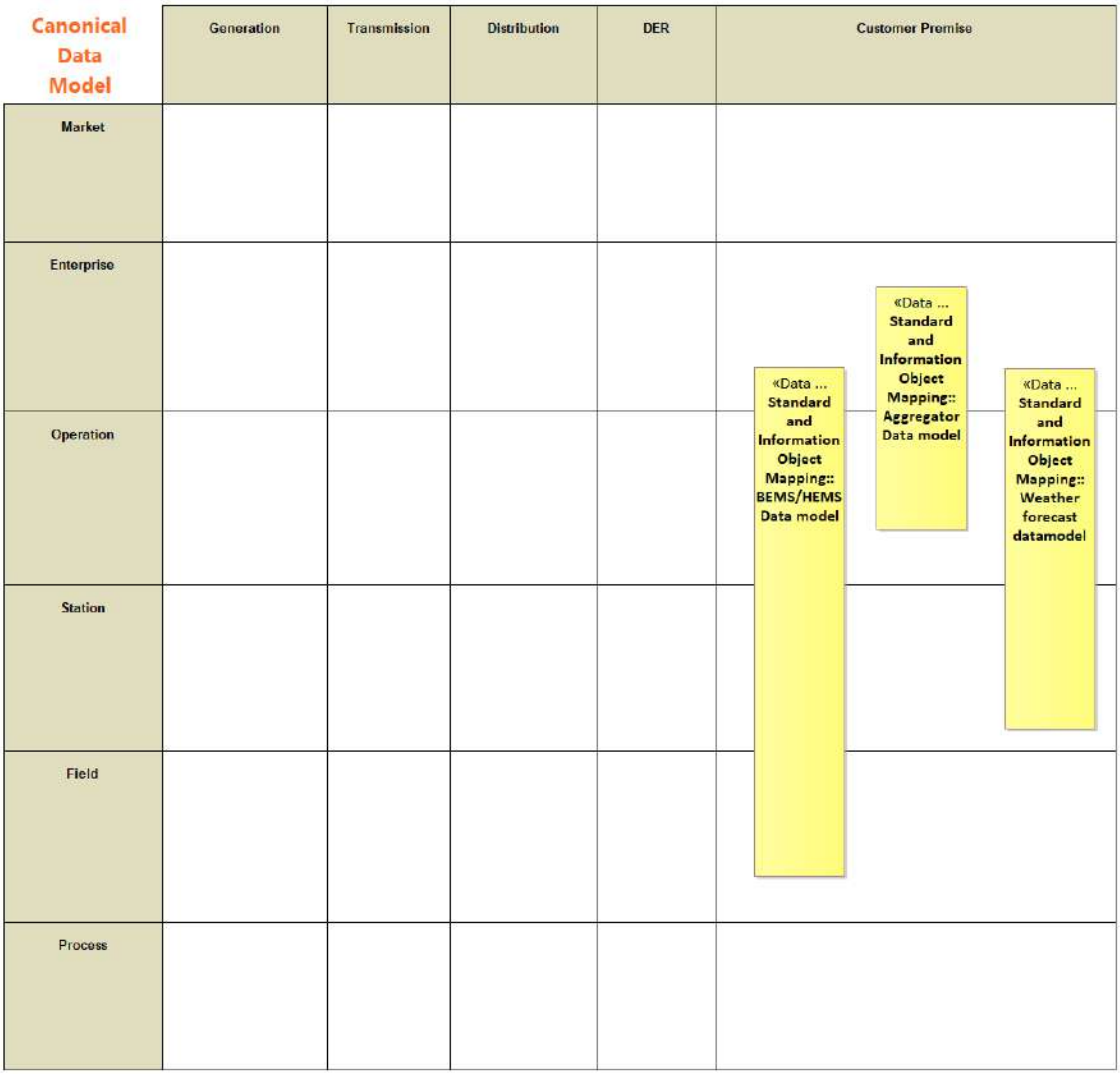

Figure 115. UC 3.2 Canonical data model

Table 69. UC 3.2 Data models

Data Models
Aggregator data model
BEMS/HEMS data model
Weather forecast data model

5.13.5 Standards and information object mapping

SGAM Standards and Information Objects Mapping for UC3.2 is presented in the following figure.

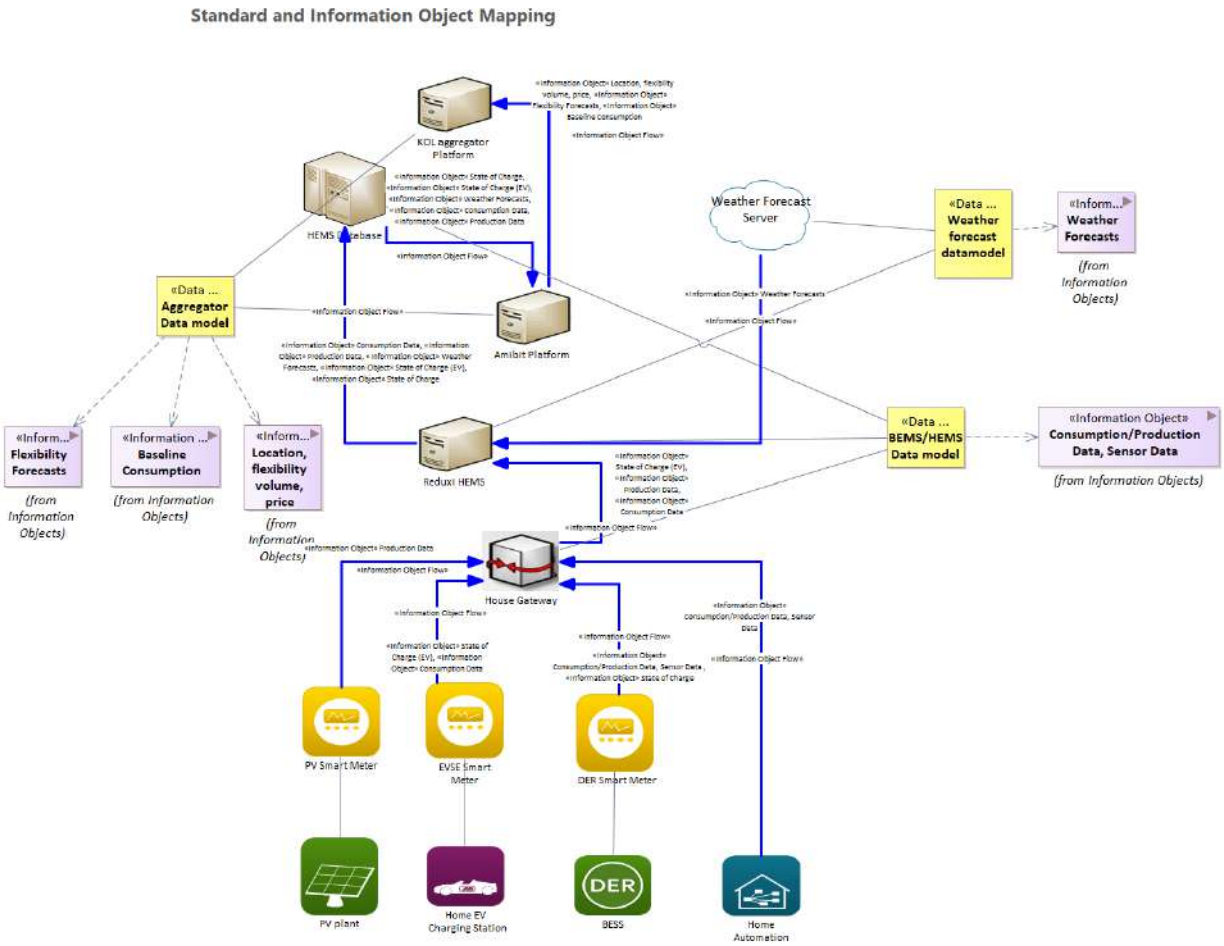

Figure 116. UC 3.2 Standards and Information Object Mapping

Table 70. List of Information Objects, link with Data Standards in UC 3.3

Information Object	DATA Models	Information
Weather Forecasts	Weather Forecast Model	Weather forecast data like temperature, wind speed, etc.
Consumption/Production data, Sensor data	BEMS/HEMS data model	State of Charge of Electric Vehicles, consumption of EVs
Baseline Consumption	Aggregator Data model	Consumption profile without flexibility activation
Location, Flexibility volume, price	Aggregator Data model	Flexibility sell offer
Baseline Consumption	Aggregator Data model	Consumption profile without activation of flexibility
Flexibility Forecasts	Aggregator Data model	Schedule of available flexibility that can be offered.

5.13.6 Activity Diagram

The detailed activity diagram for UC 3.2 is presented in the following figure.

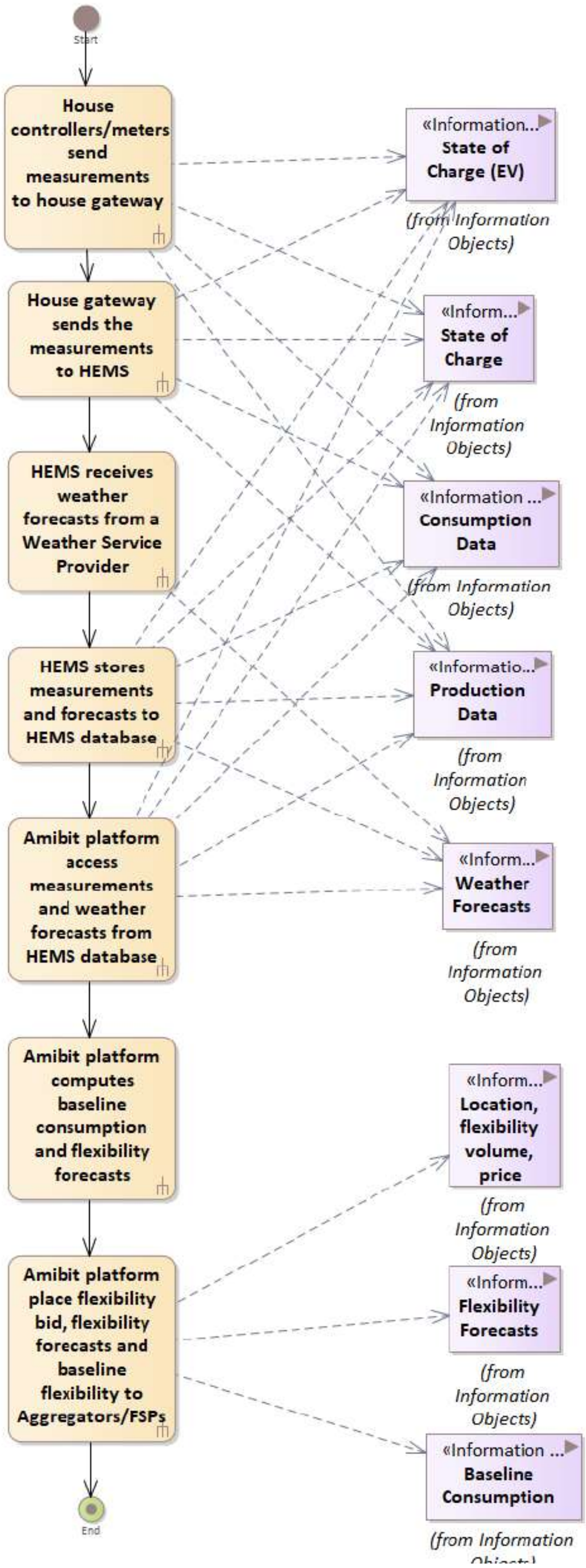

Figure 117. UC 3.2 Activity Diagram

5.13.7 Sequence Diagram

The detailed sequence diagram for UC 3.2 is presented in the following figure.

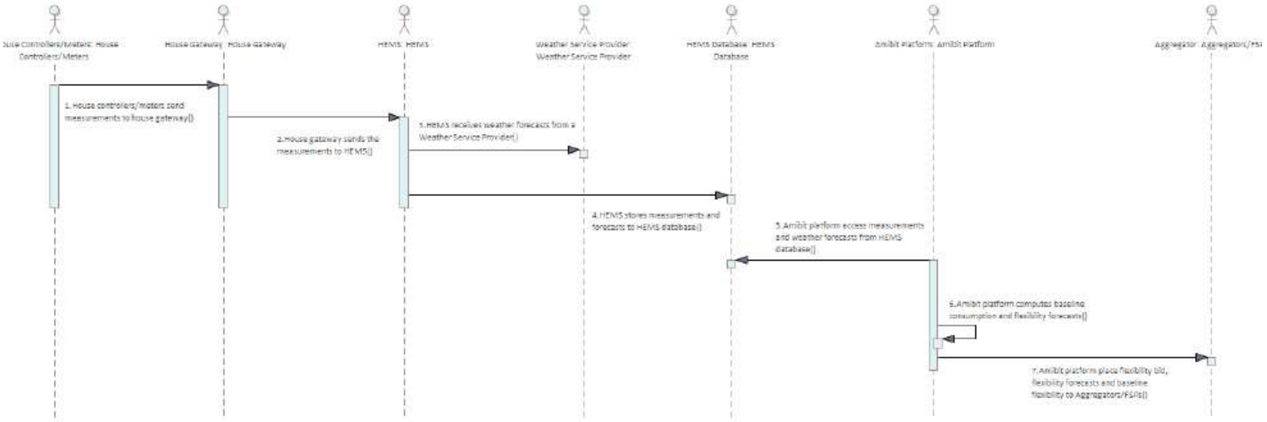

Figure 118. UC 3.2 Sequence diagram

5.13.8 Communication Layer

The communication layer of UC 3.2 is presented in the following figure, highlighting the key communication protocols among the different modules.

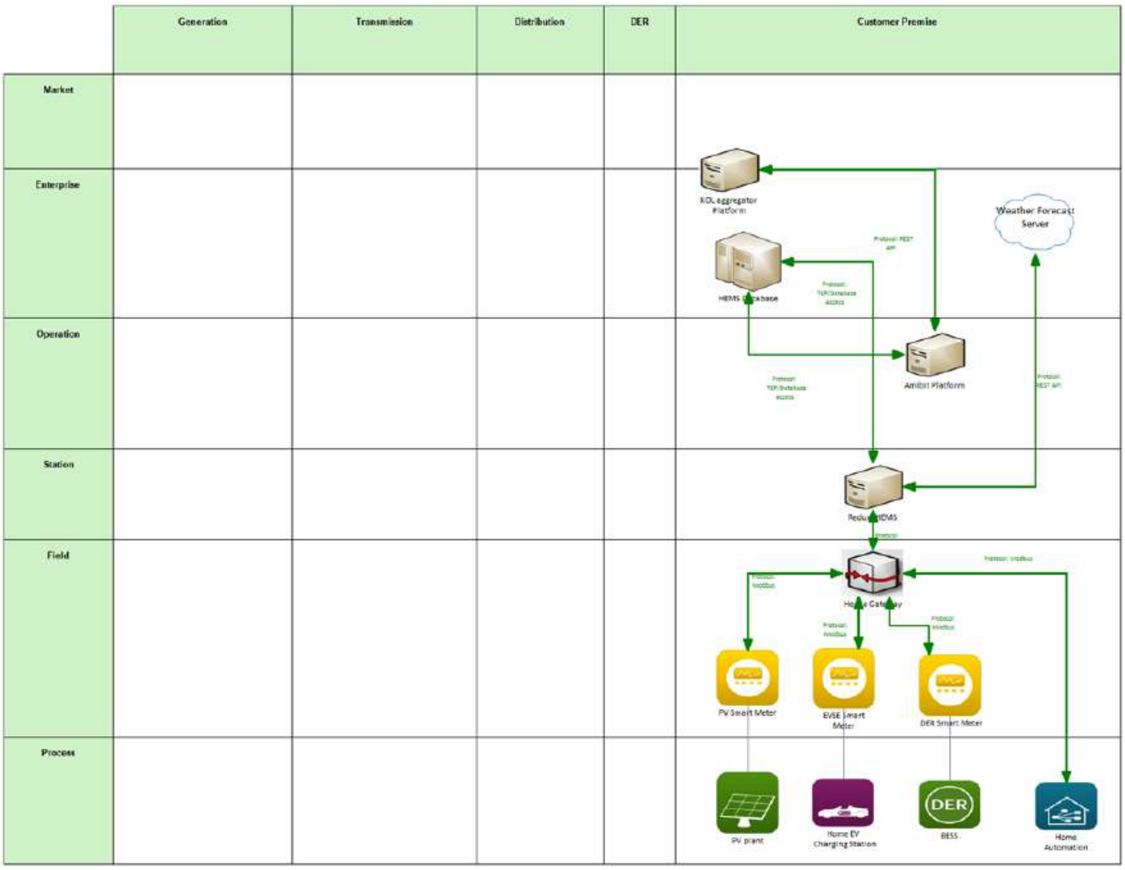

Figure 119. UC. 3.2 Communication Layer

Table 71. List of Communication technologies linked with UC 3.2

Communication Technology	Description
REST	Representational State Transfer. Set of software constraints for web services, to provide interoperability between computer systems on the Internet. A RESTful web service defines a uniform and predefined set of stateless operations that accept requests through a URI.
TCP/IP	Transmission Control Protocol/Internet Protocol. Conceptual model and set of communication protocols used on the Internet. They provide end-to-end data communication, specifying how data should be packetized, addressed, transmitted, routed, and received, through four abstraction layers (link, internet, transport, and application).
Modbus	Communication protocol for programmable logic controllers (PLCs). It is openly published, easy to deploy and maintain, and does not present many restrictions on integration with different vendors. Modbus TCP covers the use of Modbus messaging using the TCP/IP protocols .

5.13.9 Component Layer

The components included in the use case are depicted below, including the technology used for connecting each other.

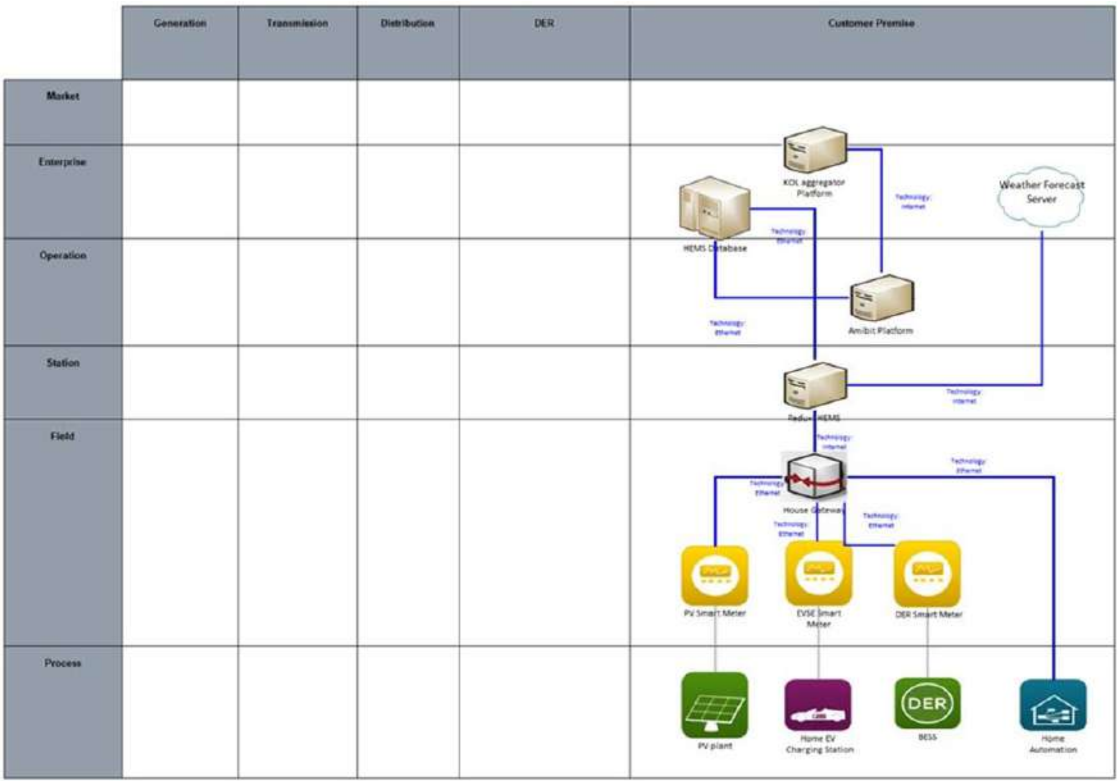

Figure 120. UC 3.2 Component Layer

Table 72. List of Components linked with UC 3.2

Component	Component Type
PV, BESS, EV, Home automation, PV ,EVSE DER smart meter, HEMS database	Devices
Reduci HEMS, Amibit Platform, KOL aggregator platform, Weather Service Provider	System

5.14 UC 3.3: Optimal selection of available flexibility

5.14.1 Use Case Description

The primary objective of this Use Case is to form the selection process for available flexibility sources. The selection process will be, in the scope of this project, based on flexibility from the Electric Vehicle (EV) fleet owned by AVANTCAR and the HEMS (Reduxi) fleet owned by AMIBIT. The algorithm should be conceptualized for expansion and the use of additional flexibility sources.

This will be done by via an algorithm, which will be integrated into the aggregator platform (SETUP). The algorithm will be triggered after a bid sent to the market is accepted, with the requested activation time and power serving as inputs for the algorithm. Based on these a list of optimal devices is formed, and the aggregator sends the activation signal to these devices.

The optimized selection process for flexibility sources in the EV and HEMS fleets benefits both the companies and the System Operators. By utilizing this flexibility, System Operators can avoid or defer costly network reinforcement measures, reduce congestion on the grid, and improve the stability and reliability of the local electricity grid.

This enables System Operators to save costs and enhance the overall quality of service for customers by reducing the likelihood of power outages and other grid-related issues.

5.14.2 Function Layer

The functional layer of UC 3.3 is presented in the following graph highlighting the key actors of the use case.

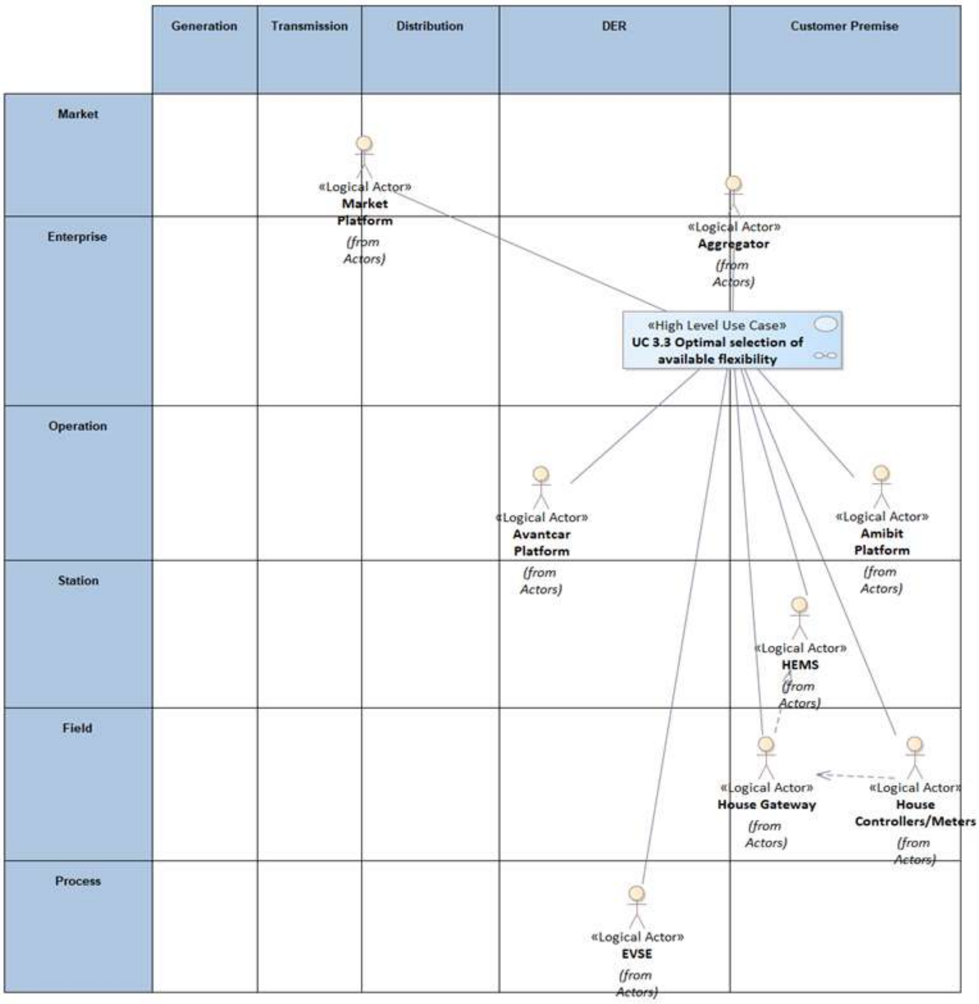

Figure 121. UC 3.3 Function Layer

Table 73. List of actors involved in UC 3.3

Actor Name	Actor Type
Market Platform	System
Aggregator	Organization
Avantcar Platform	System
Amibit Platform	System
HEMS	HEMS
House Gateway	Device
House controllers/meters	Device
EVSE	Device

5.14.3 Information Layer

Details about information layer of UC3.3 are presented in the following figure, highlighting the key information objects.

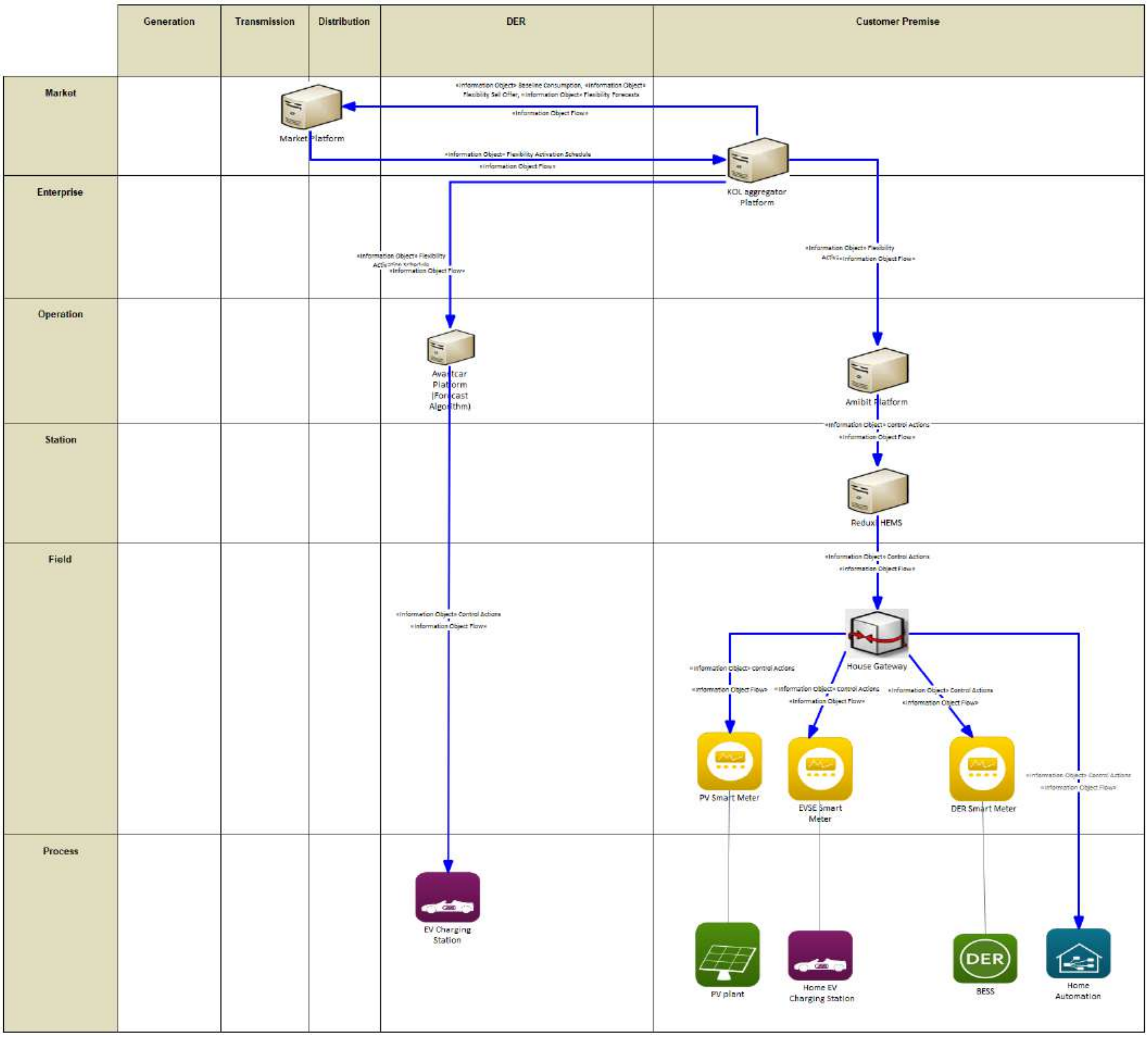

Figure 122. UC 3.3 Information Layer

5.14.4 Canonical Data model

The identified canonical data models for UC3.3 are described below.

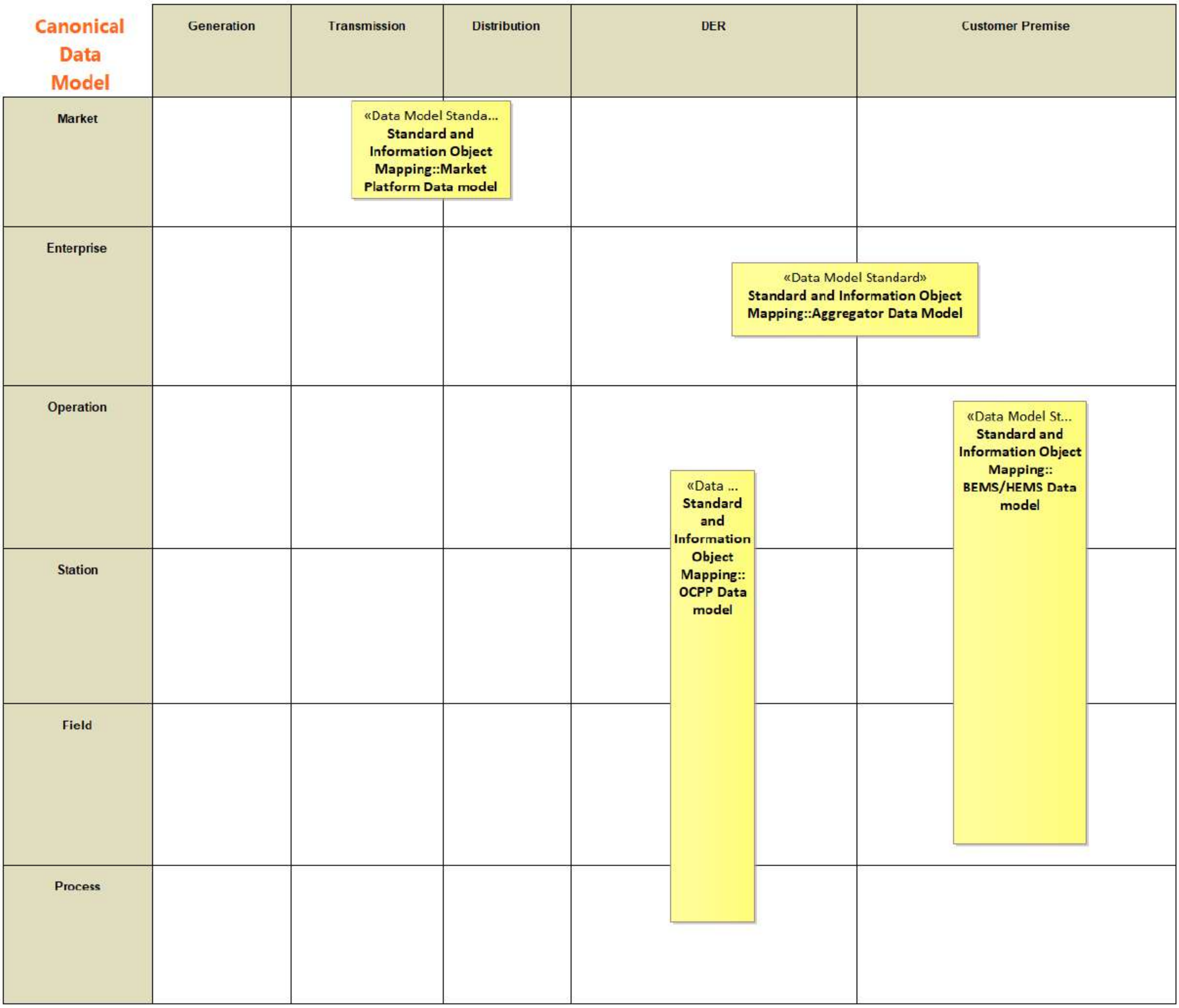

Figure 123. UC 3.3 Canonical data model

Table 74. UC 3.3 Data models

Data Models
Market Platform data model
Aggregator data model
BEMS/HEMS data model
OCPP data model

5.14.5 and information object mapping

SGAM Standards and Information Objects Mapping for UC 3.3 is presented in the following figure.

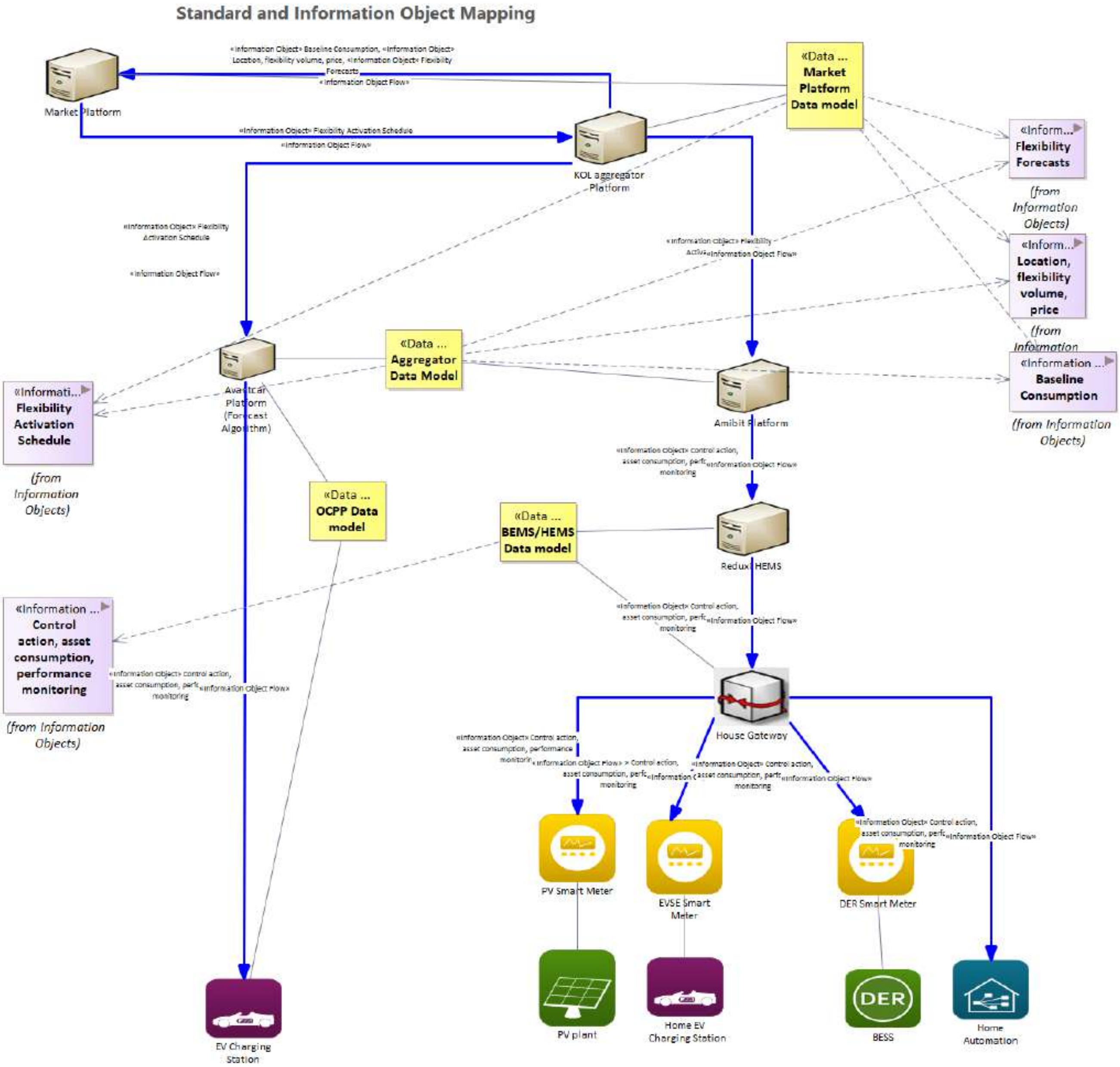

Figure 124. UC 3.3 Standards and Information Object Mapping

Table 75. List of Information Objects, link with Data Standards in UC 3.3

Information Object	DATA Models	Information
Flexibility Forecasts	Market Platform Data model, Aggregator Data model	Schedule of available flexibility that can be offered.
Location, Flexibility volume, price	Aggregator Data model	Flexibility sell offer
Baseline Consumption	Aggregator Data model	Consumption profile without activation of flexibility
Flexibility Activation Schedule	Market Platform Data model, Aggregator Data model	Schedule of available flexibility that has been purchased and has to be activated..
Control action, asset consumption, performance monitoring	BEMS/HEMS model, OCPP	Control actions for the BEMS/HEMS and EV charging station.

5.14.6 Activity Diagram

The detailed activity diagram for UC 3.3 is presented in the following figure.

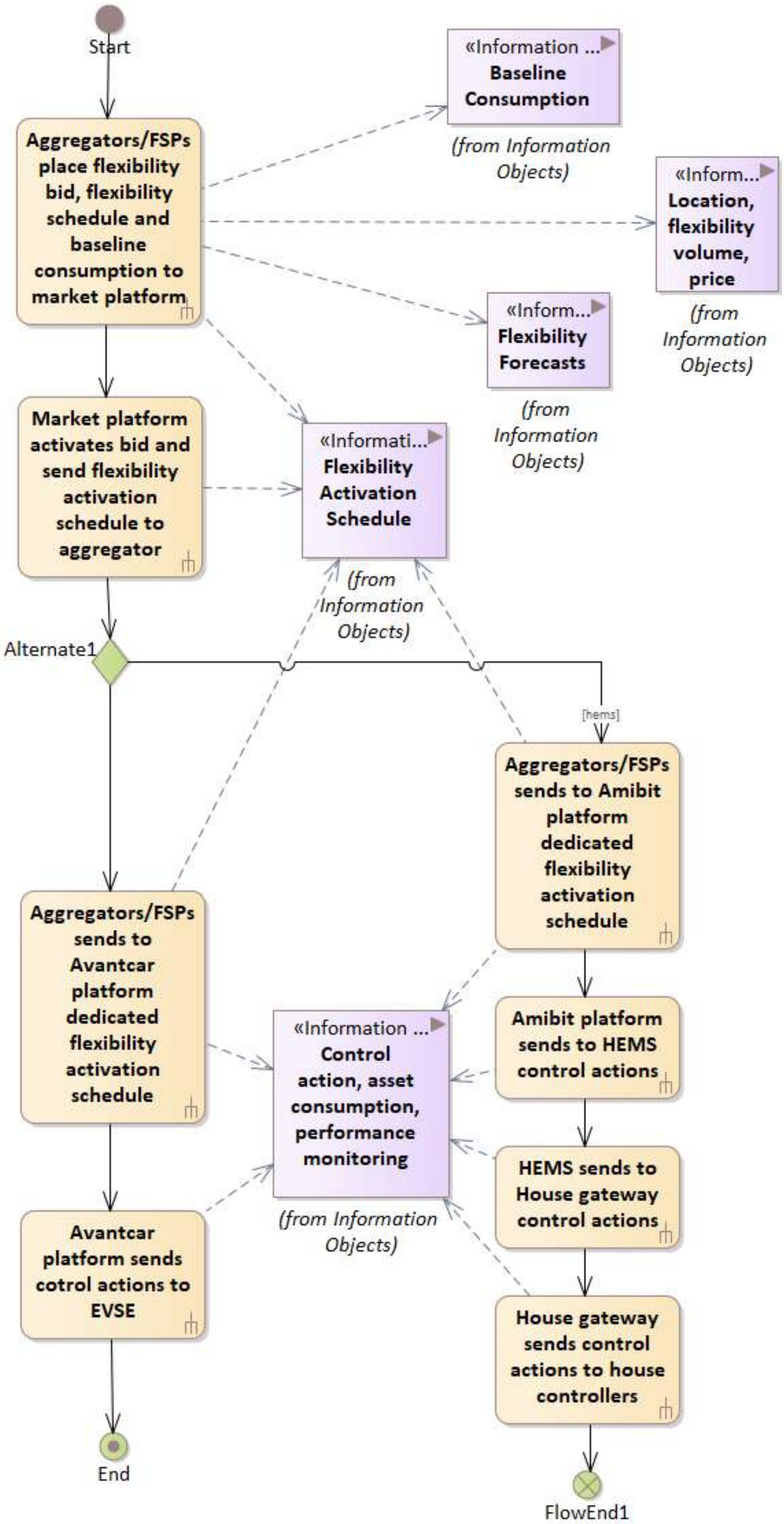

Figure 125. UC 3.3 Activity Diagram

5.14.7 Sequence Diagram

The detailed sequence diagram for UC 3.3 is presented in the following figure.

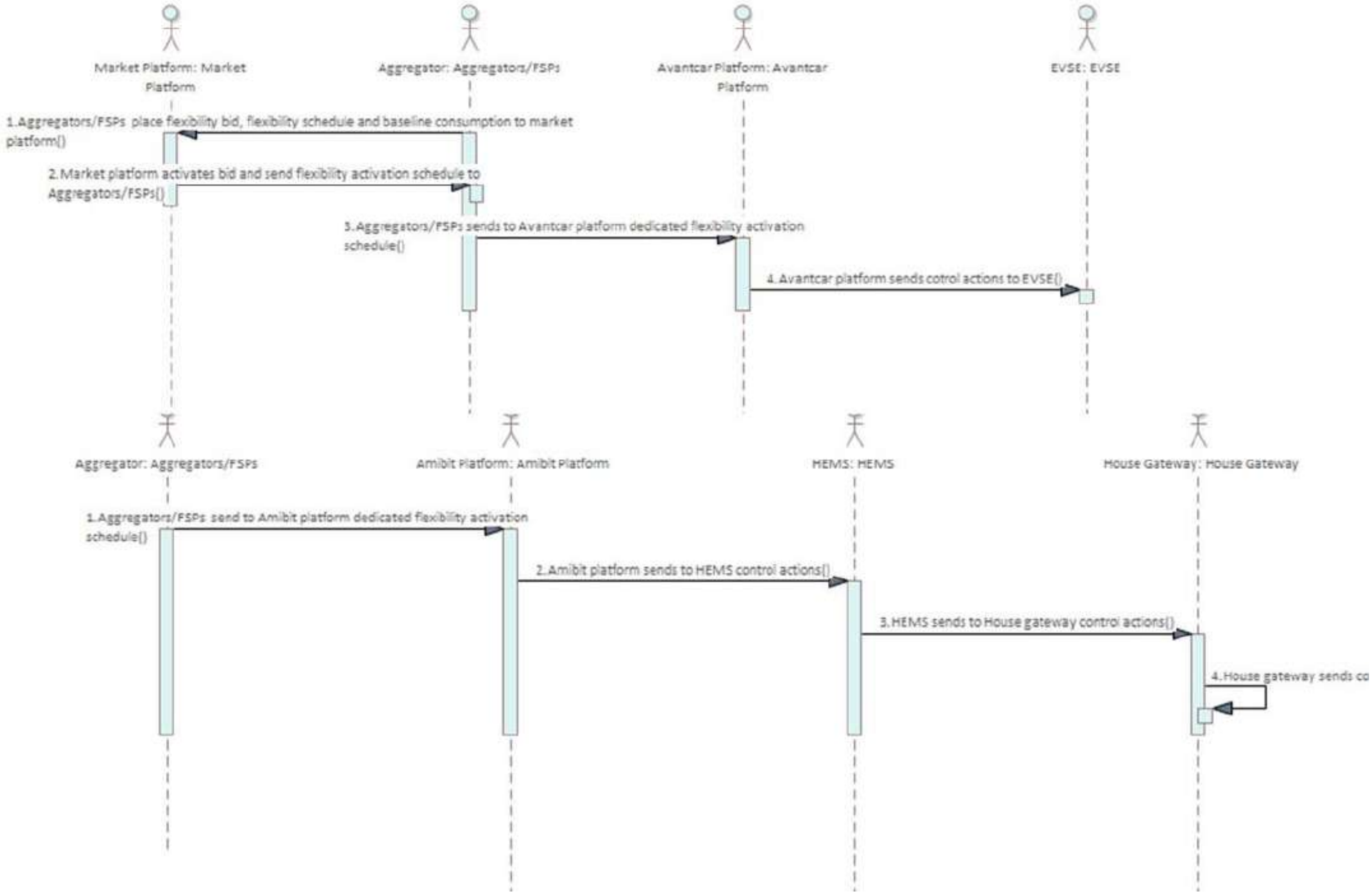

Figure 126. UC 3.3 Sequence diagram

5.14.8 Communication Layer

The communication layer of UC 3.2 is presented in the following figure, highlighting the key communication protocols among the different modules.

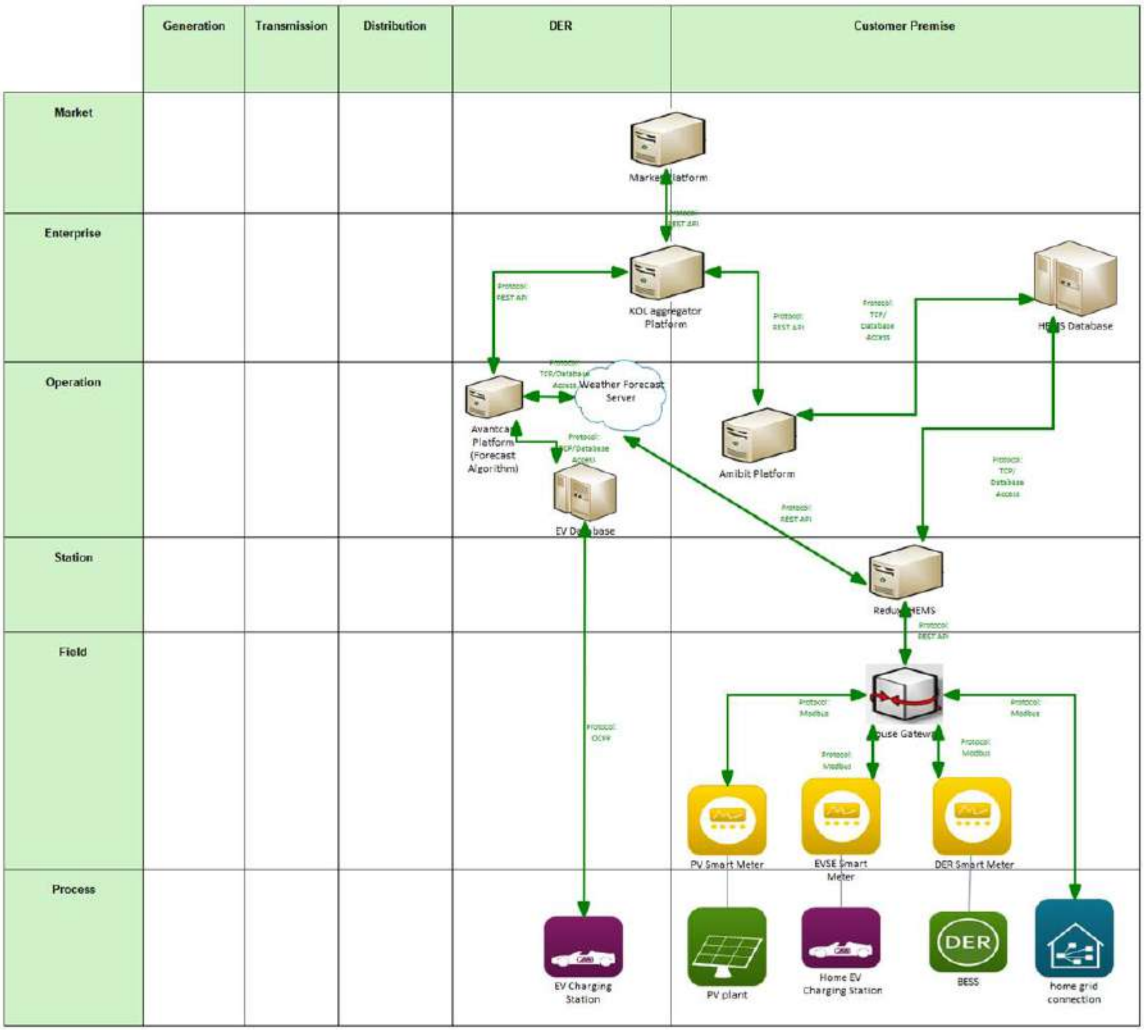

Figure 127. UC. 3.3 Communication Layer

Table 76. List of Communication technologies linked with UC 3.3

Communication Technology	Description
REST	Representational State Transfer. Set of software constraints for web services, to provide interoperability between computer systems on the Internet. A RESTful web service defines a uniform and predefined set of stateless operations that accept requests through a URI.
TCP/IP	Transmission Control Protocol/Internet Protocol. Conceptual model and set of communication protocols used on the Internet. They provide end-to-end data communication, specifying how data should be packetized, addressed, transmitted, routed, and received, through four abstraction layers (link, internet, transport, and application).
Modbus	Communication protocol for programmable logic controllers (PLCs). It is openly published, easy to deploy and maintain, and does not present many restrictions on integration with different vendors. Modbus TCP covers the use of Modbus messaging using the TCP/IP protocols .
OCPP	The Open Charge Point Protocol (OCPP) is an application protocol for communication between Electric vehicle (EV) charging stations and a central management system

5.14.9 Component Layer

The components included in the use case are depicted below, including the technology used for connecting each other.

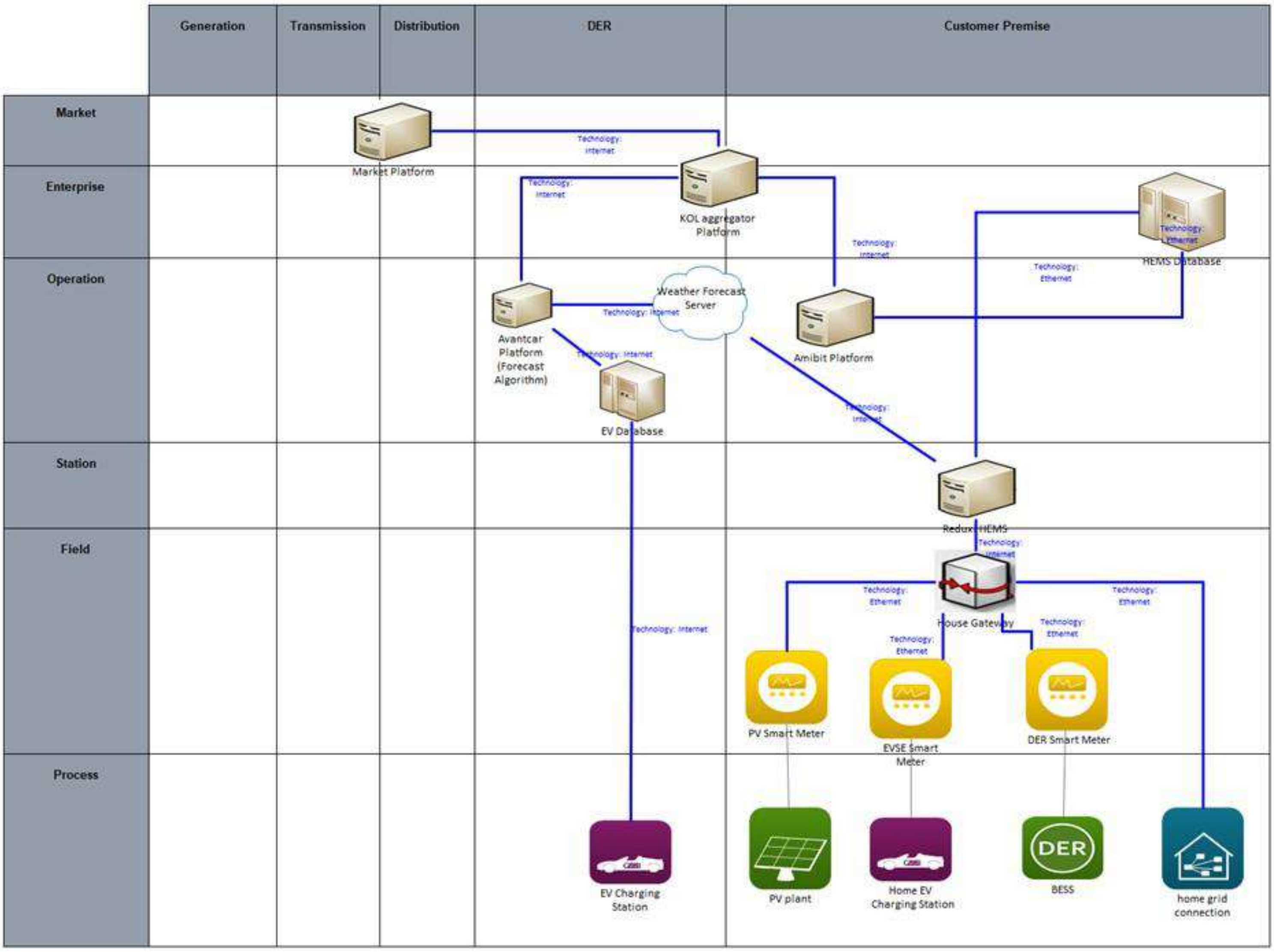

Figure 128. 3.3 Component Layer

Table 77. List of Components linked with UC 3.3

Component	Component Type
EV charging station, PV plant, BESS, home grid automation, PV/EVSE/DER smart meter, house gateway, HEMS database, EV database	Devices
Reduxi HEMS, Avantcar Platform, Amibit Platform, KOL Aggragator Platform, Market Platform	System

5.15 UC 4.1: Topology detection

5.15.1 Use Case Description

This Use Case focuses on performing a topology analysis for distribution networks. In this Use Case, the network operator knows the line infrastructure and their impedances and needs to determine the ones that are currently energized.

The aim is to confirm that the observed data from the topology corresponds to the topology assumed by the network operator and detect if there are discrepancies (errors, things that are connected where they should not and short-circuits) and locate faults.

5.15.2 Function layer

The functional layer of UC 4.1 is presented in the following graph highlighting the key actors of the use case

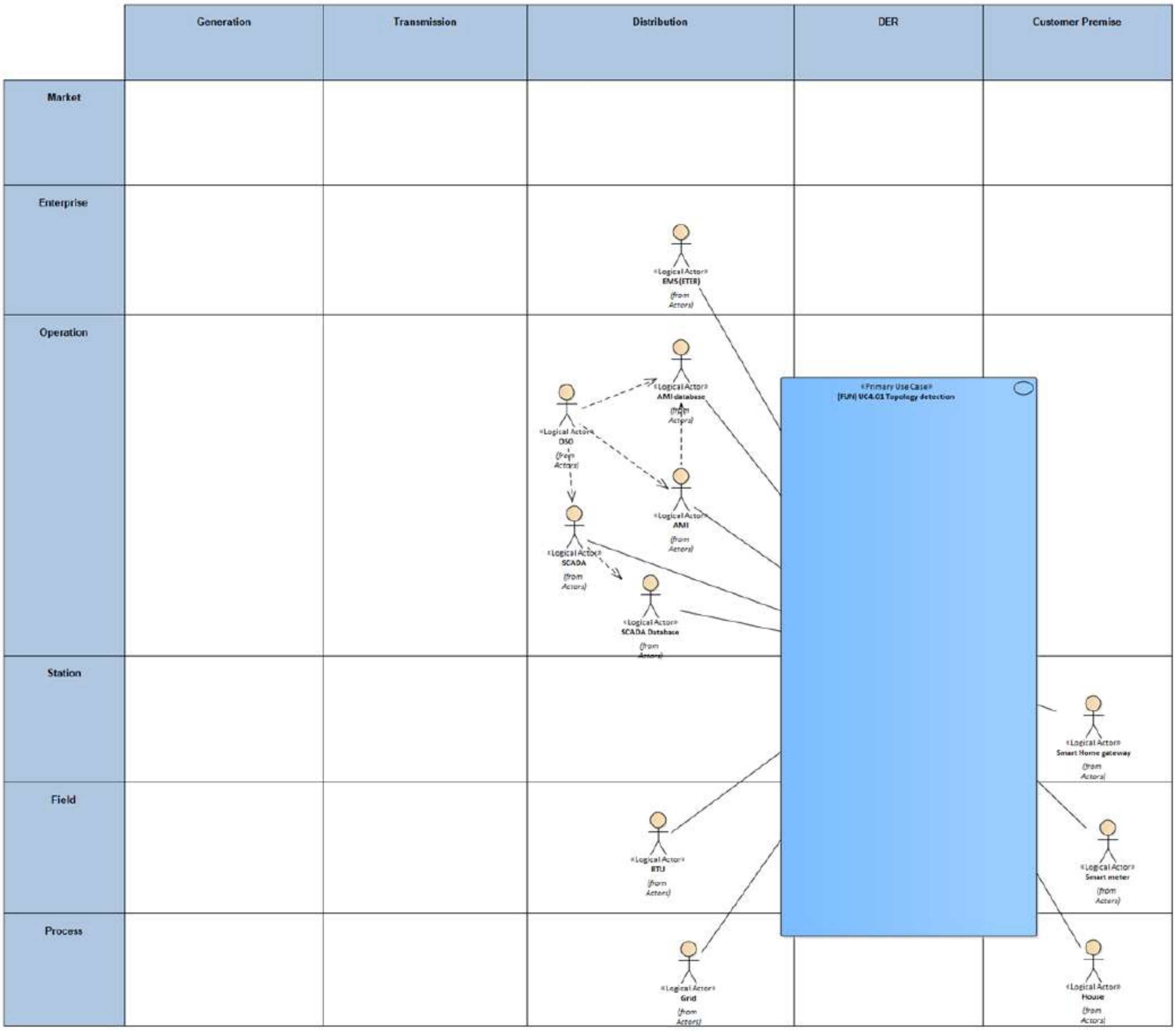

Figure 129. UC4.1 Function Layer

Table 78. List of actors involved in UC 4.1

Actor Name	Actor Type
DSO	Organization
AMI	System
AMI Database	Device
SCADA	System
SCADA Database	Device
EMS (ETER)	System
Smart home gateway	Device
Smart meter	Device
House	Device
RTU	Device
Grid	Device

5.15.3 Information layer

Details about information layer of UC 4.1 are presented in the following figure, highlighting the key information objects.

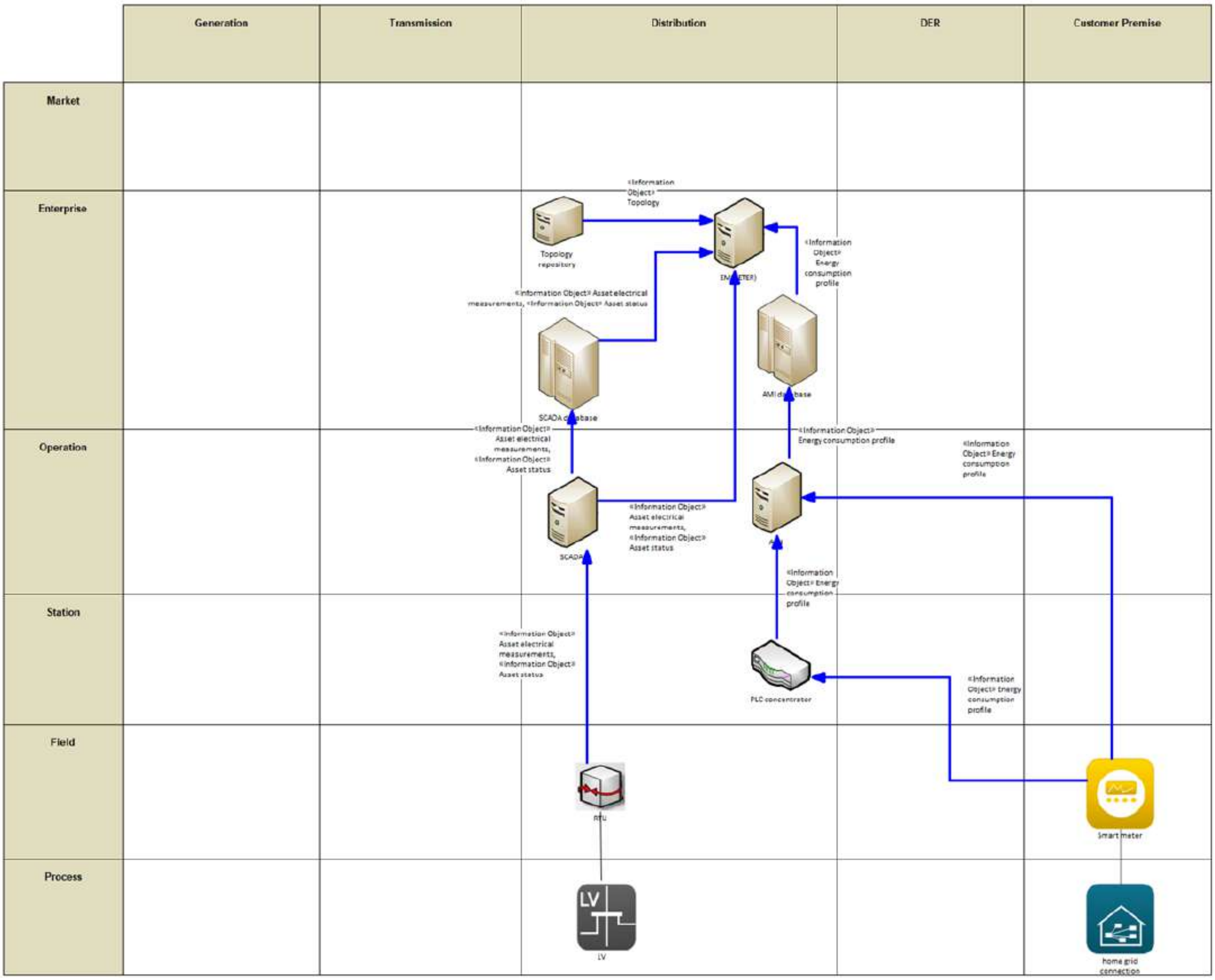

Figure 130. UC 4.1 Information Layer

5.15.4 Canonical Data Model

The identified canonical data models for UC4.1 are described below.

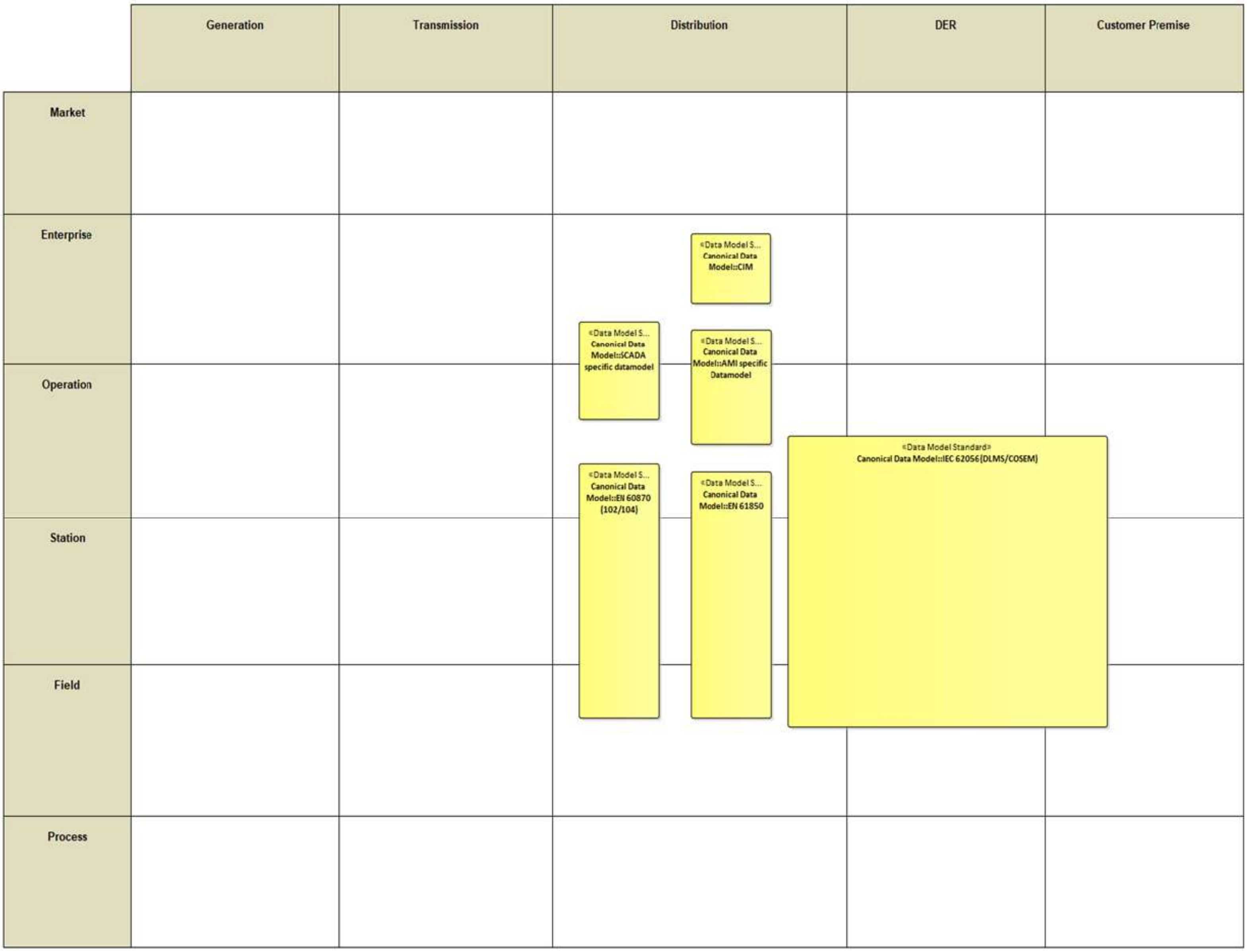

Figure 131. UC 4.1 Canonical data model

Table 79. List of Data models involved in UC 4.1

Data Models
CIM
SCADA specific data model
AMI specific data model
En 60870 (102/104)
EN 61850
EC 62056 (DLMS/COSEM)

5.15.5 Standards and Information Object Mapping

SGAM Standards and Information Objects Mapping for UC4.1 is presented in the following figure.

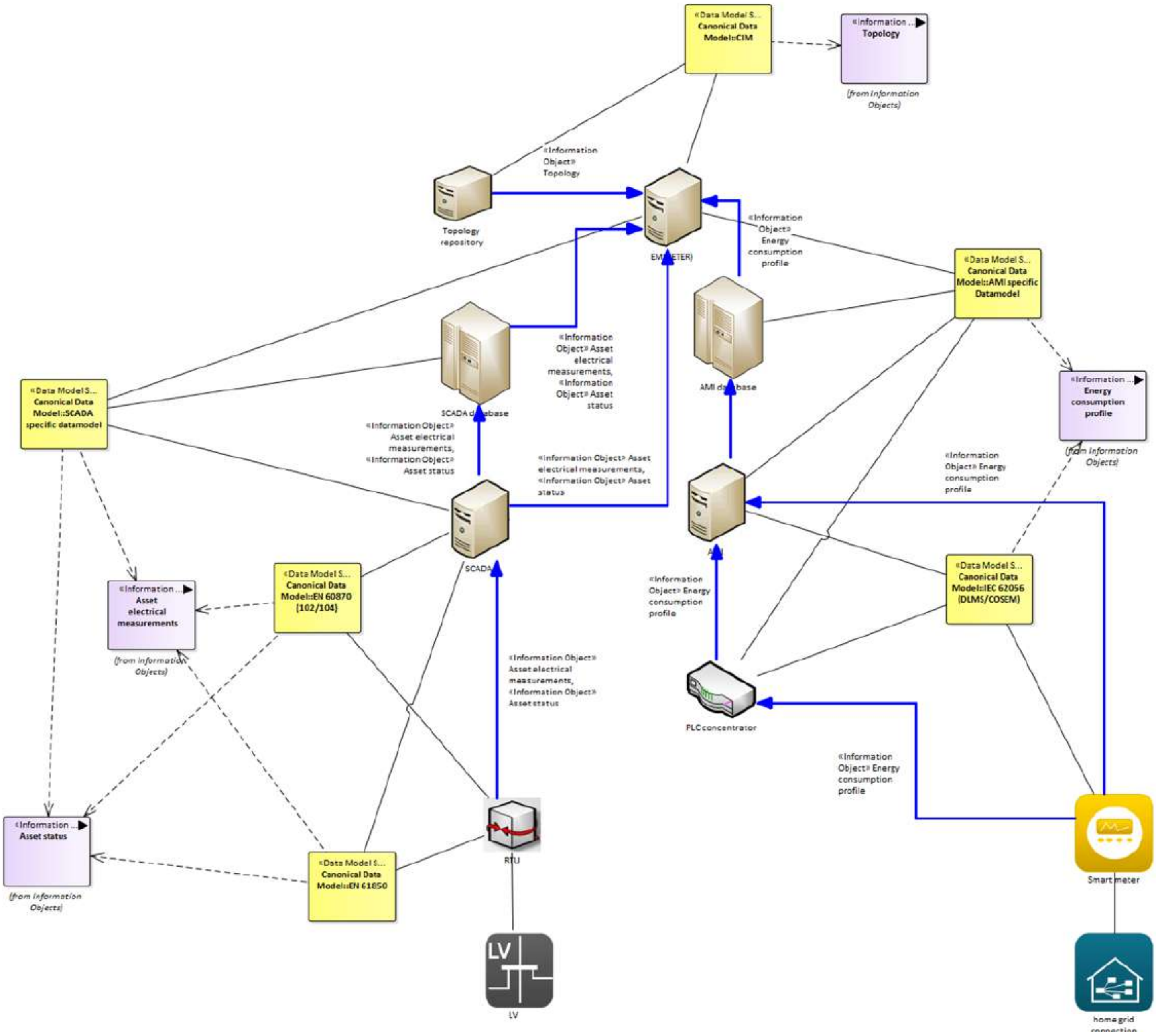

Figure 132. UC 4.1 Standards and Information Object Mapping

Table 80. List of Information Objects, link with Data Standards in UC 4.1

Information Object	DATA Models	Information
Information Topology	CIM	Network Topology
Energy Consumption Profile	AMI specific data model, EC 62056 (DLMS/COSEM)	Energy consumption data
Asset Electrical Measurements	SCADA specific data model, En 60870 (102/104), EN 61850	Voltage, Current, Active/Reactive power
Asset Status	SCADA specific data model, En 60870 (102/104), EN 61850	On/off condition of asset.

5.15.6 Activity Diagram Layer

The detailed activity diagram for UC 4.1 is presented in the following figure.

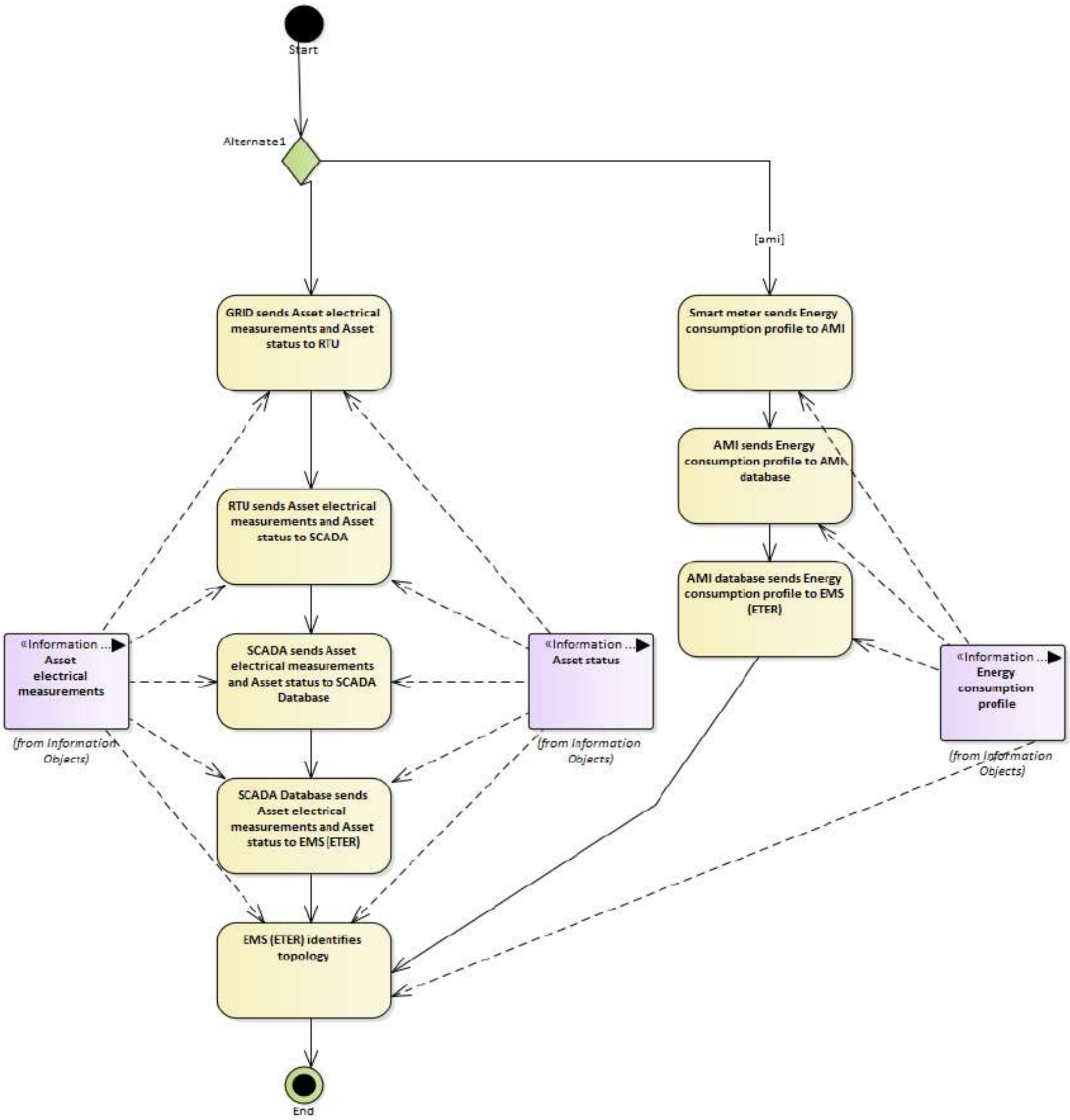

Figure 133. UC 4.1 Activity Diagram

5.15.7 Sequence Diagram

The detailed sequence diagram for UC 4.1 is presented in the following figure.

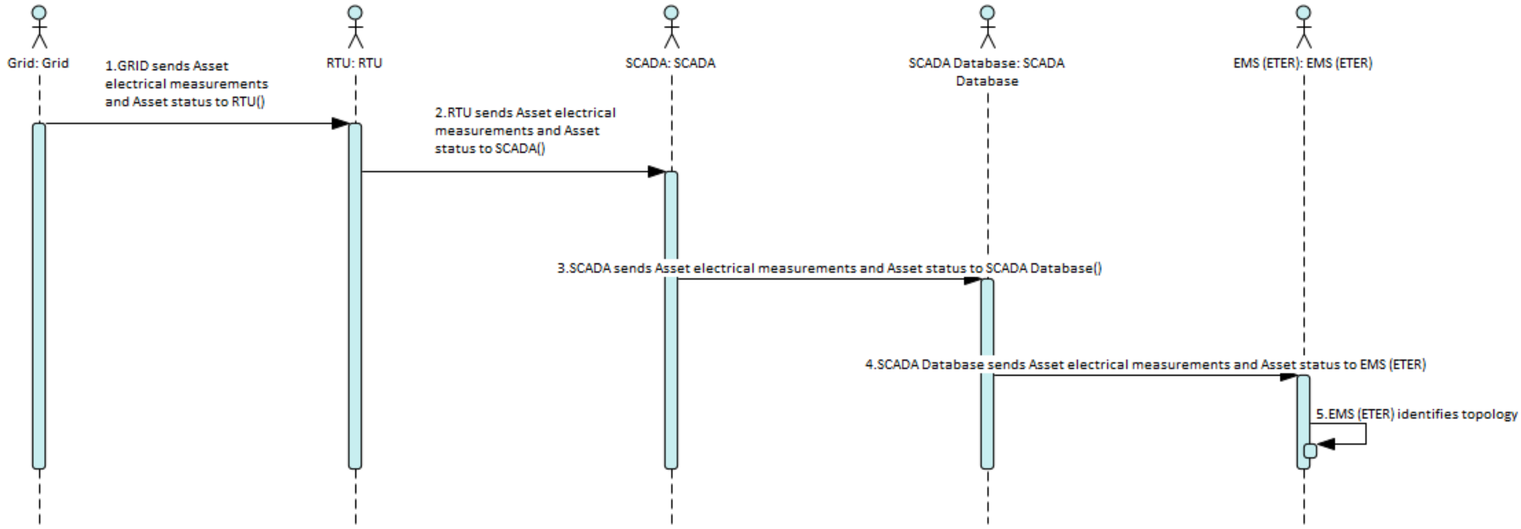

Figure 134. UC 4.1 Sequence Diagram

5.15.8 Communication Layer

The communication layer of UC 4.1 is presented in the following figure, highlighting the key communication protocols among the different modules.

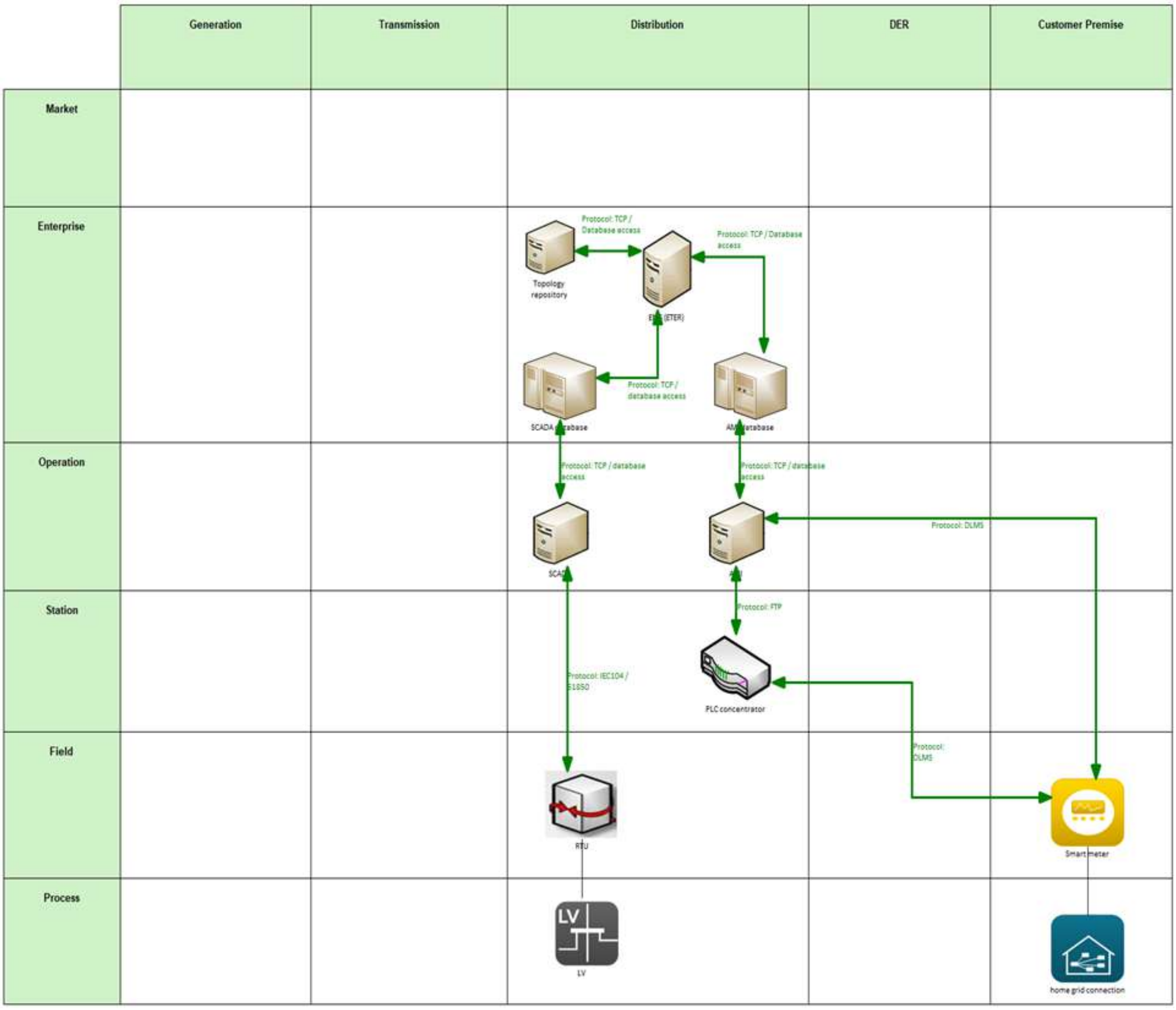

Figure 135. UC4.1 Communication Layer

Table 81. List of Communication technologies linked with UC 4.1

Communication Technology	Description
FTP	The File Transfer Protocol (FTP) is a standard communication protocol used for the transfer of computer files from a server to a client on a computer network. FTP is built on a client–server model architecture using separate control and data connections between the client and the server.
TCP/IP	Transmission Control Protocol/Internet Protocol. Conceptual model and set of communication protocols used on the Internet. They provide end-to-end data communication, specifying how data should be packetized, addressed, transmitted, routed, and received, through four abstraction layers (link, internet, transport, and application).

IEC104/61850	IEC 104 is a standard telecontrol protocol used for remote control and monitoring of substations, while IEC 61850 is a comprehensive standard for substation automation, covering various aspects such as data modeling, communication services, and system configuration.
DLMS	Device Language Message specification/Companion Specification for Energy Metering. Standards for electricity metering data exchanged defined in IEC 62056. DLMS defines the data model specification of the messages, while COSEM includes directives that define the transport and application layers of the DLMS protocol. It is the main global standard for smart energy metering, control and management. It includes specifications for media-specific communication profiles, an object-oriented data model and an application layer protocol.

5.15.9 Component Layer

The components included in the use case are depicted below, including the technology used for connecting each other.

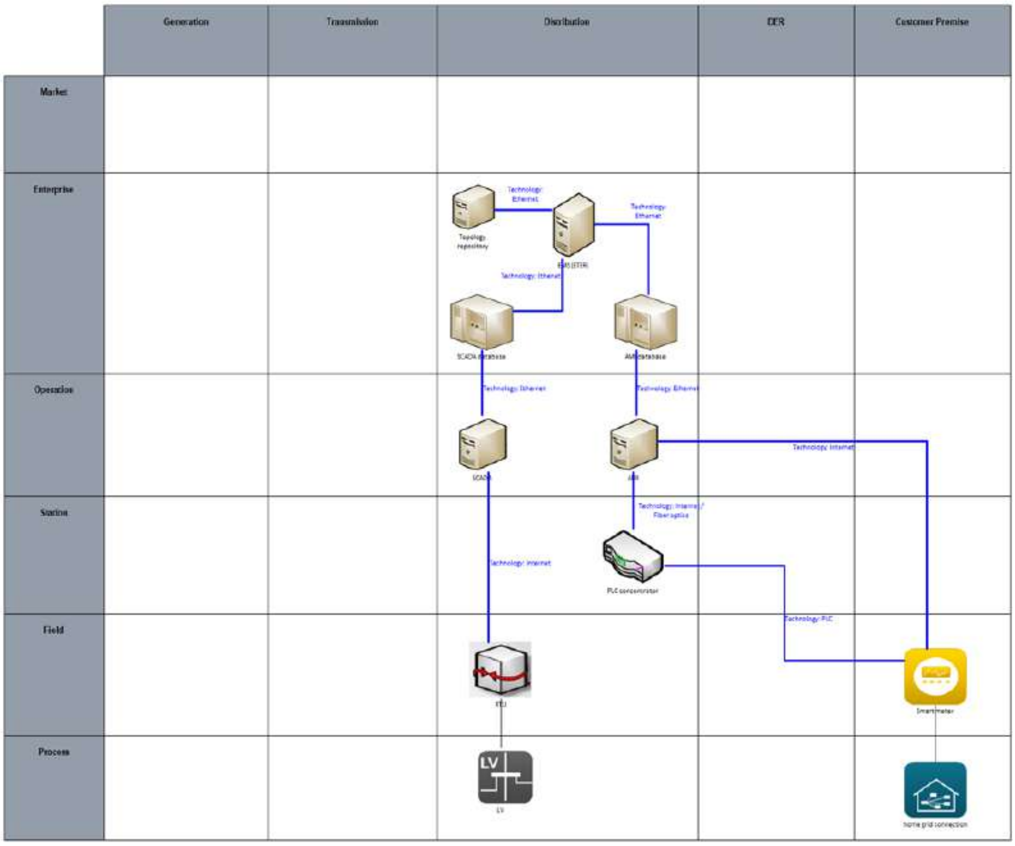

Figure 136. UC4.1 Component Layer

Table 82. List of Components linked with UC 4.1

Component	Component Type
LV grid, Home grid connection, RTU, Smart meter, PLC concentrator, SCADA database, AMI database, Topology repository	Devices
SCADA, AMI, EMS (ETER)	System

5.16 UC 4.2: Fraud detection (non-technical losses)

5.16.1 Use Case Description

The main objective of this Use Case is to identify and forecast the potential theft attempts in order to illegally reduce their electricity bills. These attempts are made by reversing the meters, by-passing or slowing down the meters or inaccurate readings.

In order to do so, it is required to recognize the consumption patterns of the consumers of electricity. OPENTUNITY will rank the end-users using a score of anomalous behaviour to each supply point using machine learning and big data techniques. This information can be further used by grid operator to schedule visual inspections of the end-user installations.

5.16.2 Function layer

The functional layer of UC 4.2 is presented in the following graph highlighting the key actors of the use case.

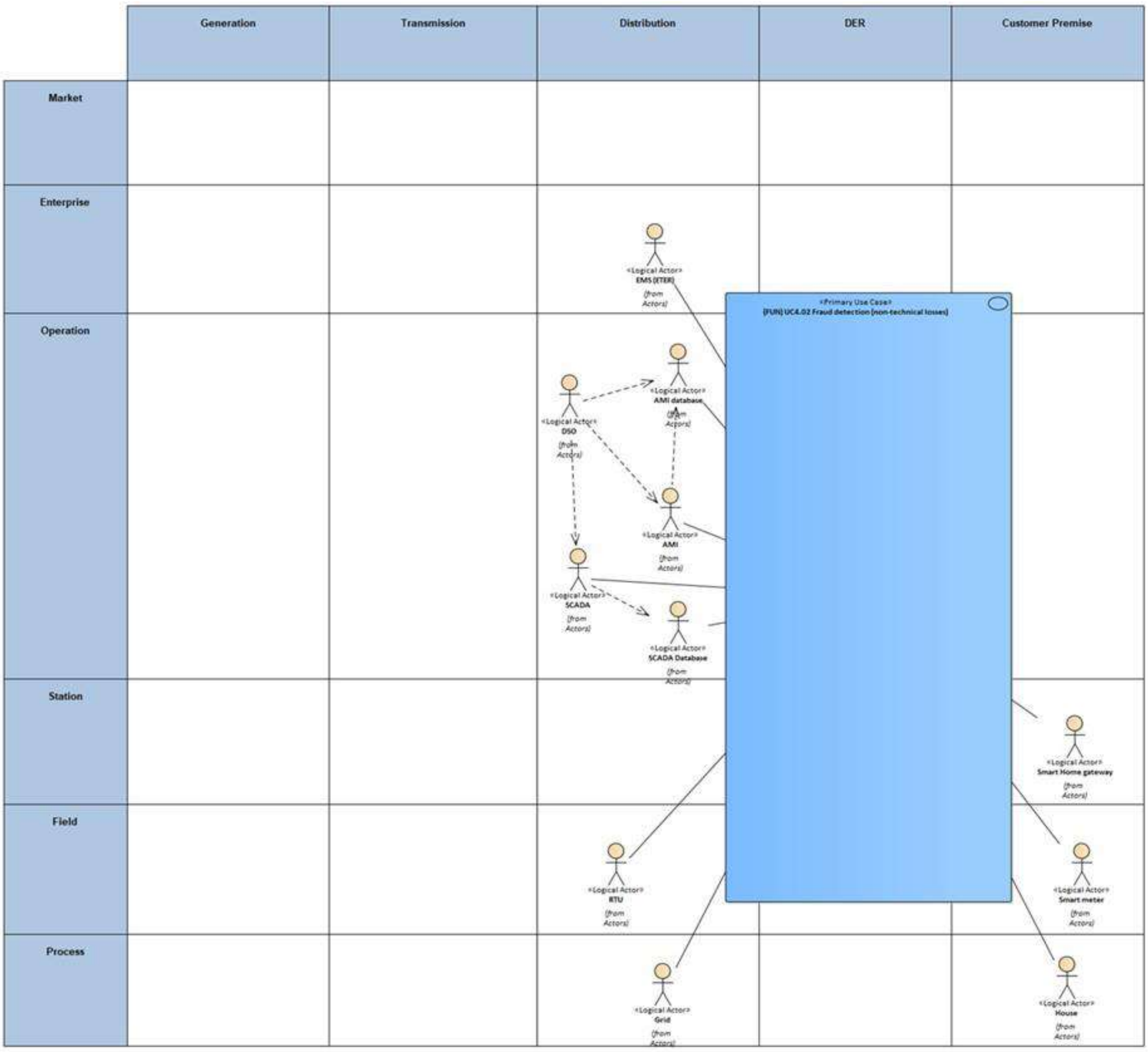

Figure 137. UC 4.2 Function Layer

Table 83. List of actors involved in UC 4.2

Actor Name	Actor Type
DSO	Organization
AMI	System
AMI Database	Device
SCADA	System
SCADA Database	Device
EMS (ETER)	System
Smart home gateway	Device
Smart meter	Device
House	Device
RTU	Device
Grid	Device

5.16.3 Information layer

Details about information layer of UC4.2 are presented in the following figure, highlighting the key information objects.

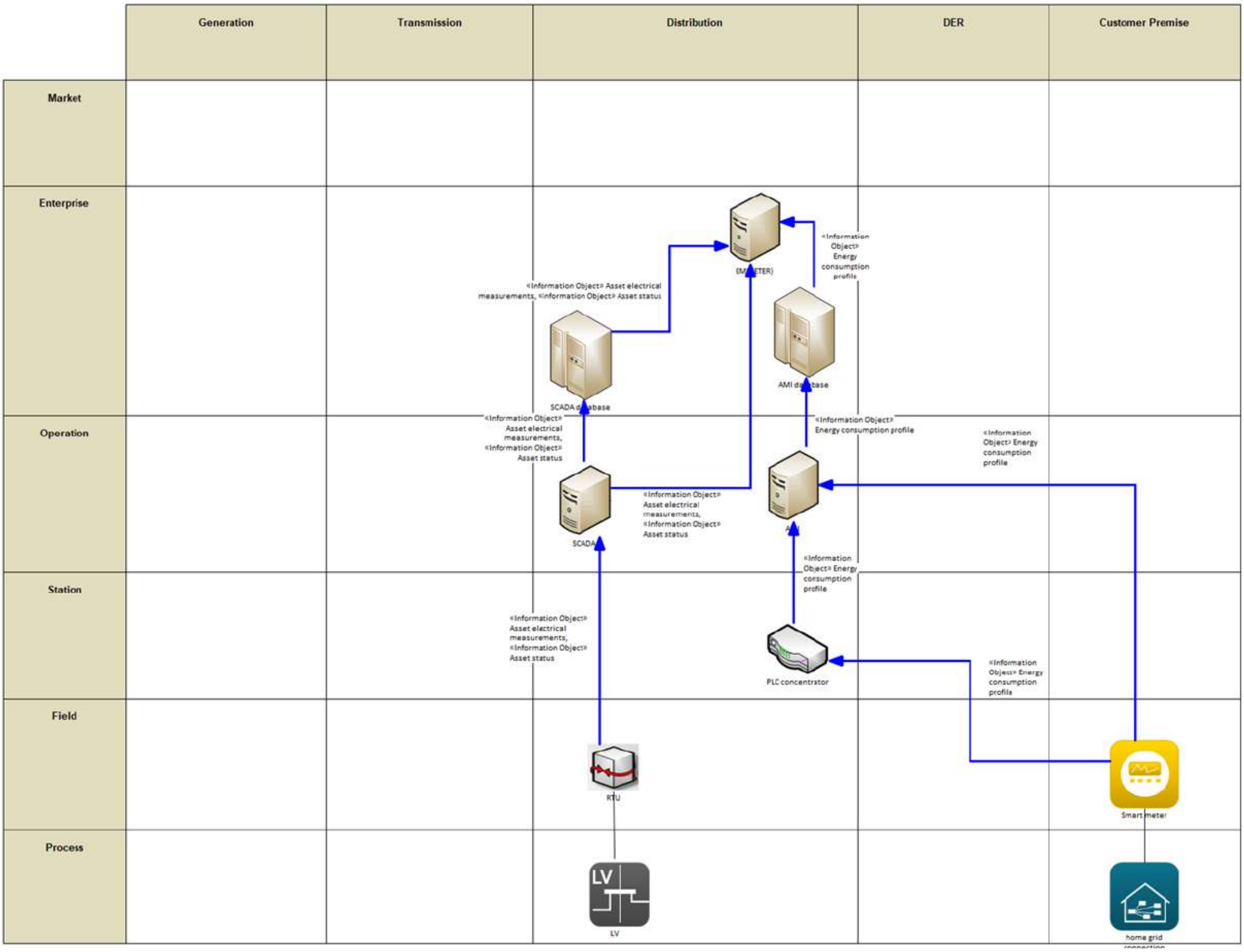

Figure 138. UC 4.2 Information Layer

5.16.4 Canonical Data Model

The identified canonical data models for UC4.2 are described below.

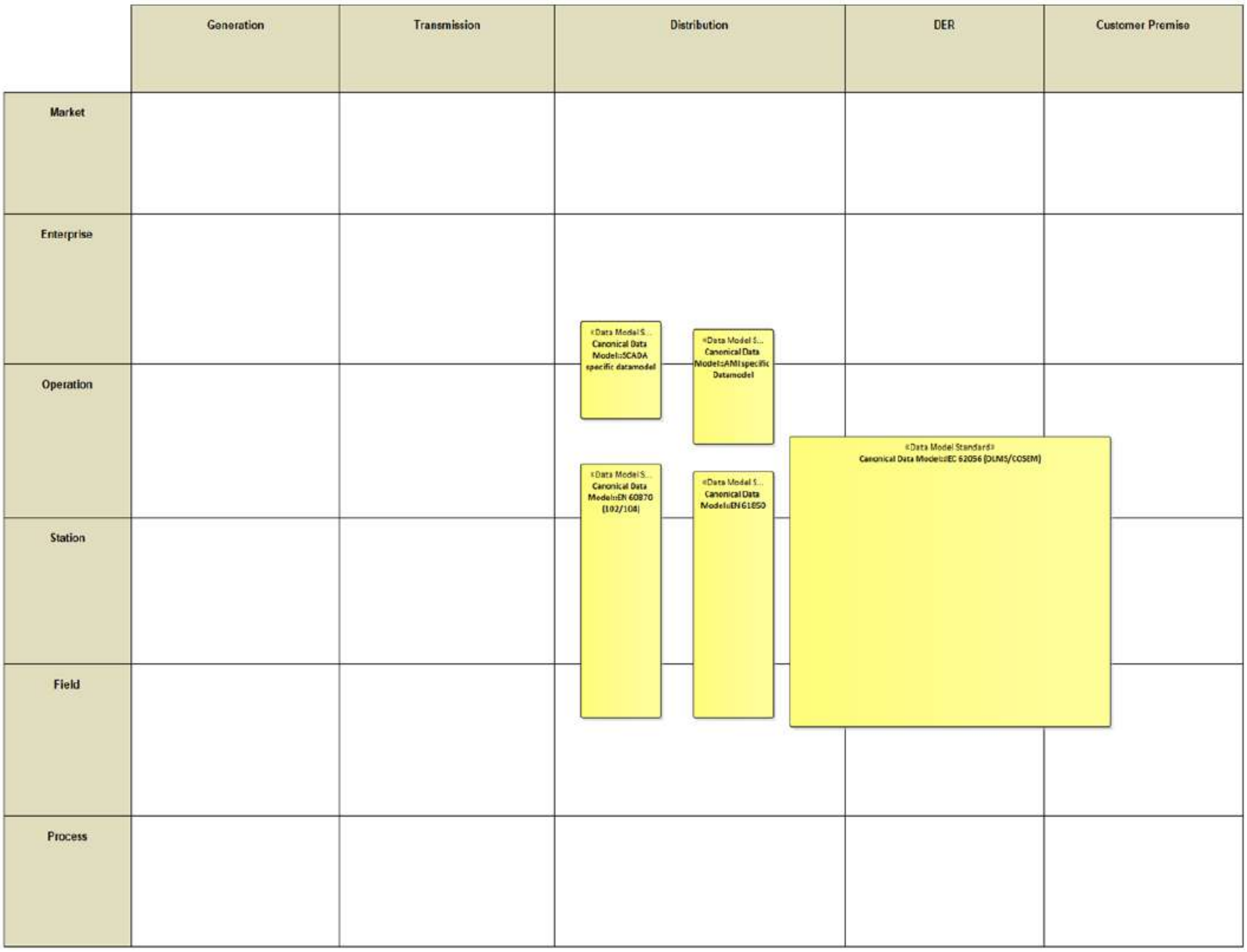

Figure 139. UC 4.2Canonical data model

Table 84. List of Data models involved in UC 4.2

Data Models
SCADA specific data model
AMI specific data model
En 60870 (102/104)
EN 61850
EC 62056 (DLMS/COSEM)

5.16.5 Standards and Information Object Mapping

SGAM Standards and Information Objects Mapping for UC4.2 is presented in the following figure.

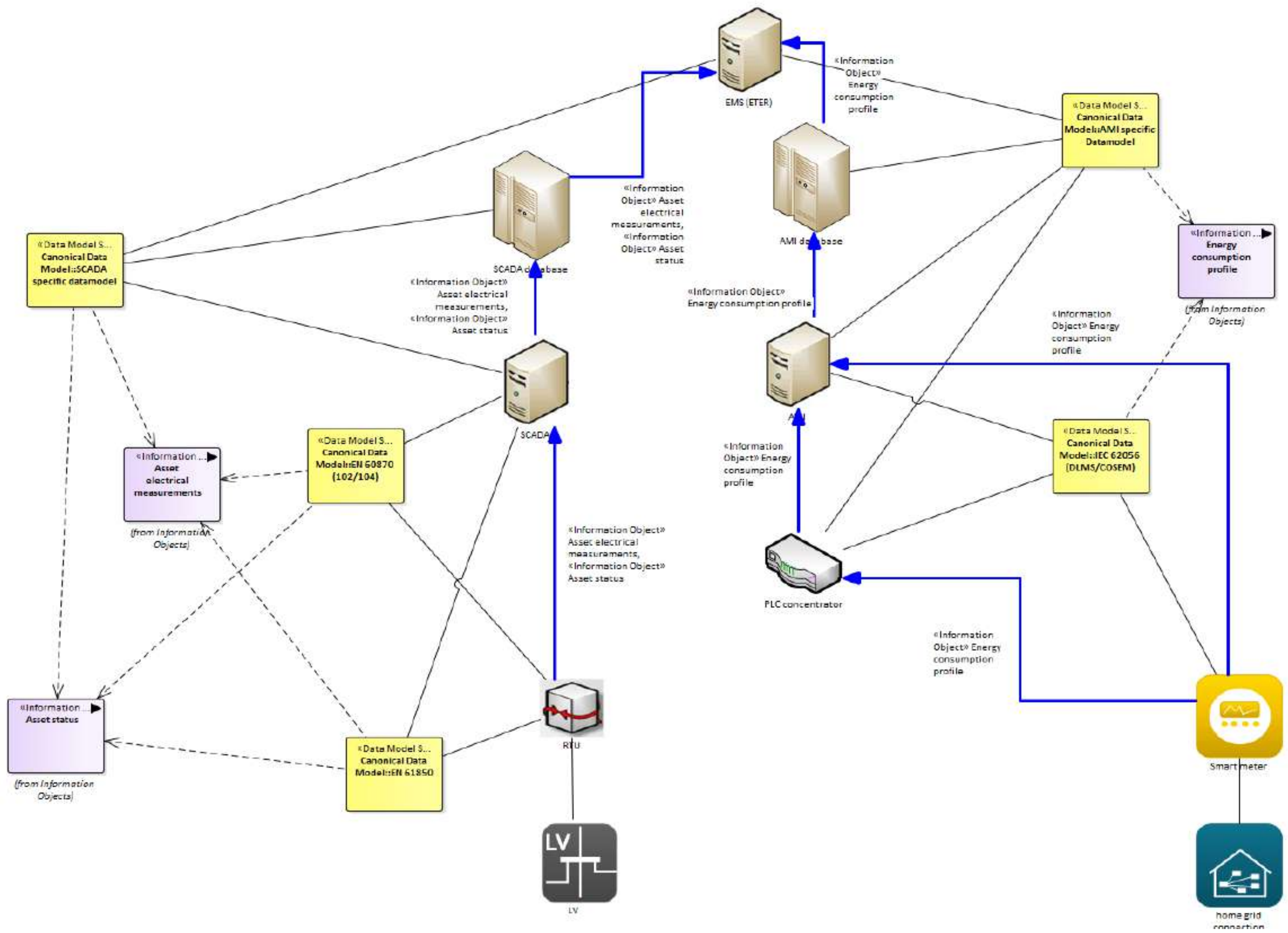

Figure 140. UC 4.2 Standards and Information Object Mapping

Table 85. List of Information Objects, link with Data Standards in UC 4.2

Information Object	DATA Models	Information
Energy Consumption Profile	AMI specific data model, EC 62056 (DLMS/COSEM)	Energy consumption data from smart meters
Asset Electrical Measurements	SCADA specific data model, En 60870 (102/104), EN 61850	Voltage, current, active reactive power/energy
Asset Status	SCADA specific data model, En 60870 (102/104), EN 61850	On/off condition of asset.

5.16.6 Activity Diagram Layer

The detailed activity diagram for UC 4.2 is presented in the following figure.

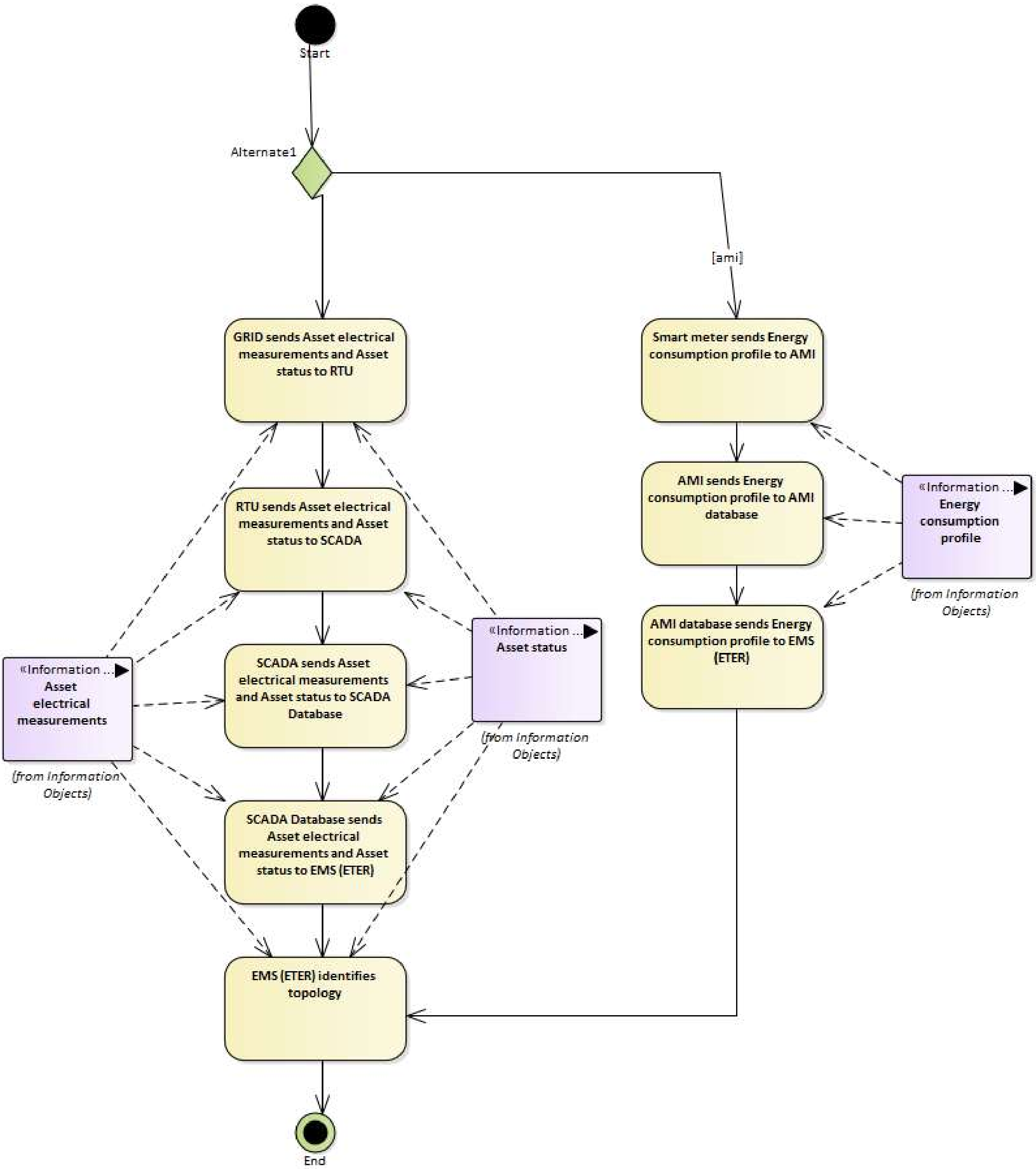

Figure 141. UC 4.2 Activity Diagram

5.16.7 Sequence Diagram

The detailed sequence diagram for UC 4.2 is presented in the following figure.

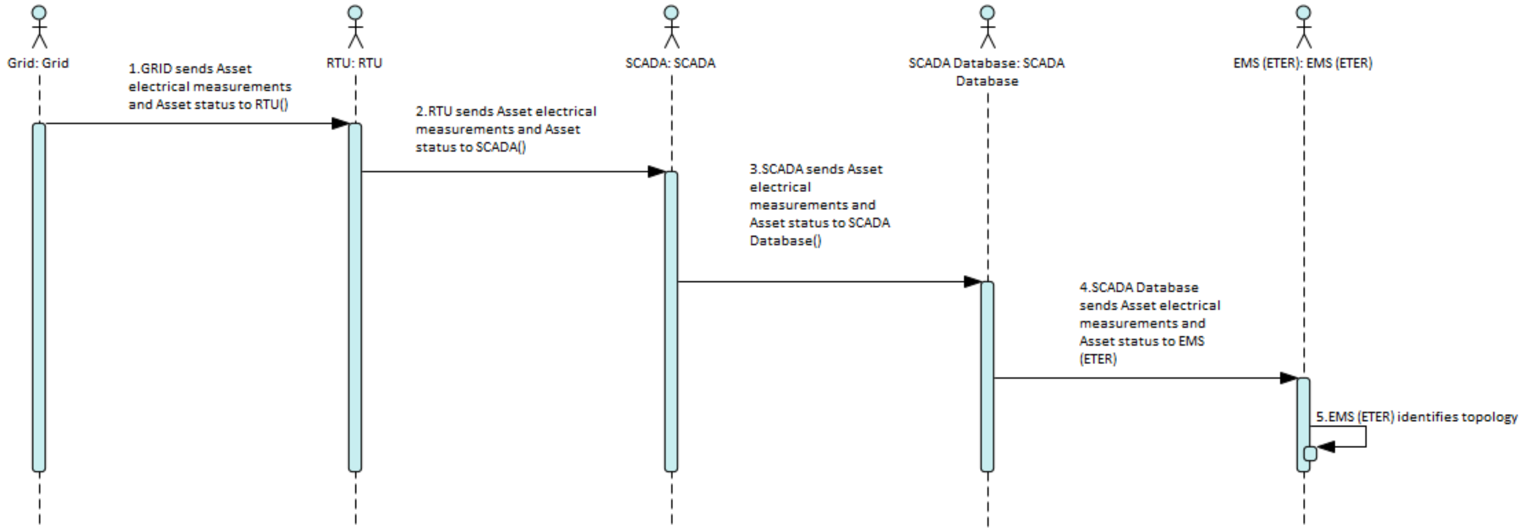

Figure 142. UC 4.2 Sequence Diagram

5.16.8 Communication Layer

The communication layer of UC 4.2 is presented in the following figure, highlighting the key communication protocols among the different modules.

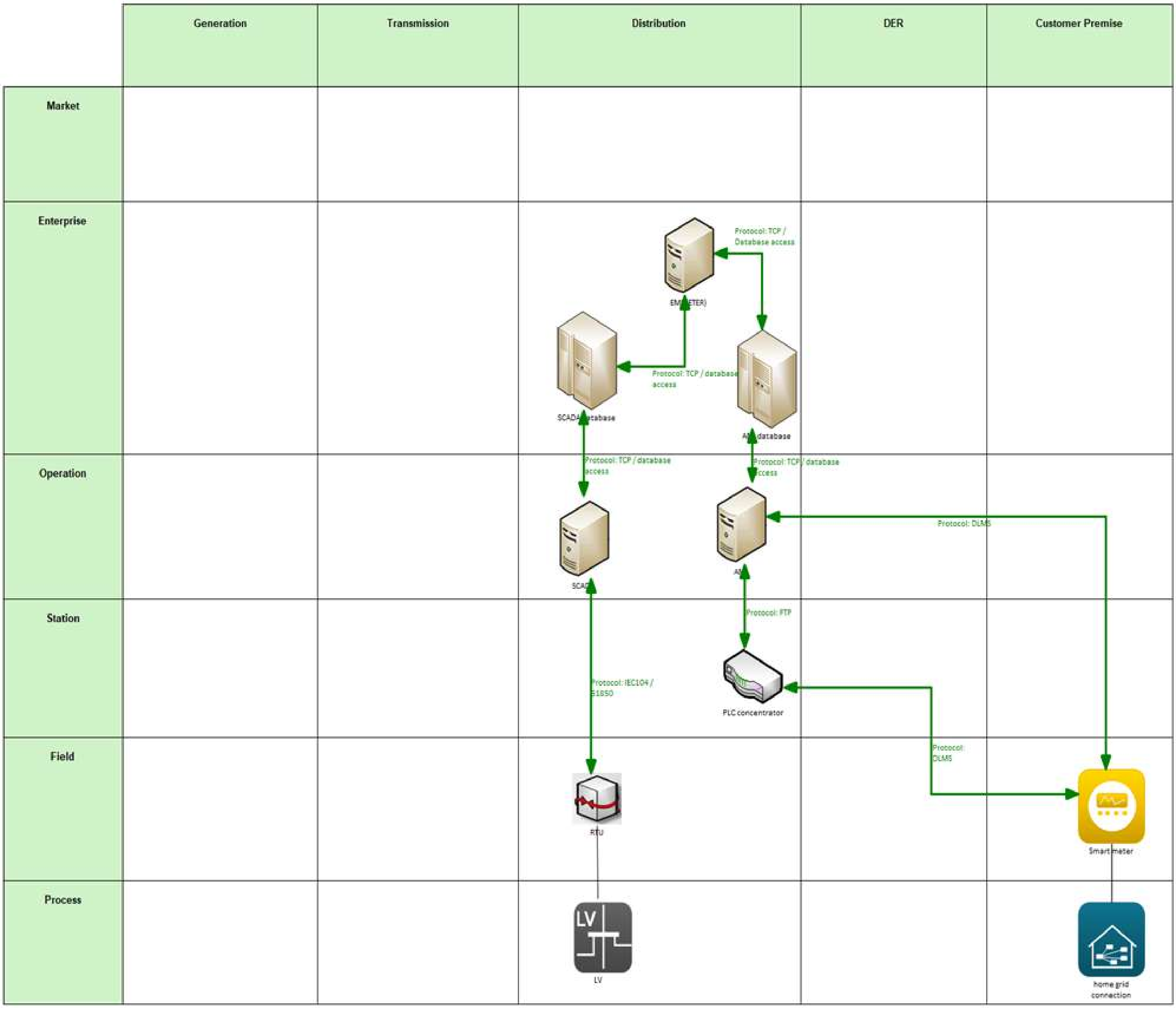

Figure 143. UC4.2 Communication Layer

Table 86. List of Communication technologies linked with UC 4.2

Communication Technology	Description
FTP	The File Transfer Protocol (FTP) is a standard communication protocol used for the transfer of computer files from a server to a client on a computer network. FTP is built on a client–server model architecture using separate control and data connections between the client and the server.
TCP/IP	Transmission Control Protocol/Internet Protocol. Conceptual model and set of communication protocols used on the Internet. They provide end-to-end data communication, specifying how data should be packetized, addressed, transmitted, routed, and received, through four abstraction layers (link, internet, transport, and application).
IEC104/61850	IEC 104 is a standard telecontrol protocol used for remote control and monitoring of substations, while IEC 61850 is a comprehensive standard for substation automation, covering various aspects such as data modeling, communication services, and system configuration.
DLMS	Device Language Message specification/Companion Specification for Energy Metering. Standards for electricity metering data exchanged defined in IEC 62056. DLMS defines the data model specification of the messages, while COSEM includes directives that define the transport and application layers of the DLMS protocol. It is the main global standard for smart energy metering, control and management. It includes specifications for media-specific communication profiles, an object-oriented data model and an application layer protocol.

5.16.9 Component Layer

The components included in the use case are depicted below, including the technology used for connecting each other.

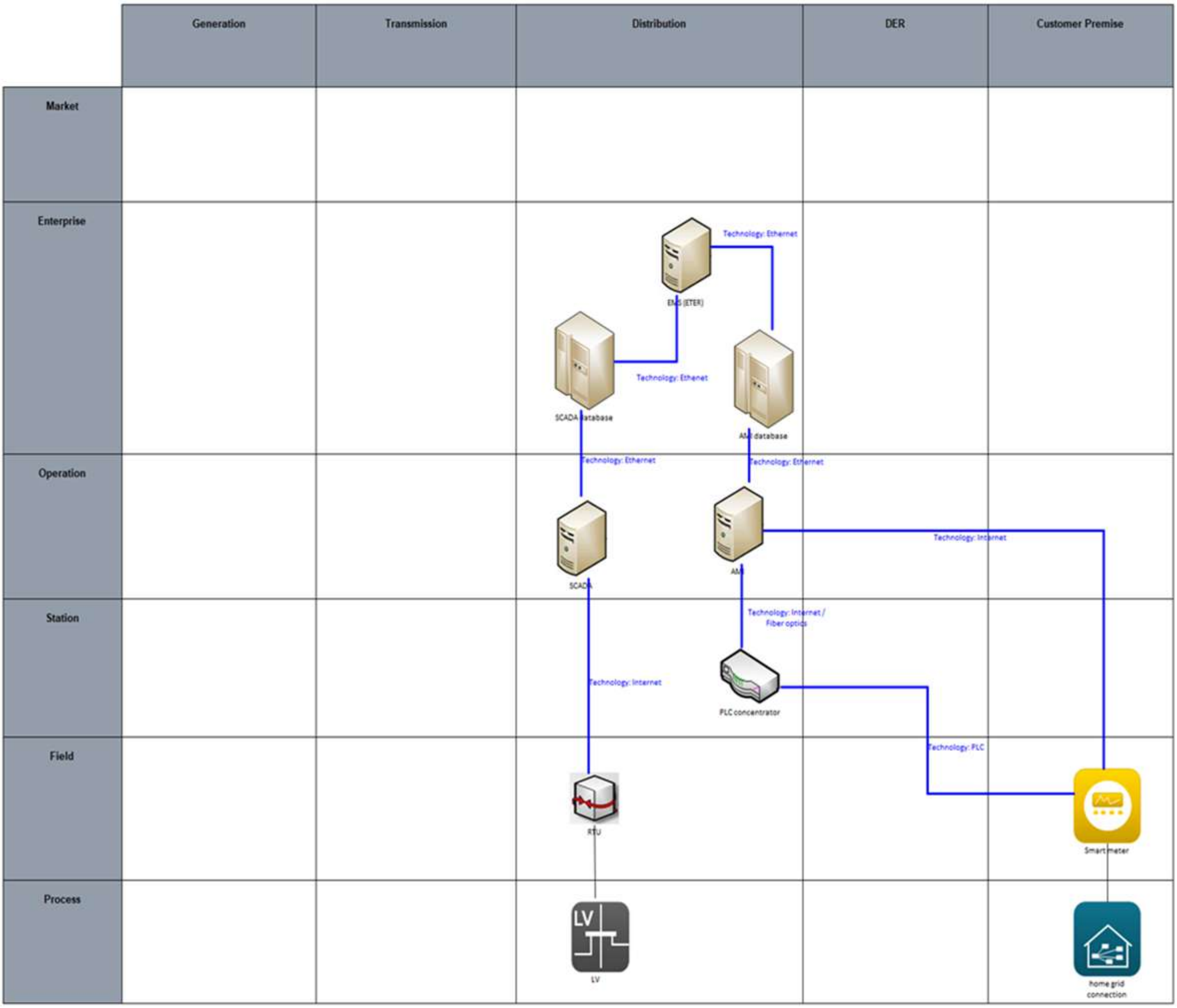

Figure 144. UC4.2 Component Layer

Table 87. List of Components linked with UC 4.2

Component	Component Type
LV grid, Home grid connection, RTU, Smart meter, PLC concentrator, SCADA database, AMI database, Topology repository	Devices
SCADA, AMI, EMS (ETER)	System

5.17 UC 4.3: Detection of unwanted or unexpected islands for PV panels

5.17.1 Use Case Description

In a normal operation of the grid, LV grid supplies consumers and prosumers. There's also the possibility that prosumers inject energy to the grid, but the same grid maintain the quality of the electricity when PV generation is injected. However, in certain cases, the normal operation of a triphasic line gets disrupted when a fuse from one phase blows. When this happens, the grid can't manage the line and it can happen that energy generated from the prosumer's PVs is consumed by a consumer in the same line. As there is no control over this injection, this energy can be of bad quality, supposing a problem for other consumers.

The aim of the Use Case is to detect the blown fuse through the monitoring of the voltage at end user level and an algorithm to undertake the calculations.

5.17.2 Function layer

The functional layer of UC 4.3 is presented in the following graph highlighting the key actors of the use case

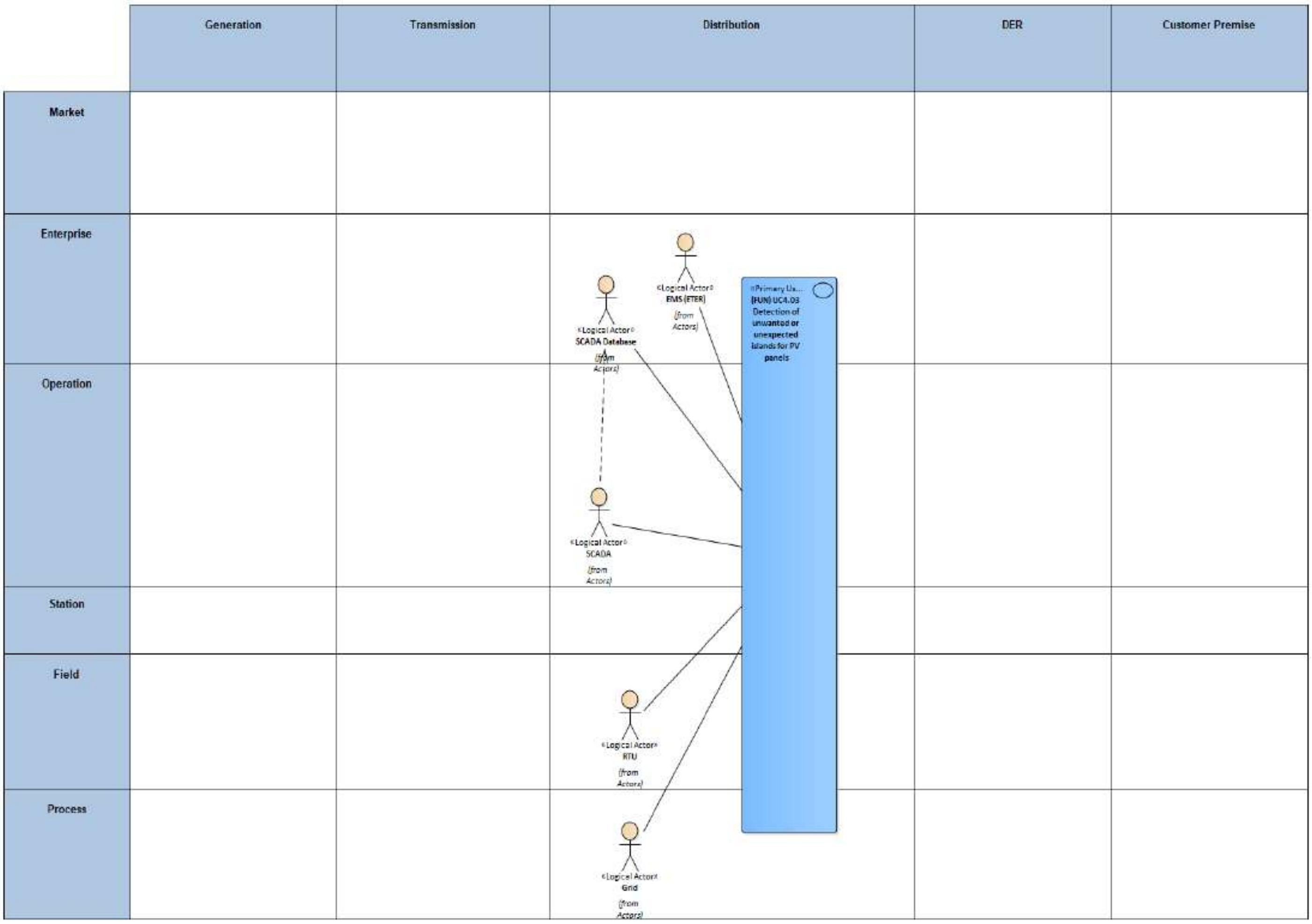

Figure 145. UC 4.3 Function Layer

Table 88. List of actors involved in UC 4.3

Actor Name	Actor Type
EMS (ETER)	System
SCADA	System
SCADA Database	Device
RTU	Device
Grid	Device

5.17.3 Information layer

Details about information layer of UC4.3 are presented in the following figure, highlighting the key information objects.

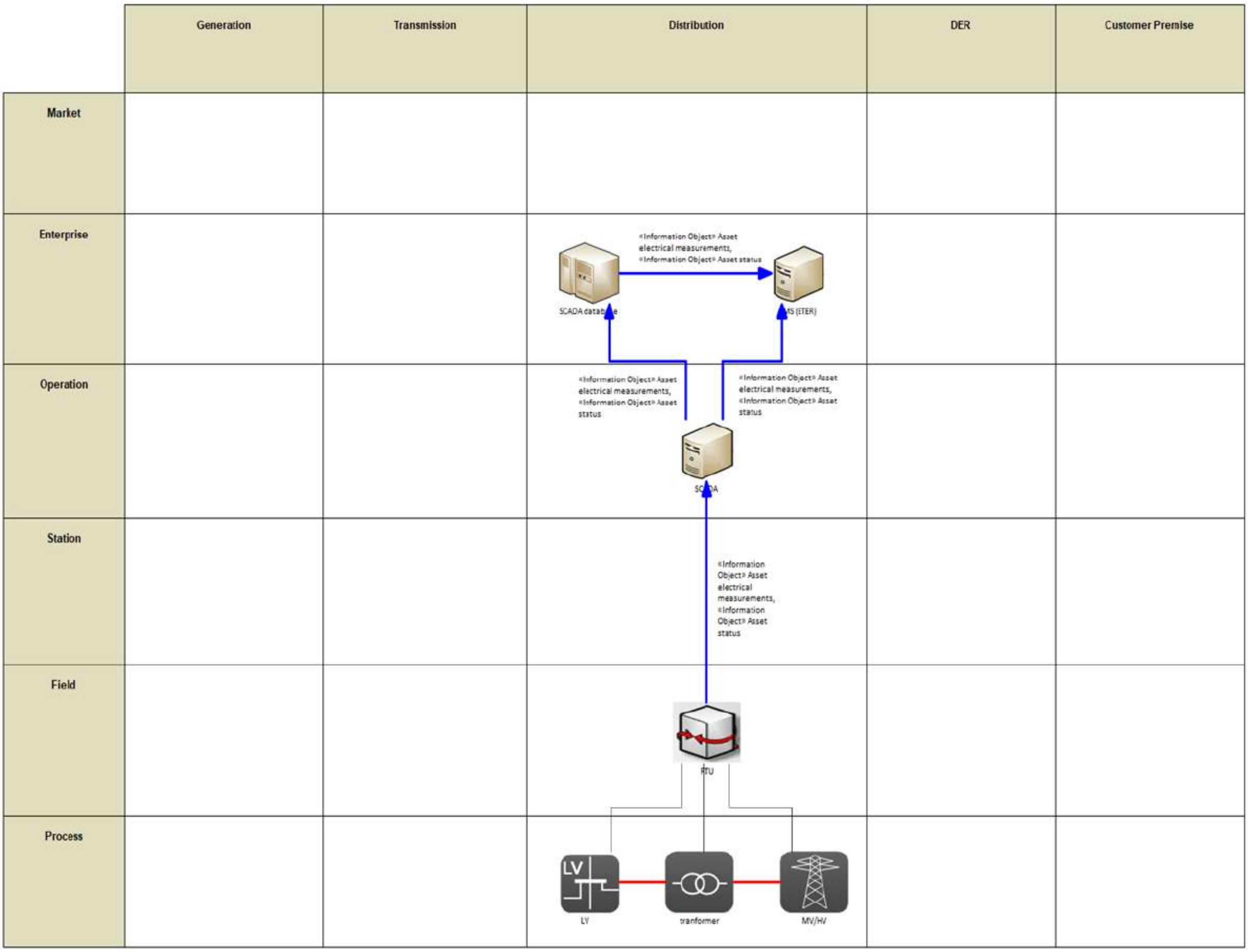

Figure 146. UC 4.3 Information Layer

5.17.4 Canonical Data Model

The identified canonical data models for UC4.3 are described below.

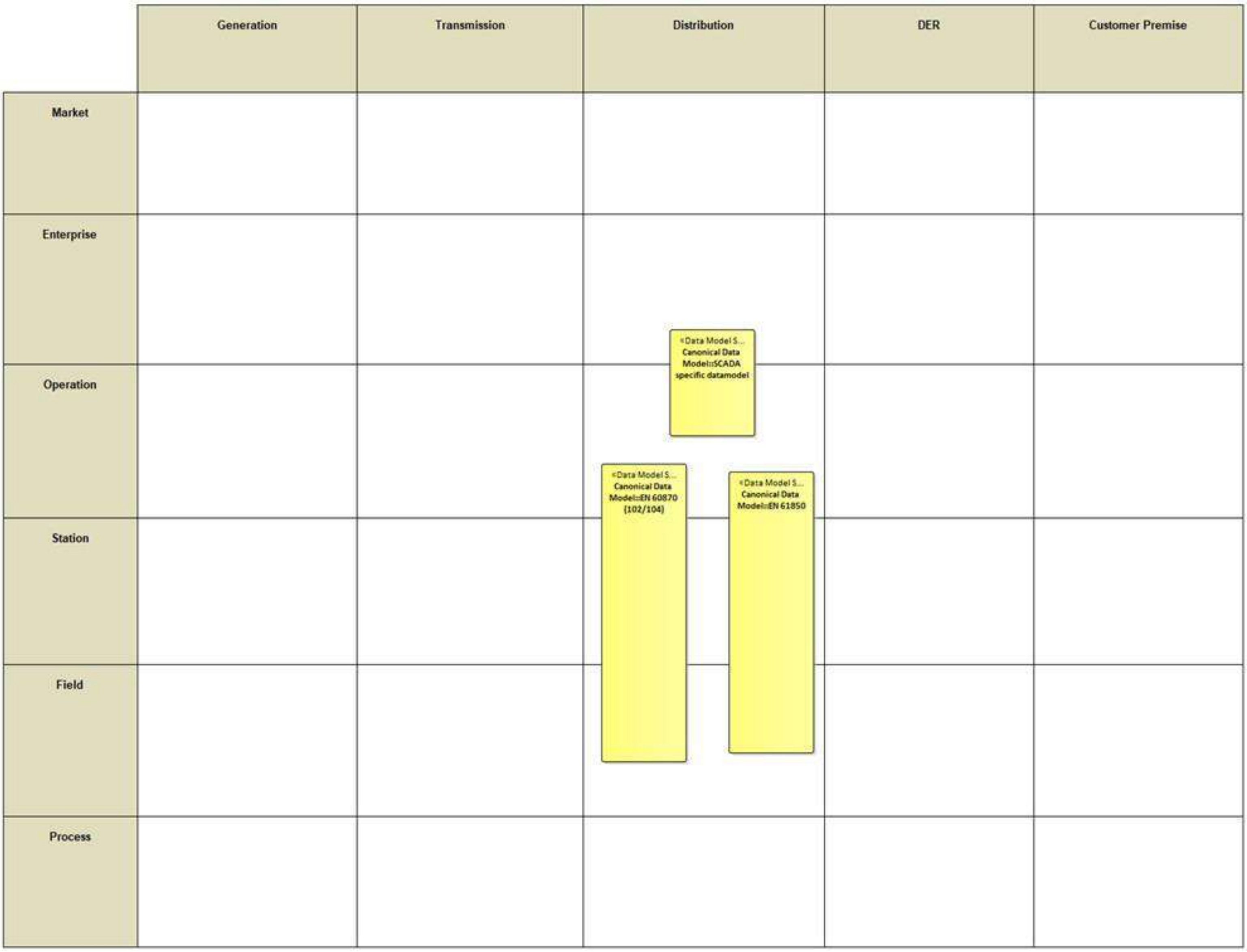

Figure 147. UC 4.3 Canonical data model

Table 89. List of Data models involved in UC 4.3

Data Models
Scada specific data model
En 60870 (102/104)
EN 61850

5.17.5 Standards and Information Object Mapping

SGAM Standards and Information Objects Mapping for UC4.3 is presented in the following figure.

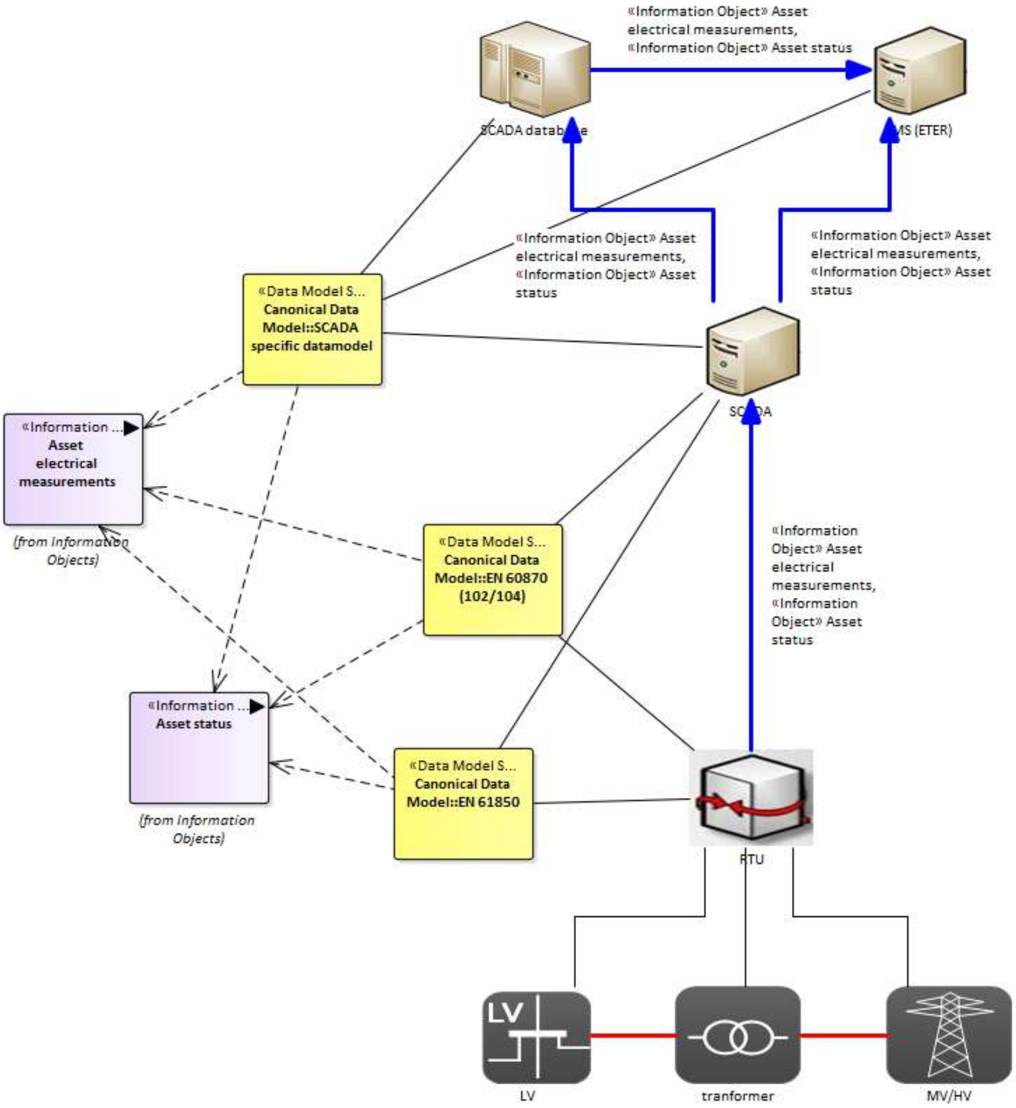

Figure 148. UC 4.3 Standards and Information Object Mapping

Table 90. List of Information Objects, link with Data Standards in UC 4.3

Information Object	DATA Models	Information
Asset Electrical Measurements	SCADA specific data model, En 60870 (102/104), EN 61850	Current. Voltage, Active/Reactive power and energy
Asset Status	SCADA specific data model, En 60870 (102/104), EN 61850	On/off condition of asset.

5.17.6 Activity Diagram Layer

The detailed activity diagram for UC 4.3 is presented in the following figure.

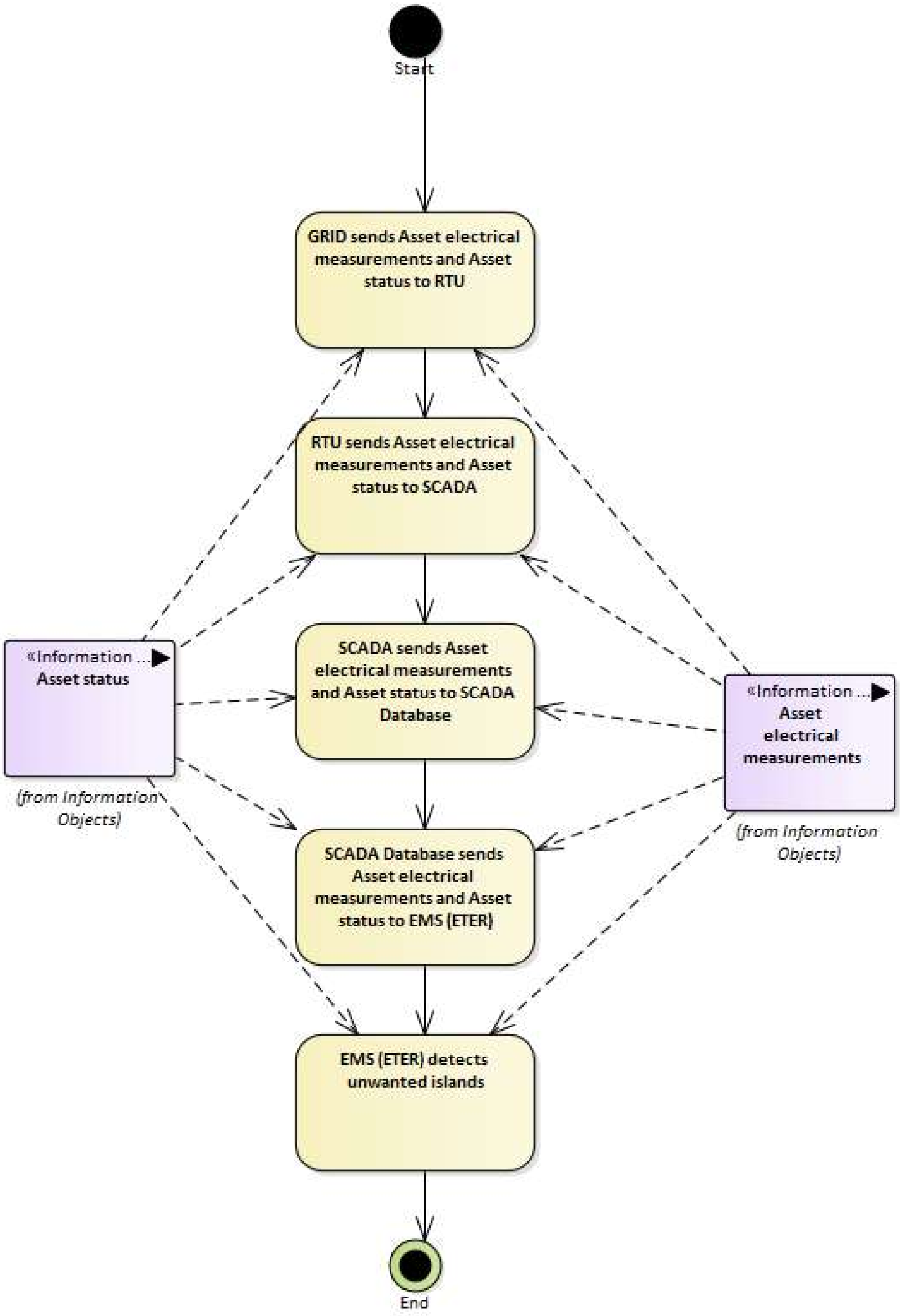

Figure 149. UC 4.3 Activity Diagram

5.17.7 Sequence Diagram

The detailed sequence diagram for UC 4.3 is presented in the following figure.

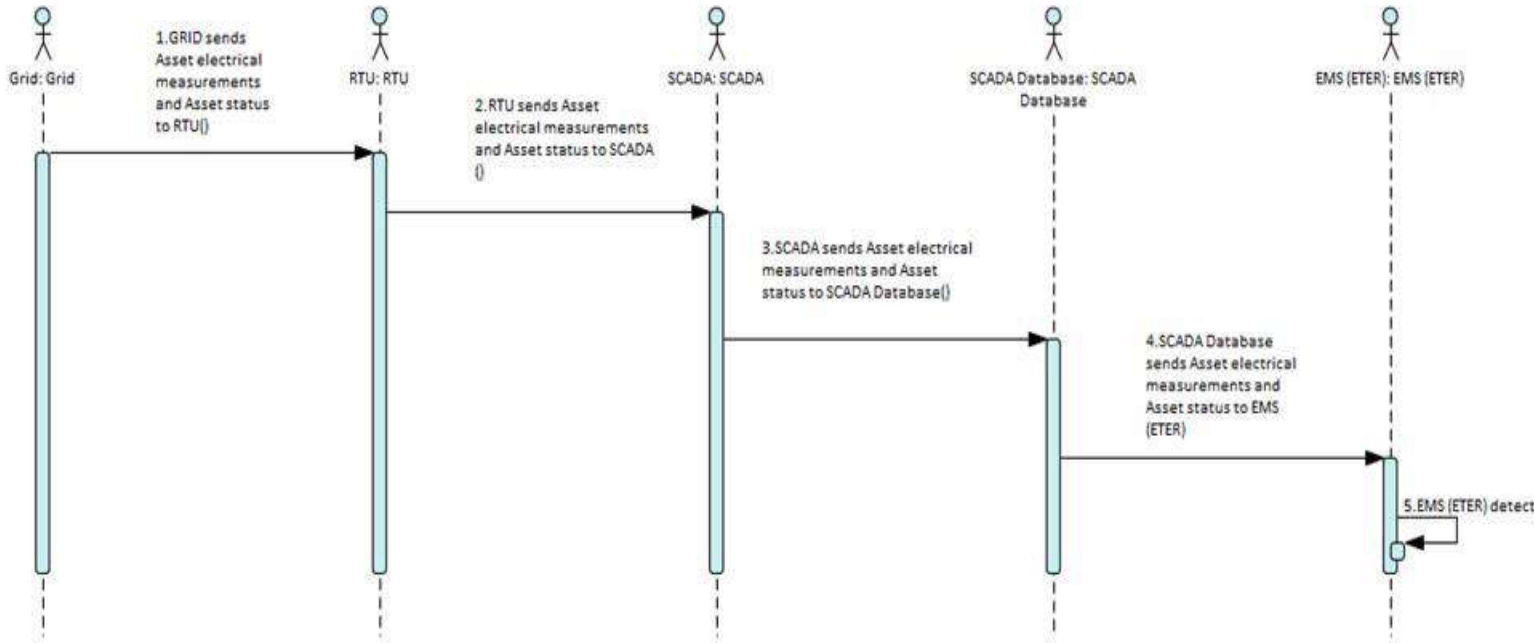

Figure 150. UC 4.3 Sequence Diagram

5.17.8 Communication Layer

The communication layer of UC 4.3 is presented in the following figure, highlighting the key communication protocols among the different modules.

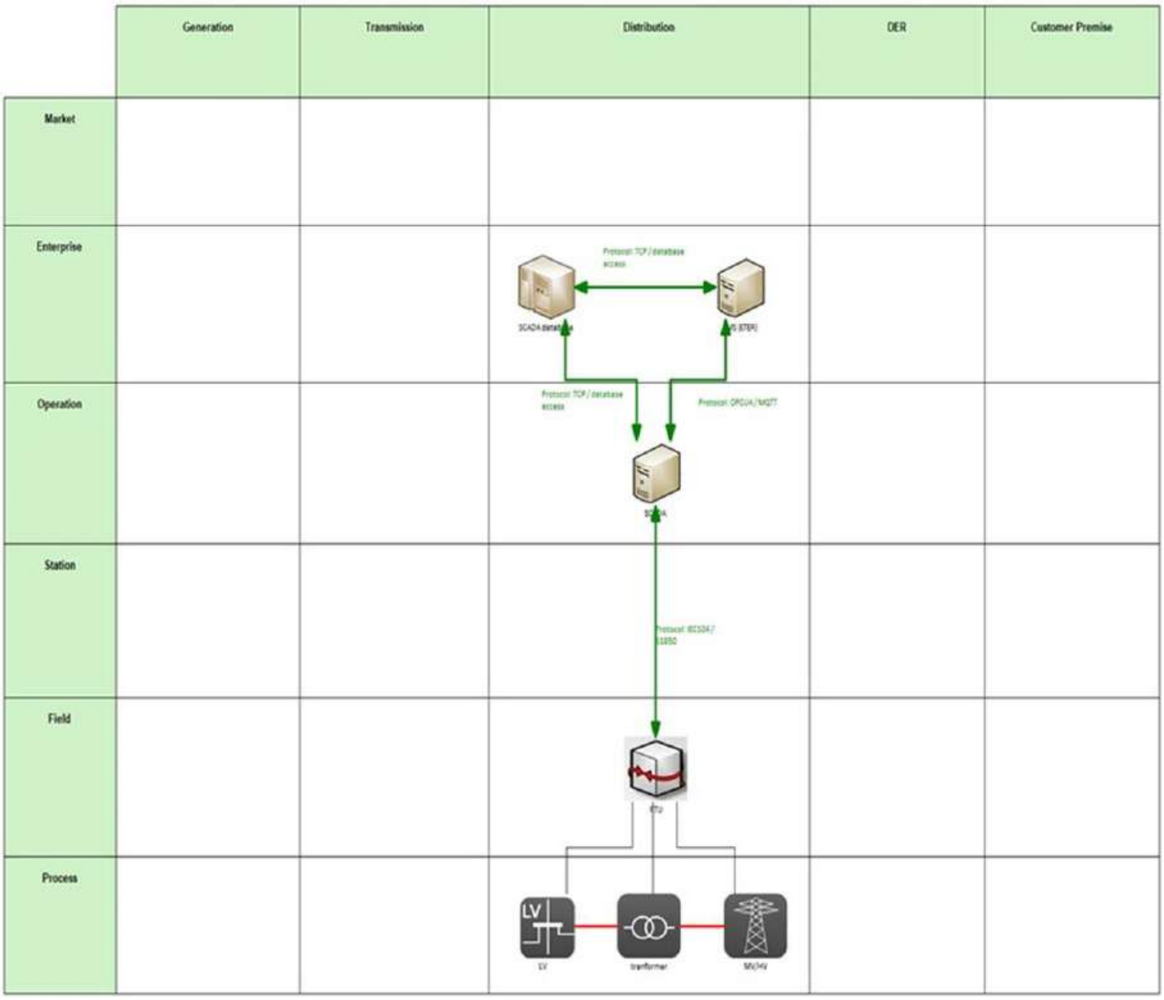

Figure 151. UC4.3 Communication Layer

Table 91. List of Communication technologies linked with UC 4.3

Communication Technology	Description
TCP/IP	Transmission Control Protocol/Internet Protocol. Conceptual model and set of communication protocols used on the Internet. They provide end-to-end data communication, specifying how data should be packetized, addressed, transmitted, routed, and received, through four abstraction layers (link, internet, transport, and application).
IEC104/61850	IEC 104 is a standard telecontrol protocol used for remote control and monitoring of substations, while IEC 61850 is a comprehensive standard for substation automation, covering various aspects such as data modeling, communication services, and system configuration.
OPCUA/MQTT	Message Queuing Telemetry Transport. Publish-subscribe message protocol over TCP/IP defined in ISO/IEC PRF 20922 standard. It is designed for connections where network bandwidth is limited and a lightweight messaging mechanism is required. OPC UA Connection Protocol (UACP) is an abstract protocol that establishes a full duplex channel between a Client and Server and utilizes an hierarchical object model to organize data.

5.17.9 Component Layer

The components included in the use case are depicted below, including the technology used for connecting each other.

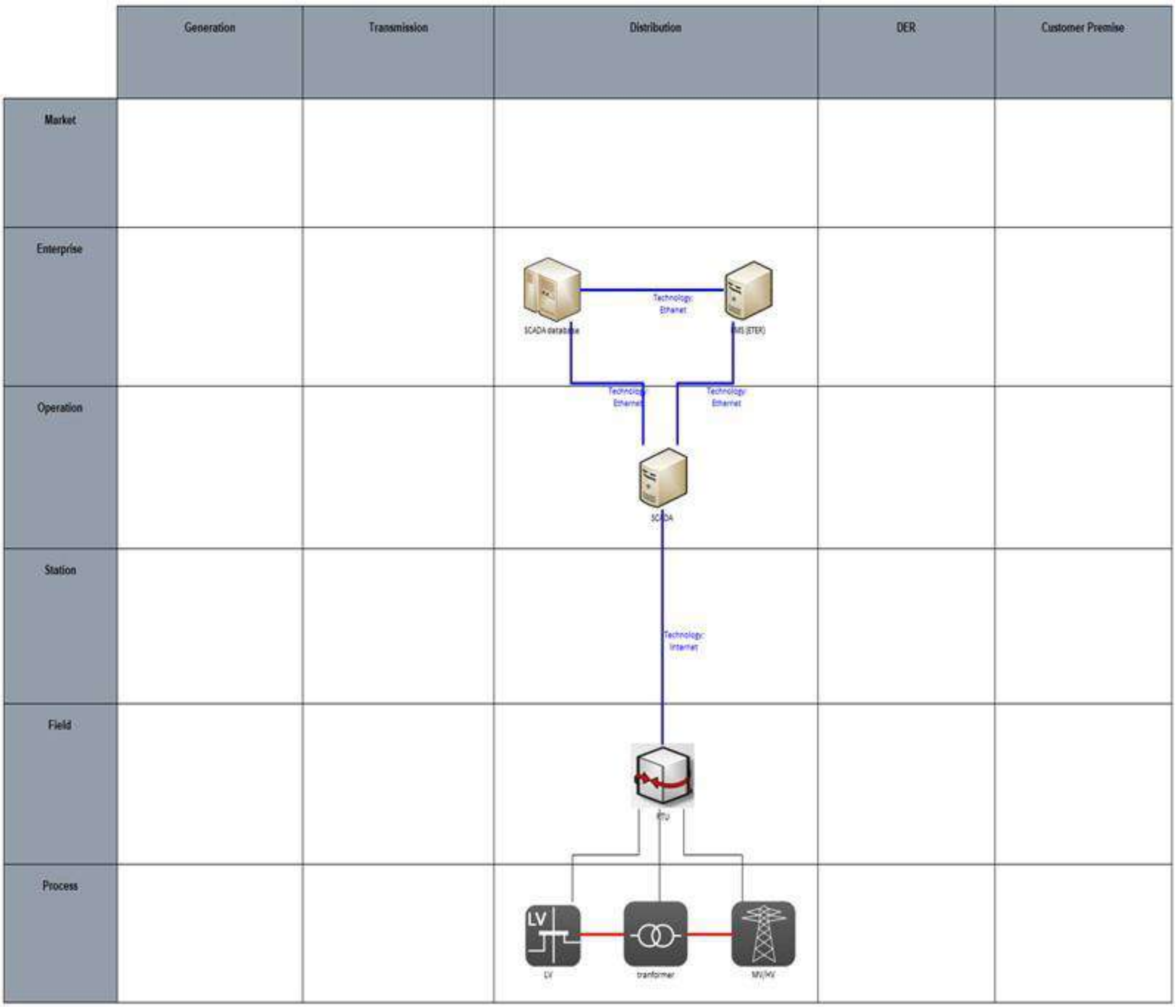

Figure 152. UC4.3 Component Layer

Table 92. List of Components linked with UC 4.3

Component	Component Type
LV grid, transformer, MV/HV grid, RTU, SCADA database	Devices
SCADA, EMS (ETER)	System

5.18 UC 4.4: Detection of critical points in a electrical line

5.18.1 Use Case Description

DSO's electrical lines can experience changes of section of the same line as it goes further away from the transformer. Since the section goes smaller and the penetration of PV for sef-consumption and EV goes higher, there's a potential risk of congestion in parts of the line with lower section of cable. The aim of this Use Case is to detect these critical points in accordance to the capacity limits of the different cables in the same line.

5.18.2 Function layer

The functional layer of UC 4.4 is presented in the following graph highlighting the key actors of the use case

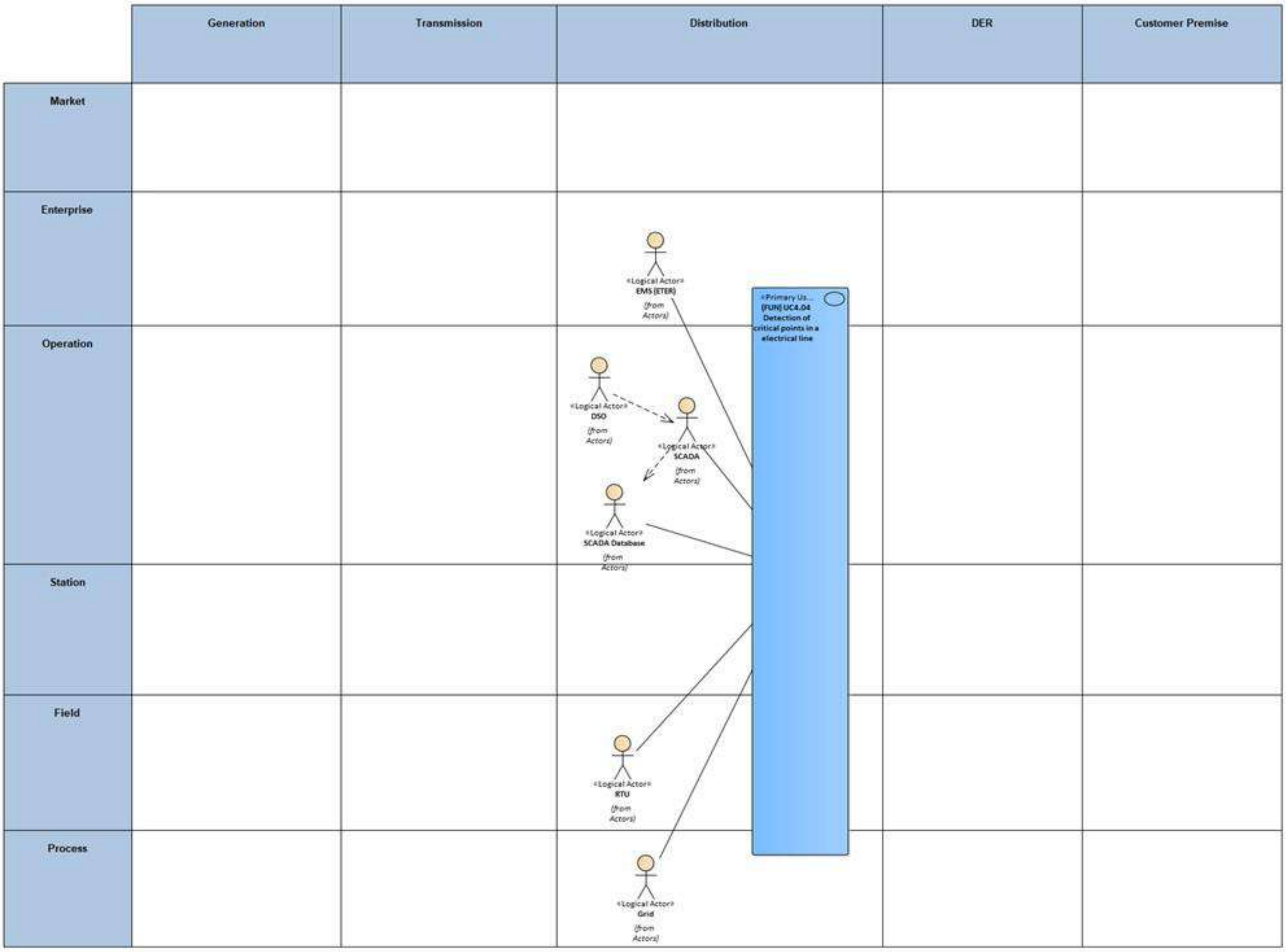

Figure 153. UC 4.4 Function Layer

Table 93. List of actors involved in UC 4.4

Actor Name	Actor Type
EMS (ETER)	System
DSO	Organization
SCADA	System
SCADA database	Device
RTU	Device
Grid	Device

5.18.3 Information layer

Details about information layer of UC4.4 are presented in the following figure, highlighting the key information objects.

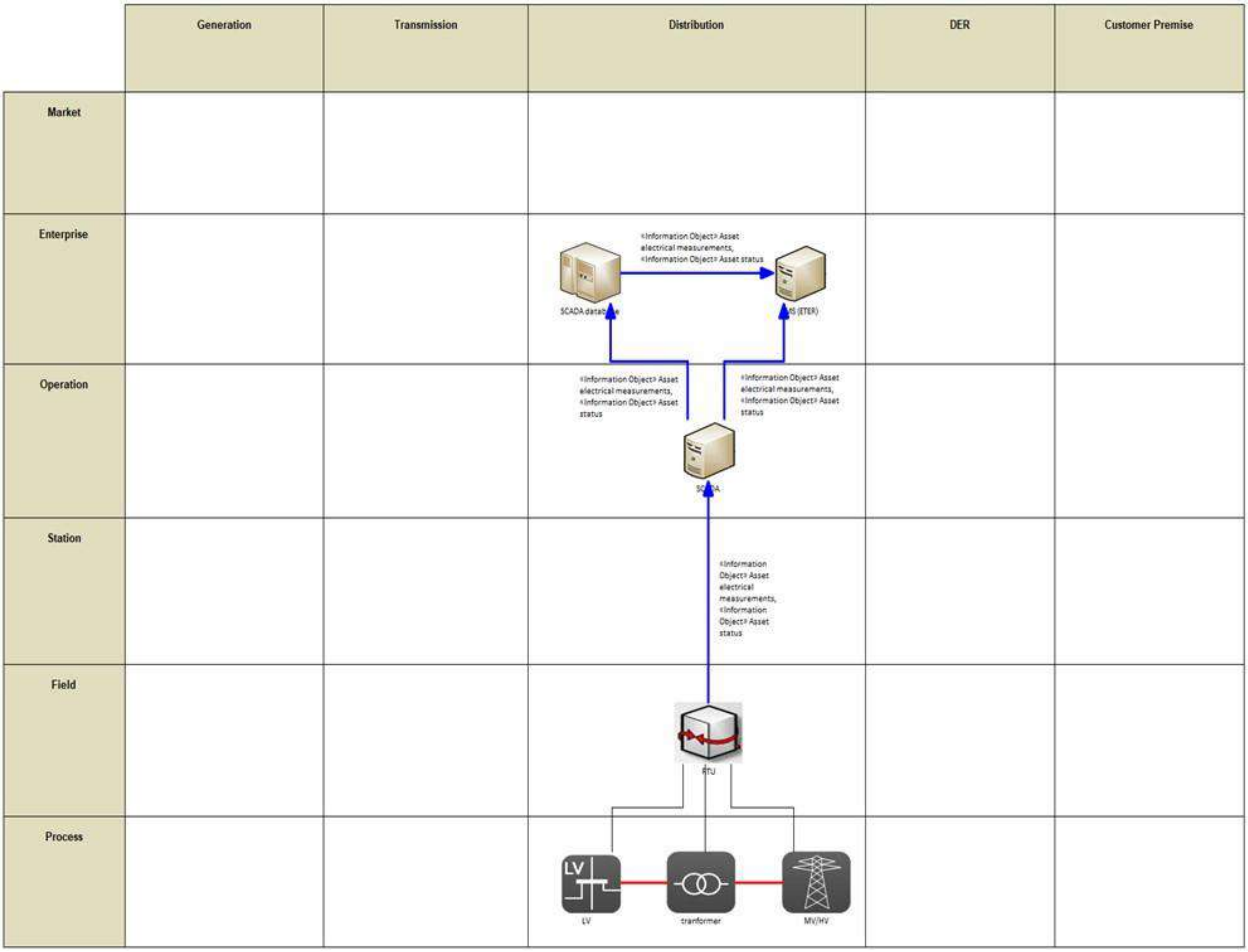

Figure 154. UC 4.4 Information Layer

5.18.4 Canonical Data Model

The identified canonical data models for UC4.4 are described below.

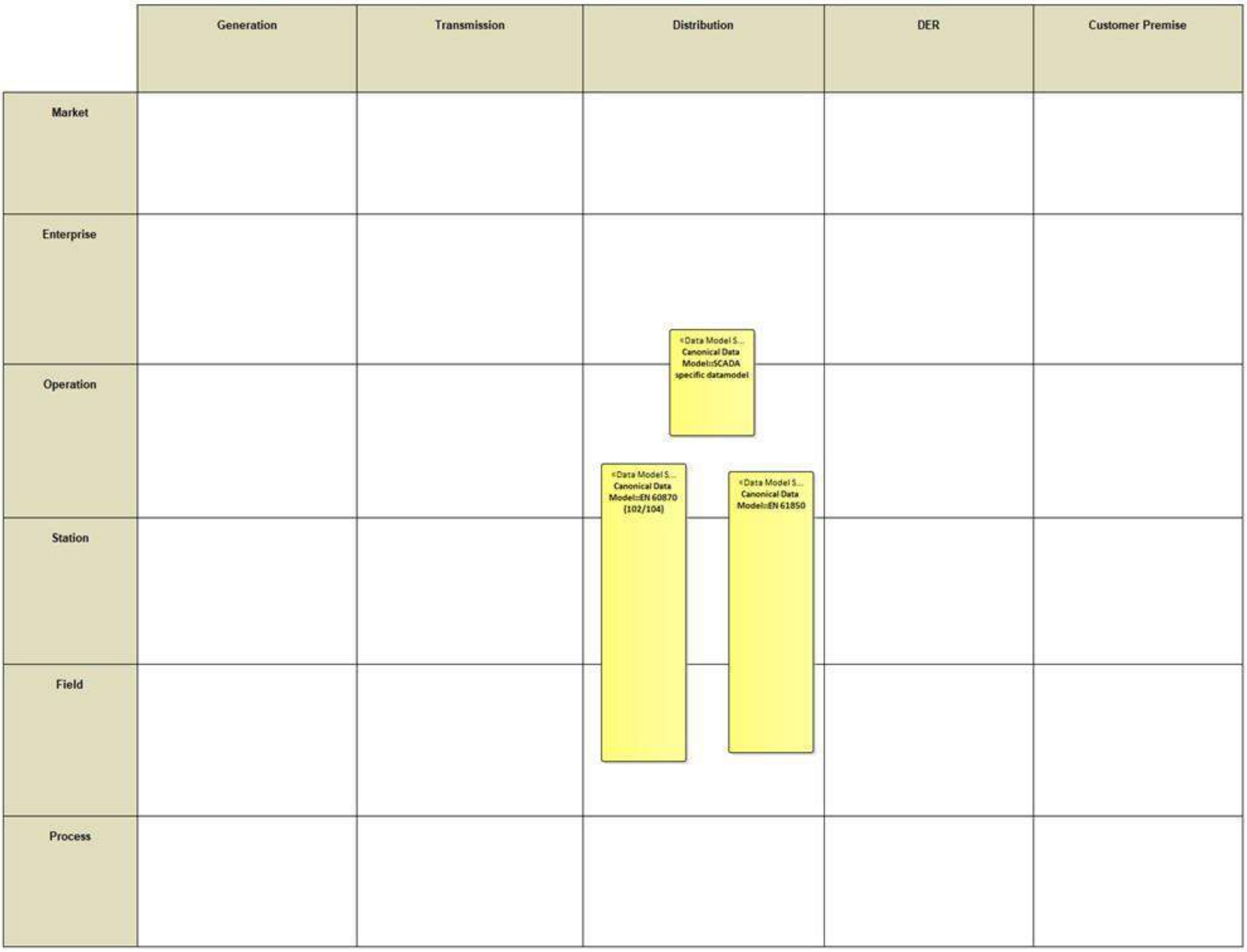

Figure 155. UC 4.4 Canonical data model

Table 94. List of Data models involved in UC 4.4

Data Models
Scada specific data model
En 60870 (102/104)
EN 61850

5.18.5 Standards and Information Object Mapping

SGAM Standards and Information Objects Mapping for UC4.4 is presented in the following figure.

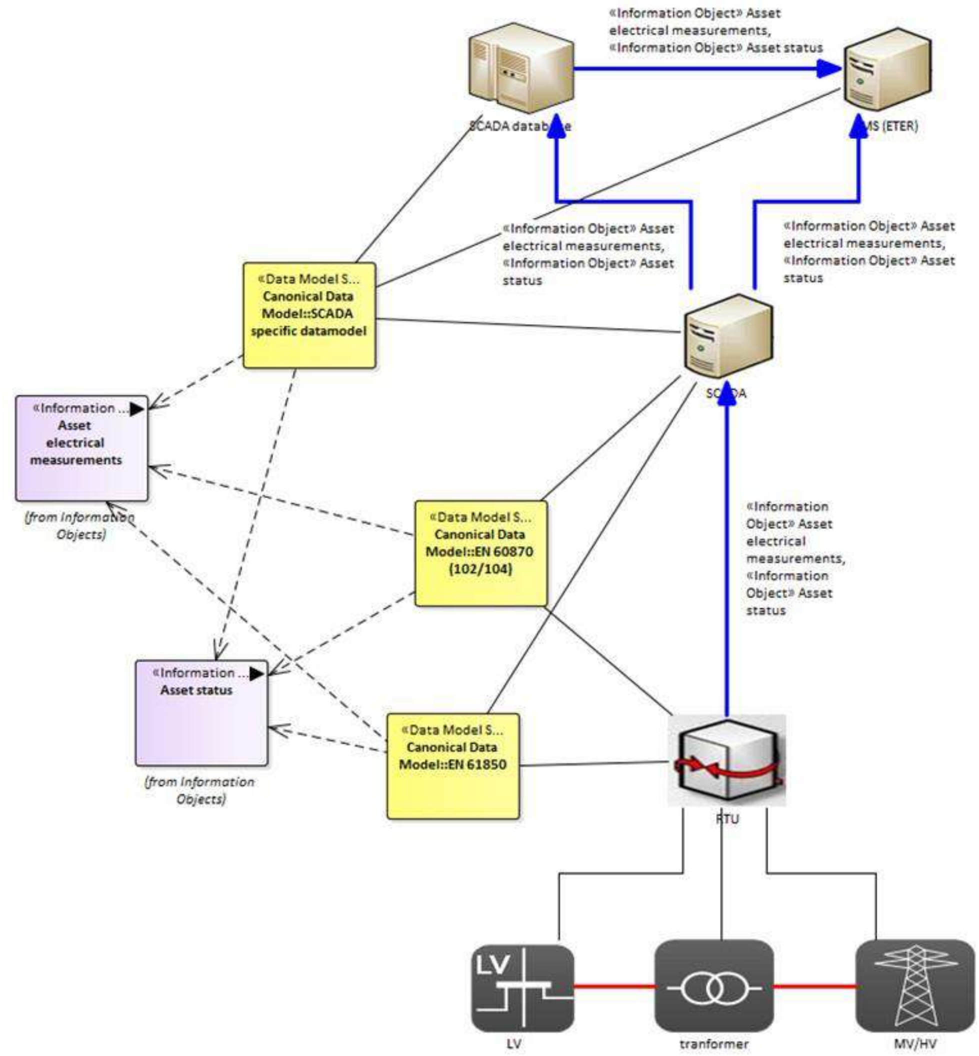

Figure 156. UC 4.4 Standards and Information Object Mapping

Table 95. List of Information Objects, link with Data Standards in UC 4.4

Information Object	DATA Models	Information
Asset Electrical Measurements	SCADA specific data model, En 60870 (102/104), EN 61850	Voltage, current, active reactive power/energy
Asset Status	SCADA specific data model, En 60870 (102/104), EN 61850	On/off condition of asset.

5.18.6 Activity Diagram Layer

The detailed activity diagram for UC 4.4 is presented in the following figure.

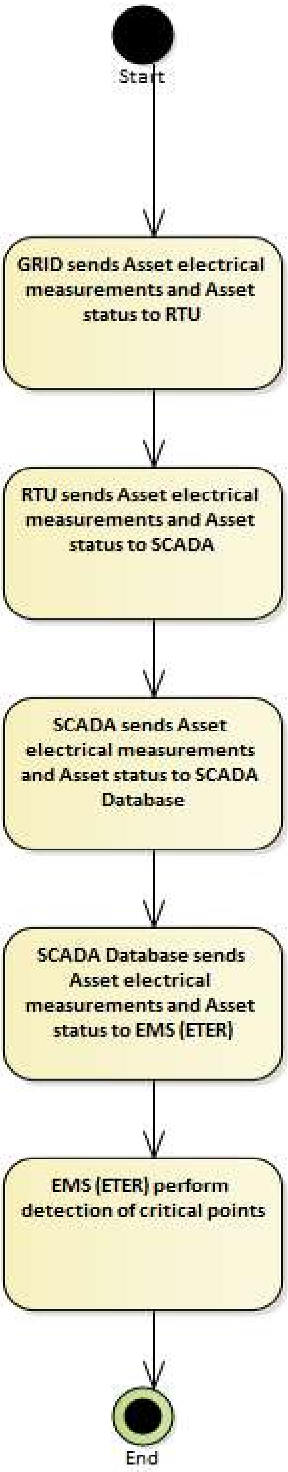

Figure 157. UC 4.4 Activity Diagram

5.18.7 Sequence Diagram

The detailed sequence diagram for UC 4.4 is presented in the following figure.

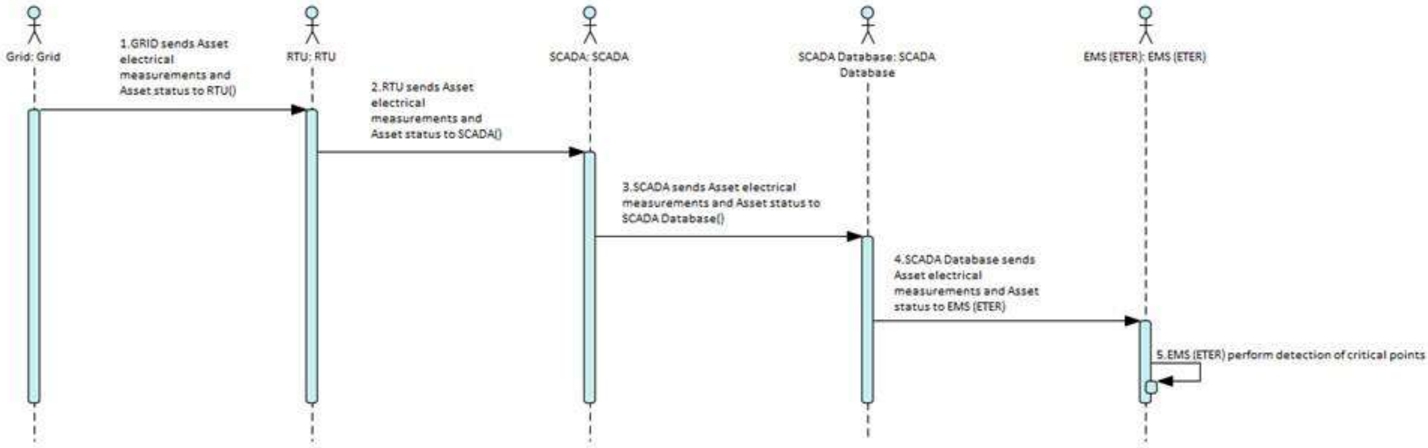

Figure 158 UC 4.4 Sequence Diagram

5.18.8 Communication Layer

The communication layer of UC 4.3 is presented in the following figure, highlighting the key communication protocols among the different modules.

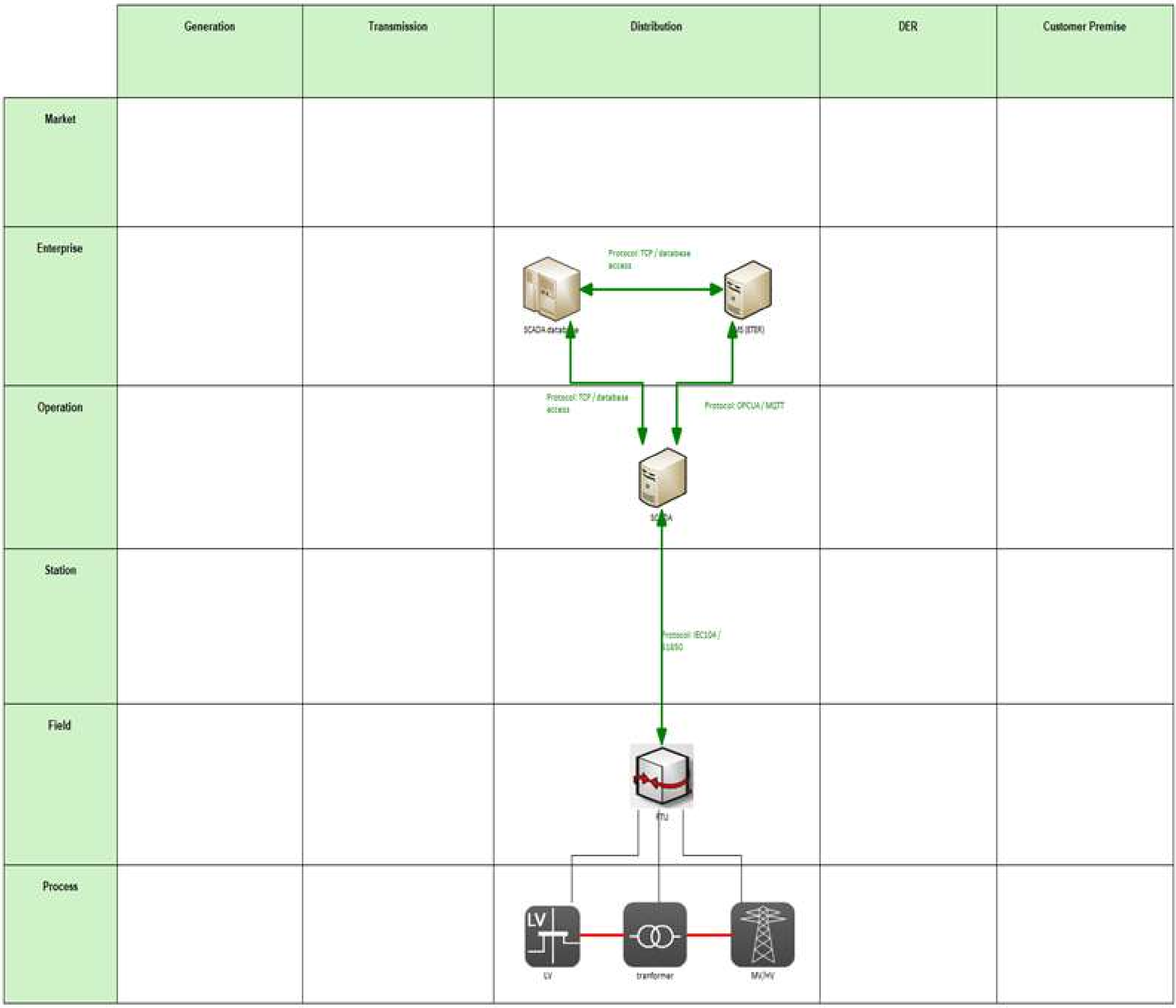

Figure 159. UC4.4 Communication Layer

Table 96. List of Communication technologies linked with UC 4.4

Communication Technology	Description
TCP/IP	Transmission Control Protocol/Internet Protocol. Conceptual model and set of communication protocols used on the Internet. They provide end-to-end data communication, specifying how data should be packetized, addressed, transmitted, routed, and received, through four abstraction layers (link, internet, transport, and application).
IEC104/61850	IEC 104 is a standard telecontrol protocol used for remote control and monitoring of substations, while IEC 61850 is a comprehensive standard for substation automation, covering various aspects such as data modeling, communication services, and system configuration.
OPCUA/MQTT	Message Queuing Telemetry Transport. Publish-subscribe message protocol over TCP/IP defined in ISO/IEC PRF 20922 standard. It is designed for connections where network bandwidth is limited and a lightweight messaging mechanism is required. OPC UA Connection Protocol (UACP) is an abstract protocol that establishes a full duplex channel between a Client and Server and utilizes an hierarchical object model to organize data.

5.18.9 Component Layer

The components included in the use case are depicted below, including the technology used for connecting each other.

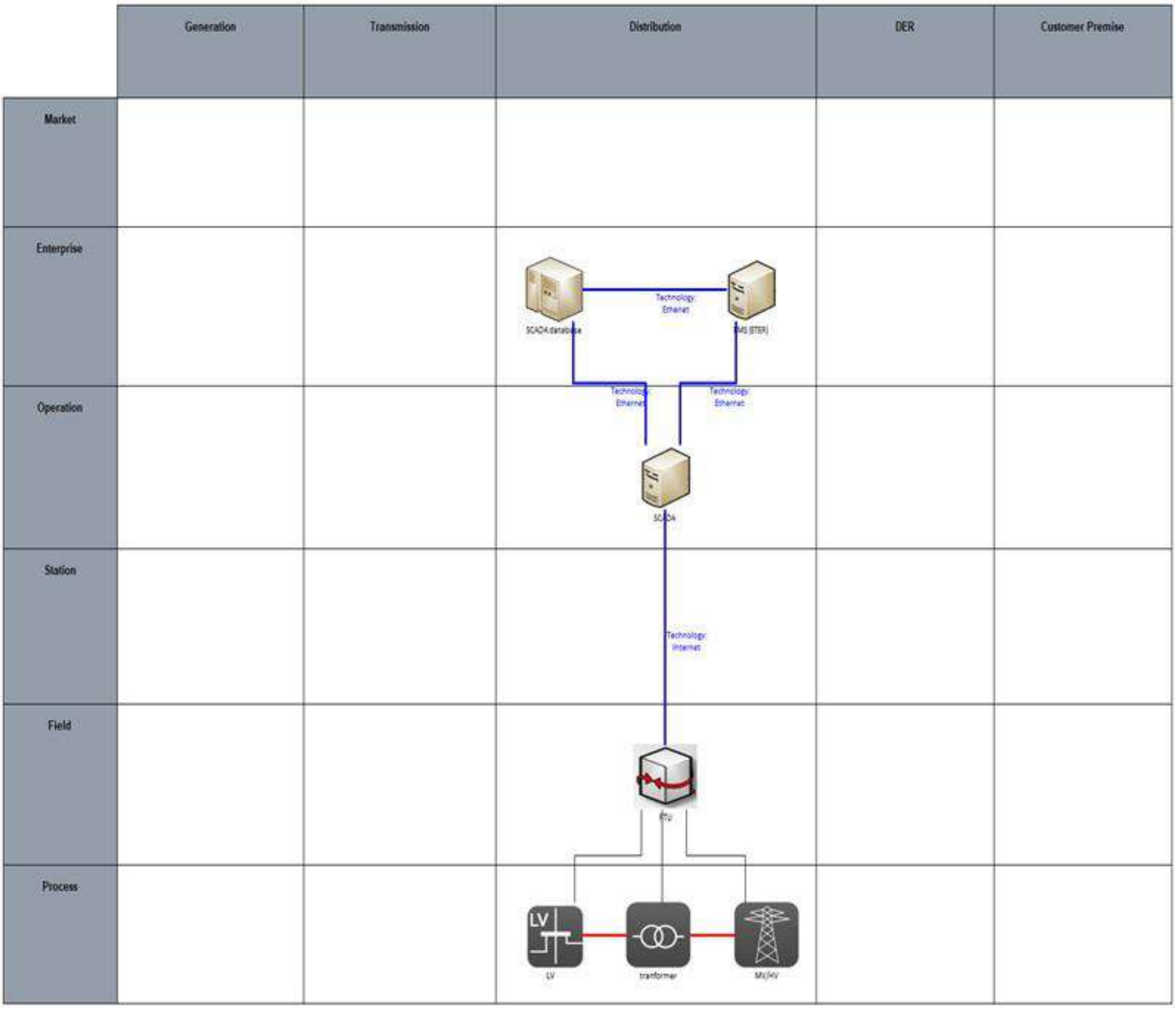

Figure 160. UC4.4 Component Layer

Table 97. List of Components linked with UC 4.4

Component	Component Type
LV grid, transformer, MV/HV grid, RTU, SCADA database	Devices
SCADA, EMS (ETER)	Applications

5.19 UC 4.5: Improving the Grid Infrastructure

5.19.1 Use Case Description

The Spanish redistributive model (the model followed to provide funding for DSOs) is becoming more and more selective. Even if it was not so, an investment must always be done in the smartest way possible, bringing the best possible outcome to the investor. Grid planning methodologies will assist the DSOs on planning their investments for improving the grid infrastructure, increasing RES integration and decarbonisation of the grid in the most cost-efficient manner.

5.19.2 Function Layer

The functional layer of UC 4.5 is presented in the following graph highlighting the key actors of the use case.

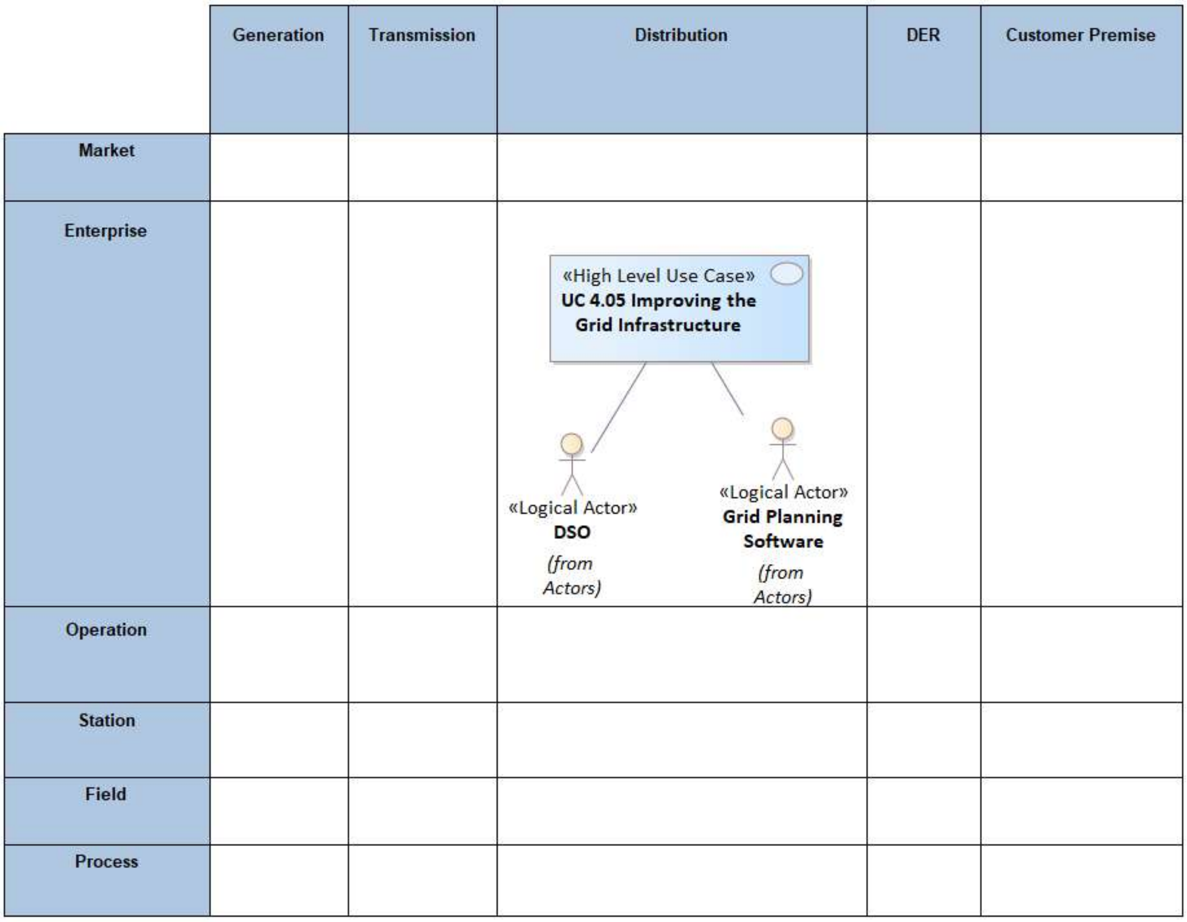

Figure 161. UC 4.5 Function Layer

Table 98. List of actors involved in UC 4.5

Actor Name	Actor Type
DSO	Organization
Grid Planning Software	Software application

5.19.3 Information Layer

Details about information layer of UC4.5 are presented in the following figure, highlighting the key information objects.

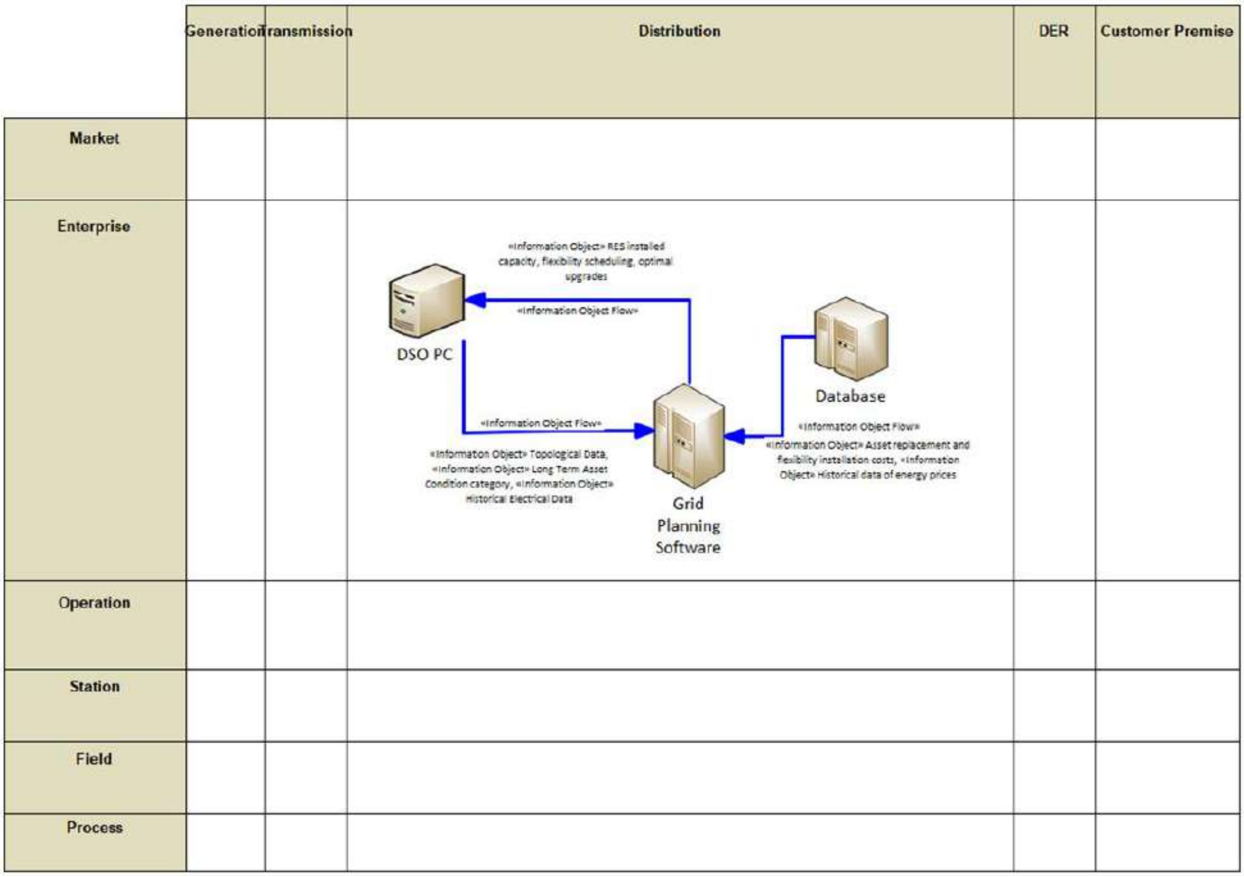

Figure 162.UC 4.5 Information Layer

5.19.4 Canonical Data model

The identified canonical data models for UC4.5 are described below.

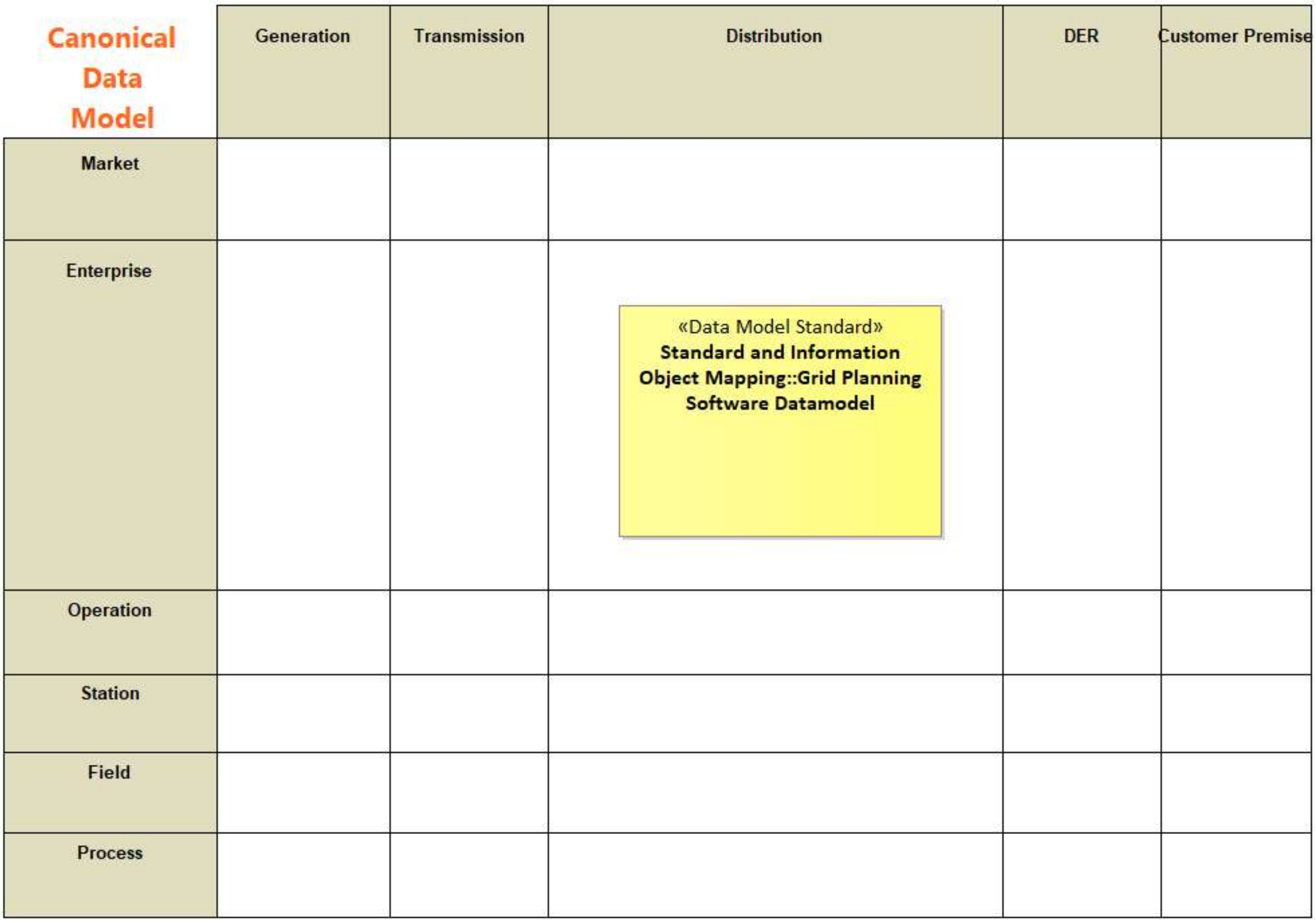

Figure 163. UC 4.5 Canonical Data model

Table 99. List of Data models involved in UC 4.5

Data Models
Grid Planning Software Data model

5.19.5 Standards and information object mapping

SGAM Standards and Information Objects Mapping for UC4.5 is presented in the following figure.

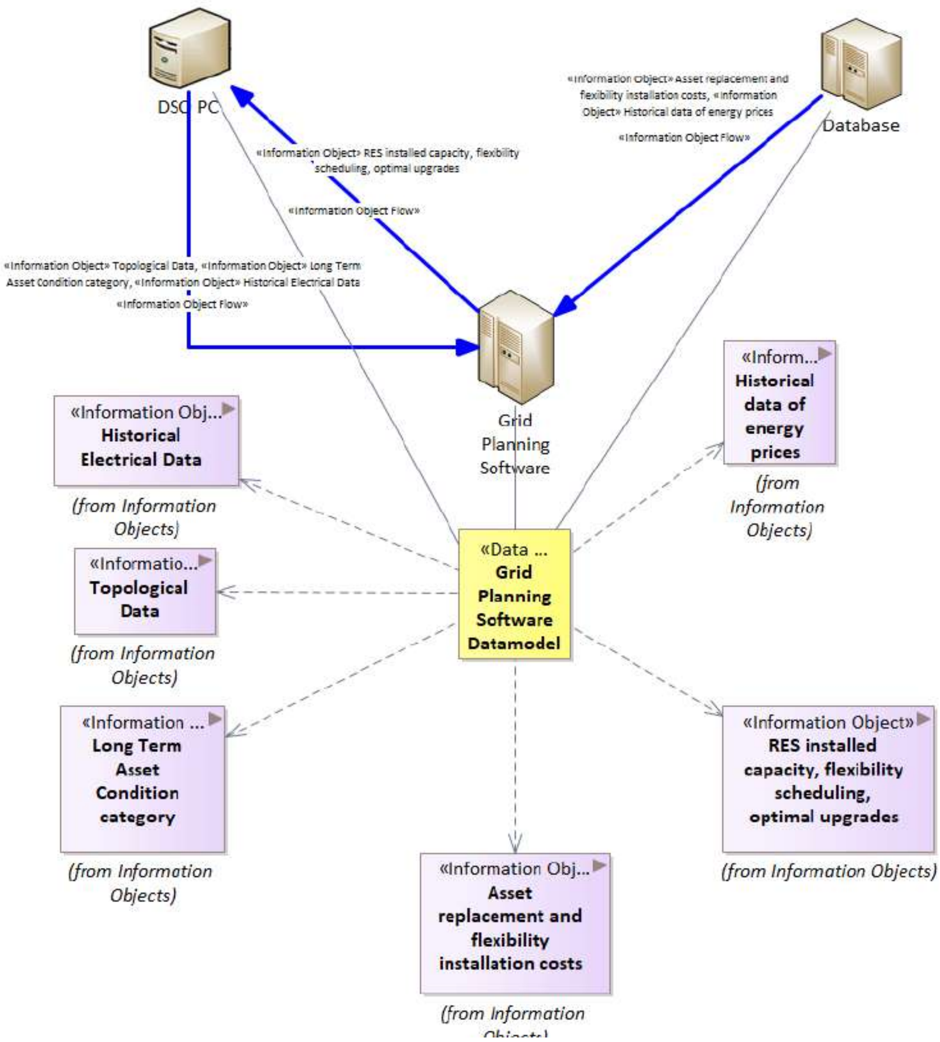

Figure 164. UC 4.5 Standards and Information Object Mapping

Table 100. List of information Objects, link with Data Standards in UC 4.5

Information Object	DATA Models	Information
Historical Electrical Data	Grid Planning Software Data model	Annual load curve(s) available for the distribution system considered for RES and demand.
Topological Data	Grid Planning Software Data model	Grid topology, future RES installations
Historical Data of Energy Prices	Grid Planning Software Data model	Historical data on energy price with hourly resolution
Long Term Asset Condition category	Grid Planning Software Data model	Information up to which year an asset should be replaced
Asset replacement and flexibility energy costs	Grid Planning Software Data model	Cost of asset installation and flexibility activation
RES installed capacity, flexibility scheduling, optimal upgrades	Grid Planning Software Data model	Yearly output of flexibility schedule and asset investment periods, optimal RES installed

5.19.6 Activity Diagram

The detailed activity diagram for UC 4.5 is presented in the following figure.

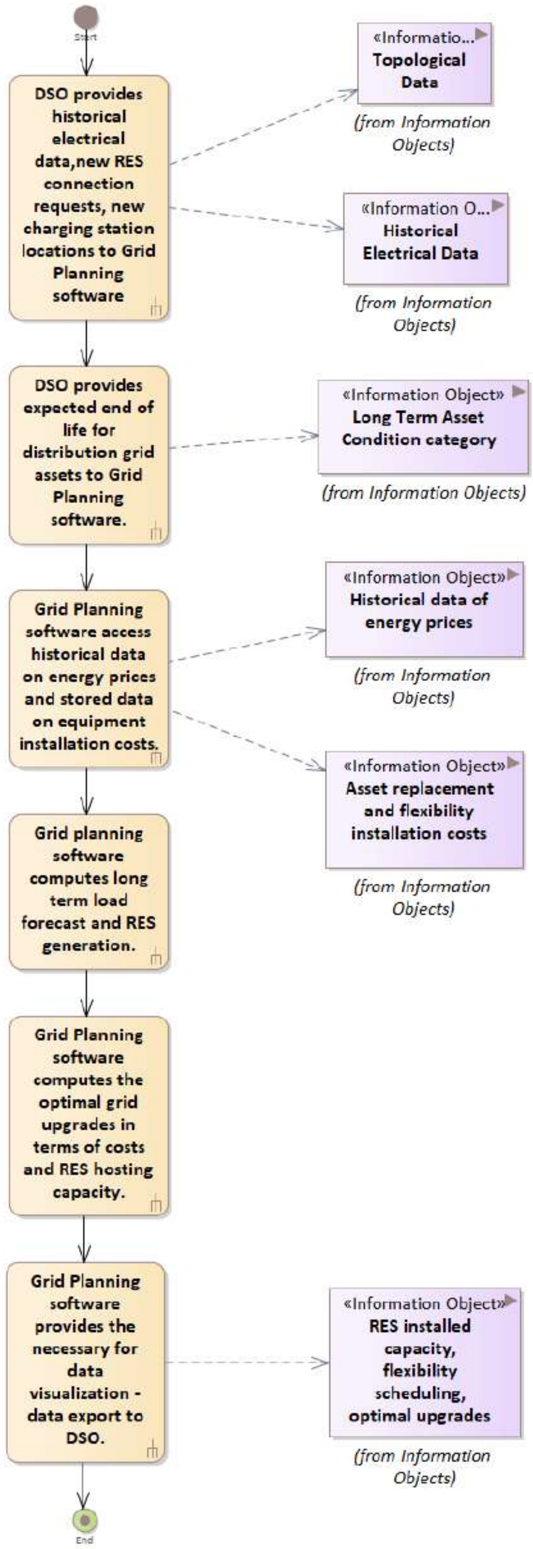

Figure 165. UC 4.5 Activity Diagram

5.19.7 Sequence Diagram

The detailed sequence diagram for UC 4.5 is presented in the following figure.

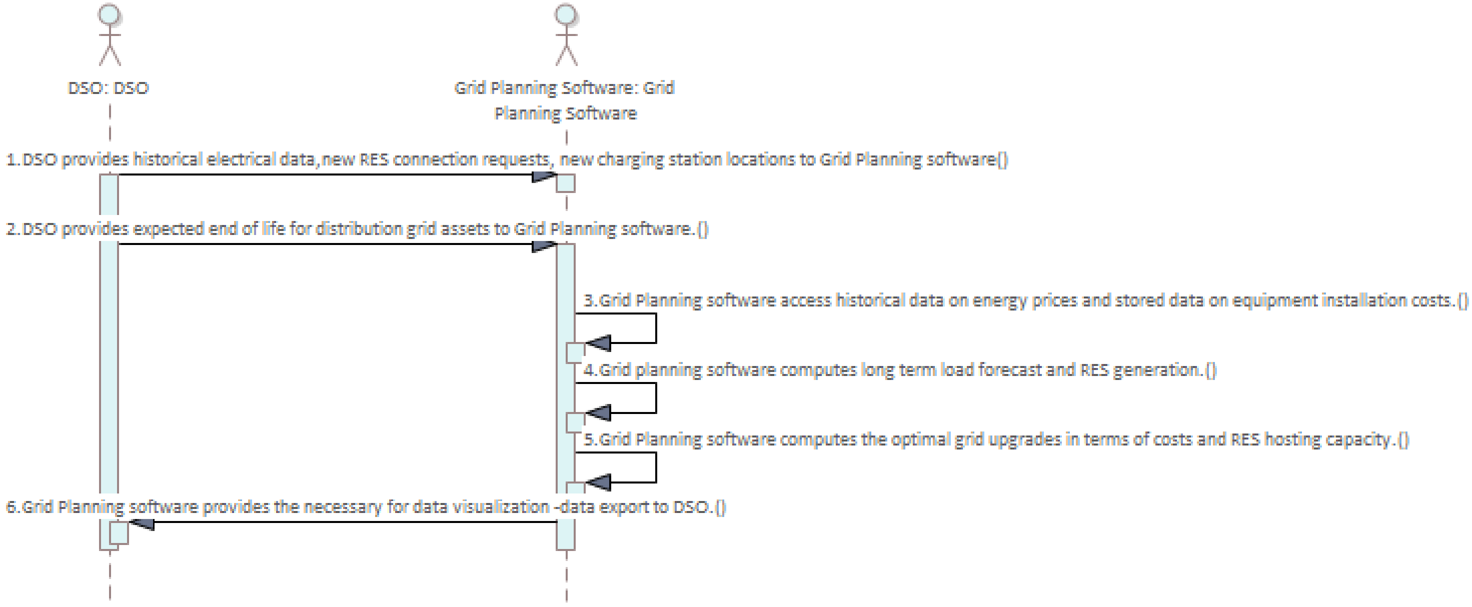

Figure 166. UC 4.5 Sequence Diagram

5.19.8 Communication Layer

The communication layer of UC 4.5 is presented in the following figure, highlighting the key communication protocols among the different modules.

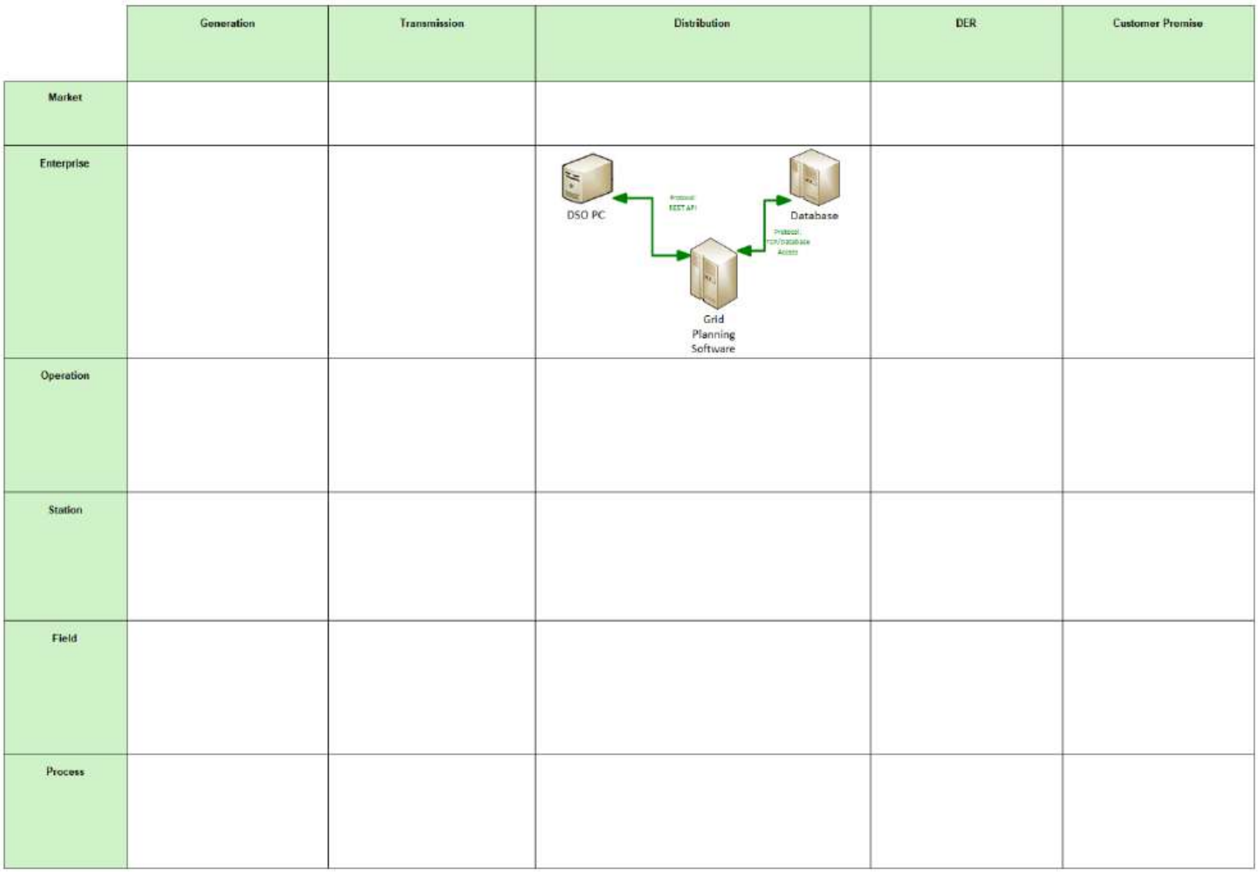

Figure 167. UC4.5 Communication Layer

Table 101. List of Communication technologies linked with UC 4.5

Communication Technology	Description
REST	Representational State Transfer. Set of software constraints for web services, to provide interoperability between computer systems on the Internet. A RESTful web service defines a uniform and predefined set of stateless operations that accept requests through a URI.
TCP/IP	Transmission Control Protocol/Internet Protocol. Conceptual model and set of communication protocols used on the Internet. They provide end-to-end data communication, specifying how data should be packetized, addressed, transmitted, routed, and received, through four abstraction layers (link, internet, transport, and application).

5.19.9 Component Layer

The components included in the use case are depicted below, including the technology used for connecting each other.

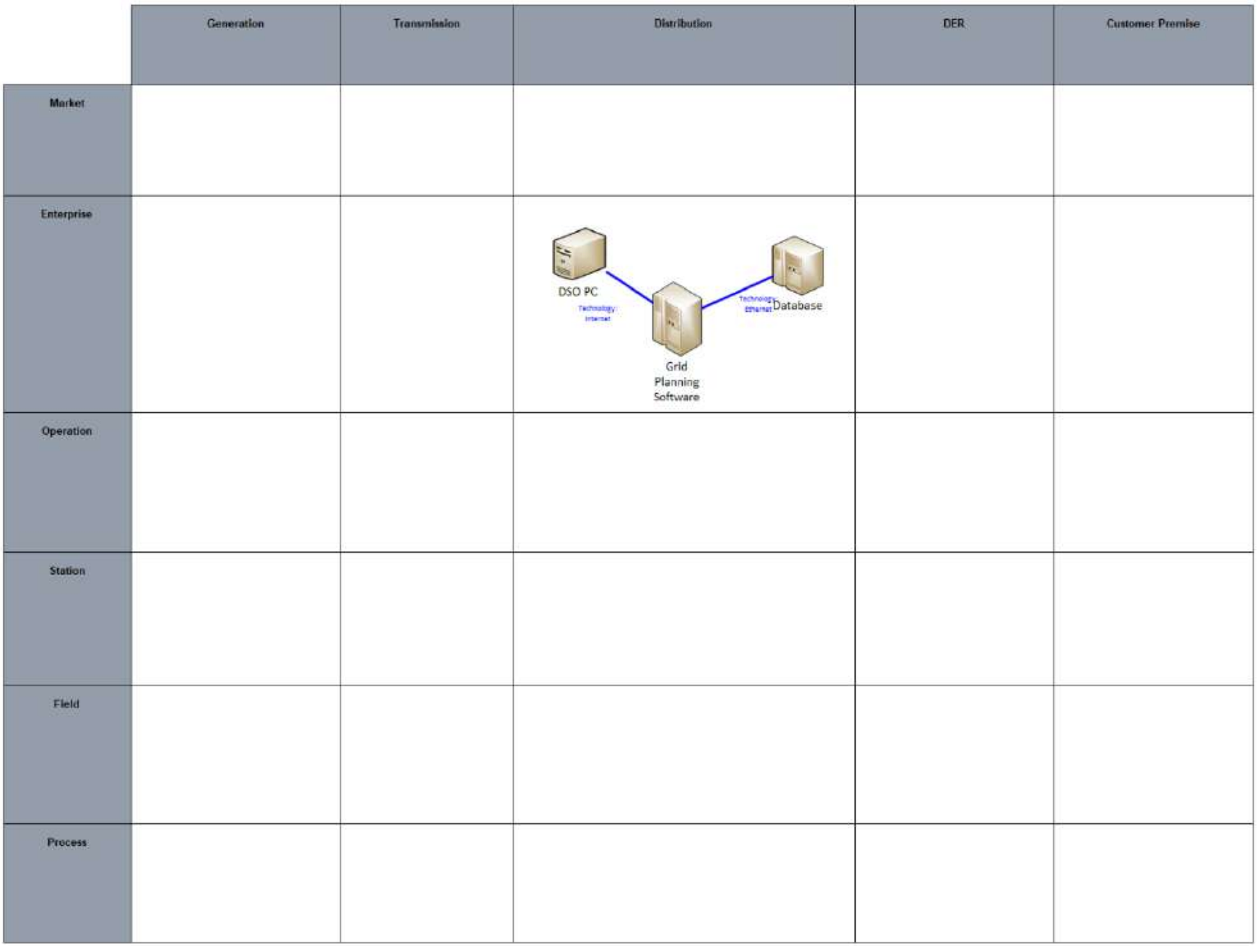

Figure 168. UC4.5 Component Layer

Table 102. List of Components linked with UC 4.5

Component	Component Type
DSO PC, Database	Device
Grid Planning Software	Software application

5.20 UC 5.1: Improve congestion management to facilitate DERs penetration

5.20.1 Use Case Description

Despite the distribution system's resilient design, capable of accommodating various transfer capacities, the growing prevalence of Distributed Energy Resources (DERs), particularly solar photovoltaic systems, coupled with the rising energy demands in low voltage (LV) power supplies, is heightening the probability of congestion and overvoltage events.

The following Use Case focuses on the creation and implementation of an active congestion management system capable of predicting and preventing congestions and overvoltages on the LV distribution grid leveraging the local available flexibility. By adopting Demand Side Management (DSM) techniques and incorporating cross-vector integration (e.g., Power-to-Heat and Power-to-Mobility), Renewable Energy Sources (RES) and flexible assets can be utilised and managed effectively to ensure greater grid efficiency and stability by reducing the occurrence of these events.

List of advantages:

- Defer costly investments for the Distribution System Operator (DSO)
- Improve the overall system efficiency, resulting in reduced billing costs for end-users

5.20.2 Function Layer

The functional layer of UC 5.1 is presented in the following graph highlighting the key actors of the use case.

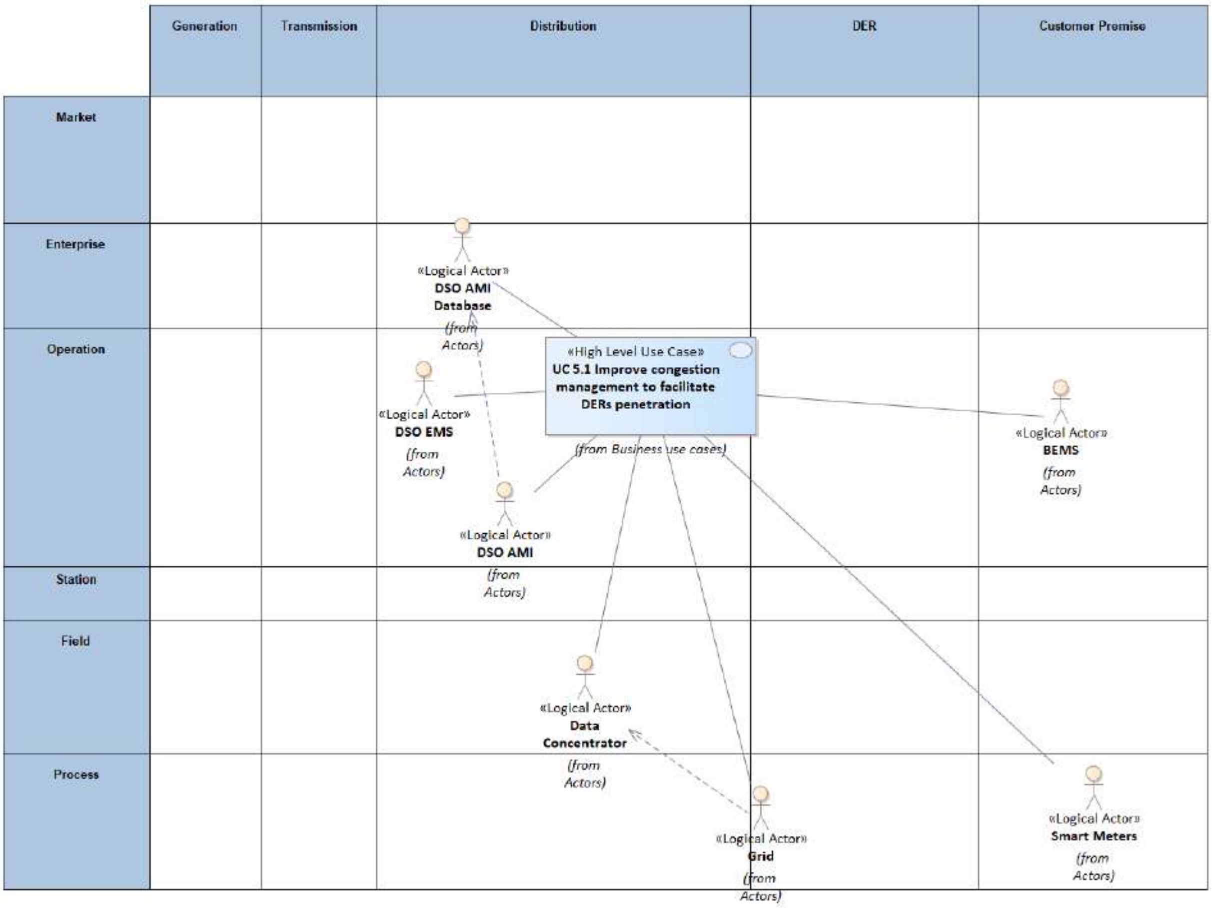

Figure 169. UC 5.1 Function layer

Table 103. List of actors involved in UC 5.1

Actor Name	Actor Type
DSO EMS	System
BEMS	System
DSO AMI	System
DSO AMI database	Device
Data Concentrator	Device
Grid	Device
Smart Meters	Device

5.20.3 Information Layer

Details about information layer of UC5.1 are presented in the following figure, highlighting the key information objects.

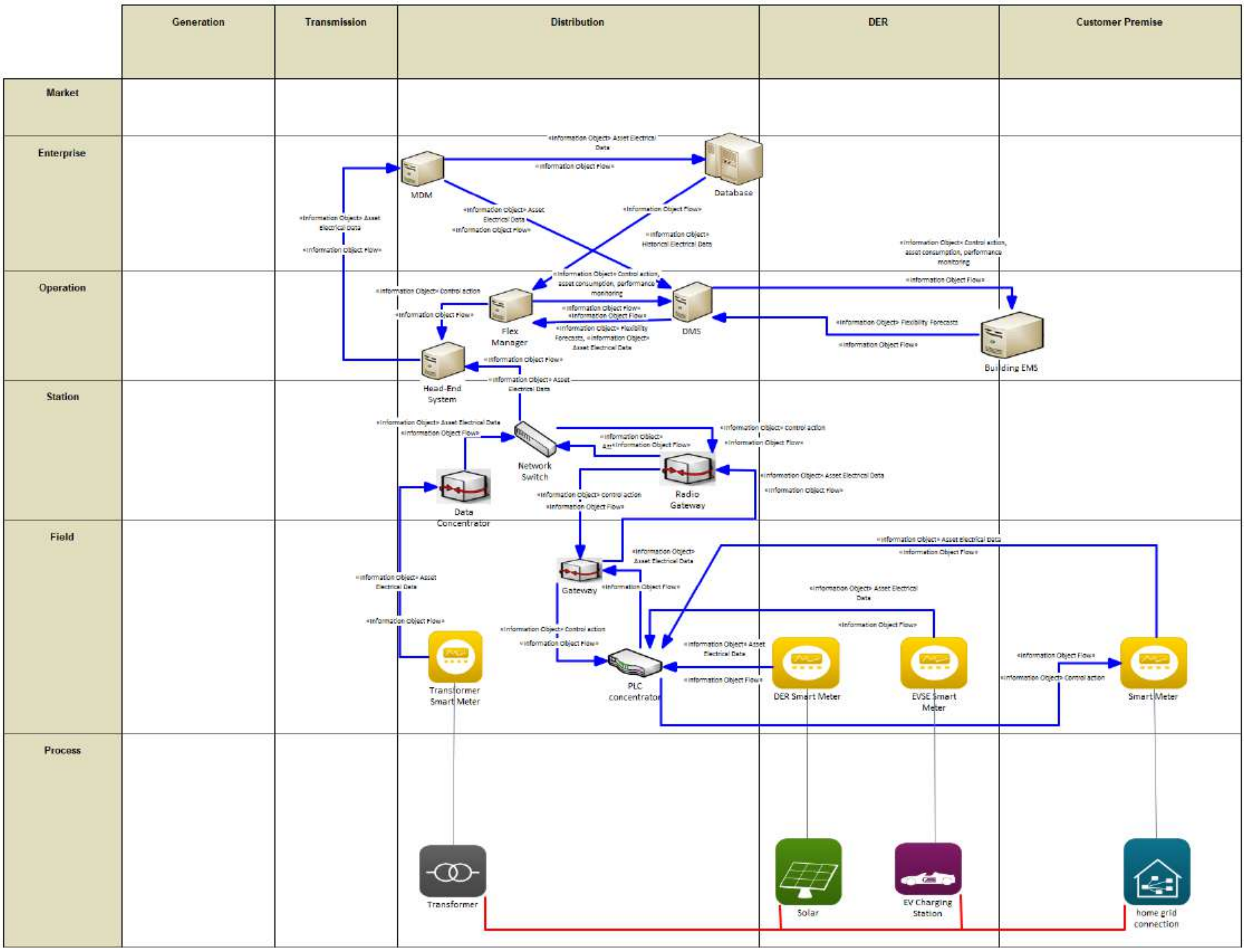

Figure 170. UC 5.1 Information Layer

5.20.4 Canonical Data model

The identified canonical data models for UC5.1 are described below.

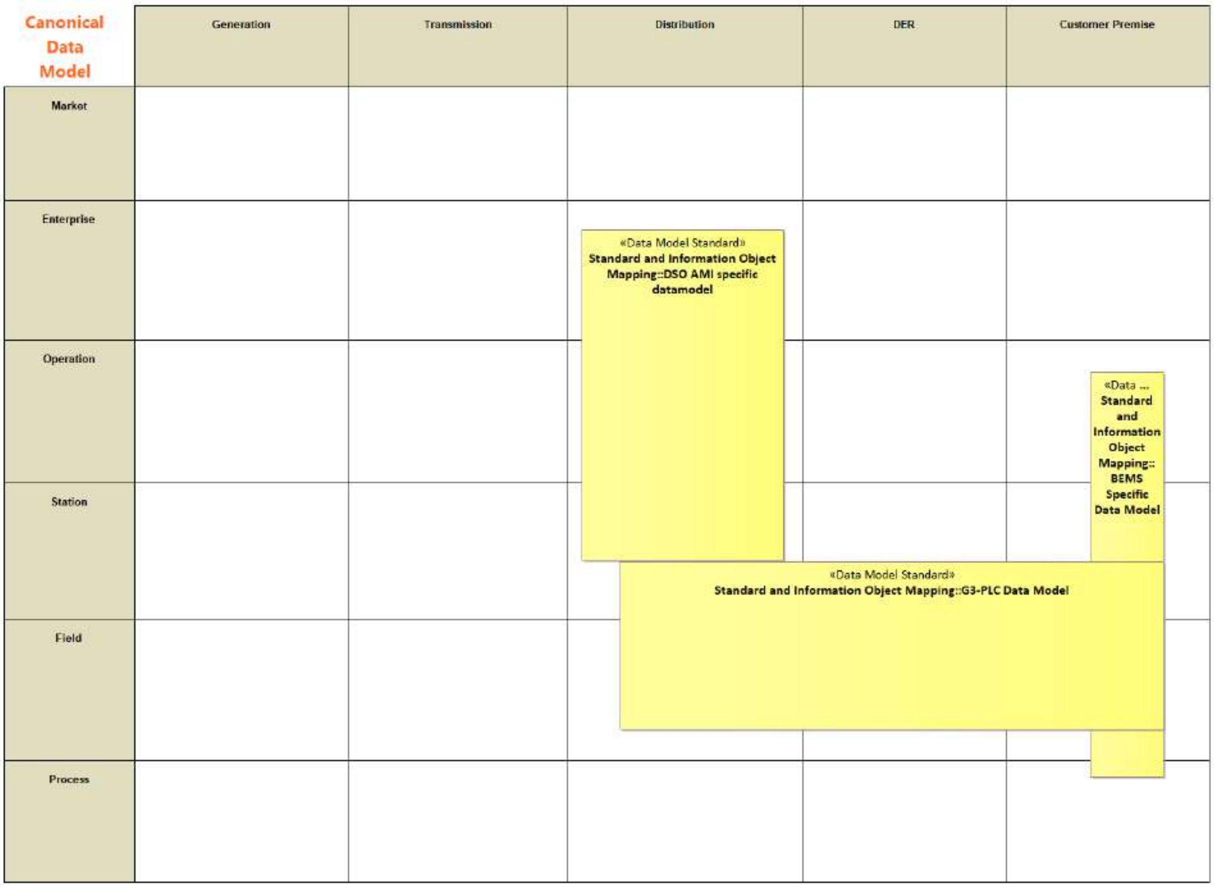

Figure 171. UC 5.1 Canonical Data model

Table 104. List of Data models involved in UC 5.1

Data Models
DSO AMI specific data model
BEMS Specific data model
G3-PLC data model

5.20.5 Standards and information object mapping

SGAM Standards and Information Objects Mapping for UC5.1 is presented in the following figure.

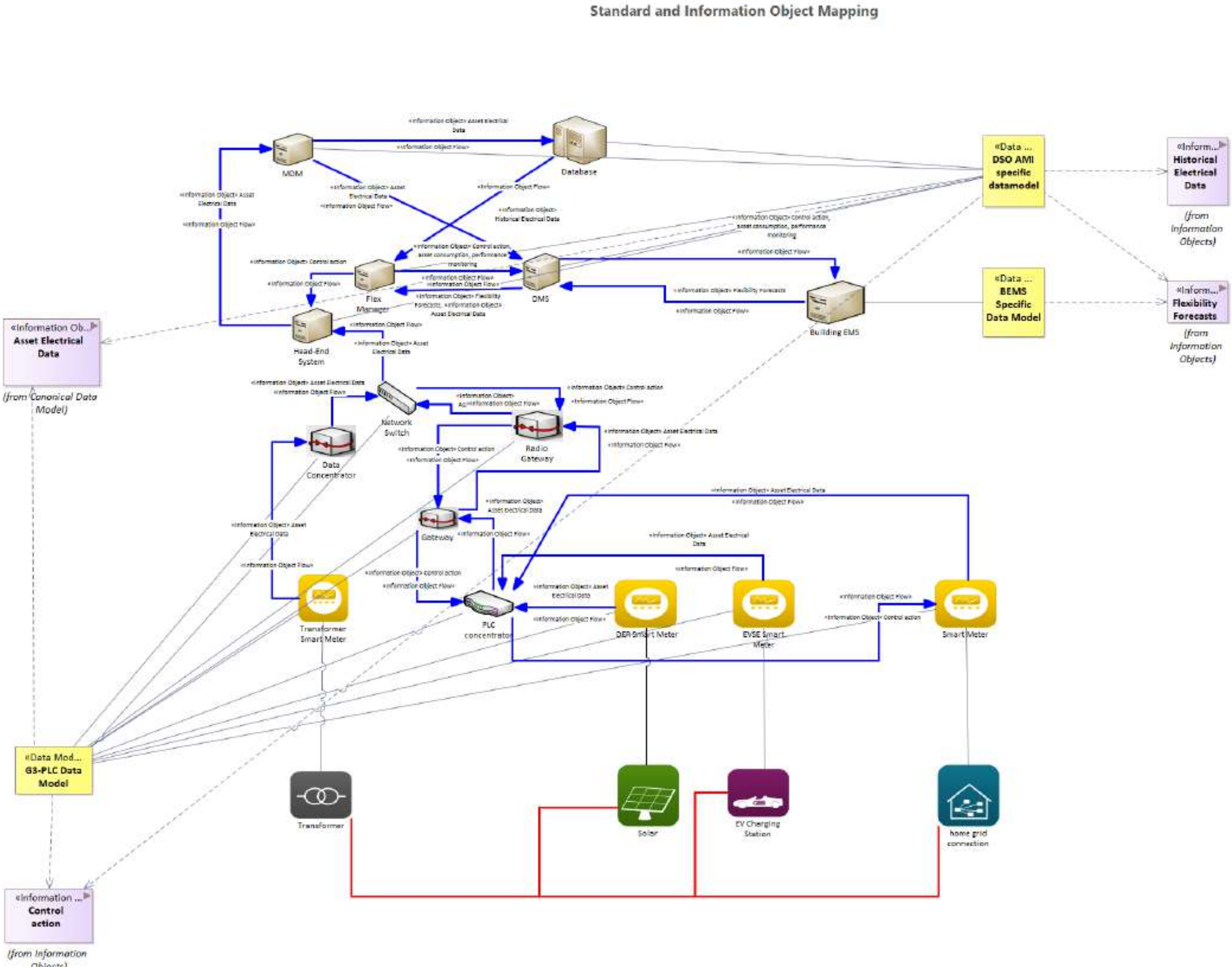

Figure 172. UC 5.1 Standards and Information Object Mapping

Table 105. List of Information Objects, link with Data Standards in UC 5.1

Information Object	DATA Models	Information
Historical Electrical Data	DSO AMI specific data model	Historical data on current, voltage, active/reactive power.
Flexibility Forecasts	DSO AMI specific data model, BEMS Specific data model	Schedule of available flexibility that can be offered.
Control action	DSO AMI specific data model, BEMS Specific data model, G3-PLC data model	.Control signals sent for the activation of flexibility
Asset electrical data	DSO AMI specific data model, G3-PLC data model	Current, Voltage, Active & Reactive Power

5.20.6 Activity Diagram

The detailed activity diagram for UC 5.1 is presented in the following figure.

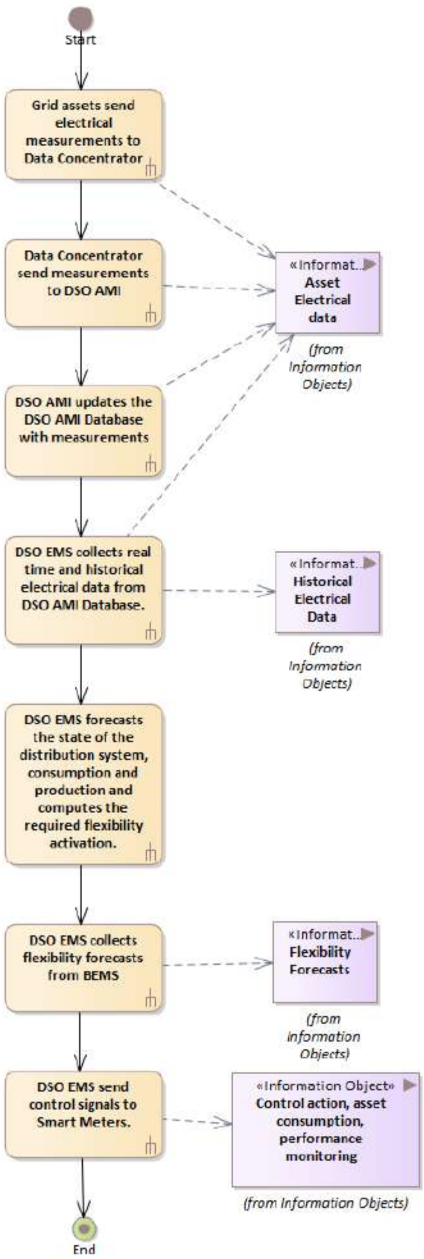

Figure 173. UC 5.1 Activity Diagram

5.20.7 Sequence Diagram

The detailed sequence diagram for UC 5.1 is presented in the following figure.

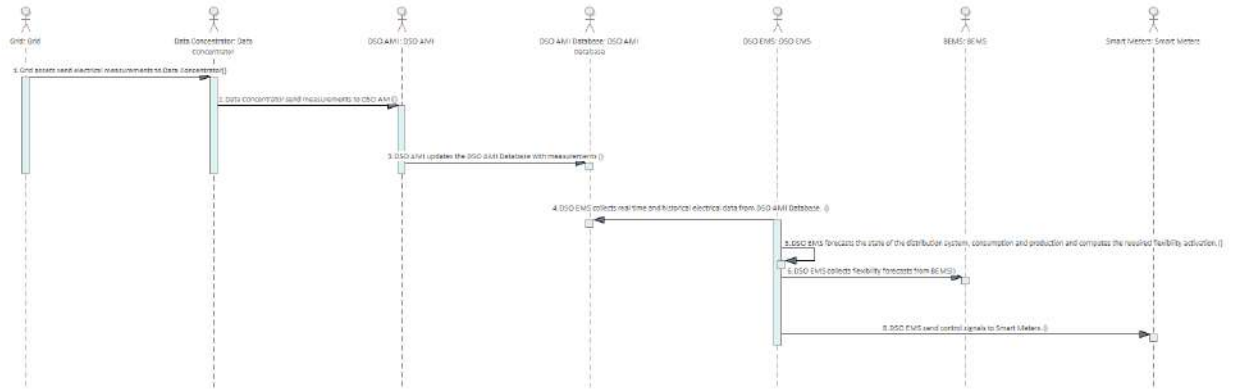

Figure 174. UC 5.1 Sequence Diagram

5.20.8 Communication Layer

The communication layer of UC 5.1 is presented in the following figure, highlighting the key communication protocols among the different modules.

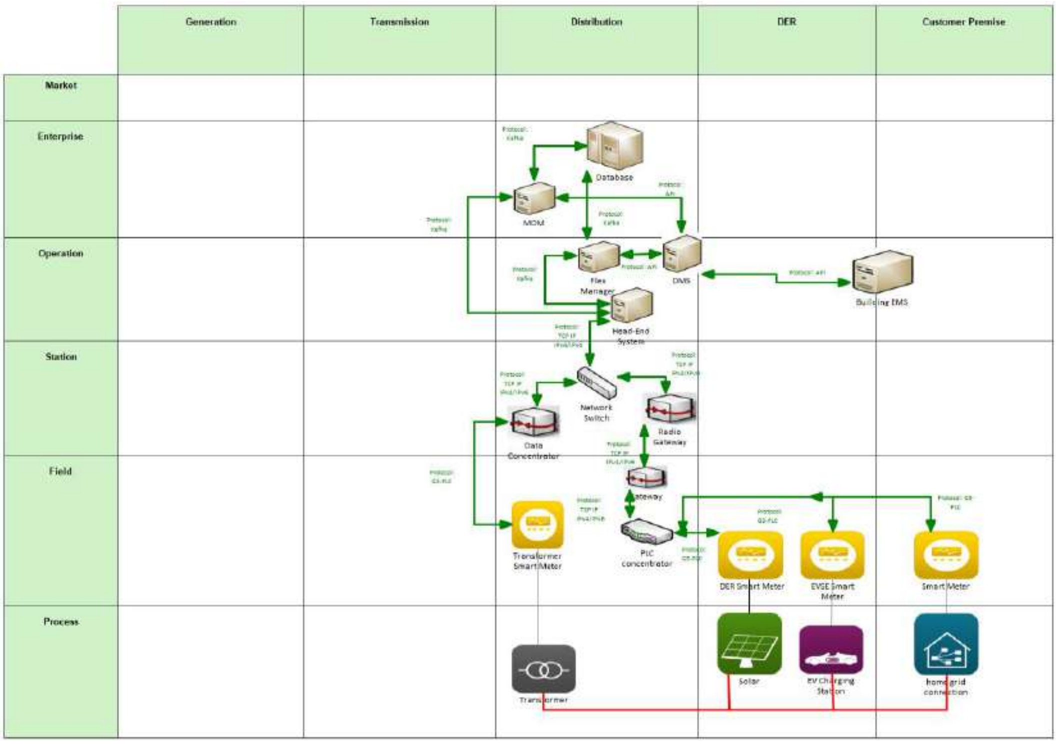

Figure 175. UC 5.1 Communication Layer

Table 106. List of Communication technologies linked with UC 5.1

Communication Technology	Description
KAFKA	Kafka uses a binary protocol over TCP. The protocol defines all APIs as request response message pairs. All messages are size delimited and are made up of the following primitive types.
REST	Representational State Transfer. Set of software constraints for web services, to provide interoperability between computer systems on the Internet. A RESTful web service defines a uniform and predefined set of stateless operations that accept requests through a URI.
TCP/IP	Transmission Control Protocol/Internet Protocol. Conceptual model and set of communication protocols used on the Internet. They provide end-to-end data communication, specifying how data should be packetized, addressed, transmitted, routed, and received, through four abstraction layers (link, internet, transport, and application).
G3-PLC	The G3-PLC protocol developed and maintained through the G3-PLC alliance is a Power line Communication technology which has recently been established a new standard for wired communication through existing power cables. G3-PLC enables faster and cost-efficient data transfer over existing power lines: higher volumes of data can be transmitted over electricity networks using G3, either on low frequency CENELEC A band (up to 95 KHz) or if desired, in the high frequency band (150-500kHz).
IEC 61968-9	Typical uses of the message types include meter reading, controls, events, customer data synchronization and customer switching. Although intended primarily for electrical distribution networks, IEC 61968-9 can be used for other metering applications, including non-electrical metered quantities necessary to support gas and water networks.

5.20.9 Component Layer

The components included in the use case are depicted below, including the technology used for connecting each other.

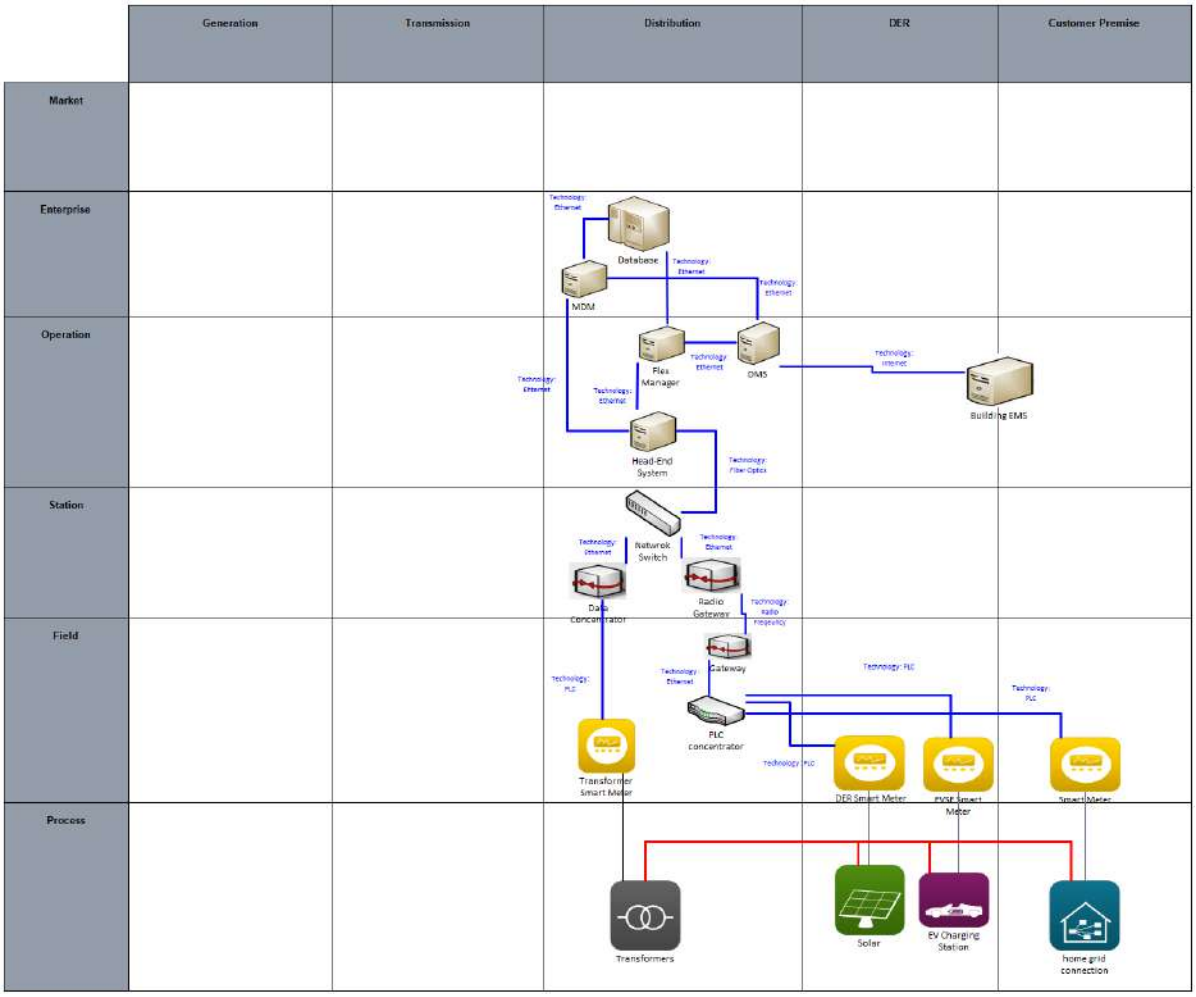

Figure 176. UC 5.1 Component Layer

Table 107. List of Components linked with UC 5.1

Component	Component Type
Transformer, Solar, EV charging station, home grid connection, Transformer/DER/EVSE/House smart meter, PLC concentrator, gateway, Data concentrator, Radio gateway, network switch, database	device
EMS, DMS, flex manager, head-end system, MDM	system

5.21 UC 5.2: Integrate flexibility with the distribution grid to provide balancing services

5.21.1 Use Case Description

In relation to the flexibility market, a highly relevant topic involves the potential aggregation of small Distributed Energy Resources (DERs) to offer flexibility services to the Distribution System Operators (DSOs) and entities operating in the ancillary service market, such as Balancing Service Providers (BSPs)

The flexibility accessible from small renewable assets connected to the low voltage grid can be utilised either to directly influence individual feeders within the distribution grid (service to the DSO) or to be consolidated into larger volumes for services like grid balancing.

The following Use Case considers as main validation case a service to the DSO, where the flexibility will be used to improve the health of the local distribution grid. A second optional validation case is also considered to investigate the possibility of integrating other buyers such as a BSP.

The implementation and testing of the asset management control system will be carried out directly at the pilot site, while the management and operational aspects of the flexibility market will be simulated using real data from the energy community.

List of advantages:

- Enable small DERs owners to amortize their investment making the flexibility market more accessible and inclusive.
- Present a cost-effective solution for providing local grid and balancing services to grid operators and energy companies.
- Investigate an efficient solution for optimal management of energy surplus at the community level.

5.21.2 Function Layer

The functional layer of UC 5.2 is presented in the following graph highlighting the key actors of the use case..

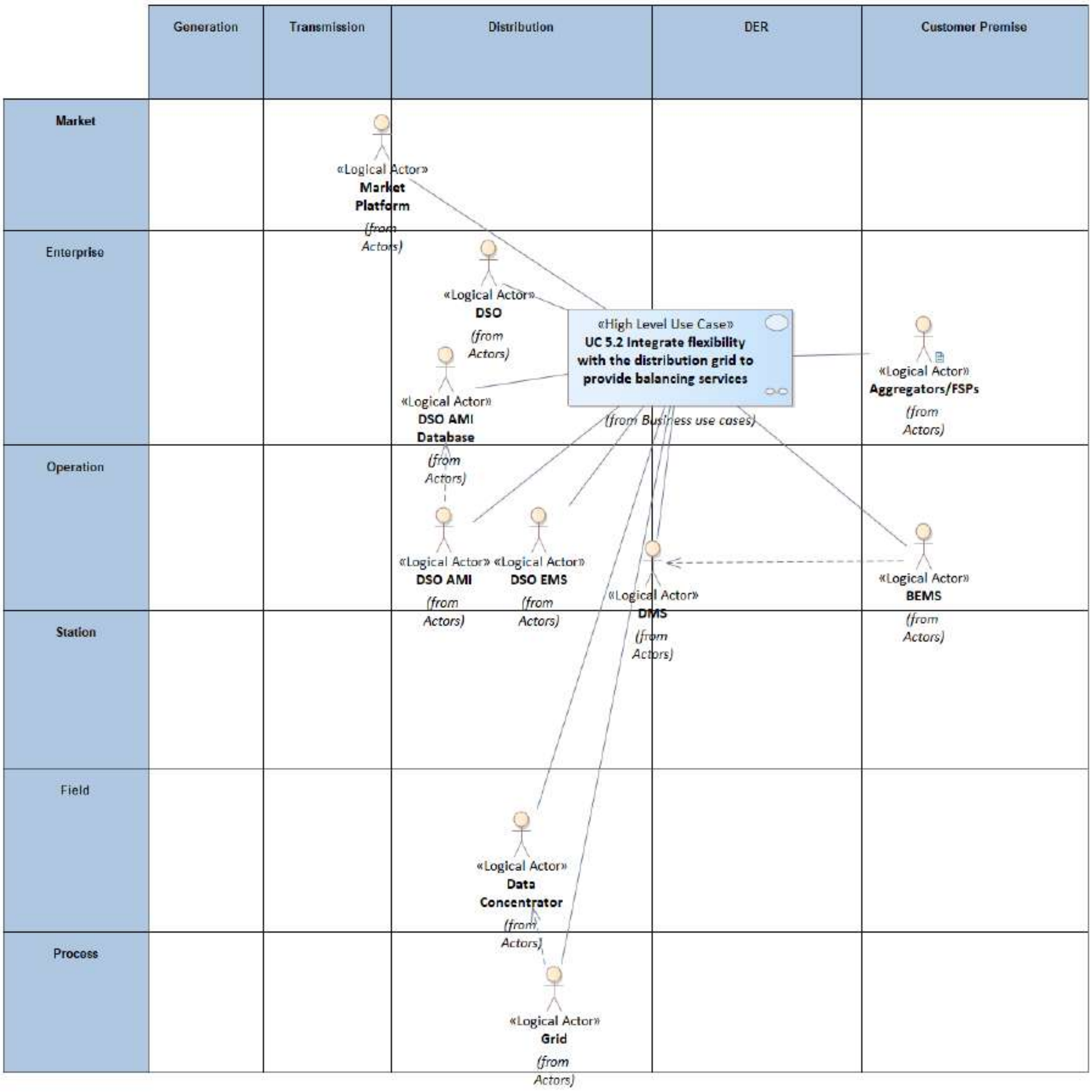

Figure 177. UC 5.2 Function Layer

Table 108. List of actors involved in UC 5.2

Actor Name	Actor Type
Market Platform	System
DSO	Organization
Aggregators/FSPs	Organization
DSO EMS	System
BEMS	System
DMS	System
DSO AMI	System
DSO AMI database	Device
Data Concentrator	Device
Grid	Device
Smart Meters	Device

5.21.3 Information Layer

Details about information layer of UC5.2 are presented in the following figure, highlighting the key information objects.

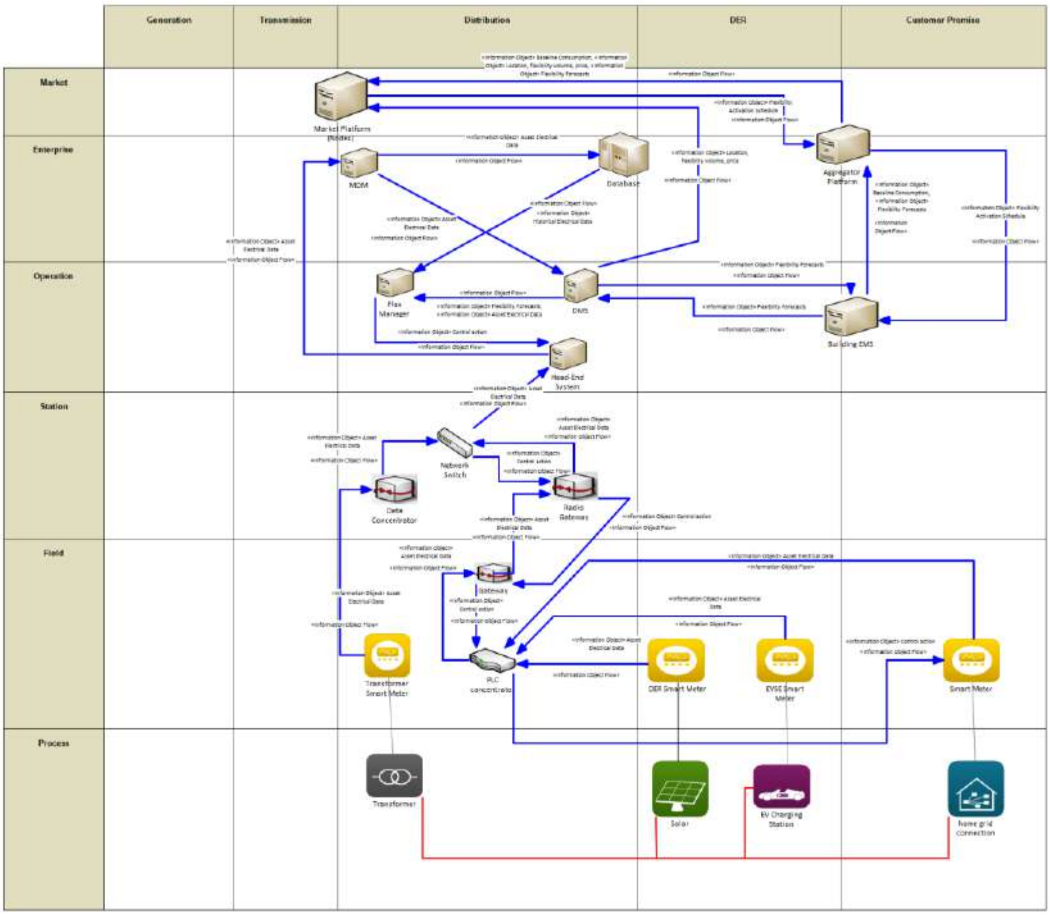

Figure 178. UC 5.2 Information Layer

5.21.4 Canonical Data model

The identified canonical data models for UC5.2 are described below.

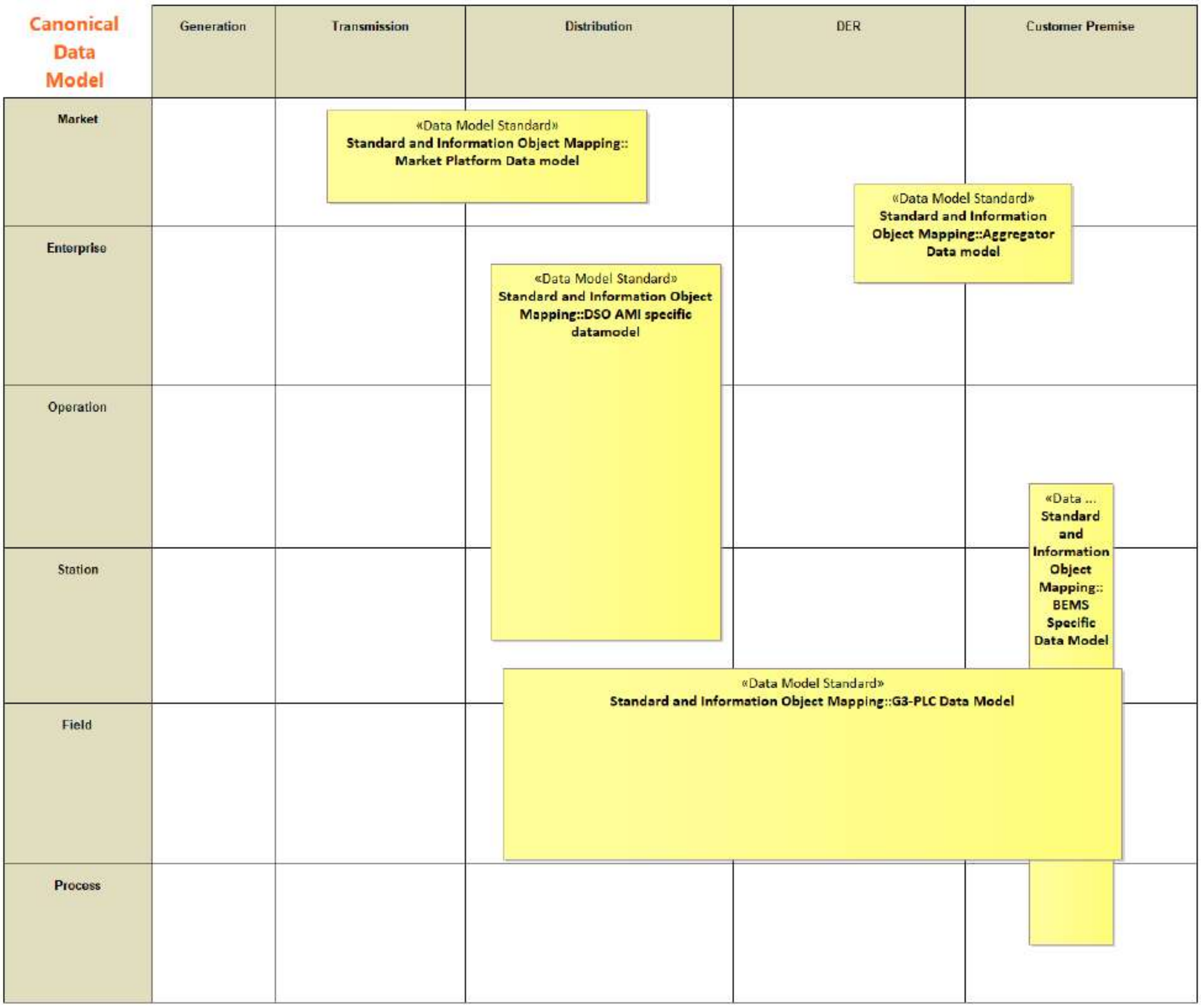

Figure 179. UC 5.2 Canonical Data model

Table 109. List of Data models involved in UC 5.2

Data Models
Market platform data model
Scada specific data model
Aggregator Data model
BEMS Specific data model
G3-PLC Data Model

5.21.5 Standards and information object mapping

SGAM Standards and Information Objects Mapping for UC5.2 is presented in the following figure.

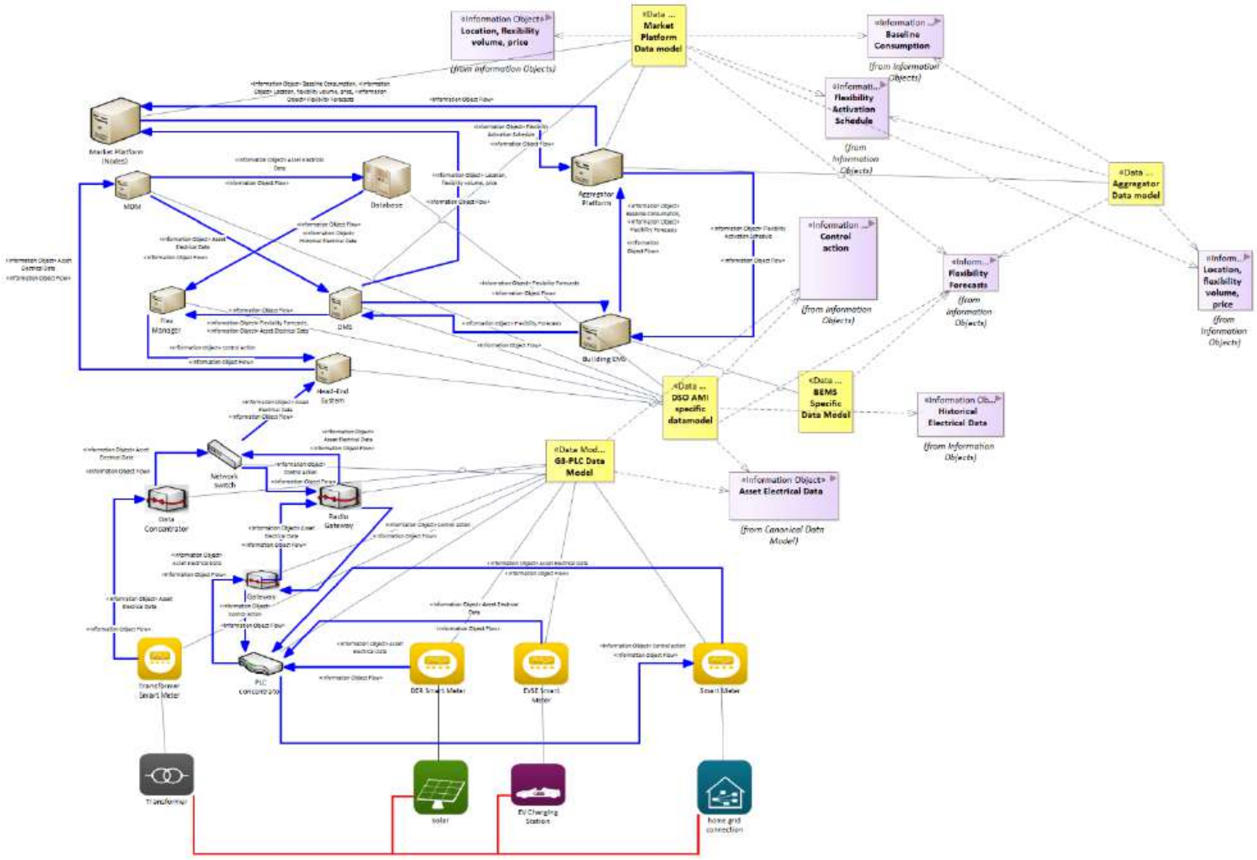

Figure 180. UC 5.2 Standards and Information Object Mapping

Table 110. List of Information Objects, link with Data Standards in UC 5.2

Information Object	DATA Models	Information
Historical Electrical Data	DSO AMI specific data model	Historical data on current, voltage, active/reactive power.
Flexibility Forecasts	DSO AMI specific data model, BEMS Specific data model, Market platform data model, Aggregator Data model	Schedule of available flexibility that can be offered.
Control action, asset consumption, performance monitoring	DSO AMI specific data model, BEMS Specific data model, G3-PLC Data model	Control signals sent for the activation of flexibility
Asset electrical data	DSO AMI specific data model, G3-PLC Data model	Current, Voltage, Active & Reactive Power
Flexibility Activation Schedule	Market platform data model, Aggregator Data model	Schedule of available flexibility that has been purchased and has to be activated.
Location, Flexibility Volume, Price	Market platform data model	The sell or buy bid placed in nodes platform by FSP or DSO/TSO that responds to specific location (node or asset) volume in terms of energy and price
Baseline Consumption	Market platform data model, Aggregator Data model	The energy consumption without flexibility activation

5.21.6 Activity Diagram

The detailed activity diagram for UC 5.2 is presented in the following figure.

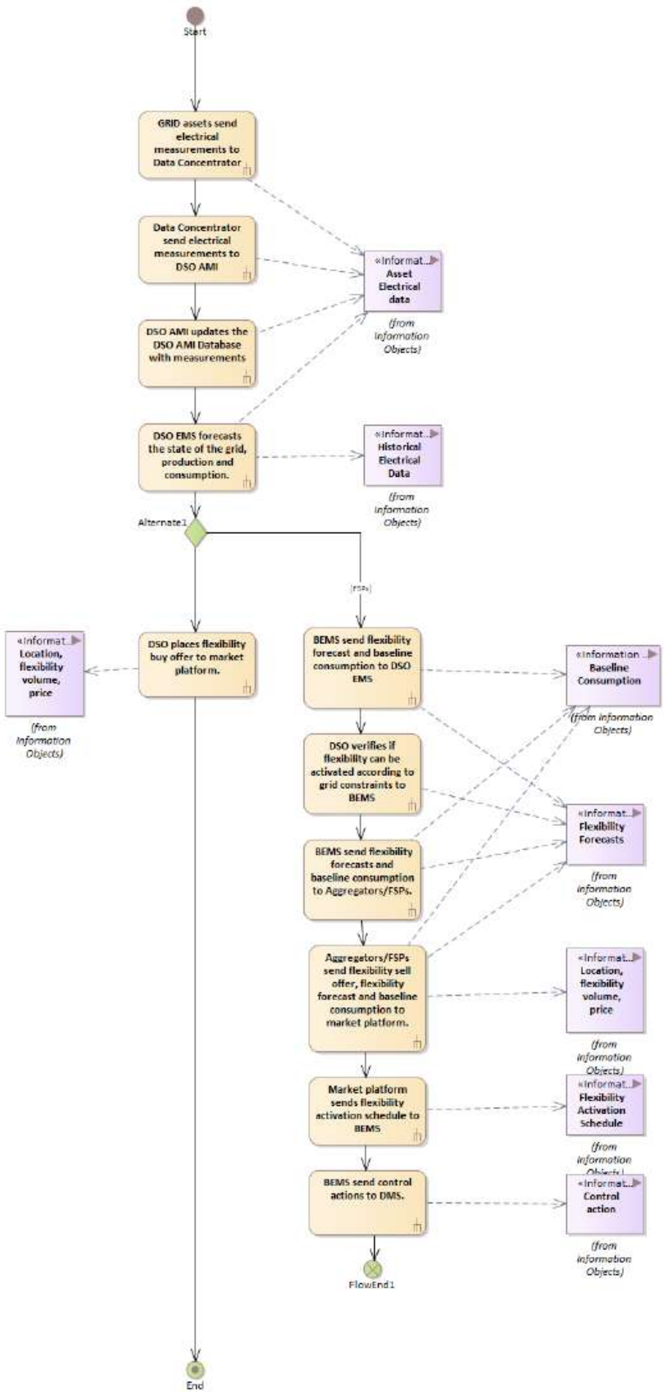

Figure 181. UC 5.2 Activity Diagram

5.21.7 Sequence Diagram

The detailed sequence diagram for UC 5.2 is presented in the following figure.

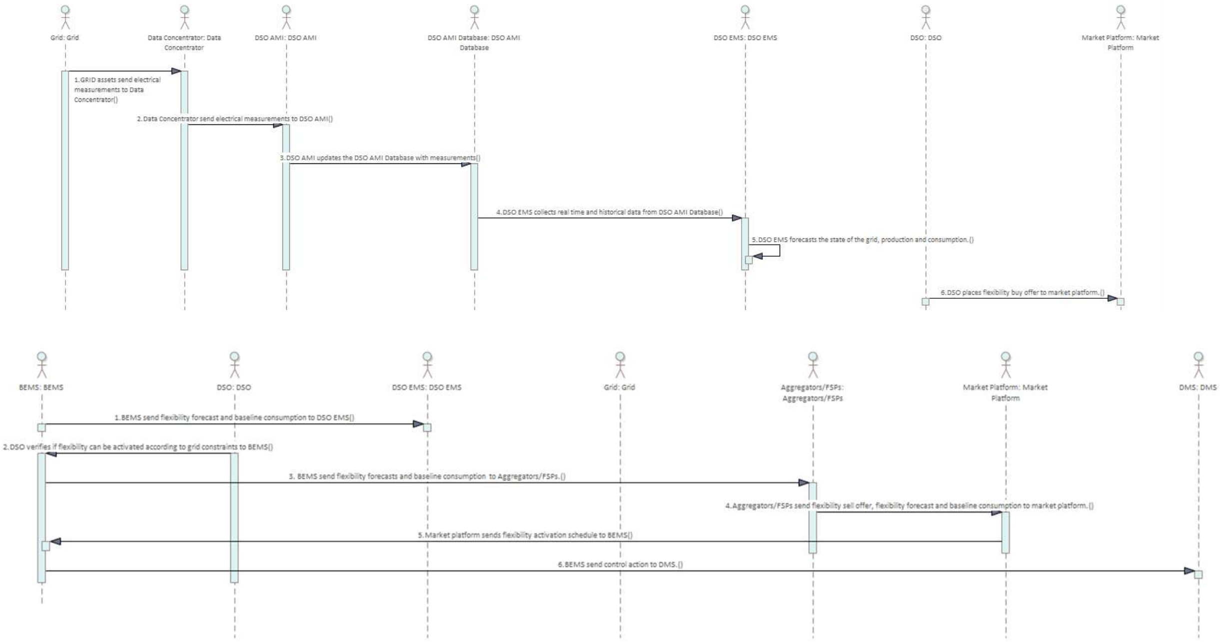

Figure 182. UC 5.2 Sequence Diagram

5.21.8 Communication Layer

The communication layer of UC 5.1 is presented in the following figure, highlighting the key communication protocols among the different modules.

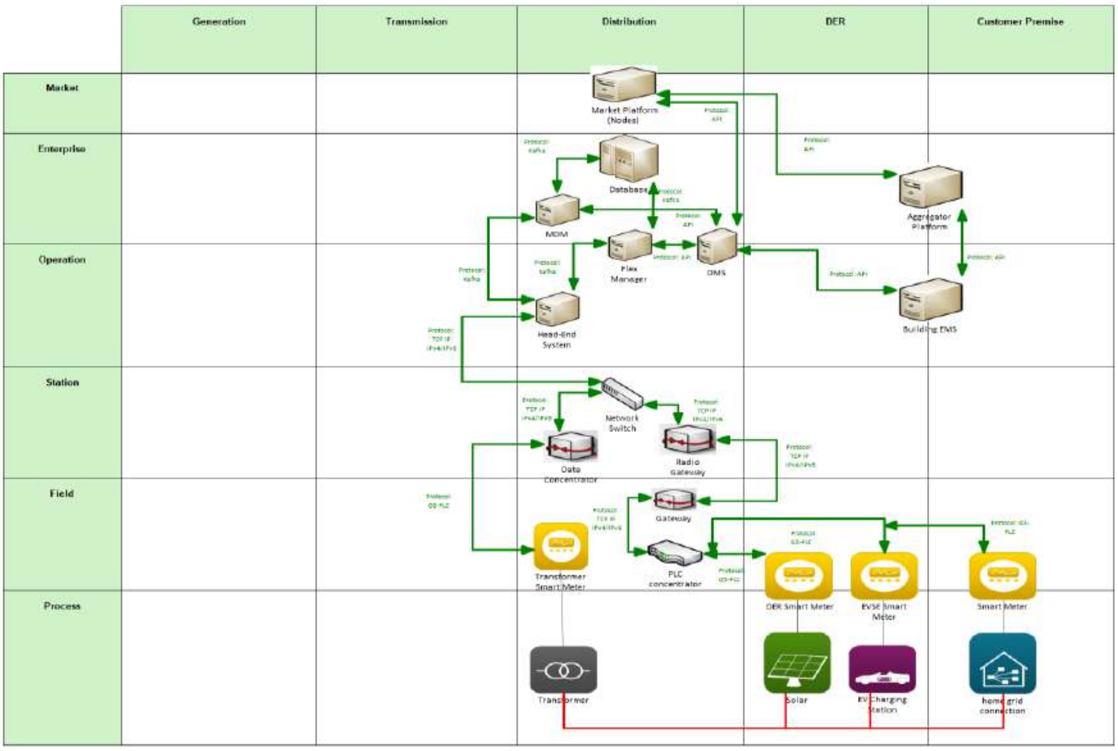

Figure 183. UC 5.2 Communication Layer

Table 111. List of Communication technologies linked with UC 5.2

Communication Technology	Description
KAFKA	Kafka uses a binary protocol over TCP. The protocol defines all APIs as request response message pairs. All messages are size delimited and are made up of the following primitive types.
REST	Representational State Transfer. Set of software constraints for web services, to provide interoperability between computer systems on the Internet. A RESTful web service defines a uniform and predefined set of stateless operations that accept requests through a URI.
TCP/IP	Transmission Control Protocol/Internet Protocol. Conceptual model and set of communication protocols used on the Internet. They provide end-to-end data communication, specifying how data should be packetized, addressed, transmitted, routed, and received, through four abstraction layers (link, internet, transport, and application).
G3-PLC	The G3-PLC protocol developed and maintained through the G3-PLC alliance is a Power line Communication technology which has recently been established a new standard for wired communication through existing power cables. G3-PLC enables faster and cost-efficient data transfer over existing power lines: higher volumes of data can be transmitted over electricity networks using G3, either on low frequency CENELEC A band (up to 95 KHz) or if desired, in the high frequency band (150-500kHz).
IEC 61968-9	Typical uses of the message types include meter reading, controls, events, customer data synchronization and customer switching. Although intended primarily for electrical

	distribution networks, IEC 61968-9 can be used for other metering applications, including non-electrical metered quantities necessary to support gas and water networks.

5.21.9 Component Layer

The components included in the use case are depicted below, including the technology used for connecting each other.

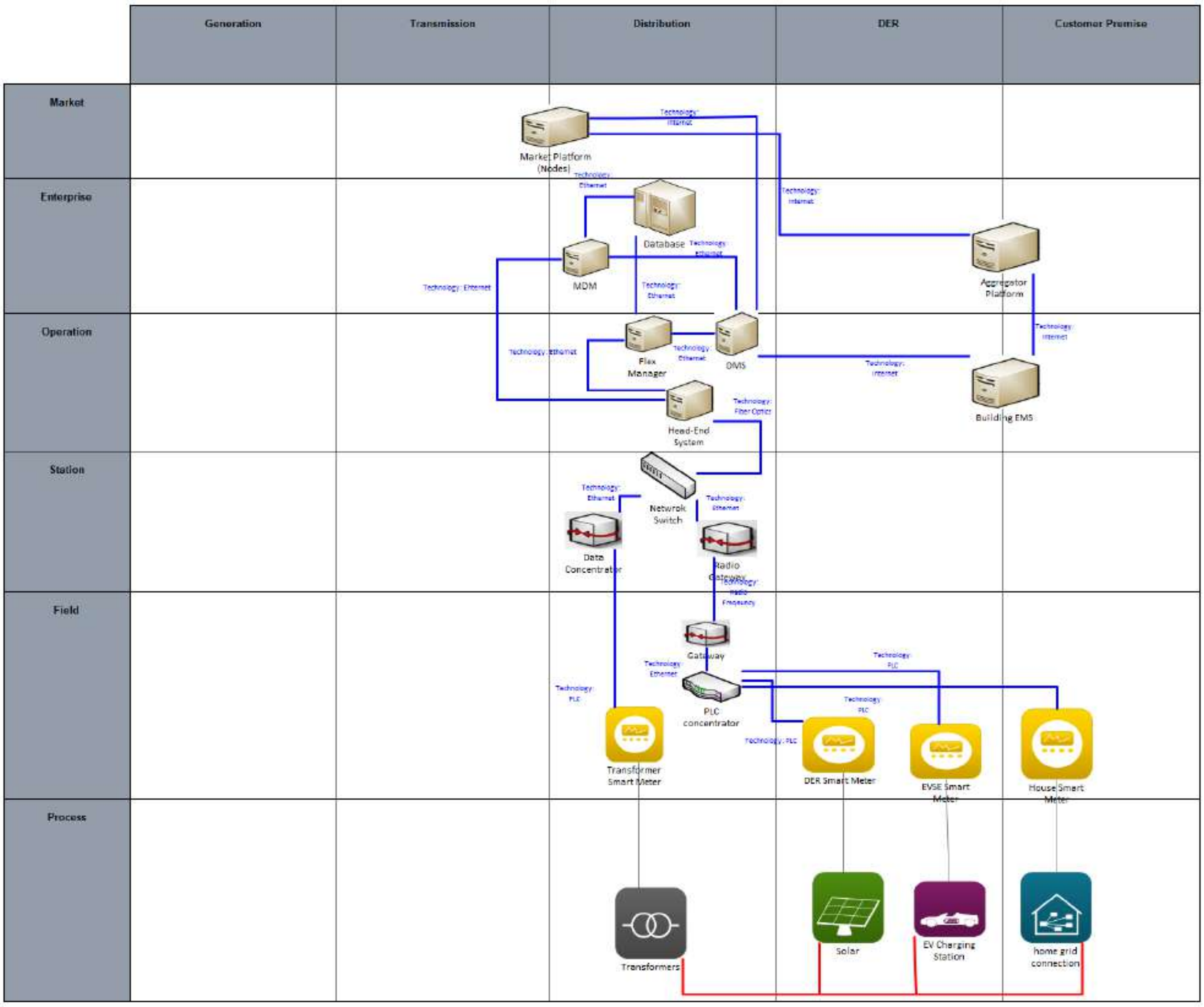

Figure 184. UC 5.2 Component Layer

Table 112. List of Components linked with UC 5.2

Component	Component Type
Transformer, Solar, EV charging station, home grid connection, Transformer/DER/EVSE/House smart meter, PLC concentrator, gateway, Data concentrator, Radio gateway, network switch, database	device
EMS, Aggregator platform, DMS, flex manager, head-end system, market platform, MDN	system

6 CONCLUSIONS

This deliverable's target was to develop an interoperable, secure and flexible architecture for OPENTUNITY use cases developed in T2.1. To fulfil this task, the Smart Grid Architecture Model (SGAM) framework and underlying methodology have been applied to analyse and design the architecture of OPENTUNITY innovations and use cases in systematic and unified manner.

Initially, the innovations of OPENTUNITY project are defined as business use cases in the business layer of SGAM framework, where are linked with the three core objectives, **Decarbonization of EU society**, **Citizen and stakeholder empowerment** and **Ensure quality of supply in a context of increase of RES**, the project actors as well as with the use cases defined in T 2.1.

Every UC is then analysed using the SGAM framework and specifically the function, innovation, information and component layer, producing an analytic and detailed object, where the role of each stakeholder is clearly defined. In the function layer, the high level overview of the UC is presented, analysing the actors involved, the sequence of actions that take place in the UCs. The information layer presents the various components in each UC and the information exchange between them, the information models and the data standards applied. Finally, the communication layer presents the communication protocols used for the interaction of the various assets and the component layer their connectivity in the physical domain.

In addition, an extension of SGAM to include blockchain technologies has been briefly discussed and an example UC (UC 1.10) has been included in the annexes section to present how blockchain can be introduced to SGAM and how different is the modelling compared to the conventional modelling presented in section 5.

7 References and acronyms

7.1 References

1. [1] *Opentunity Grant Agreement. EC, 2022.* (s.f.).
2. [2] IEC - International Electrotechnical Commission, "*IEC 61850-6 - Communication networks and systems in substations – Part 6: Configuration description language for communication in electrical substations related to IEDs,*" 2009.
3. [3] G. A. Council, "*GridWise Interoperability Context-Setting Framework,*" Smart Grids Interoperability, pp. 1–52, 2008, [Online]. Available: https://www.gridwiseac.org/pdfs/interopframework_v1_1.pdf
4. [4] CEN-CENELEC-ETSI Smart Grid Coordination Group, "*Smart Grid Reference Architecture*" 2012.
5. [5] Christian Neureiter "*Introduction to the SGAM Toolbox*", 2014, [Online]. Available: www.en-trust.at

7.2 Acronyms

Table 113. Acronyms

Acronym	Explanation
AAM	Advanced Asset Management
AMI	Advanced Metering Infrastructure
API	Application Programming Interface
BEMS	Building Energy Management System
BESS	Battery Energy Storage System
BFMS	Building Flexibility Management System
BMS	Building Management System
BSP	Balancing Service Provider
CIM	Common Information Model
COSEM	Companion Specification for Energy Metering
CP	Charging Point
DER	Distributed Energy Resource

DG	Distributed Generator
DHW	Domestic Hot Water
DLMS	Device Language Message
DLR	Dynamic Line Rating
DMS	Distribution Management System
DSM	Demand Side Management
DSO	Distribution System Operator
DR	Demand Response
EMS	Energy Management System
ESCO	Energy Service COmpany
EU	European Union
EV	Electric Vehicle
EVSE	Electric Vehicle Supply Equipment
FSP	Flexibility Service Provider
FTP	File Transfer Protocol
HEMS	Home Energy Management System
HLUC	High-Level Use Case
HV	High Voltage
HVAC	Heating, Ventilation and Air-Conditioning
IEC	International Electrotechnical Commission
ICT	Information and Communication Technology
IoT	Internet of Things
IP	Internet Protocol
ISO	International Organization for Standardization
LV	Low Voltage
MDG	Model-Driven Generation
MV	Medium Voltage
MQTT	Message Queuing Telemetry Transport
NATS	Neural Autonomic Transport System

NILM	Non-Intrusive Load Monitoring
OEM	Original Equipment Manufacturers
OCPP	Open Charge Point Protocol
OPCUA	Open Platform Communications Unified Architecture
PIM	Platform Independent Model
PLC	Power Line Carrier
PRF	Proof of a new International Standard
PSI	Platform Specific Implementation
PSM	Platform Specific Model
PUC	Primary Use Case
PV	Photovoltaic
RA	Reference Architecture
RES	Renewable Energy Source
REST	Representational State Transfer
RTTR	Real Time Thermal Rating
RTU	Remote Terminal Unit
SAP	System Analysis Phase
SCADA	Supervisory, Control and Data Acquisition
SG	Smart Grid
SG-RA	Smart Grid Reference Architecture
SGAM	Smart Grid Architecture Model
SUC	Secondary Use Case
TSO	Transmission System Operator
UACP	Unified Architecture Connection Protocol
UC	Use Case
URI	Uniform Resource Identifier
WP	Work Package
WSS	WebSocket Secure

8 ANNEXES

8.1 Data Model Standards

There are several data model standards described in the defined SGAM architecture. Many off them are proprietary (e.g. DSOs/TSOs SCADA specific data models, BEMS/HEMS data models, weather service providers data models, market platform data model) and their model is provided by the owner of the service or they will be developed in the course of the project (e.g. Grid Planning software data model). Nevertheless, several widespread protocols and data models have been used in the aforementioned open architecture design that will be described briefly here.

The **IEC 60870-5** is a protocol standard developed by the IEC for teleprotection, telecontrol, and telecommunications for electrical engineering and power system automation. It defines systems used by SCADA systems, including details related to communications between devices. **IEC** 60870-5-103 is a companion standard that allows interoperability between devices in a control system and protection equipment. IEC 60870-5 was designed for wide-spread telecontrol networks. It is an international standard based on an international accepted and proven enhanced performance architecture (EPA) model. **IEC 60870-5-102** specifies the communication between SCADA and remote devices. It primarily addresses serial communication over long distances using balanced or unbalanced transmission lines. **IEC 60870-5-104** defines the communication over network protocols, especially for wide area networks (WANs) or local area networks (LANs) using TCP/IP-based protocols. Regarding the data model within these standards, they define a structured way of organizing and representing information transmitted between control centers and remote devices. This model includes various data objects, such as measured values, status information, control commands, and event notifications, all organized in a standardized format. It ensures that information exchanged between different devices and systems follows a uniform structure and can be accurately interpreted and processed. In OPENTUNITY environment it is used by DSOs in demo sites to collect measurements from substation devices, e.g. feeder relays and substation RTUs overall.

IEC 61850 standard serves as the internationally adopted norm for communication within electric substations used by many utilities. Initially conceptualized for facilitating communication among control, measurement, and protection devices within automated substations, this standard has evolved to encompass broader aspects. Beyond communication, it now encompasses the vital elements involved in designing, maintaining, and operating electric substations, particularly in the realms of control and protection. Consequently, it ensures that the control mechanisms within electric substations remain vendor-agnostic, irrespective of the manufacturers producing the installed devices.

In pursuit of achieving interoperability, this standard delineates an object-oriented data model. This model allows for the segmentation of substations into fundamental functions via the definition of logic nodes, simplifying associated databases accordingly.

The data models specified in this standard are adaptable to various protocols. Presently, the standard accommodates several protocols, including GOOSE (Generic Object Oriented Substation Event), MMS (Manufacturing Message Specification), SMV (Sampled Measured Values), and Web Services, enhancing its versatility and compatibility within diverse operational frameworks. In OPENTUNITY environment it is used by TSOs/DSOs in demo sites to collect measurements from substation devices, e.g. feeder relays and substation RTUs overall.

CIM (Common Information Model) was initially developed by the electric power industry and afterward it was officially adopted by the International Electrotechnical Commission (IEC). Originally conceptualized to create a unified power system network model, its primary aim was to establish a shared foundation for information exchange. Presently, this standard enjoys widespread adoption among major vendors, facilitating seamless information exchange between diverse devices. Over time, its scope has broadened to encompass tasks crucial to the electric power industry, including asset tracking, customer billing, and work scheduling. At its core, the CIM model is chiefly structured around two key standards: IEC 61970-301 and IEC 61968-11. IEC 61970-301 delineates the components of a power system from an electrical standpoint and elucidates the relationships between these components. Conversely, IEC 61968-11 focuses on defining the semantics of other aspects of power system software data exchange, such as work scheduling and customer billing.

Given that the CIM model operates as an ontological model, it necessitates interfacing with diverse systems like GIS (Geographical Information Systems), CSS (Customer Support Systems), or ERP (Enterprise-Resource Planning). To accomplish this, CIM encompasses 53 UML packages (Unified Modeling Language), comprising approximately 820 classes and over 8500 attributes. Moreover, it offers various serializations, including XML and XML schema, to construct custom EAI (Enterprise Application Integration) messages based on the CIM, alongside utilizing pre-defined messages established by the IEC. For modeling power grid graphs, CIM also features RDF (Resource Description Framework) serializations and RDF schemas. These diverse serializations culminate in the development of CIM OWL (Web Ontology Language) serializations, enhancing its flexibility and utility across varied applications. In OPENTUNITY environment will be used by software applications to receive topology information data directly from DSOs topology repositories.

DLMS (Device Language Message Specification)/COSEM (Companion Specification for Energy Metering) is an international standard published as IEC 62056. In OPENTUNITY environment is the main protocol used by smart meters over PLC, its concentrators and DSO AMI. Its objective is to provide an interoperable environment for structured modeling and meter data exchange. DLMS supports applications such as remote meter reading, remote control, and value-added services for metering any kind of energy, such as electricity, water, gas or heat. COSEM is an interface model for communicating with energy metering equipment, providing a view of the functionality available through the communications interfaces. The model uses an object-oriented approach. The COSEM model allows for a manufacturer-independent and controlled method to identify, retrieve and interpret the information held in any meter.

The information of an object is organized in attributes. The attributes represent the characteristics of an object by means of attribute values. The value of an attribute may affect the behavior of an object. An object may offer a number of methods to either examine or modify the values of the attributes. Objects that share common characteristics are generalized as an interface class with a class_id. Within a specific class, the common characteristics (attributes and methods) are described once for all objects. Each instance of an interface class is called a COSEM object. To sum up, DLMS/COSEM standardizes communication and data formats for energy metering devices, ensuring interoperability, efficient data exchange, and enhanced functionality in managing energy consumption and metering infrastructure.

OCPP (Open Charge Point Protocol) is a widespread open protocol used by various charging station manufacturers for the communication between charging stations and central management systems. It can facilitate control of multiple charging stations using a single management platform, simplifying operations, enabling remote monitoring and facilitating updates. OCPP has multiple versions (1.6, 2.0, 2.0.1) that differ in their capabilities and supported functionalities. The protocol is based on HTTP communication combined with JSON formatting, describing the structure of requests, responses and data models. In OPENTUNITY environment it is used by EVSE management platforms and flexibility management platforms in order to communicate in demo sites with charging stations for the measurement acquisition and charging profile updates based on activated flexibility.

8.2 Modelling of UC 1.10: Establishment of a flexibility market and flexibility procurement using blockchain technology

8.2.1 Use Case Description

The main difference from the main UC 1.10 description is that the entities participating in the market (NODES market platform, DSO, TSO, Aggregators/FSPs) are interacting only with blockchain through blockchain access services. These access points use the information receive for the different actors and generate the blockchain data model introducing also blockchain metadata, like DIDs.

8.2.2 Function Layer

The functional layer of UC 1.10 is presented in the following graph highlighting the key actors of the use case.

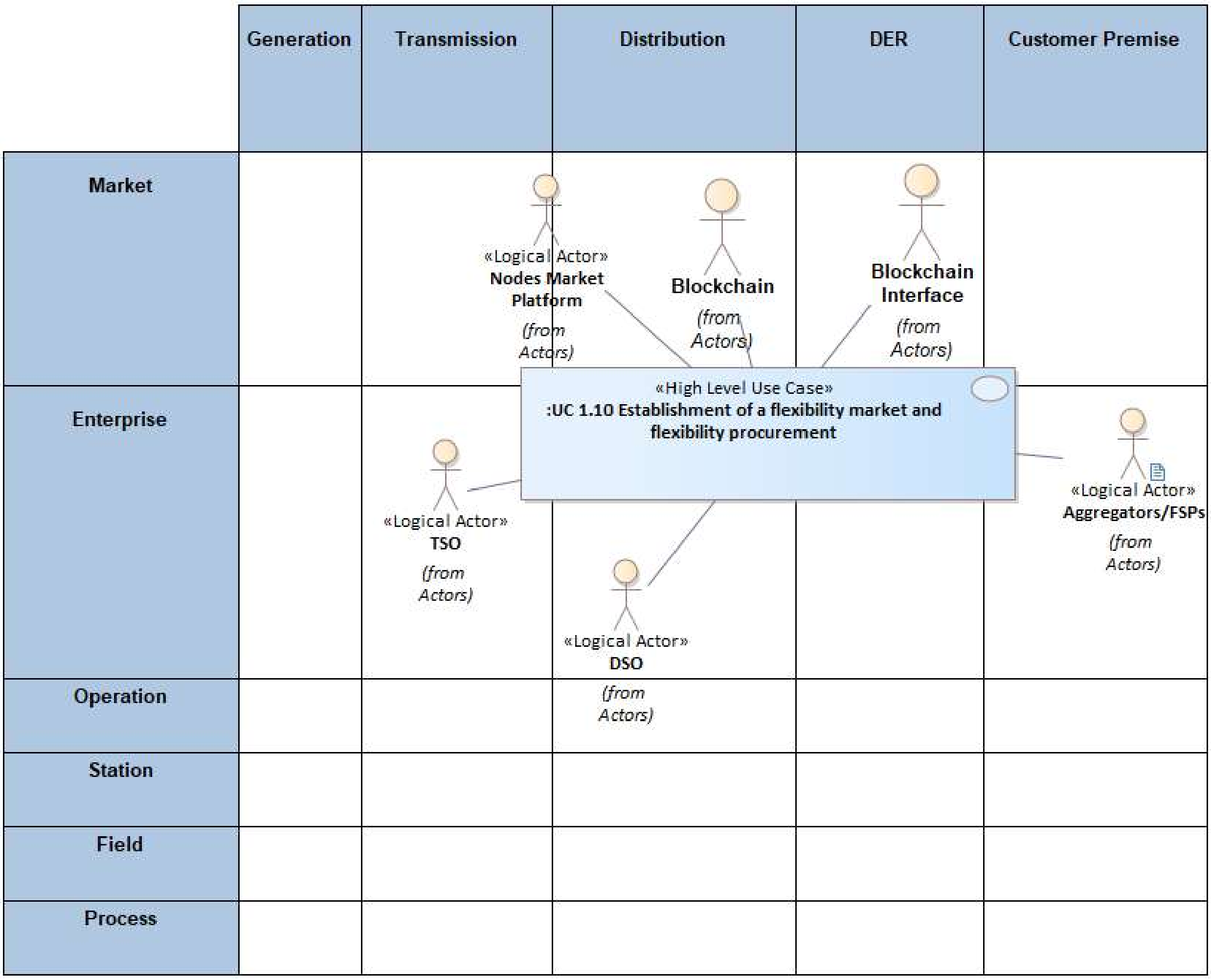

Figure 185. UC 1.10 version 2 Function layer

Table 114. List of actors involved in version 2 of UC 1.10

Actor Name	Actor Type
Nodes Market Platform	System
TSO	Organization
DSO	Organization
Aggregators/FSP	Organization
Blockchain Interface	System
Blockchain	Implementation of blockchain functions

8.2.3 Information Layer

Details about information layer of UC1.10 are presented in the following figure, highlighting the key information flows. The information objects are the same as in section 5.10. The main difference here the blockchain connectors presence which provides the access to the different parties to blockchain transforming the information to the blockchain data structures that contain DID, etc.

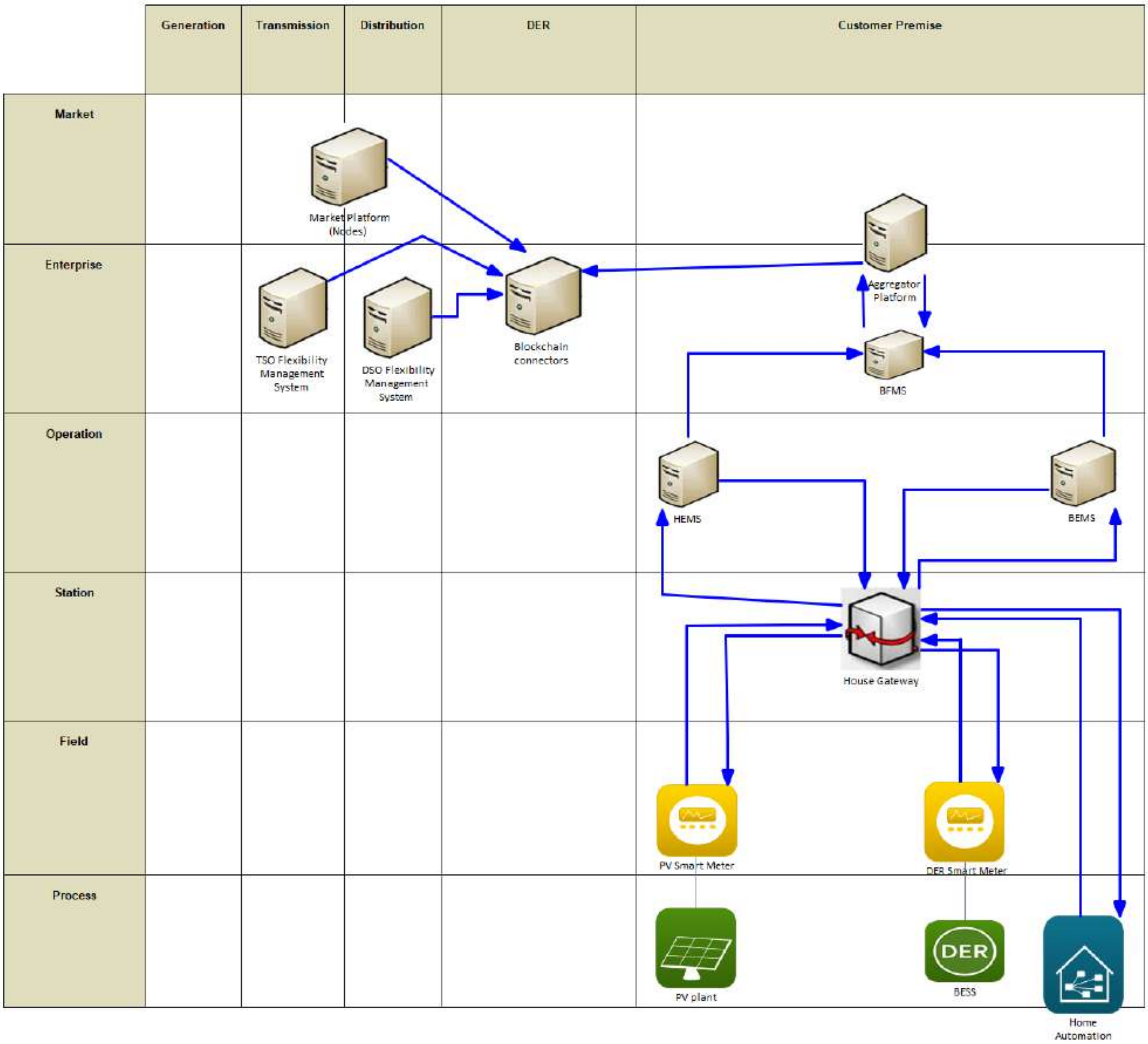

Figure 186. UC 1.10 version 2 Information Layer

8.2.4 Canonical Data Model

The identified canonical data models for UC1.10 are described below. The blockchain data model is also added compared to the previous UC 1.10 modelling.

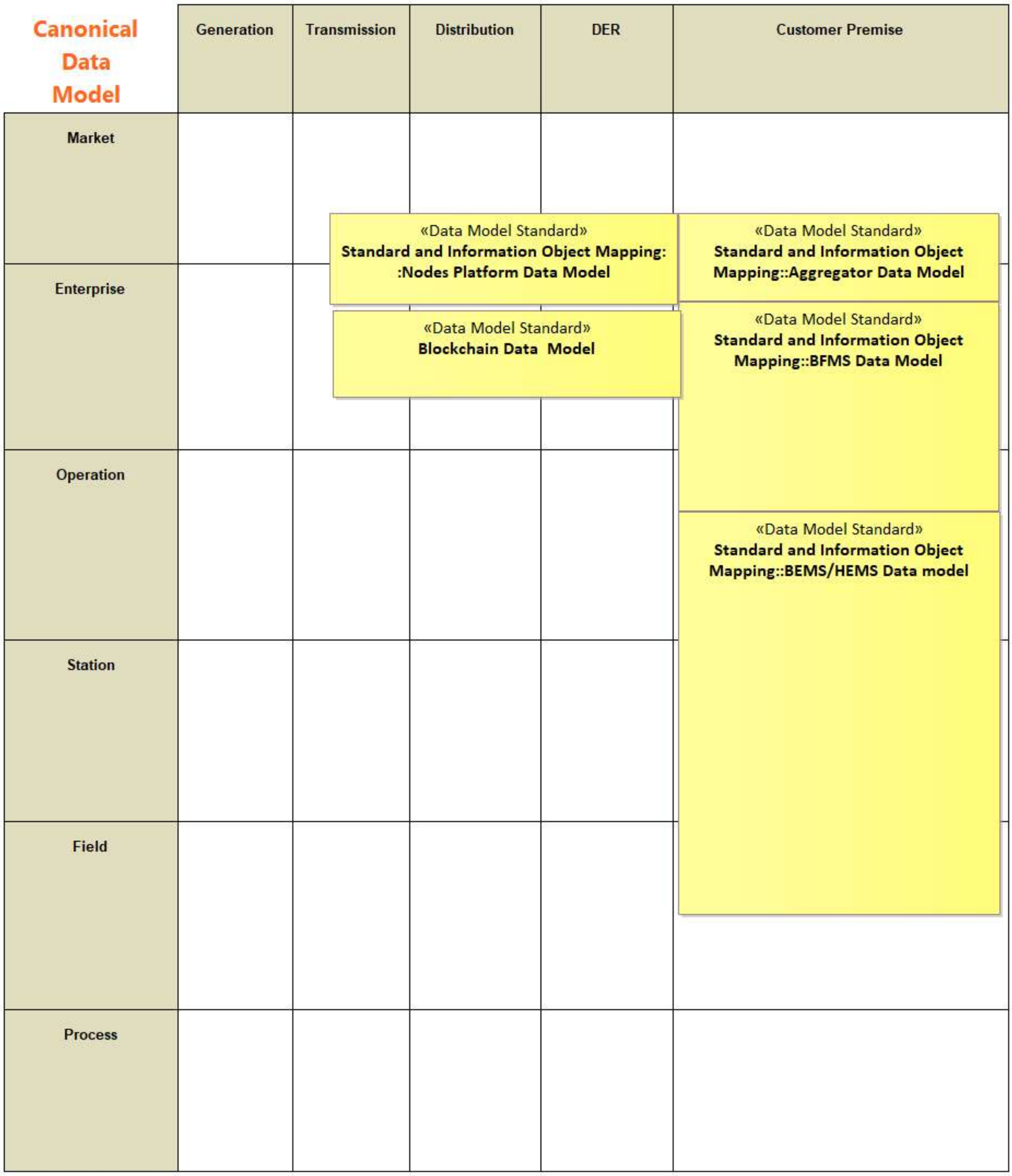

Figure 187. UC 1.10 version 2 Canonical data model

8.2.5 Standards and Information Object Mapping

SGAM Standards and Information Objects Mapping for UC1.10 is presented in the following figure. The main difference is again the presence of blockchain access service (oracle) that structures the information to blockchain data structures adding also the necessary blockchain metadata (e.g. DIDs, smart contract information ,etc.) to it.

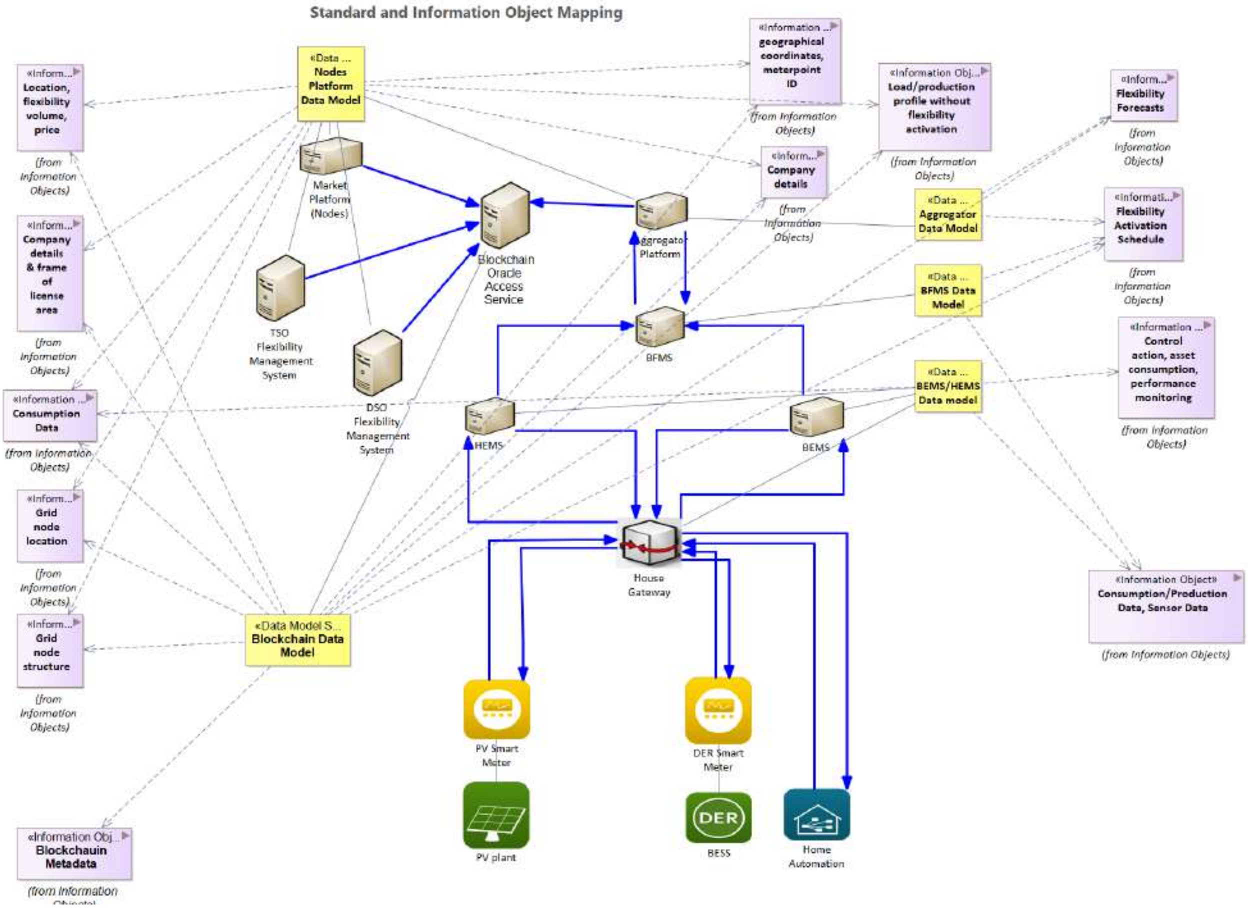

Figure 188. UC 1.10 version 2 Standards and Information Object Mapping

8.2.6 Activity Diagram

The detailed activity diagram for UC 1.10 is presented in he following figure. The information objects are omitted for visualization purposes.

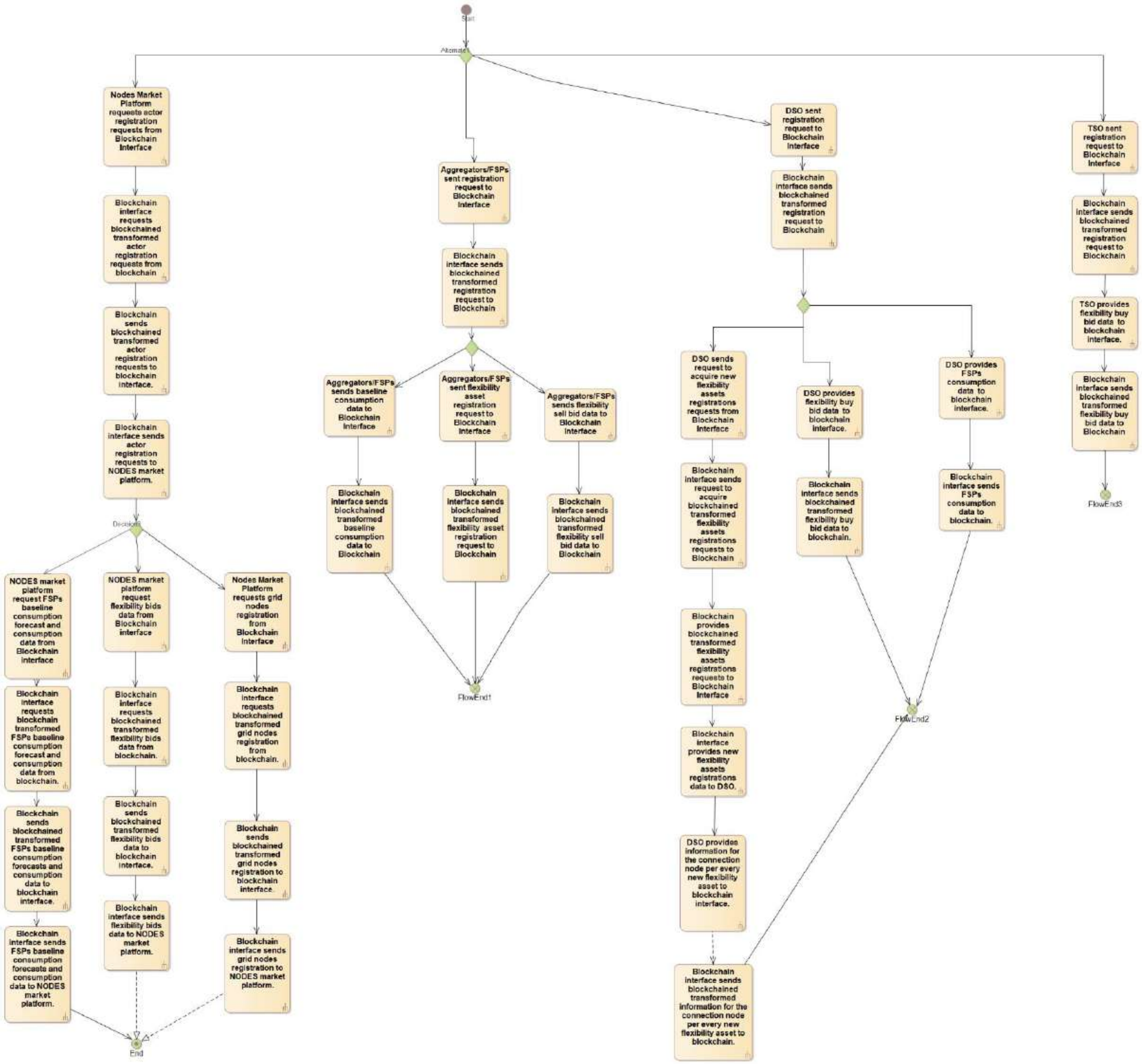

Figure 189. UC 1.10 version 2 Activity Diagram

8.2.7 Sequence Diagram

The detailed sequence diagram for every actor of UC 1.10 is presented in the following figures.

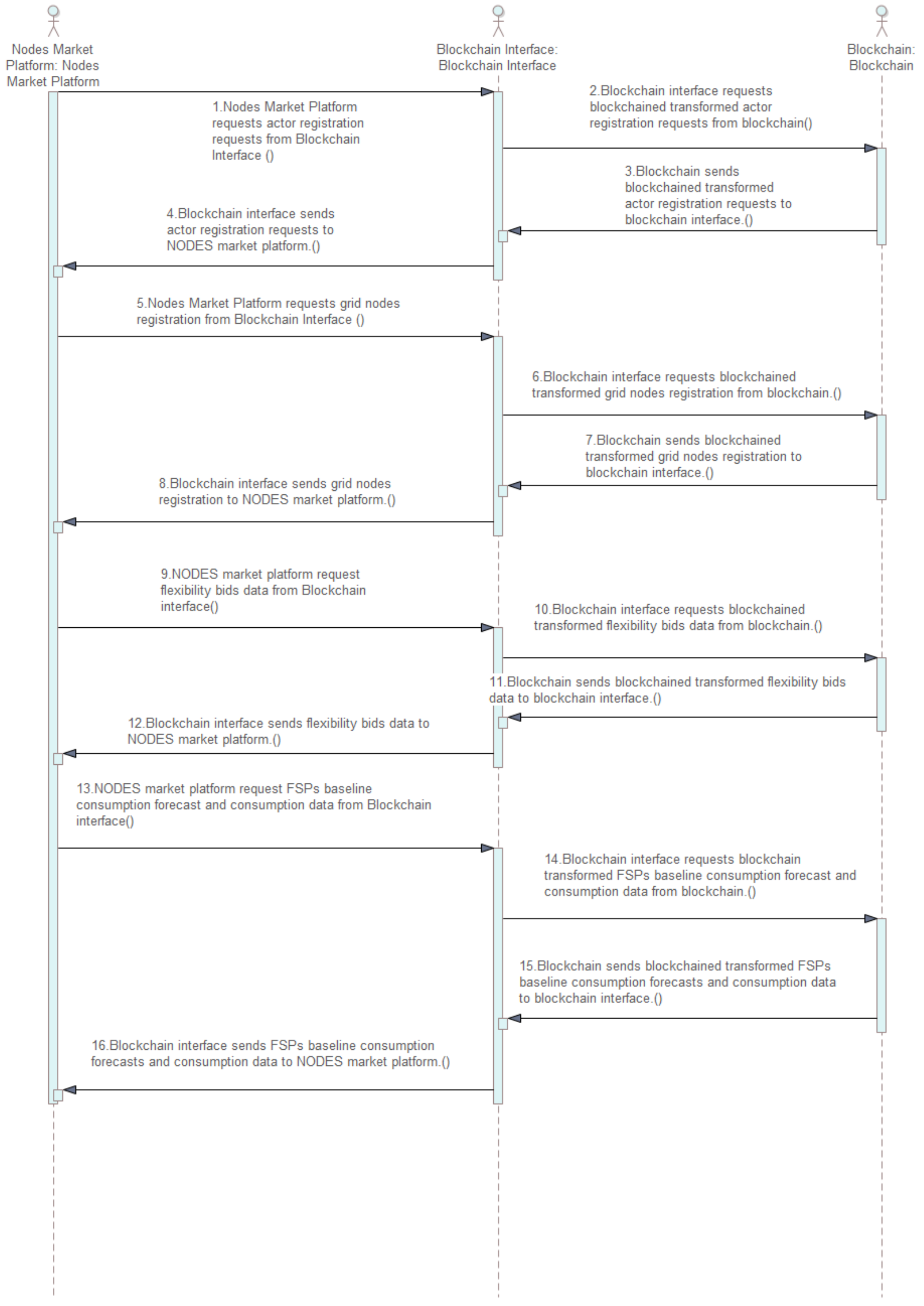

Figure 190. UC 1.10 Nodes Market Platform Sequence diagram

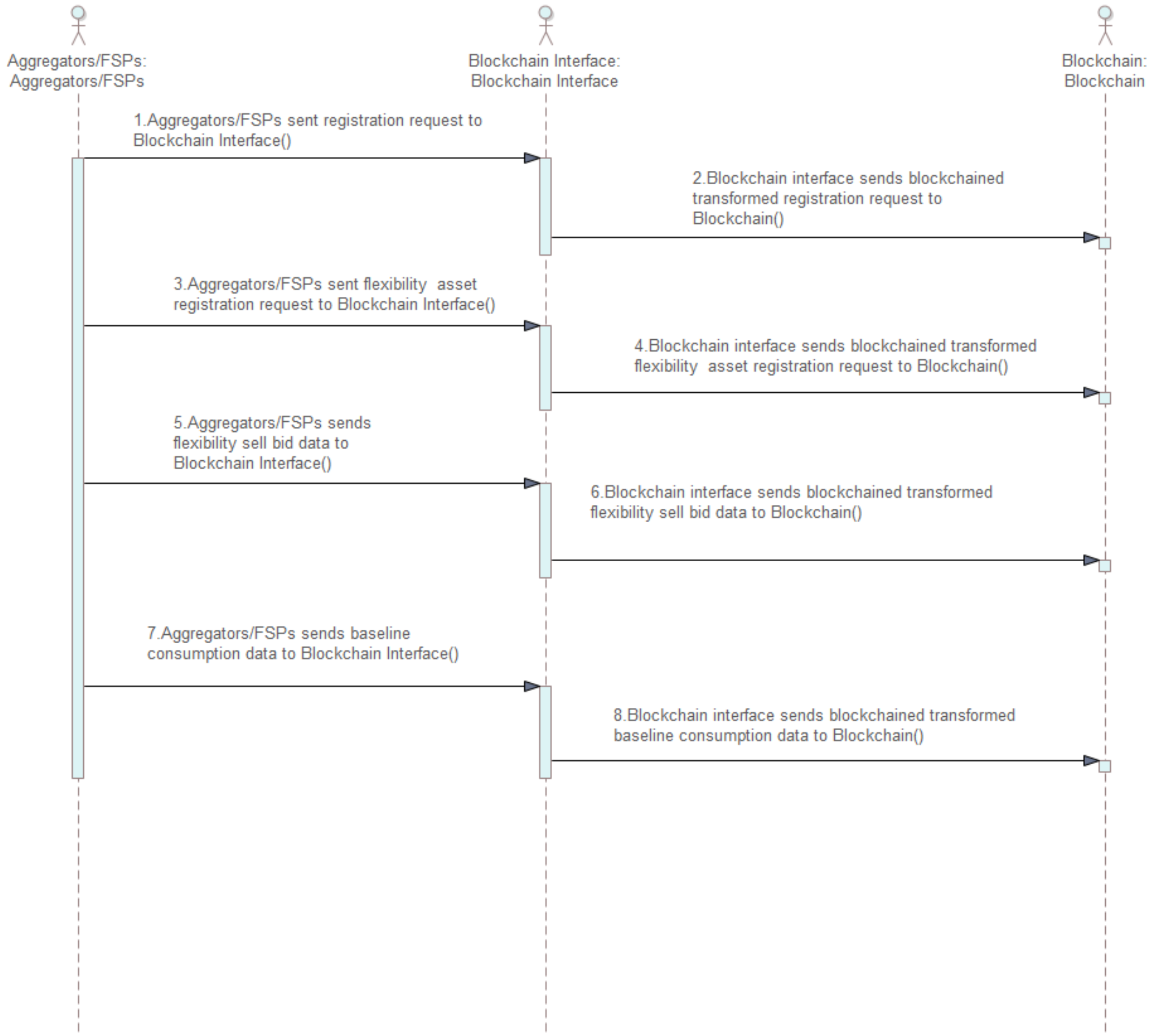

Figure 191. UC 1.10 Aggregator/FSP Sequence diagram

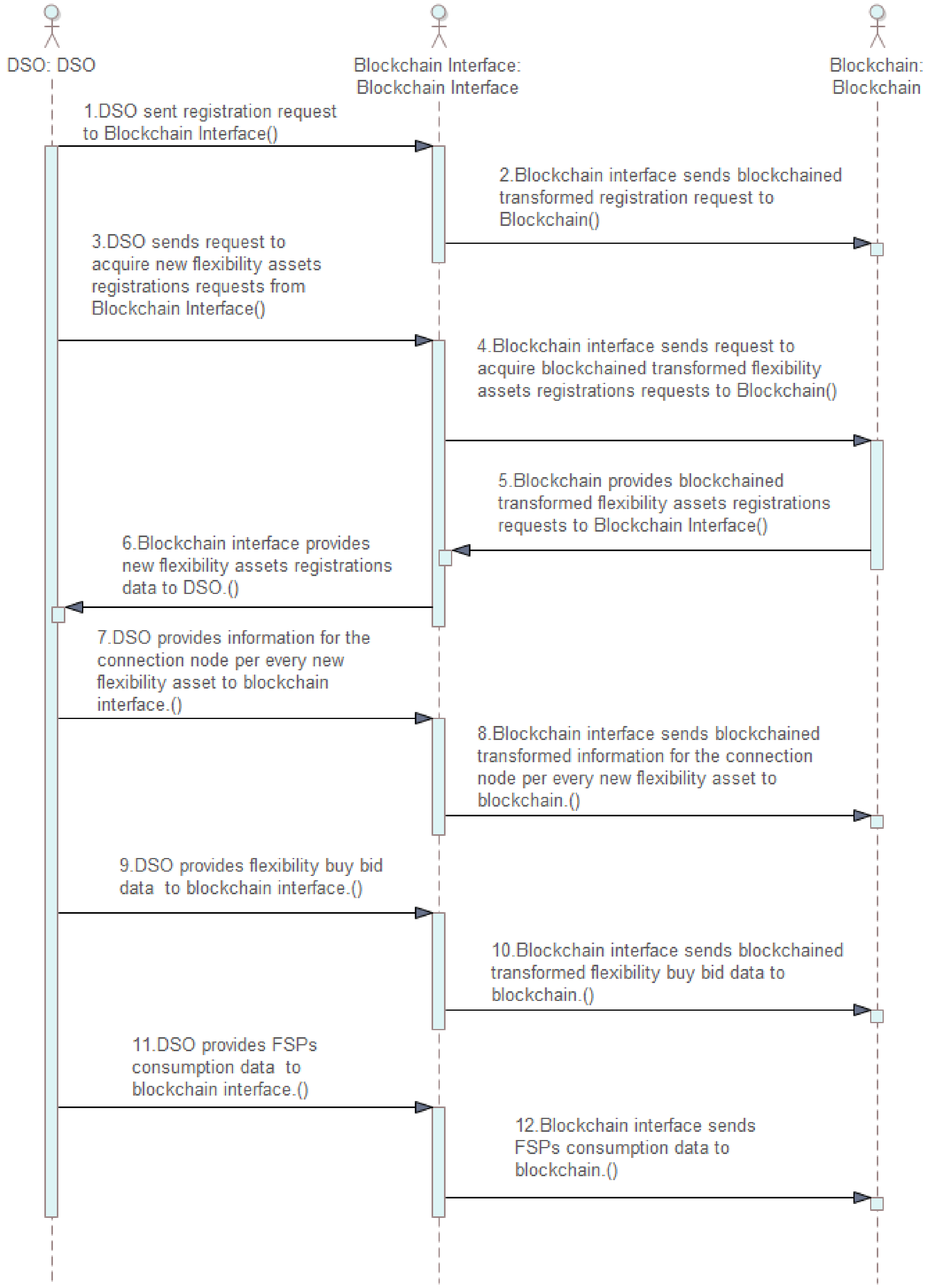

Figure 192. UC 1.10 DSO Sequence diagram

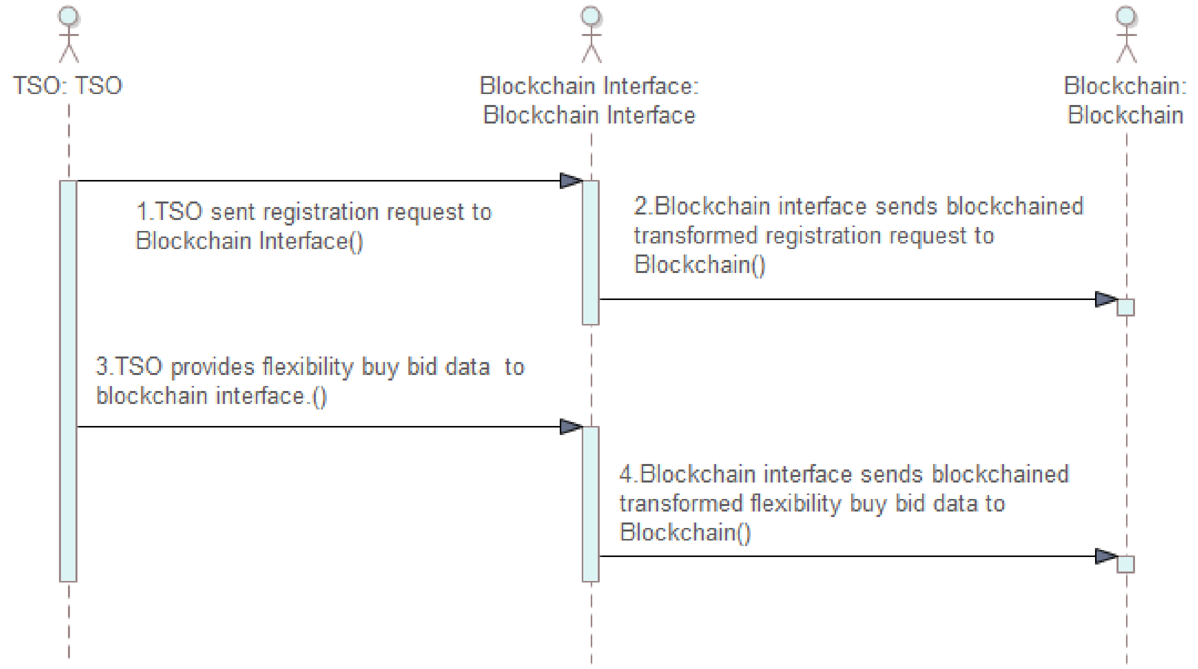

Figure 193. UC 1.10 TSO Sequence diagram

8.2.8 Communication Layer

The communication layer of UC 1.10 is presented in the following figure, highlighting the key communication protocols among the different modules.

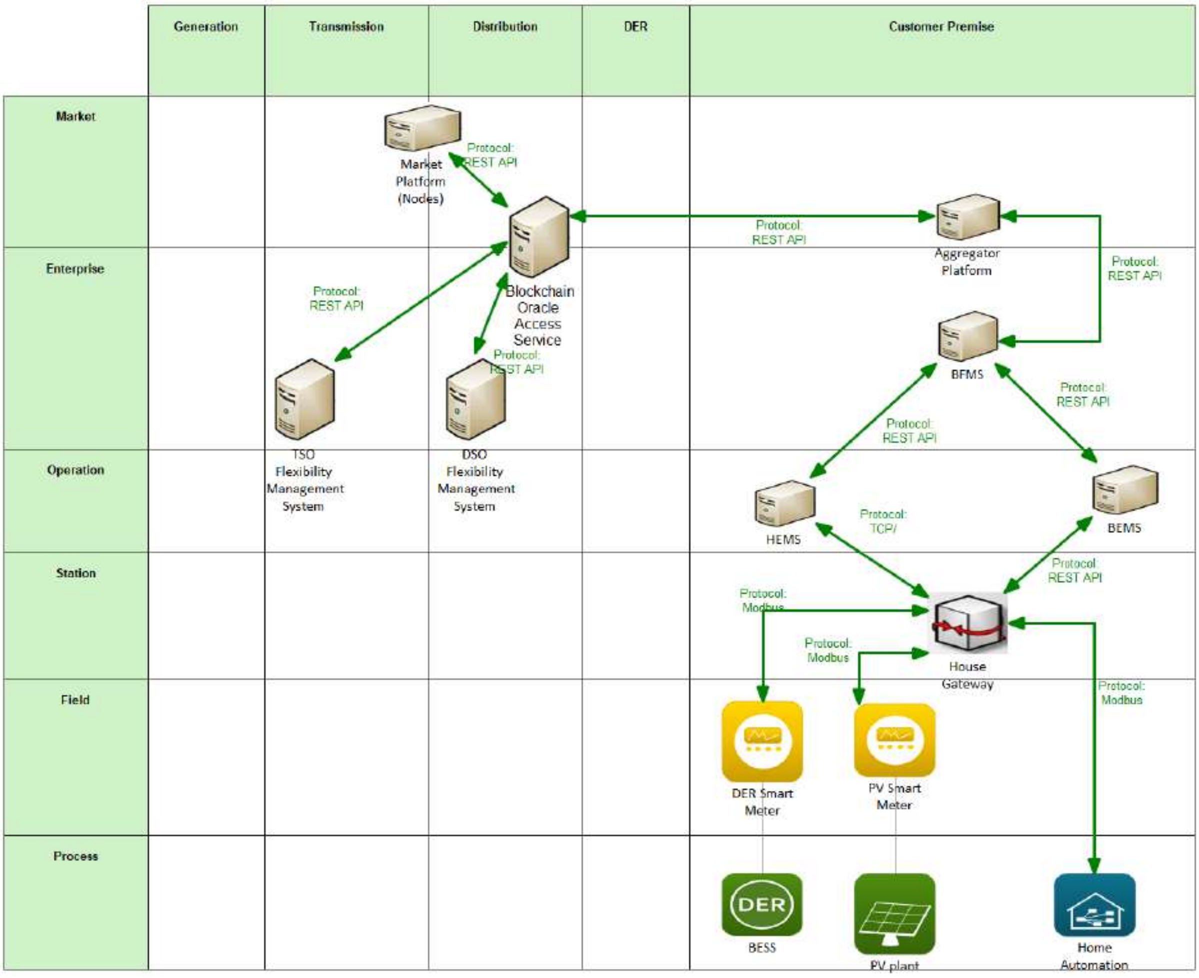

Figure 194. UC 1.10 second version Communication Layer

8.2.9 Component Layer

The components included in the use case are depicted below, including the technology used for connecting each other. The main difference here is the addition of blockchain access service (oracle) system.

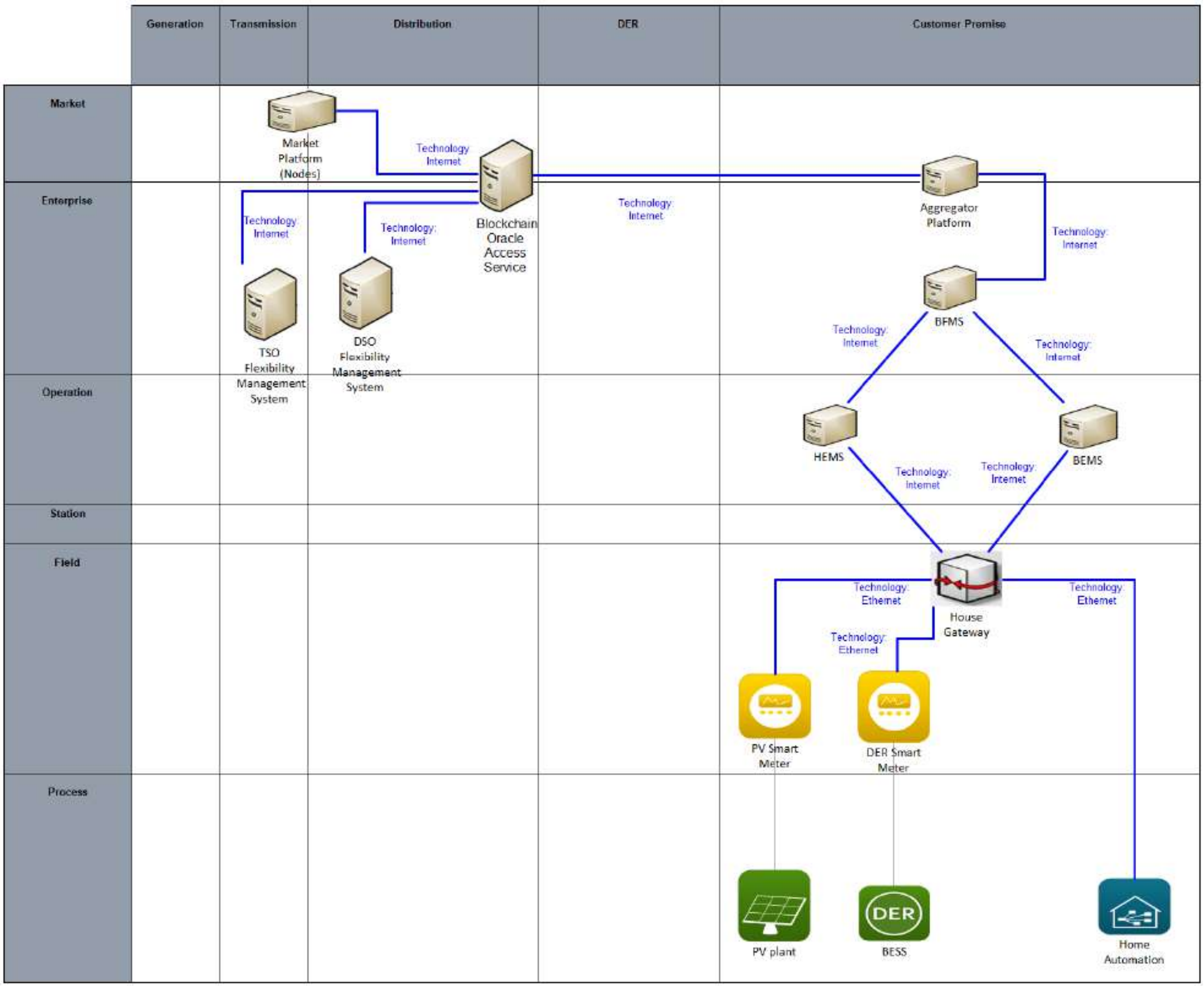

Figure 195. UC 1.10 second version Component Layer