CEN-CENELEC-ETSI Smart Grid Coordination Group

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SG-CG/M490/K_ SGAM usage and examples

SGAM User Manual -

Applying, testing & refining the Smart Grid Architecture Model (SGAM)

Version 3.0

Foreword

Based on the content of the M/490 EU mandate in its phase 1 (2011-2012), the general scope of work on standardization of the Smart Grid might be considered as follows:

> CEN, CENELEC, and ETSI are requested to develop a framework to enable European Standardization Organizations to perform continuous standard enhancement and development in the field of Smart Grids, while maintaining transverse consistency and promoting continuous innovation.

In the light of the discussions held in late 2012 between the EC Reference Group (EG1) and the Smart Grid Coordination Group (SG-CG), the need to iterate the EC Mandate M/490 was considered and agreed by both sides.

As a main objective of the mandate phase 2, the SG-CG wishes to implement the methodology developed in phase 1, which set the foundations for managing the continuous engineering and deployment of standards to ensure a real end-to-end interoperability for all generic use cases, explicitly including security.

A further refinement of the methodology will be used for the set of consistent standards [SG-CG/G] (under item 3.1 and 3.2 of M/490).

The work is based on [SG-CG/C] and [SG-CG/E].

A set of documents addresses this objective:

- The main report, which is a summary of different tools, elements and methodologies developed by the different working groups of the Smart Grid Coordination Group [SG-CG/F],

and additional separate reports detailing specific issues addressed by the working group “Methodology and New Applications”:

- The conceptual model and its relation to market models for Smart Grids [SG-CG/J]
- SGAM User Manual - Applying, testing & refining the Concepts, Elements and Tools for the Smart Grid Architecture Model (SGAM) [SG-CG/K] (this document)
- An overview of the main concepts of flexibility management [SG-CG/L]

For this report:

One of the key objectives of phase 2 of the mandate was to demonstrate the application of the SGAM methodology developed in phase 1, validating it by reference to use cases, systems and communications, and testing it by consideration of new use cases. In this way, the SGAM can be seen to represent the foundations for managing the continuous engineering and deployment of standards for all generic use cases, explicitly including security, and helping to ensure real end-to-end interoperability

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History of document

Number	Date	Content
V1.0	18/12/2013	For publication and review by the BTs and TCs.
V2.0	29/08/2014	Final for distribution to the SG-CG, commenting phase
V3.0	31/10/2014	Final version after commenting period in SG-CG and integrating of the received comments

1. Executive summary

This report seeks to present a 'user manual' demonstrating the application of the SGAM methodology developed in phase 1, validating it by reference to use cases, systems and communications, and testing it by considering new use cases in order to identify whether any adaptations are required to the SGAM. The SGAM is also related to systems and communications in order to show its application and value as a methodology.

At a general and strategic level, the user manual presented in this report confirms the value of the SGAM and the approach to mapping of use cases against the SGAM, illustrating how use cases can be considered and incorporated within the present SGAM framework. The analysis shows that the SGAM is a powerful, useful and robust tool. It also demonstrates the need for ready access to the use case repository and to the templates and examples of use case descriptions and shows the desirability of ready access to the detailed mapping tools used in presentation of the SGAM.

The new high-level use cases selected for consideration deal with the co-ordination of distributed generation and loads at neighborhood level based upon peer-to-peer communication between several Central Energy Management Systems and brokerage within a multi-agent system. The choice of such a "leading edge" use case was dictated by the desire to test the SGAM to the limits.

When the SGAM was applied to the selected new use cases, it was also clear that there is no lack of European standards for these two use cases. The main challenge presented by the possibility of peer-to-peer communications as envisaged relates to the market, industry, legal and regulatory framework for such activity. Member States and others wishing to develop the concept at national level are still exploring what arrangements would be required, and it may be necessary to review this preliminary conclusion in the light of such national use cases.

2. References

Smart Grid Coordination Group Phase 1 Documents

[SG-CG/A] SG-CG/M490/A Framework for Smart Grid Standardization

[SG-CG/B] SG-CG/M490/B_ Smart Grid First set of standards

[SG-CG/C] SG-CG/M490/C_ Smart Grid Reference Architecture

[SG-CG/D] SG-CG/M490/D_ Smart Grid Information Security

[SG-CG/E] SG-CG/M490/E_ Smart Grid Use Case Management Process

Smart Grid Coordination Group Phase 2 Documents

[SG-CG/F] SG-CG/M490/F_ Overview of SG-CG Methodologies

[SG-CG/G] SG-CG/M490/G_ Smart Grid Set of standards

[SG-CG/H] SG-CG/M490/H_ Smart Grid Information Security

[SG-CG/I] SG-CG/M490/I_ Smart Grid Interoperability

[SG-CG/J] SG-CG/M490/J_ General Market Model Development

[SG-CG/K] SG-CG/M490/K_ SGAM usage and examples (this document)

[SG-CG/L] SG-CG/M490/L_ Flexibility Management

Other references made in this report

[Cockburn]	"Writing Effective Use Cases", Alistair Cockburn, Addison-Wesley, 2001
[DPIA template]	Data Protection Impact Assessment Template
[EN 50438]	Requirements for micro-generating plants to be connected in parallel with public low-voltage distribution networks
[EN 50549-1]	Requirements for the connection of a generating plant to a distribution system - Part 1: Connection to a LV distribution system and above 16A (Draft)
[EN 50549-2]	Requirements for the connection of a generating plant to a distribution system - Part 2: Connection to a MV distribution system
[EnWG §52]	Energy Industry Act (Germany)
[GWAC:2008]	GridWise Interoperability Context-Setting Framework (March 2008), GridWise Architecture Council, online: www.gridwiseac.org
[IEC 60870-5-101]	Telecontrol equipment and systems - Part 5-101: Transmission protocols; Companion standard for basic telecontrol tasks
[IEC 60870-5-104]	Telecontrol equipment and systems - Part 5-104: Transmission protocols - Network access for IEC 60870-5-101 using standard transport profiles
[IEC 61131]	Programmable controllers
[IEC 61158]	Industrial communication networks - Fieldbus specifications
[IEC 61400-25-2]	Wind turbines - Part 25-2: Communications for monitoring and control of wind power plants - Information models
[IEC 61400-25-3]	Wind turbines - Part 25-3: Communications for monitoring and control of wind power plants - Information exchange models
[IEC 61400-25-4]	Wind turbines - Part 25-4: Communications for monitoring and control of wind power plants - Mapping to communication profile
[IEC 61499]	Function blocks
[IEC 61698]	Datasheets
[IEC 61784-1]	Industrial communication networks - Profiles - Part 1: Fieldbus profiles
[IEC 61850]	Communication networks and systems for power utility automation, 2010.
[IEC 61850-7-4]	Communication networks and systems for power utility automation - Part 7-4: Basic communication structure - Compatible logical node classes and data classes
[IEC 61850-7-410]	Communication networks and systems for power utility automation - Part 7-410: Basic communication structure - Hydroelectric power plants - Communication for monitoring and control
[IEC 61850-7-420]	Communication networks and systems for power utility automation - Part 7-420: Basic communication structure - Distributed energy resources logical nodes
[IEC 61850-8-1]	Communication networks and systems for power utility automation - Part 8-1: Specific communication service mapping (SCSM) - Mappings to MMS (ISO 9506-1 and ISO 9506-2) and to ISO/IEC 8802-3
[IEC 61850-8-2]	Part 8-2, Web service mapping
[IEC 61850-90-10]	Part 90, IEC 61850-10, Object models for schedules
[IEC 61850-90-11]	Part 90-11, Methodologies for modeling of logics for IEC 61850 based applications
[IEC 61850-90-15]	Part 90-15, Hierarchical DER system model
[IEC 61850-90-2]	part 90-2, Using IEC 61850 for SS-CC communication

[IEC 61850-90-7] IEC/TR 61850-90-7, Communication networks and systems for power utility automation - Part 90-7: Object models for power converters in distributed energy resources (DER) systems

[IEC 61850-90-9] Part 90-9, Object Models for Batteries

[IEC 61968] Application integration at electric utilities - System interfaces for distribution management

[IEC 61968-100] Application integration at electric utilities - System interfaces for distribution management - Part 100: Implementation Profiles

[IEC 61970] Energy management system application program interface (EMS-API)

[IEC 62056] Electricity metering data exchange - The DLMS/COSEM suite

[IEC 62264:2003] IEC 62262, Enterprise-control system integration

[IEC 62264-1] Enterprise system integration - Part 1: Models and terminology

[IEC 62351-3] IEC/TS 62351-3, Power systems management and associated information exchange - Data and communications security - Part 3: Communication network and system security - Profiles including TCP/IP

[IEC 62351-4] IEC/TS 62351-4, Power systems management and associated information exchange - Data and communication security - Part 4: Profiles including MMS

[IEC 62351-6] IEC/TS 62351-6, Power systems management and associated information exchange - Data and communication security - Part 6: Security for IEC 61850

[IEC 62351-8] IEC/TS 62351-8, Power systems management and associated information exchange - Data and communications security - Part 8: Role-based access control

[IEC/TR 62357:2003] IEC/TR 62357, Power system control and associated communications - Reference architecture for object models, services and protocols, 2003

[IEC/TR 62357:2012] Power systems management and associated information exchange - Part 1: Reference architecture

[IEC 62559-2] "Use case methodology – Part 2: Definition of the templates for use cases, actor list and requirements list", CDV, 2013

[IEC 62559-3] Use case methodology - Part 3: Definition of use case template artefacts into an XML serialized format

[IEC 62746] System-Schnittstelle zwischen Kunden-Energiemanagementsystemen und Energieversorgungsmanagementsystemen

[IEC 8/1356/NP] "Specific application of method & tools for defining Part 1 – Generic smart grid requirements", NP, 2014

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[NIST IR-7628] Guidelines for Smart Grid Cyber Security, www.nist.gov/smartgrid/upload/nistir-7628_total.pdf, 2010

[R&TTE] Radio and Telecommunications Terminal Equipment (R&TTE) 2014/53/EU (previous version 1999/5/EC).

[WGSP-0600, 2136, 2137] Use cases, refer to [SG-CG/E]

3. Terms and definitions

Refer to [SG-CG/F]

4. Symbols and abbreviations

AC	Altering Current
AES	Advanced Encryption Standard
AMI	Advanced Metering Infrastructure
AS	
BACS	Building Automation and Control System
BNetzA	German Federal Network Agency
BRP	Balance Responsible Party
BT	Technical Board
BUC	Business Use Case
CA	Certification Authority
CapEx	Capacity Expansion
CEM	Customer Energy Management
CEMS	Customer Energy Management System
CEN	Comité Européen de Normalisation
CENELEC	Comité Européen de Normalisation Electrotechnique
CFC	Continuous Function Chart
CIM	Common Information Model
COSEM	Companion Specification Energy Metering
CRL	Certificate revocation list
CSP	Concentrated Solar Power
DER	Distributed Energy Resources
DMS	Distribution Management System
DSO	Distribution System Operator
EC	European Commission
EDM	Energy Data Management
EMG	Energy Management Gateway
EMS	Energy Management System
ETSI	European Telecommunications Standard Institude
EV	electric vehicle
FACTS	Flexible Altering Current Transmission System
FEP	Features, Events and Processes
FLIR	Forward looking infrared
FTP	File Transfer Protocol
GUC	Generic Use Case
HRM	Harmonized Role Model
HES	Hypertext Editing System
HL-UC	High Level Use Cases
HTTP	Hypertext Transfer Protocol
HTTPS	Hypertext Transfer Protocol Secure
HV/MV	High Voltage / Medium Voltage
HVAC	Heating, Ventilation and Air Conditioning
HVDC	High-Voltage Direct Current
HW/SW	Hardware/ Software

IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronics Engineers
IETF	Internet Engineering Task Force
IP	Internet Protocol
LDAP	Lightweight Directory Access Protocol
LV	Low Voltage
MDM	Meter Data Management
MID	Measuring instruments directive (EC)
MMS	Manufacturing Messaging Specification
MV	Medium Voltage
NIST	National Institute of Standards and Technology
NNAP	Network Access Point
OCSP	Online Certificate Status Protocol
OMS	Outage Management System
OpEx	Operation Expenses
OSI	Open Systems Interconnect
PAS	Publicly Available Specification
PKI	Public Key Infrastructure
PUC	Primary Use Case
QoS	Quality of Service
RBAC	Role Based Access Conrol
RDF	Resource Description Framework
RTU	Remote Terminal Unit
PV	Photovoltaic
SAIDI	System Average Interruption Duration Index
SAIFI	System Average Interruption Frequency Index
SCADA	Supervisory Control and Data Acquisition
SGAM	Smart Grid Architecture Model
SG-CG	Smart Grid Coordination Group
SG-CG/Meth	SG-CG "Methodology and New Applications" Working Group
SG-CG/SP	SG-CG "Sustainable Process" Working Group (in phase 1)
SGIS	Smart Grid Information Security
SIP	Session Initiation Protocol
SOAP	Simple Object Access Protocol
SP	Sustainable Processes
SSH	Secure Shell
TC	Technical Committee
TCP	Transmission Control Protocol
TLS	Transport Layer Security
TOGAF	The Open Group Architecture Framework
UC	Use Case
UDP	User Datagram Protocol
UML	Unified Modeling Language
VAr	Unit of reactive power
VPN	Virtual Private Network
VPP	Virtual Power Plant
WAMS	Wide Area Monitoring protection and control Systems
WAN	Wide Area Network
WG	Working Groups
XML	Extensible Markup Language

5. SGAM: Smart Grids Architecture Model description

5.1 Introduction

The Smart Grid Architecture Model (SGAM) [SG-CG/C] is a reference model to analyse and visualise smart grid use cases in a technology-neutral manner. Furthermore, it supports comparison of different approaches to Smart Grid solutions so that differences and commonalities between various paradigms, roadmaps, and viewpoints can be identified. By supporting the principles of universality, localization, consistency, flexibility and interoperability, it also provides a systematic approach to cope with the complexity of smart grids, allowing a representation of the current state of implementations in the electrical grid as well as the evolution to future smart grid scenarios.

The SGAM builds on proven approaches from power systems as well as interdisciplinary fields like systems engineering and combines them in a simple but comprehensive model. The work on the SGAM is specifically based on significant existing material such as the NIST Conceptual Model [NIST 2009], the GridWise Architecture Council Stack interoperability categories [GWAC 2008], the IntelliGrid Methodology [IEC PAS 62559:2008-01], the European Conceptual Model and architecture standards like TOGAF and Archimate [Jonkers 2010, refer also to http://pubs.opengroup.org/architecture/togaf9-doc/arch/ and http://pubs.opengroup.org/architecture/archimate2-doc/].

The SGAM can be used in standardization and more widely:

- to enable a structured analysis of Smart Grid use cases,
- to visualize and compare different approaches to Smart Grid architectures, paradigms, roadmaps and viewpoints,
- to provide a guide to analyze potential implementation scenarios,
- to ensure a common understanding between different stakeholders,
- to identify standards and standardization gaps,
- to visualize the scope of Smart Grid projects,
- and in summary, to cope with the complexity of Smart Grids.

It is important to qualify the main purpose of the SGAM as follows:

- the SGAM does not necessarily improve a proven architecture for a single domain or zone but shows it full strength modeling interactions between domains & zones,
- the SGAM supports the derivation of system requirements but does not replace a detailed requirements specification,
- the SGAM does not replace a detailed development specification,
- the SGAM focuses on the architecture and does not model in detail the power system in the process zone, e.g. effects of harmonics, voltage sags etc.,
- the SGAM does not replace detailed specifications on safety regulations or operational conditions.

The SGAM is outlined in detail in the remaining part of this section.

5.2 SGAM Smart Grid Plane

Power system management distinguishes between electrical process and information management. These viewpoints can be partitioned into the physical domains of the electrical energy conversion chain and the hierarchical zones for management of the electrical process (refer to [IEC 62357-1:2012, IEC 62264:2003]). The *Smart Grid Plane* spans in one dimension the complete electrical energy conversion chain, partitioned into five domains: (Bulk) Generation, Transmission, Distribution, DER and Customer Premises. And in the other dimension the hierarchical levels of power system management, partitioned into six zones: Process, Field, Station, Operation, Enterprise and Market. This smart grid plane enables the representation of the zones in which power system management interactions between domains or inside a single domain take place.

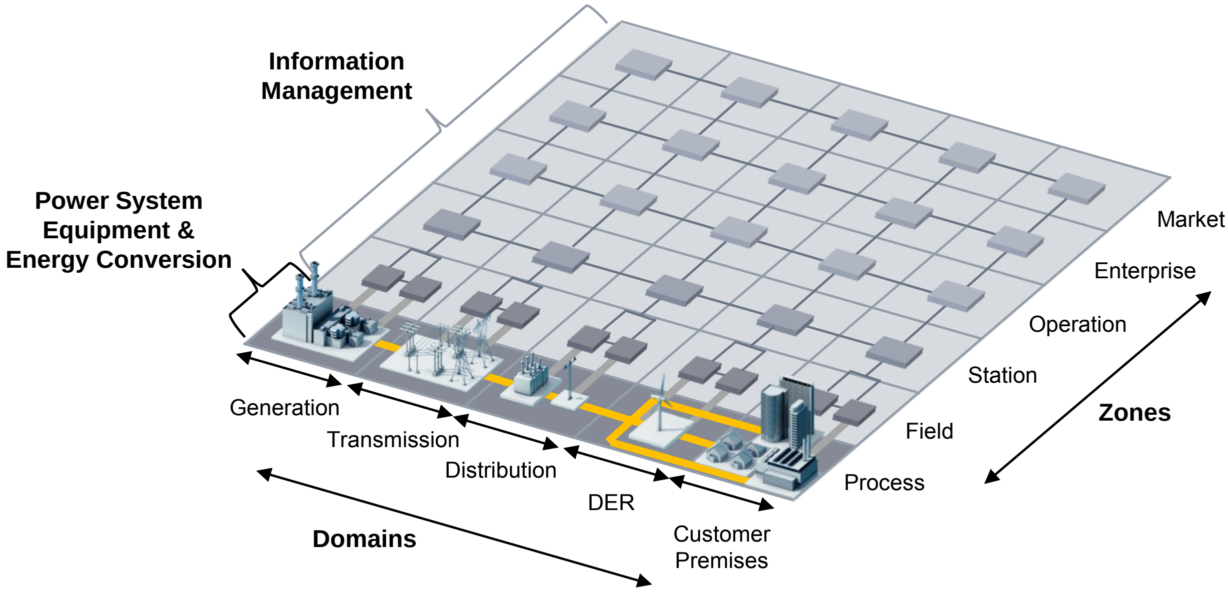


Figure 1: Smart Grid Plane – Domains & zones of SGAM

The domains are physically related to the electrical grid ((Bulk-) Generation, Transmission, Distribution, DER, Customer Premises) and they are arranged according to the electrical energy conversion chain. The conceptual domains Operations and Market[1] are part of the information management and represent specific hierarchical zones.

The *Smart Grid Plane* covers the complete electrical energy conversion chain. This includes the domains listed in Table 1.

Table 1: SGAM domains

Domain	Description
(Bulk) Generation	Representing generation of electrical energy in bulk quantities typically connected to the transmission system, such as by fossil, nuclear and hydro power plants, off-shore wind farms, large scale solar power plant (i.e. PV, CSP).
Transmission	Representing the infrastructure which transports electricity over long distances.
Distribution	Representing the infrastructure which distributes electricity to customers.
DER	Representing distributed electrical resources directly connected to the public distribution grid, applying small-scale power generation and consumption technologies (typically in the range of 3 kW to 10,000 kW). These distributed electrical resources may be directly controlled by e.g. a TSO, DSO, an aggregator or Balance Responsible Party (BRP).
Customer Premises	Hosting both end users of electricity and also local producers of electricity. The premises include industrial, commercial and home facilities (e.g. chemical plants, airports, harbors, shopping centers, homes). Also generation in form of e.g. photovoltaic generation, electric vehicles storage, batteries, micro turbines.

[1] Refer to the conceptual model explained in [SG-CG/F] and more detailed in [SG-CG/J]

Although the domains DER and Customer Premises can include generation, the domains are separated from each other. The DER domain includes any kind of distributed energy resources or related processes, having as primary business goals the objective of contributing to the electricity grid as production and/or storage and/or any types of ancillary services. The Customer Premises domain on the other hand includes any kind of processes not having the primary business objective of contributing to the electricity grid (but using the grid as one energy source), such as home management processes, or building or industry management processes, or e-mobility systems.

The SGAM zones represent the hierarchical levels of power system management [IEC 62357-1:2012]. These zones reflect a hierarchical model that considers the concept of aggregation and functional separation in power system management. The basic idea of this hierarchical model is laid down in the Purdue Reference Model for computer-integrated manufacturing that was adopted by the IEC 62264-1 standard for “enterprise-control system integration” [IEC 62264-1:2003]. This model was also applied to power system management. This is described in IEC 62357 “Reference architecture for object models services” [IEC/TR 62357:2003, IEC/TR 62357-1:2012].

The concept of aggregation considers multiple aspects in power system management:

- Data aggregation – data from the field zone is usually aggregated or concentrated in the station zone in order to reduce the amount of data to be communicated and processed in the operation zone.
- Spatial aggregation – from distinct location to wider area (e.g. HV/MV power system equipment is usually arranged in bays, with several bays forming a substation; multiple DER form a plant station, and DER meters in customer premises are aggregated by concentrators for a neighborhood).

In addition to aggregation, the partitioning in zones follows the concept of functional separation. Different functions are assigned to specific zones. The reason for this assignment is typically the specific nature of functions, but also reflects user philosophies. Real-time functions are typically in the field and station zones (protection, phasor-measurement, automation…). Functions that cover an area, multiple substations or plants, or city districts are usually located in the operation zone (e.g. wide area monitoring, generation scheduling, load management, balancing, area power system supervision and control, meter data management…). The SGAM zones are described in Table 2.

Table 2: SGAM zones

Zone	Description
Process	Including the physical, chemical or spatial transformations of energy (electricity, solar, heat, water, wind …) and the physical equipment directly involved (e.g. generators, transformers, circuit breakers, overhead lines, cables, electrical loads, any kind of sensors and actuators which are part or directly connected to the process,…).
Field	Including equipment to protect, control and monitor the process of the power system, e.g. protection relays, bay controller, any kind of intelligent electronic devices which acquire and use process data from the power system.
Station	Representing the areal aggregation level for field level, e.g. for data concentration, functional aggregation, substation automation, local SCADA systems, plant supervision…
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, microgrid management systems, virtual power plant management systems (aggregating several DER), electric vehicle (EV) fleet charging management systems.
Enterprise	Including commercial and organizational processes, services and infrastructures for enterprises (utilities, service providers, energy traders …), e.g. asset management, logistics, work force management, staff training, customer relation management, billing

Zone	Description
	and procurement…
Market	Reflecting the market operations possible along the energy conversion chain, e.g. energy trading, retail market.

In general, organizations can have actors in several domains and zones. The areas of the activity of these actors can be shown in the smart grid plane. E.g. for the business area of a transmission utility it is likely that the utility covers all segments of the transmission domain, from process to market, whereas a service provider offering weather forecast information for distribution system and DER operators could be located to the market zone interacting with the operation zone in the distribution and DER domains.

5.3 SGAM interoperability layers

For interoperability between systems or components, the SGAM consists of five layers representing business objectives and processes, functions, information exchange and models, communication protocols and components. These five interoperability layers represent an abstract and condensed version of the interoperability categories introduced by the GridWise Architecture Council [GWAC2008].

Table 3: SGAM layers

Layer	Description
Business	The business layer represents the business view on the information exchange related to smart grids. SGAM can be used to map regulatory and economic (market) structures (using harmonized roles and responsibilities) and policies, business models and use cases, business portfolios (products & services) of market parties involved. Also business capabilities, use cases and business processes can be represented in this layer.
Function	The function layer describes system use cases, 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 that is independent from actors.
Information	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	The emphasis 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	The emphasis of the component layer is the physical distribution of all participating components in the smart grid context. This includes system & device actors, power system equipment (typically located at process and field level), protection and tele-control devices, network infrastructure (wired / wireless communication connections, routers, switches, servers) and any kind of computers.

Each layer covers the whole smart grid plane, which is spanned by electrical domains and information management zones.

5.4 SGAM framework

The SGAM framework is established by merging the concept of the interoperability layers with the previous introduced smart grid plane. This merging results in a model that spans three dimensions:

- SGAM domains
- Zones
- Interoperability layers

The complete three-dimensional representation of SGAM is depicted in Figure 2.

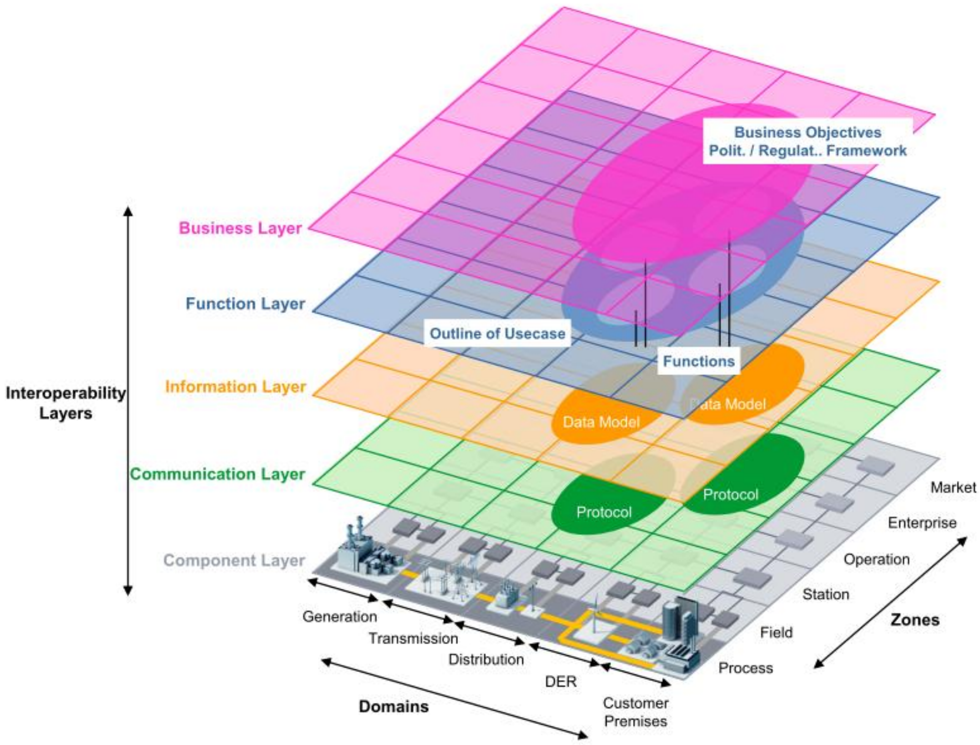


Figure 2: SGAM – Smart Grid Architecture Model

Using the SGAM, Smart Grid use cases can be visualized and detailed and mapped to the layers of the model to test if a use case is supported by existing standards or to identify gaps in standardization. A use case analysis with the SGAM is based on the use case description. The different fields in the use case template provide the information for the analysis, e.g. the field *Domain(s)/Zone(s)* specifies directly how the use case maps onto the Smart Grid Plane. Furthermore, the actor list in the use case description provides - depending on the type of the actor - information on the roles involved to model the business layer in SGAM or information on the systems and devices involved to model the component layer.

Use case descriptions vary in their level of abstraction as well as in design scope as described in detail in chapter 6.2.1. Thus, analysis with SGAM also varies as described in the following section.

5.5 SGAM levels of abstraction

This section provides an overview for each interoperability layer in the SGAM on different levels of abstraction on which an SGAM analysis can be applied. These SGAM analysis patterns are intended to provide guidance on how to model with the SGAM on a level of abstraction chosen, starting from a concept up to a detailed level required for implementation. There can be different abstraction levels defined for each layer. Ideally a fixed number of abstraction levels is defined per SGAM layer including respective concepts that are relevant in a specific SGAM development iteration. In addition to that, there could also be interrelations between the abstraction levels on different layers. However, generally the number of abstraction levels depends on the purpose of the modelling effort/project and interrelations between abstraction levels must not necessarily exist.

An overview of exemplary abstraction levels is given in Figure 3. Each layer therein depicts some concepts (examples) used in steps of successive model refinements that can be carried out on the respective interoperability layer. The identification may then finally support a definition of interoperability requirements. The abstraction levels on different layers depicted in Figure 3 do not necessarily relate to abstraction levels on the same level of abstraction on other layers.

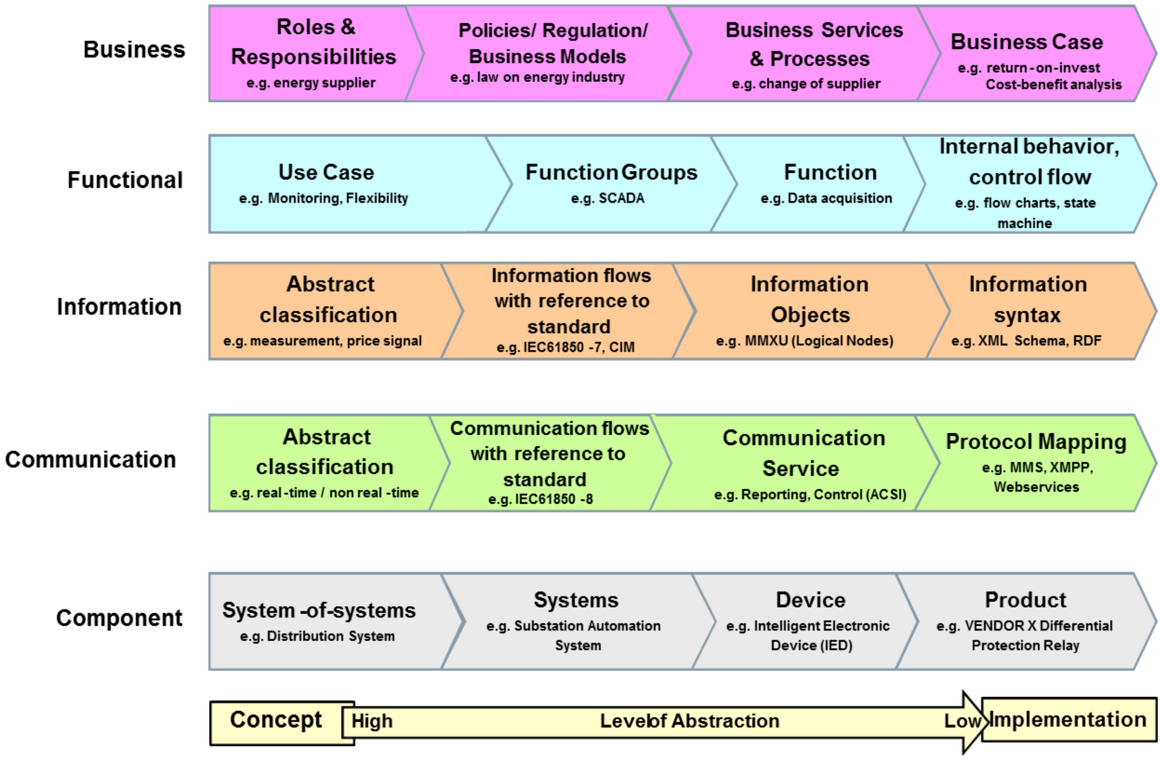


Figure 3: Exemplary categorization of different abstraction levels per SGAM layer (SGAM analysis pattern)

6 The SGAM and use cases

6.1 Overview

The SGAM analysis patterns can also support the writing of use case descriptions, by providing sufficient information needed for a SGAM analysis at the chosen level of detail. For example, on the business layer we can start with a use case concept (e.g. the concept of demand and generation flexibility for technical and commercial operations as described in [SG-CG/E]). This concept can be augmented by identifying the roles and their responsibilities on the business layer (e.g. customer, supplier and aggregator). Based on a high level use case the ‘system-of-systems’ involved (e.g. distribution system, marketplaces and smart buildings) can also be defined on the component layer. Additionally, abstract classifications on the information layer (e.g. price signals, incentives, control signals and measurements) and communication layer (e.g. real-time or non-real-time requirements) are possible.

However, to derive the next level of detail we need further information from the use case description. For example, for the business layer the use case should also outline the business models including policies and regulations for the roles involved. Subsequently, the business services and processes can be specified, based on a step-by-step analysis.

The other layers from function to component provide more a technical view of system use cases. The use case concept can be detailed on the function layer by defining function groups, functions and their internal behavior e.g. as flow charts. Similarly, on the information and communication layer we can derive further details by identifying the information & communication flows between the function groups and provide references to standards that could be applied (see [SG-CG/B] for examples). This gives a first indication which standards are relevant for the particular use case and which experts need to be involved in the detailed analysis of the use case. In the next step the experts define the information objects exchanged on the information layer and the communication services required on the communication layer. By identifying these details for the use case under discussion we derive profiles for the information and communication layers for the particular use case. Subsequently, by harmonizing the results from several use case descriptions we can derive more complete profile descriptions. This detailing is followed by the definition of the information syntax and the mapping on protocols for the information and communication layers respectively. On the component layer we can identify the systems involved and in the following step of detailing the devices also.

The SGAM framework and the analysis pattern presented are not only valid for standardization activities but can be used in general as a methodology for Smart Grid projects. Hence, although it is beyond the scope of the SG-CG we indicate in Figure 3 that the detailed level of abstraction can also include products on the component layer and a business case on the business layer for the stakeholders concerned.

Figure 4 outlines the mapping of parts of an exemplary use case (WGSP 2136) to concepts on the different SGAM interoperability layers. Beyond concepts being related to concepts on the same layer (like components can be physically connected to other components or functions interacting with other functions, or business processes are performed by roles) interrelations between concepts on different layers exist. In Figure 4 for instance it is illustrated that certain elements from the component layer "support" data models (as concepts from the information layer) or communication protocols (as concepts from the communication layer). Also realization relationships are depicted: A business process (as concept from the business layer) is realized by (technical) functions (of the function layer) and the latter ones are realized by physical elements depicted on the component layer (systems).

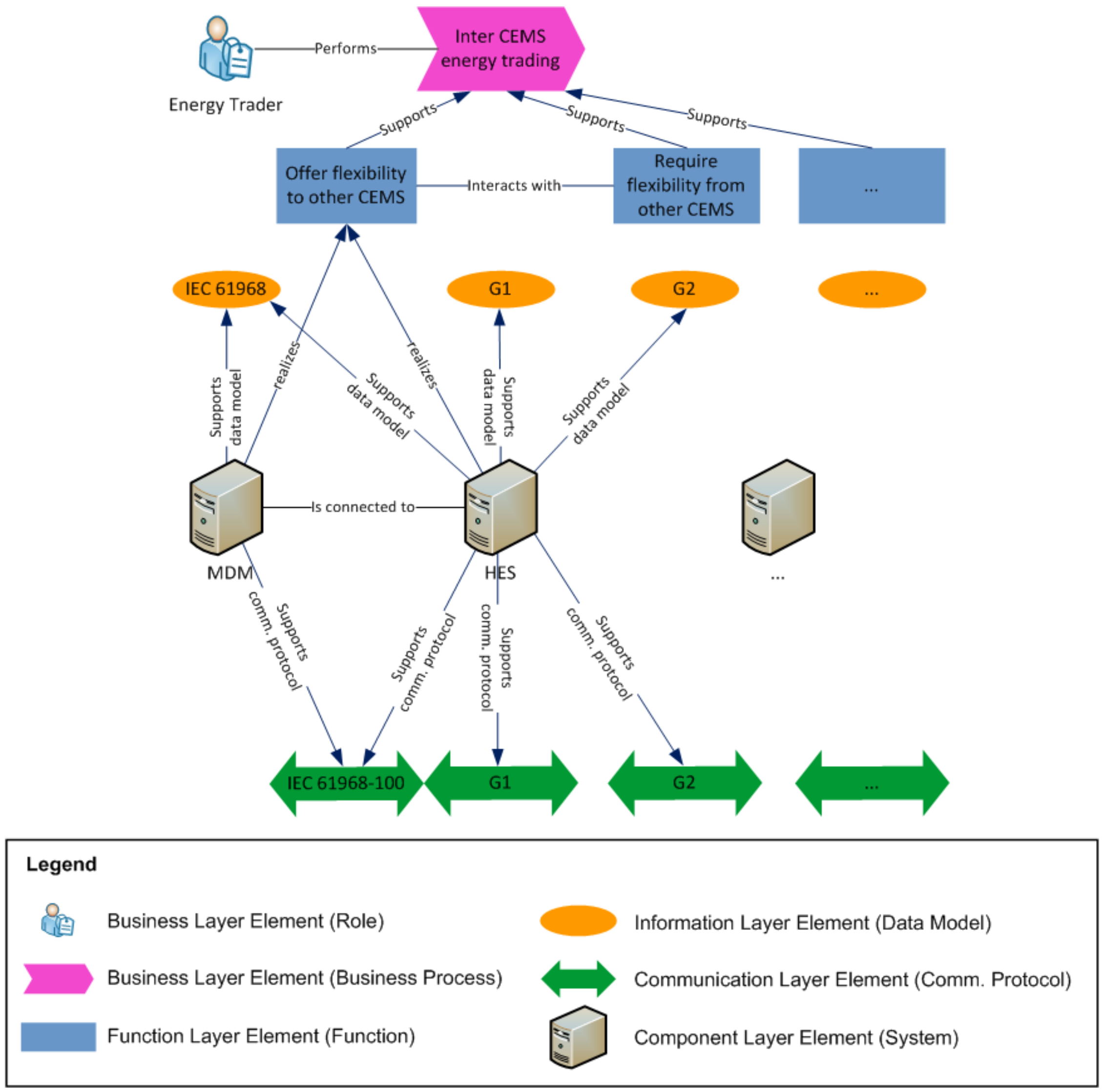


Figure 4: Example of interrelationships between concepts on different levels in an SGAM model (for details refer to Appendix A)

6.2 Use case analysis with SGAM

6.2.1 Classification of use case design scope

Use cases are a well-proven approach in systems engineering and used worldwide to derive a common understanding for Smart Grids. Despite (or because of) the large set of use cases available in different databases, the level of granularity differs widely in these use case descriptions. We use a simple classification for the design and scope of use cases to map the different types of use cases to the SGAM analysis pattern introduced in the previous section. We differentiate between use case concepts (or high-level use cases), business use cases and device/system use cases.

Use case concepts describe a general idea by defining the roles involved and sketching their responsibilities but not the underlying business models or processes. The target audience is system engineers, business developers, regulators and key experts in standardization having a very good overview on the whole Smart Grid landscape. Conceptual business requirements are refined in one or several business use cases written by business architects or regulators which describe them within an enterprise scope (i.e. the operation of businesses) and the interaction between different roles, e.g. to contract or negotiate services. In the next step of refinement the technical view is added by specifying one or multiple device/system use cases to realize the goal of a business use case. For these technical use cases we can define the device/system boundaries. Requirements for HW/SW engineers describe the interactions between the system(s) and external actors (i.e. other systems/devices).

The following figure as well as following table clarifies the use case classification for the design scope in further detail. We would note that this classification of the use case design scope is complementary to the level of abstraction of the use case description outlined in clause 5.. Each use case type can be described additionally with different levels of abstraction. As outlined in [Cockburn], the key difference between the classification of design scope and the level of abstraction for use case descriptions is that

- the design scope defines the boundary box of the use case, i.e. “what is in?”, ”what is out?” for the system under design.
- the level of abstraction refers to the details in describing the objective of the use case.

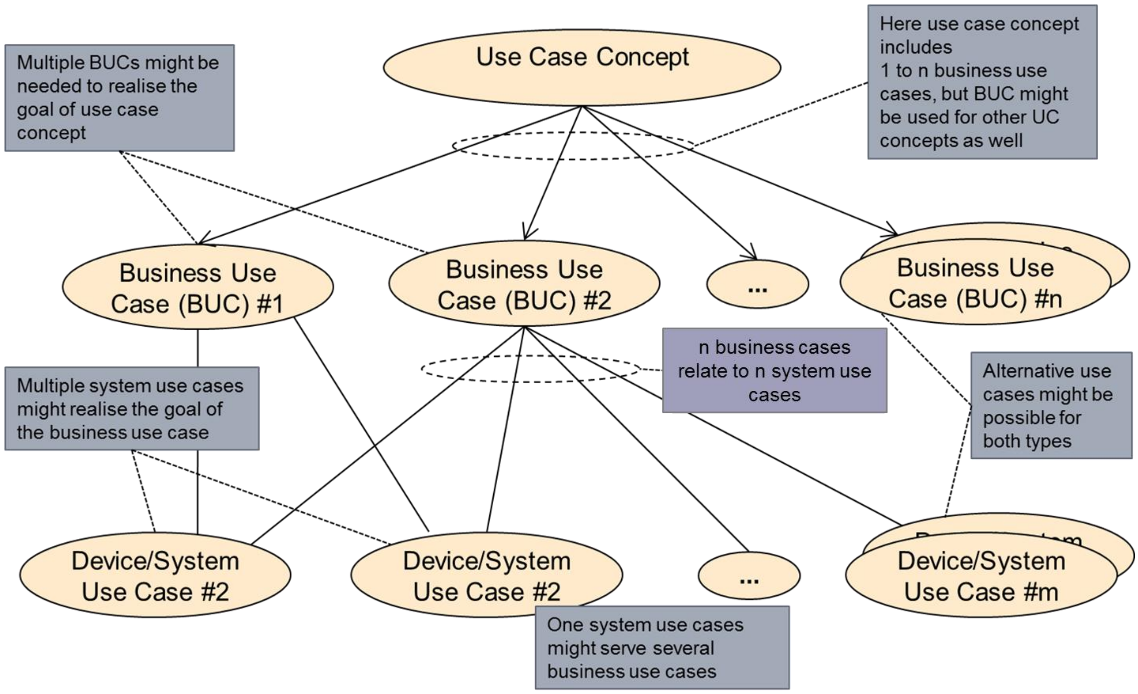


Figure 5: Classification of use case design scope

Because use case descriptions support various tasks, the granularity, type and content of the use case description vary widely. In general a use case describes the functions of a system and related information exchange, mainly in a technology-neutral way (depending on the level of detail). It identifies participating actors that for instance can be other systems or human actors which are linked to the particular use case.

In the following, various use case types are classified highlighting different views and task of the respective use cases, e.g.:

- Level of detail (see Figure 6 below): for brainstorming / collection (cluster, high level use cases, conceptual description), engineering or testing;
- Nature of the use case: Business (business use case) or technical (system use case)[2];
- Users of the use case: Project (Individual use cases), technology group (specialized use cases), standardization (generic use cases)

[2] or even political / legislative use cases might be possible.

- Geographical view: national, regional or international use cases
- Maturity of the use case (e.g. vision, R&D or near to real implementation)

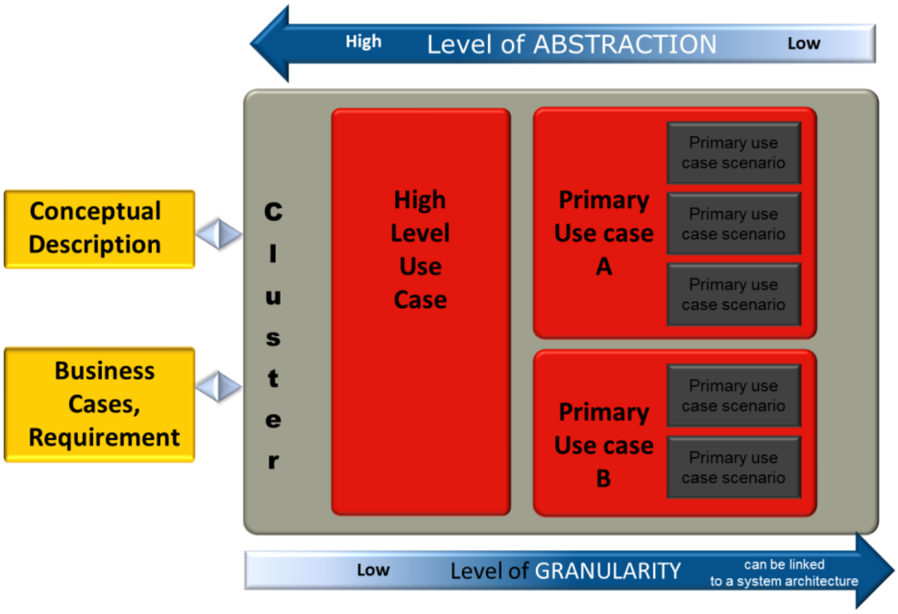


Figure 6: Use case structure (based on SM-CG)

Therefore the following list describes those different characteristics of use cases :

Table 4: Types of use cases

Types of use cases	Description
Conceptual description / Use case concept / User stories	A conceptual description describes a general idea or concept, provides an overview or background for a cluster of use cases and does not use necessarily the use case template. The conceptual description reflects the iterative work of describing different use cases, analyzing them, detailing them further and linking them to architectures, actors and systems. It may defines the roles involved and sketches their responsibilities (possibly with alternatives, incl. their security impact for the use case) but not the underlying business model or process. EXAMPLE: flexibility concept.
Use Case cluster	A use case cluster represents a group of use cases. EXAMPLE: Smart Charging
High level use case	A high-level use case (HL-UC) describes the general idea of a function together with generic actors. The HL-UC can be realized in different ways, so the HL-UC cannot be mapped to a specific system or architecture. Example: Fault Location, Isolation, Restoration (FLIR) in general.
Business use case[3]	Business Use Cases describe business processes that the actors of a given system must and may execute. These processes are derived from roles which have been previously identified and defined (-> Business Layer of SGAM) [based on IEC 8/1356/NP]. There is no technical view.

[3] Depending on the level of detail and purpose of the use case this might be a conceptual description, a user story, a high level use case

Types of use cases	Description
System use case[4] *(Technical or device use case)*	System Use Cases describe the Smart Grid functions required to enable / facilitate the business processes described in Business Use Cases. Their purpose is to detail the execution of those processes from an information system perspective (-> Function Layer of SGAM) [based on IEC 8/1356/NP] . Here device or system boundaries can be defined and interactions between the system(s) and external actors (i.e. other systems/devices) to fulfil a goal for the actor(s) can be described.
Primary use case	A primary use case (PUC) is a use case implemented in a specific system characterized by a defined boundary (i.e. it can be mapped on a defined architecture). This means that a higher-level abstract use case might be broken down into one or more implementation possibilities, called specializations. These use cases can be mapped to a proposed architecture (SGAM). EXAMPLE: Different FLIR use cases implementing the basic functionality within a central or decentralized architecture or which are related to different network topologies.
Scenarios (in the template)	Scenarios define different routes within one UC according to different trigger signals (within the template). EXAMPLE: Scenarios describing normal, alternative or error sequences
Steps (in the template)	Steps are used to describe activities within a scenario in a sequential order (refer to the step-by-step analysis of the use case template).
Secondary use case	A secondary use case is used to describe core functionalities that are used by multiple PUCs.
Specialized use case	A specialized use case is a UC, which is already describing specific technologies like a specific protocol (e.g. FLIR with a protocol defined by IEC 61850 or flexibility use cases within a house using one or more home automation standards).
Generic use case (GUC)	Use cases will be called generic when their description is broadly accepted in standardization and not project or technology specific. They should address the various possible approaches and answer the request for use case harmonization, which means that duplicate use cases should be avoided. The GUC can be used for further work inside standardization (e.g. mapping to architecture, development of standards or test use cases). GUC might be described on a high or more detailed level implying different systems design scope.
Individual use case	In real projects, a company might subsequently combine generic use cases, developing them further and including their own individual, company-specific use cases that belong to its knowledge base and its business cases.
Test use cases	Test use cases are developed based on the use cases in order to test interoperability, functions and processes.

6.2.2 Relation of use case design scope to SGAM analysis pattern

We introduced in the previous sections the SGAM analysis pattern and a classification for the use case design scope. Figure 7 shows how most of the concepts can roughly relate to each other.

[4] Depending on the level of detail and purpose of the use case this might be a generic, specialized, individual, primary, or secondary use case

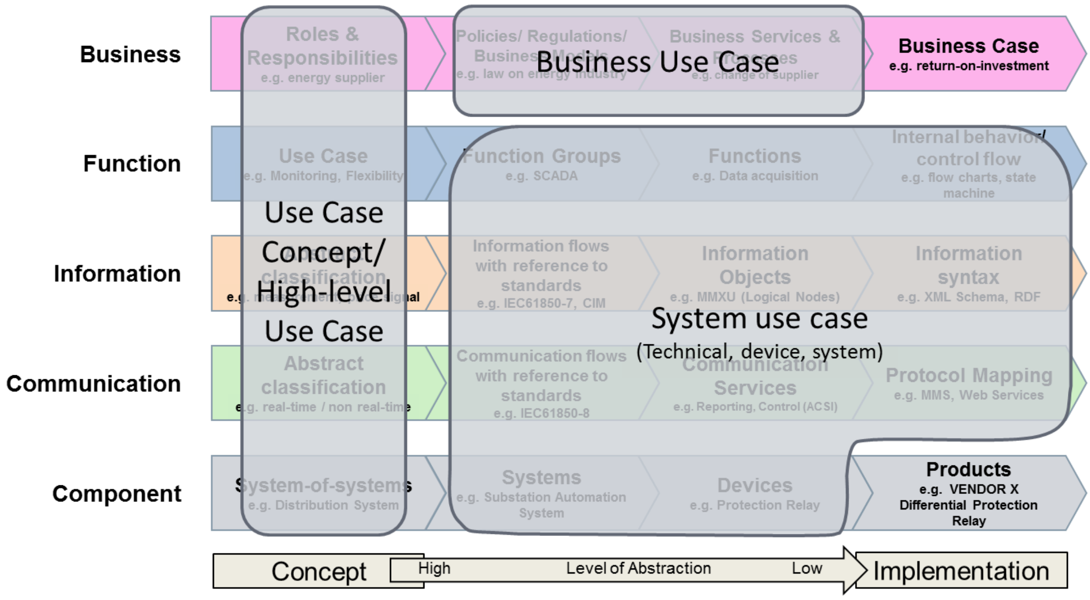


Figure 7: Relation of design-scope use case classifications with SGAM analysis pattern

Use Case Concepts (or High-level Use Cases) describe the conceptual model of a use case. This may include information on all SGAM layers at a high level of abstraction. Business Use Cases and Device/System Use Cases can be used to detail the use case concept.

Business use cases describe the SGAM business layer. Based on the roles involved and their responsibilities, relevant policies and regulations as well as business models should be identified. In a further step of detailing, the business service(s) and process(es) should be described.

The technical view of the use case is provided in the system use case description, including details on the function, information, communication and component layer of SGAM on different levels of abstraction.

Details on products and business cases are excluded from the use case description as depicted in the figure because they are specific to the company-internal strategy. Nevertheless, they might be relevant for real-world use cases projects.

6.2.3 Relation of use case template with SGAM analysis pattern

Use case templates provide a uniform way to document use case descriptions. Based on IEC PAS “Intelligrid Methodology for developing Requirements for Energy Systems”, the SG-CG/SP ("Sustainable Processes" WG) provided a use case template in the three versions *short*, *general* and *detailed* as examples. The short version included only a small number of fields and provides simple way to document use cases. The general version included e.g. additional fields on the relation to other use cases, the nature of the use case and scope & objective. Later, the detailed version included a step-by-step analysis by which exchanged information and requirements can be identified. The use case template is also explained in detail [IEC 62559-2], which also allows the definition of further versions of the template on individual demand. However, it is recommended that the definitions for the use of the fields in the template are followed.

These use case templates with different level of detail fit to the SGAM analysis pattern as depicted in Figure 8. Selected fields of the templates are listed in the figure. A use case description should provide enough information in these fields to describe the relevant level of abstraction for the SGAM layer(s). Additional fields for the management of the use case apply to all three templates and are added at the bottom of the figure.

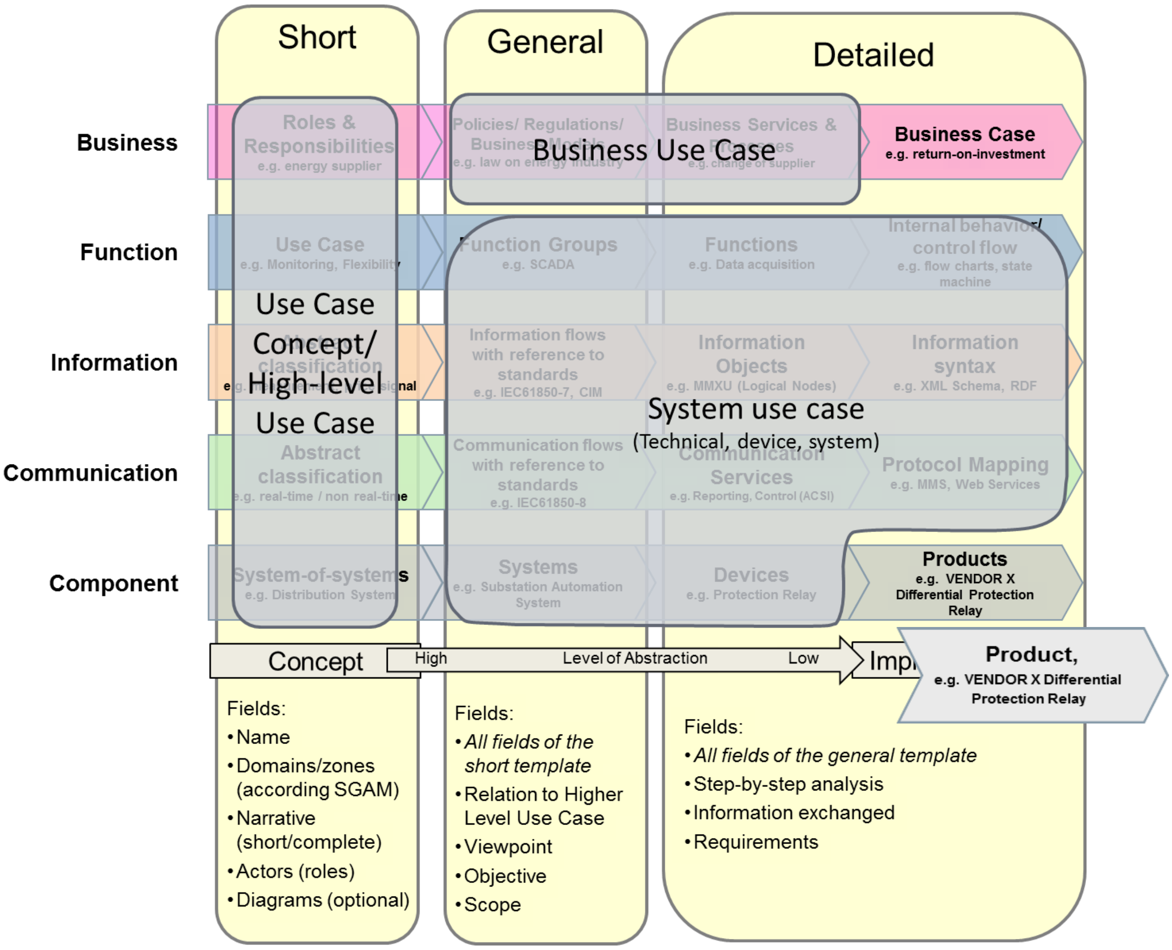


Figure 8: Relation of use case templates with SGAM analysis pattern

The short template can be used to document use case concepts. Most of the information is provided in the narrative of the use case supported by diagrams. Actors and roles can be extracted from the narrative. Furthermore, the use case can be mapped on the SGAM Smart Grid Plane to identify affected domains and zones.

The general and detailed templates can be used for both, business as well as system use cases. However, the nature of the use case should not be mixed in a single use case description; two separate documents should be created and linked to each other and the related use case concept. The business or technical orientation of the use case description can be defined in the field *nature of the use case*. For a business use case, actors are specified as roles as opposed to technical use case where actors are devices and/or systems. The fields on objective and scope should provide further information on system boundaries that, projected on all layers, may provide a reference for definition of interfaces and standards supporting the use case.

The detailed template includes a step-by-step analysis that is necessary to derive a detailed understanding of the use case. For the business layer the step-by-step analysis can be used to define the related business process(es) for the business use cases. For system use cases the step-by-step analysis provides details of the information exchanged, requirements at the communication layer, and non-functional requirements.

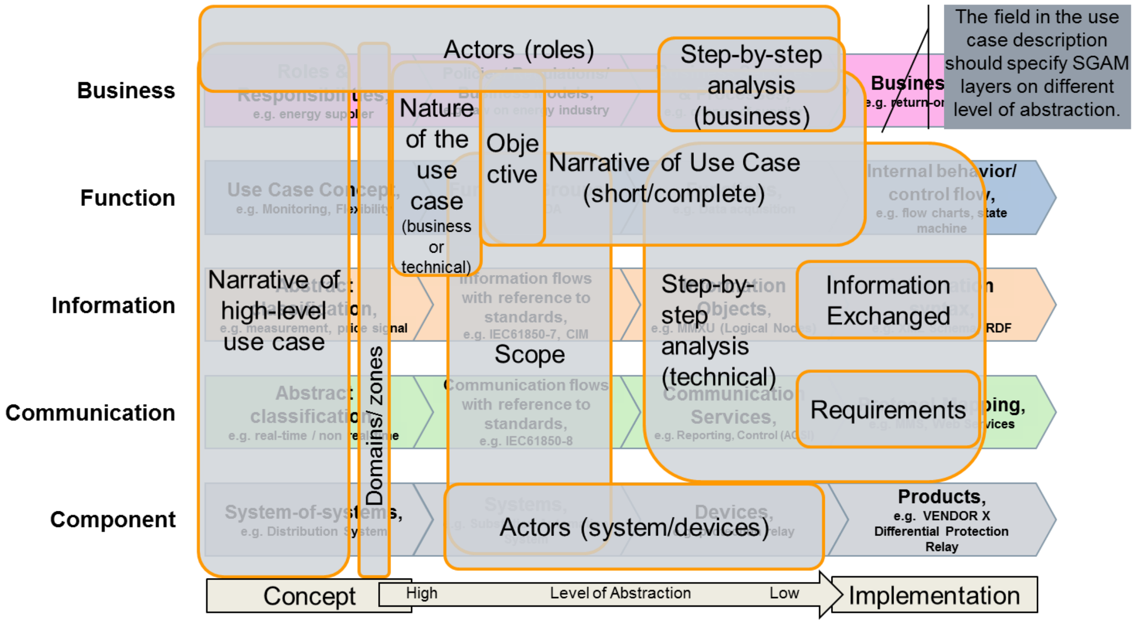


Figure 9: Mapping of fields in the use case templates to SGAM analysis pattern[5] - example

The mapping of some fields from the use case templates to SGAM analysis pattern is shown in Figure 9 depicting how information contained in use case descriptions can help to define interoperability requirements at each interoperability layer. Only those fields from the templates which provide information for the SGAM analysis are shown. These fields should specify SGAM layers on different levels of abstraction.

6.3 Relation of security requirements with SGAM layer abstraction

As depicted in the figure below, high level security requirements based on use cases have to be defined. These high level security requirements are based on a determination of the risk level and lead to the required security level. This approach is part of the SGIS concept [SG-CG/D].

[5] Please, note that this actor definition refers to the use case template [IEC 62559-2] and is slightly different from the actor / role definition used with the conceptual meta-model and role concept of the HEM-RM described in [SG-CG/J].

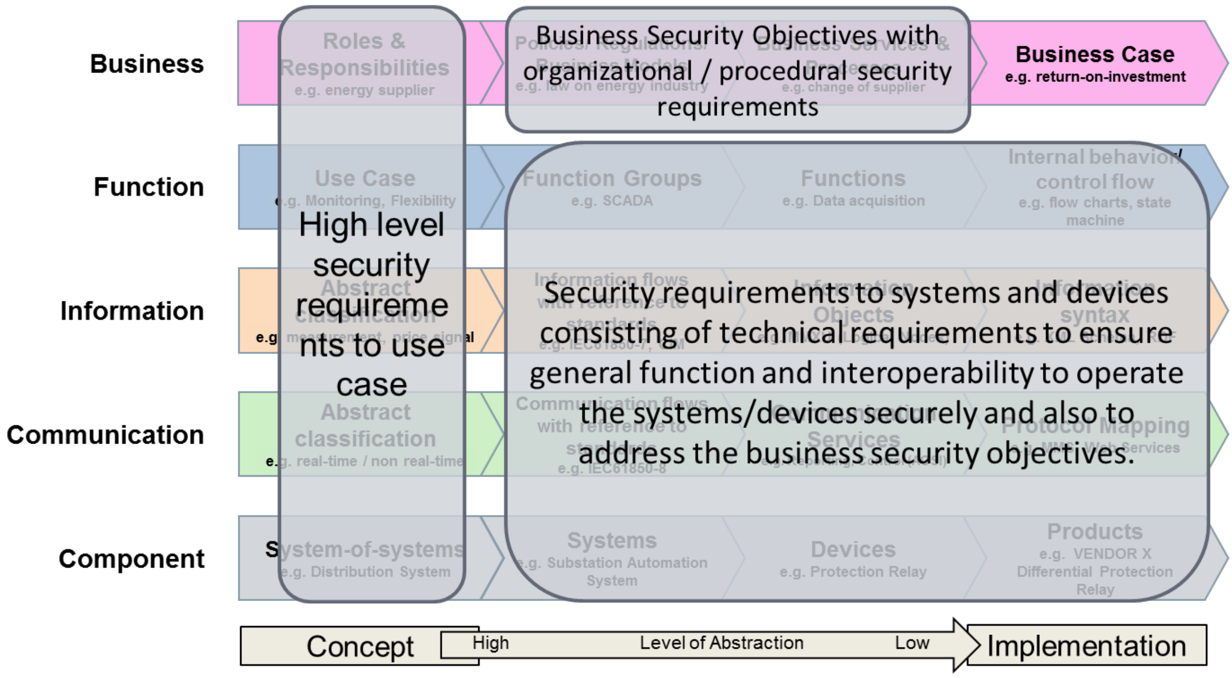


Figure 10: High level security requirements mapped on SGAM analysis patterns

The next figure provides a more detailed overview about the steps necessary to determine the security requirements. Going from the upper left to the lower right the security requirements become more detailed. Starting from functional requirements describing the requested security functionality required to protect the assets (integrity, authentication, confidentiality), these requirements get more detailed in terms of selected mechanisms to address the functional requirements by specific security measures. These measures relate to technical implementation security requirements (e.g. AES 128 bit for encryption, application of attribute certificates for role-based access control) but also to procedural security requirements necessary to operate the technical security measures (e.g. key updates, association of roles and rights for role-based access control).

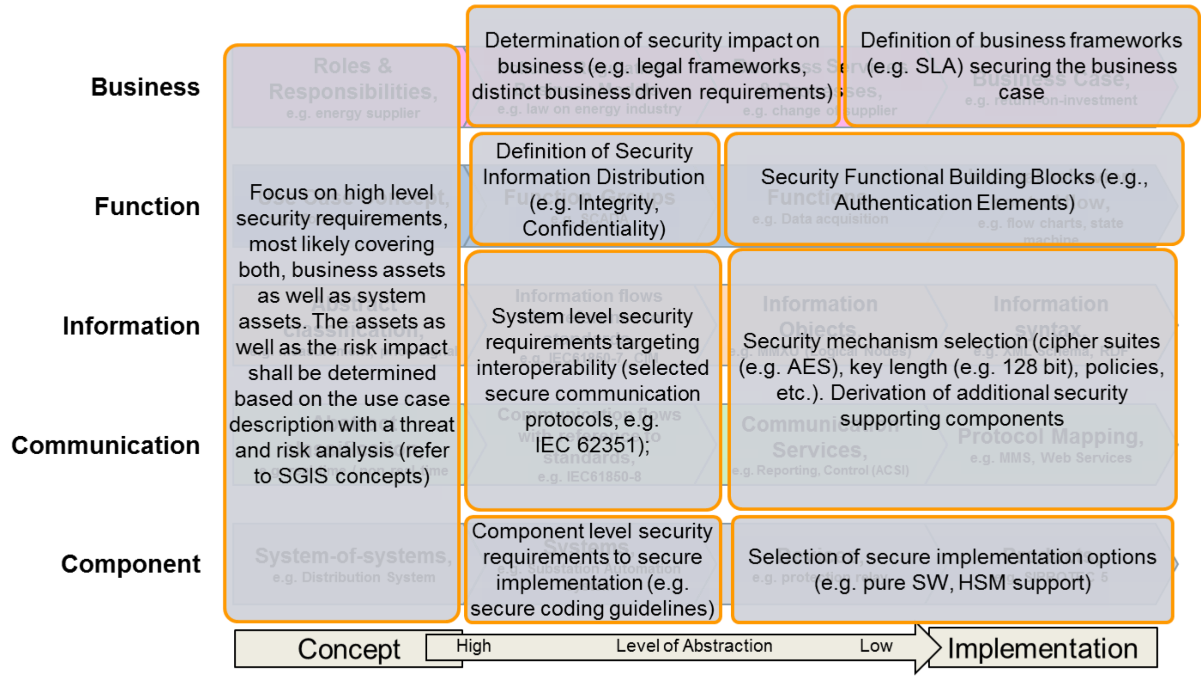


Figure 11: Detailed security requirements (examples) mapped to SGAM analysis patterns

6.4 Use case checklist

The following checklist should assist the authors of use cases in writing complete and good use case descriptions[6]. Subsequently, the information in the different fields of the use case description is used to specify the details for the SGAM layers.

Table 5: Use case checklist

Use case field (acc. IEC 62559-2)	Description
Name of use case	Is it an active-verb goal phrase, i.e. it refers to the activity of the Use Case itself using "Verb + description"? EXAMPLE: "Measure power"
Domain(s) & zone(s)	Does the description define domains & zones of SGAM?
Scope	Does the use case description define the system boundary?
Narrative of use case (short/complete)	▪ Is it clear what functions are needed to specify SGAM function layer? ▪ Which legal requirements have to be considered?

[6] refer also to [Cockburn]

Use case field **(acc. IEC 62559-2)**	**Description**
Actors	▪ Is the list of actors consistent in type and with nature of the use case, i.e. on the same SGAM layer (e.g. roles for business use cases or system/devices for component layer)? ▪ Are the actors defined in relationship to the (business) roles / responsibilities they are aimed to support?? ▪ Ensure that for business use cases the roles are based on the roles in the Conceptual Model or the Harmonized Role Model to ensure EU-wide applicability. ▪ For standardization purposes it is recommended that actor or role definitions do not force a combination of multiple in a single party. Grouped actors or roles should be used only for simplification, when commonly used (e.g. DSO).
Relation to other use cases	Does the use case relate to higher or lower level use cases, e.g. use case concept or business use case? Is there a consistent relationship of refinement (specialization) between roles and actors?
Nature of the use case	Does the description of the use case address the same SGAM layers that can be used to express the nature of the use case (e.g. business or technical (component, communication, information))?
References	Are there reference to be considered for the use case: e.g. standards, legislation, regulation, grid codes.
Step by step analysis (for detailed use case description)	
Information exchanged	Is it clear what information is being passed in each step? → Column specifies SGAM information layer. Is there a relation with a standard data model?
Requirements	Does the step-by-step analysis specify the applicable requirements (configuration, QoS, data management, privacy, security, etc.)? For example, Quality of Service (QoS) requirements for the SGAM communication layer.
Threat & risk analysis	The selection of security and privacy requirements should be based on a threat and risk analysis. The SGIS concept (security) and EG2 DPIA template (privacy) offer a mechanism to perform this selection. Resulting requirements can be linked in the template to information objects or to the step-by-step analysis.

6.5 Use case repository

Although it is possible to describe use cases in a word processing format, establishing a use case repository will provide many advantages for a standardization organization when the methodology is introduced on a broader scale.

Table 6: Advantages of a use case repository

Advantages	Description
Administration	Considering the different iterative working steps from draft via discussion to a validated use case, there is a need for a tool support: e.g. the tracking of changes or contributing authors, discussions, etc. The latest use cases and related data should always be available in the database.
Collaborative platform	As previously noted the use cases should enable an exchange of basic ideas across the different sectors and stakeholders of the industry, different TC's or even different organization. Such an exchange needs a collaborative platform, which increases the transparency of the design and the common development of new systems.
Search functions / Transparency	It will be easier to find an appropriate use case. Duplication of use cases can be minimized by using a repository for the whole community. Therefore transparency is increased, when use cases, related discussions, and the development process are visible for the community.
Harmonization of use cases	The repository provides pre-defined content for some fields like actors or domain / zones. This will be useful for the use case author, but also aligns different use cases with each other as they use the same terms.
Voting / Validation of use cases	Validated use cases are fundamental, enabling the evolution of new standards in the different TCs. The repository supports the process of validation.
Different templates	The complete template is complex and designed for a detailed analysis. Especially at the start, a use case repository provides easier short templates. Without rewriting these short templates, they can be extended in a repository. Further fields and cells can be added according to the needs of the users and the phase of the design process.
Analysis of use cases	Some fields of the use case template and some features of the use case repository support the analysis of use cases: filter functions, e.g. according to a specific actor, specific reports out of the database, gathering information from various use cases, e.g. the information exchanged between different actors in order to defined the message load or common requirements. Additionally use cases can be sorted according to the classification fields: prioritisation, maturity, etc. Another advantage of the use case repository is identification of gaps in the existing use case library when addressing new requirements during the analysis of use cases in order to provide a complete, but coherent set of use cases.
Link to other use cases	In a repository it is easier to link the use case to other use cases and to administrate / report these links (use case networks, clusters, interrelations).

Advantages	Description
Further engineering / export functions	The repository provides export functionalities, including a link to UML for further detailed engineering, reusing the developed use case (IEC 62559-3).
Status of the use case	The repository should support a work flow and the current status of a use case indicating e.g. if the use case is validated, under discussion or in editing mode.

IEC introduces on short term a use case repository for the international standardization community.

A prototype of a use cases repository had been developed in phase 1 of the M/490. This repository still is available under:

Link: https://usecases.dke.de/sandbox/ (please use Browsers Chrome or Firefox)
User with Read-only rights
Name: LookatMe
Password: LookatMe

It contains the Generic Use Cases which had been evaluated and developed by WGSP in phase 1 [SG-CG/E].

7 Mappings using the SGAM

7.1 Mapping of a system breakdown on SGAM[7]

In the scope of this document, a system is a typical industry arrangement of components and systems, based on a single architecture, serving a specific set of use cases.

In the following there are the systems which are been considered in [SG-CG/G] for the “Smart Grid Set of Standards”, and which de facto form the set of the Smart Grid systems and can be mapped to the SGAM plane (Figure 12). The guidelines mentioned in [SG-CG/G] indicate the purpose and limits associated to system definition and completeness of the considered list.

This list of systems (Table 7) is actually made of three types of systems:

- Domain specific systems (Generation, Transmission, Distribution, DER, Customer Premises)
- Function specific systems (usually crossing domain borders) (Marketplace systems, Demand flexibility systems, Smart metering systems, Weather observation and forecast systems)
- Other systems usually focusing on administration features (asset management, clock reference, communication management, device management, …). These so-called “Administration systems” are usually present in all the above one, but are generally implemented to co-habit with the domain specific domain. Depending on the implementation such cohabitation may lead to really separated systems and roles, or completely integrated systems and roles.

[7] Provided by WG SS

Table 7: Smart Grids - list of the main systems

Domain or function	Systems	Brief introduction/comments
Generation	Generation management system (Bulk)	Generation management system is the control centre for Bulk or Large renewable generation plant. Even if there may be some specificities for each of these, the rest of the document will mostly merge both into one system type.
	Generation management system (Large Renewable)	
Transmission	Substation automation system	Refer to Distribution
	Black-out prevention - WAMS Wide Area Monitoring Protection and control systems	Real-time blackout prevention systems, usually based on measurement coming from phase measurement units
	EMS SCADA system	The Energy Management System (EMS) is the control centre for the Transmission Grid. Today customers require an open architecture to enable easy IT integration and better support to avoid blackouts (e.g. visualization of the grid status, dynamic network stability analysis).
	Flexible AC Transmission Systems FACTS	Power Electronics is among the “actuators” in the power grid. Systems like HVDC and FACTS enable actual control of the power flow and can help to increase transport capacity without increasing short circuit power.
Distribution	Advanced DMS SCADA system (including Geographical Information system – GIS and outage management system - OMS)	The Distribution Management System (DMS) is the counterpart to the EMS and is therefore the control center for the distribution grid. In countries where outages are a frequent problem, the Outage Management System (OMS) is an important component of the DMS. Other important components are fault location and interfaces to Geographic Information Systems.
	Distribution automation systems - Feeder automation/smart reclosers system	Whereas automated operation and remote control is state of the art for the transmission grid, mass deployment of Distribution Automation is only recently becoming more frequent, leading to “Smart Gears”. Countries like the United States of America, where overhead lines are frequently used, benefit most. Advanced distribution automation concepts promote automatic self-configuration features, reducing outage times to a minimum (“self-healing grids”). Another step further is the use of distributed energy resources to create self-contained cells (“MicroGrids”). MicroGrids can help to assure energy supply

Domain or function	Systems	Brief introduction/comments
		in distribution grids even when the transmission grid has a blackout.
	Substation automation system	Substation Automation & Protection is the backbone for a secure grid operation. During recent years serial bus communication has been introduced (IEC 61850). Security is based on protection schemes.
	FACTS system	Refer to Transmission
DER	DER management system	Please refer to the system description in the [SG-CG/G] SG-CG/M490/G_Smart Grid Set of standards
	Electrical storage systems	Please refer to the system description in the [SG-CG/G] SG-CG/M490/G_Smart Grid Set of standards
Customer premises	AMI system	The Advanced Metering Infrastructure (AMI) system allows remote meter configuration, dynamic tariffs, power quality monitoring and load control. Advanced systems may integrate the metering infrastructure with distribution automation. (Smart Meter is a generic term for electronic meters with a communication link.)
	Metering-related back office system	Please refer to the system description in the [SG-CG/G] SG-CG/M490/G_Smart Grid Set of standards
	Demand-Response / Load management system	Please refer to the system description in the [SG-CG/G] SG-CG/M490/G_Smart Grid Set of standards
	Smart homes and buildings systems	**Smart Homes** are houses which are equipped with a home automation system that automates and enhances living. A home automation system interconnects a variety of control products for lighting, shutters and blinds, HVAC, appliances and other devices with a common network infrastructure to enable energy-efficient, economical and reliable operation of homes with increased comfort. **Building Automation** and Control System (BACS) is the brain of the building. BACS includes the instrumentation, control and management technology for all building structures, plant, outdoor facilities and other equipment capable of automation. BACS consists of all the products and services required for automatic control including logic functions, controls, monitoring, optimization,

Domain or function	Systems	Brief introduction/comments
		operation, manual intervention and management, for the energy-efficient, economical and reliable operation of buildings
	Industrial Automation systems	Brain of the industrial plant in charge of monitoring and controlling the industrial process, and associated facilities.
	E-mobility systems	Please refer to the system description in the [SG-CG/G] SG-CG/M490/G_Smart Grid Set of standards
Transverse	Micro-grid systems	Please refer to the system description in the [SG-CG/G] SG-CG/M490/G_Smart Grid Set of standards
	Market places (including trading systems)	Please refer to the system description in the [SG-CG/G] SG-CG/M490/G_Smart Grid Set of standards
	Weather observation and forecast system	Please refer to the system description in the [SG-CG/G] SG-CG/M490/G_Smart Grid Set of standards
	Asset management and condition monitoring system	Asset Management Systems and Condition Monitoring devices are promising tools to optimize the OpEx and CapEx spending of utilities. Condition-based maintenance, for example, allows the reduction of maintenance costs without sacrificing reliability. Furthermore they may also be used to utilize additional transport capacity due to better cooling of primary equipment, e.g. transmission lines on winter days.
Administration	Communication network management system	Please refer to the system description in the [SG-CG/G] SG-CG/M490/G_Smart Grid Set of standards
	Clock reference system	Please refer to the system description in the [SG-CG/G] SG-CG/M490/G_Smart Grid Set of standards
	Authentication authorization accounting system	Please refer to the system description in the [SG-CG/G] SG-CG/M490/G_Smart Grid Set of standards

NOTE So called “Administration” systems can/may be implemented superseding previous “operational systems”. There in most of the cases re-use communication capabilities already present in the “operational system”.

An overall view of all these domain or function specific systems onto the SGAM plane allows positioning each system in the domains and zones as shown in Figure 12. Note that not all administrative systems and cross-cutting technologies are shown in order to keep the figure readable.

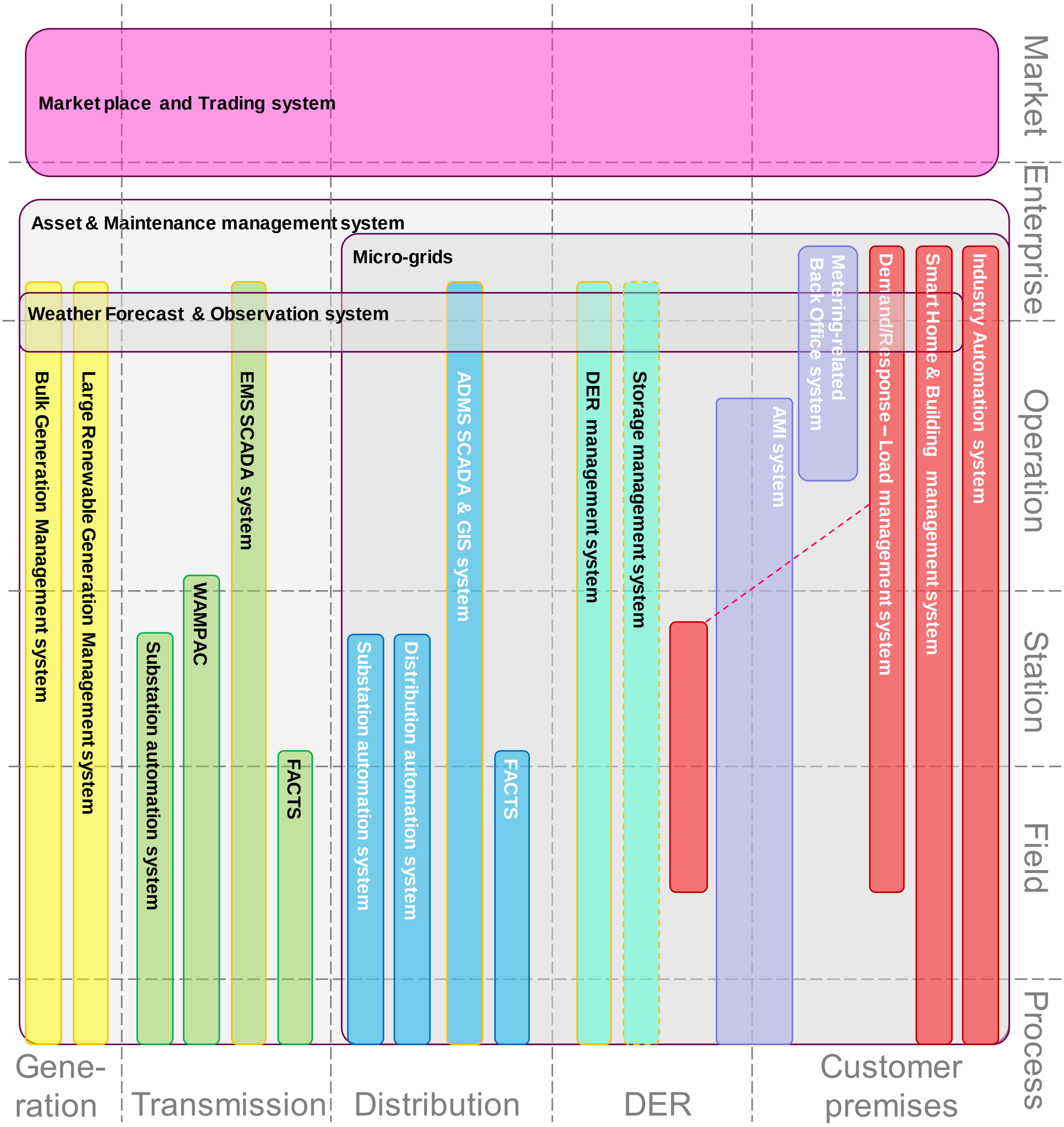


Figure 12 - Exemplary mapping of system usage on the SGAM plane

7.1.1 Mapping systems on SGAM - Principles

For a structured system description, each system may be mapped to the SGAM model described above.

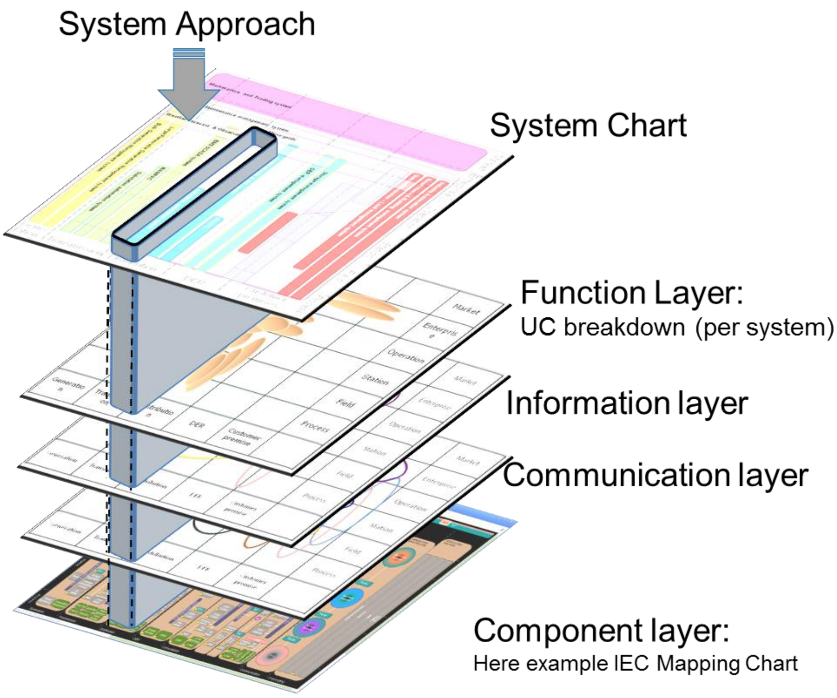


Figure 13: Mapping principles of systems over the SGAM planes

As depicted in the drawing above (Figure 13), mapping a system onto the SGAM will consist of:

- the definition of the set of “Generic use cases” the considered system can/may support.
- the drawing of the typical architecture and components used by this system (component layer).
- a list of standards to be considered for interfacing each components within this system as shown in [SG-CG/G].

The basic idea can be found also in the following example shown in Figure 14 using the SGAM plan for a more detailed breakdown to a component and device level. This mapping chart is combined with interactive lists of use cases (yellow dots) and standards (mouse-over). Similar to [SG-CG/G] the mapping tool aims to provide an overview and to guide standard users and the standard community in selecting appropriate standards.

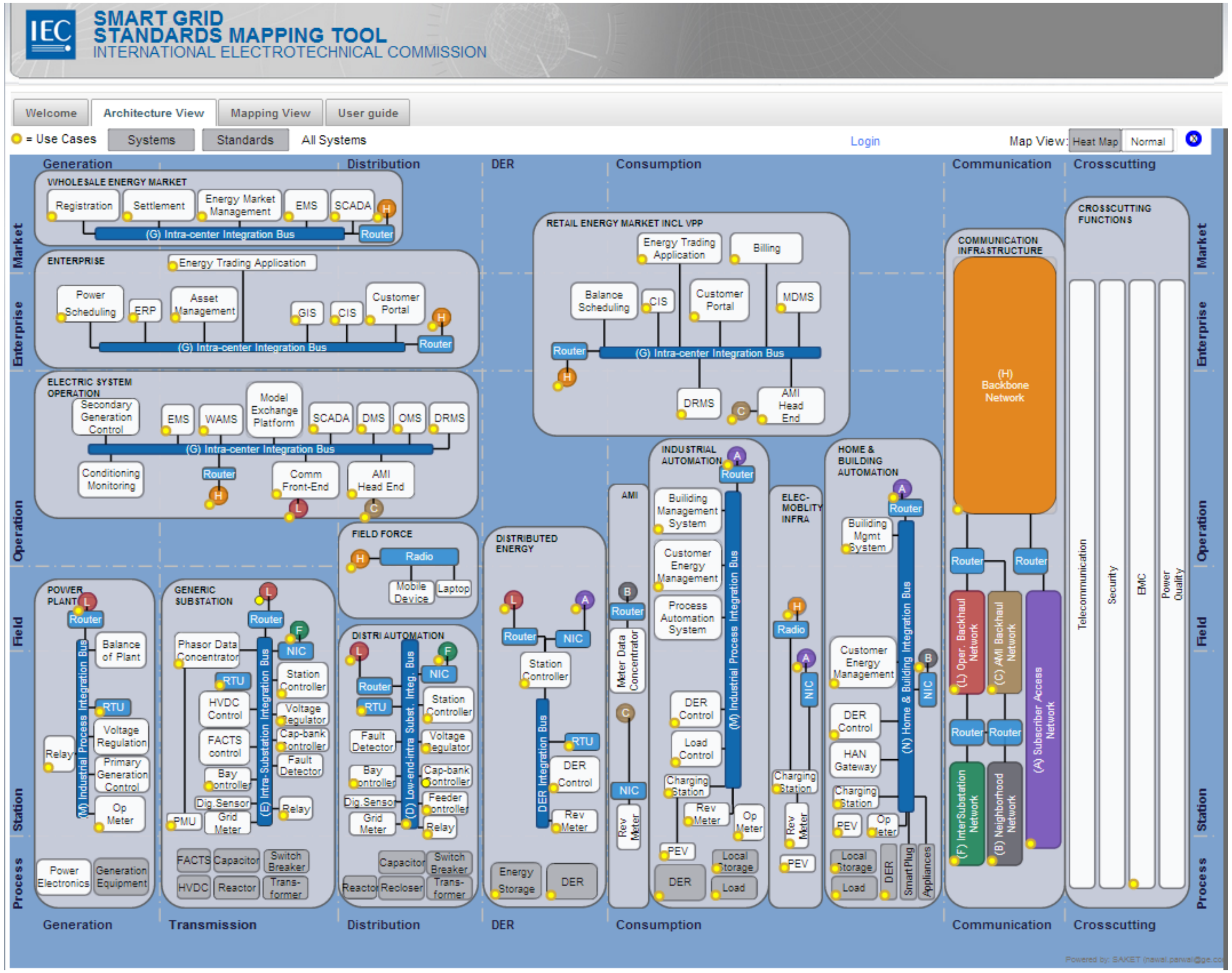


Figure 14: IEC Smart Grid mapping tool (Source: http://smartgridstandardsmap.com/)

7.2 Role mapping

Furthermore, for the business layer, we can map the Harmonized Role Model (HRM) to SGAM as depicted partly in Figure 15.

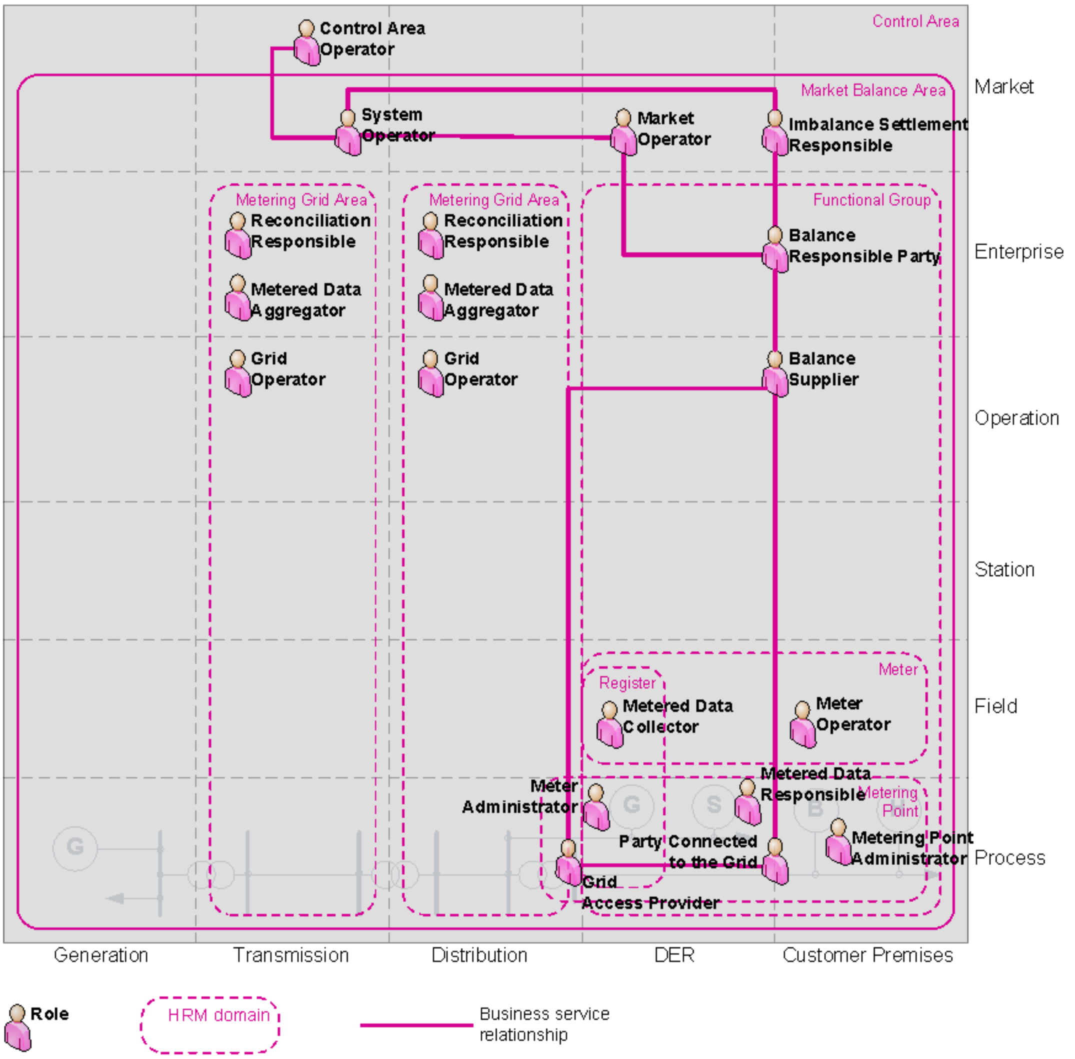


Figure 15: Mapping of Harmonized Role Model to SGAM

7.3 Analysis of communication networks using SGAM[8]

7.3.1 Description

A secure, reliable and economic power supply is closely linked to a fast, efficient and dependable telecommunication services communications.

A telecommunication service is any service provided by a telecommunication network through a communications system. A communications system is a collection of individual communications networks and communication end points capable of interconnection and interoperation to form an integrated whole.

The planning and implementation of communications systems, needed to support the expected services mentioned above, requires the same care as the installation of the power supply systems themselves.

One way to categorize the different types of telecommunications networks is by means of transmission:

- Wireless: communication through the air
- Wire line: communication through cable dedicated to telecommunications services
- Powerline: communication through cable designed for electric power transmission, but used for carrying data too.

Wireless communications may have to comply with local or regional regulations (such as the European Directive for Radio and Telecommunications Terminal Equipment (R&TTE) 2014/53/EU (previous version 1999/5/EC).

For Smart Grid communication architecture/technology, products based on specifications from (industry) consortia (e.g. IETF, W3C) have been deployed widely, notably in the area of IP protocols and web services. In the section below, the list of standards/specifications takes into account the ones which fulfill market requirements.

[SG-CG/C], Annex F provided some detailed information on standards pertaining to Smart Grid communications. This list of standards will now be hosted in the new edition of the “Set of Standards” [SG-CG/G].

7.3.2 Communication network type breakdown

Depending on the Smart Grid target applications, different types of communication networks and also collections of communication networks using different transmission technologies may be selected in order to transmit and deliver Smart Grid data.

The following network types could be defined for the Smart Grids:

- **(A) Subscriber Access Network**

  networks that provide general broadband access (including but not limited to the internet) for the customer premises (homes, building, facilities). They are usually not part of the utility infrastructure and provided by communication service providers, but can be used to provide communication service for Smart Grid systems covering the customer premises like Smart Metering and aggregated prosumers management.

[8] Provided by WG SS

- **(B) Neighborhood Network**

  networks at the distribution level between distribution substations and/or end users. They are composed of any number of purpose-built networks that operate at what is often viewed as the “last mile” or Neighborhood Network level. These networks may service metering, distribution automation, and public infrastructure for electric vehicle charging, for example.

- **(C) AMI backhaul Network**

  networks at the distribution level upper tier, which is a multi-services tier that integrates the various sub layer networks and provides backhaul connectivity in two ways: directly back to control centers via the WAN (defined below) or directly to primary substations to facilitate substation level distributed intelligence. It also provides peer-to-peer connectivity or hub and spoke connectivity for distributed intelligence in the distribution level.

- **(D) Low-end intra-substation Network**

  networks inside secondary substations or MV/LV transformer station. It usually connects RTUs, circuit breakers and different power quality sensors.

- **(E) Intra-substation Network**

  network inside a primary distribution substation or inside a transmission substation. It is involved in low latency critical functions such as tele-protection. Internally to the substation, the networks may comprise from one to three buses (system bus, process bus, and multi-services bus).

- **(F) Inter substation Network** – networks that interconnect substations with each other and with control centers. These networks are wide area networks and the high end performance requirements for them can be stringent in terms of latency and burst response. In addition, these networks require very flexible scalability and due to geographic challenges they can require mixed physical media and multiple aggregation topologies. System control tier networks provide networking for SCADA, SIPS, event messaging, and remote asset monitoring telemetry traffic, as well as peer-to-peer connectivity for tele-protection and substation-level distributed intelligence.

- **(G) Intra-Control Centre / Intra-Data Centre Network**

  networks inside two different types of facilities in the utility: utility data centers and utility control centers. They are at the same logical tier level, but they are **not** the same networks, as control centers have very different requirements for connection to real time systems and for security, as compared to enterprise data centers, which do not connect to real time systems. Each type provides connectivity for systems inside the facility and connections to external networks, such as system control and utility tier networks.

- **(H) Backbone Network**

  inter-enterprise or campus networks, including backbone Internet network, as well as inter-control center networks.

- **(L) Operation Backhaul Network**

  networks that can use public or private infrastructures, mostly to support remote operation.. They usually inter-connect network devices and/or subsystems to the “Operation level” over a wide area (region or country).

- **(M) Industrial Fieldbus Area Network** networks that interconnect process control equipment mainly in power generation (bulk or distributed) in the scope of smart grids.

- **(N) Home and Building integration bus Network**

networks that interconnect home and / or building communicating components and sub-systems to form a home or building management sub-system or system.

7.2.3 Mapping of communication network type over the SGAM

Figure 16 below provides a mapping of the different Smart Grid networks to the SGAM model.

NOTE where a circle is tangent to a zone, this means that the corresponding network type can support the interface with the tangent zone.

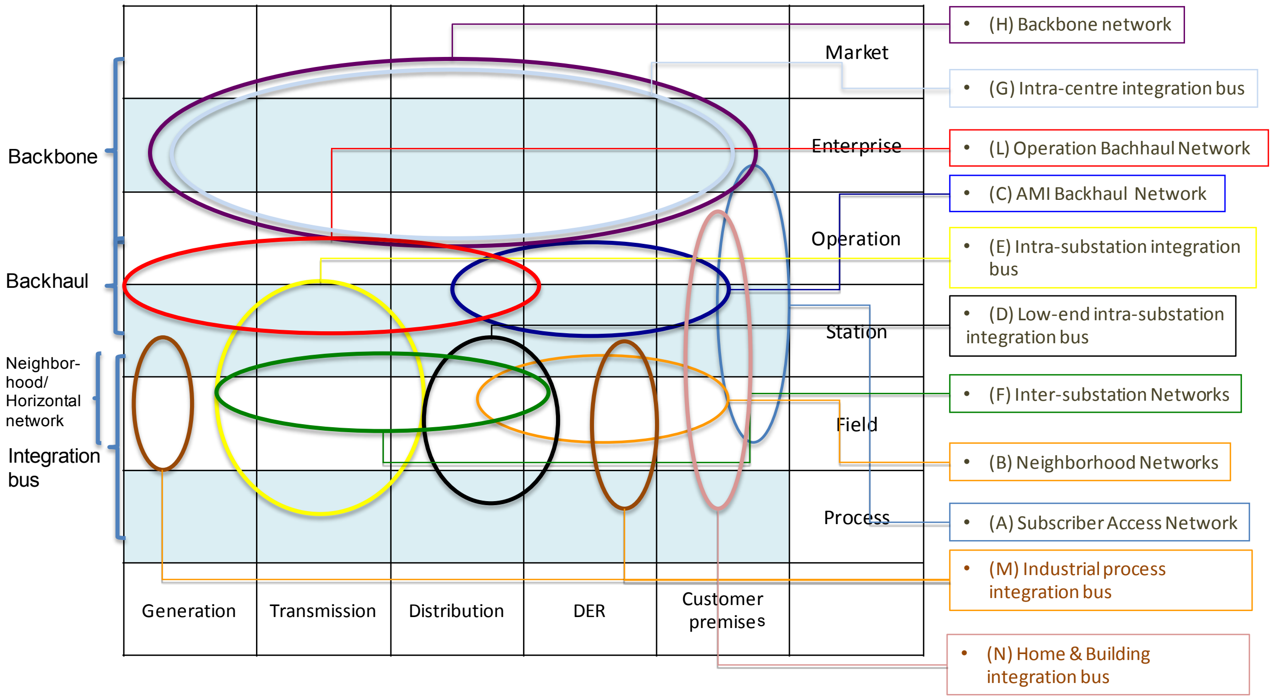


Figure 16 - Mapping of communication networks on SGAM

Note 1: These areas are a mapping example and cannot be normative to all business models.
Note 2: It is assumed that sub-networks depicted in the above figure are interconnected (where needed) to provide end-to-end connectivity to applications they support. VPNs, Gateways and firewalls could provide means to ensure network security or virtualization.

7.3.4 Data modelling with the SGAM

Because of the increasing need of many Smart Grid stakeholders to deploy solutions offering a semantic level of interoperability, data modeling appears as the cornerstone and foundation of the Smart grid framework.

In addition data modeling seems much more stable than communication technologies, which makes this foundation even more important.

Currently the IEC framework relies on 3 main pillars, as far as data modeling is concerned, represented in Figure 17.

The same figure represents also the 3 harmonization work items (i.e. the definition of unified shared semantic sub-areas, or formal transformation rules) which need to be performed in order to allow an easy bridging of these semantic domains:

- Harmonization between CIM[9] and IEC 61850, mostly to seamlessly connect the field to operation and enterprise level
- Harmonization between CIM and COSEM[10], mostly to seamlessly interconnect electricity supply and grid operation,
- Harmonization between COSEM and IEC 61850, where smart metering may co-habit with Power Utility Automation systems.

For further information about the current standardization work in this area, please refer to [SG-CG/G].

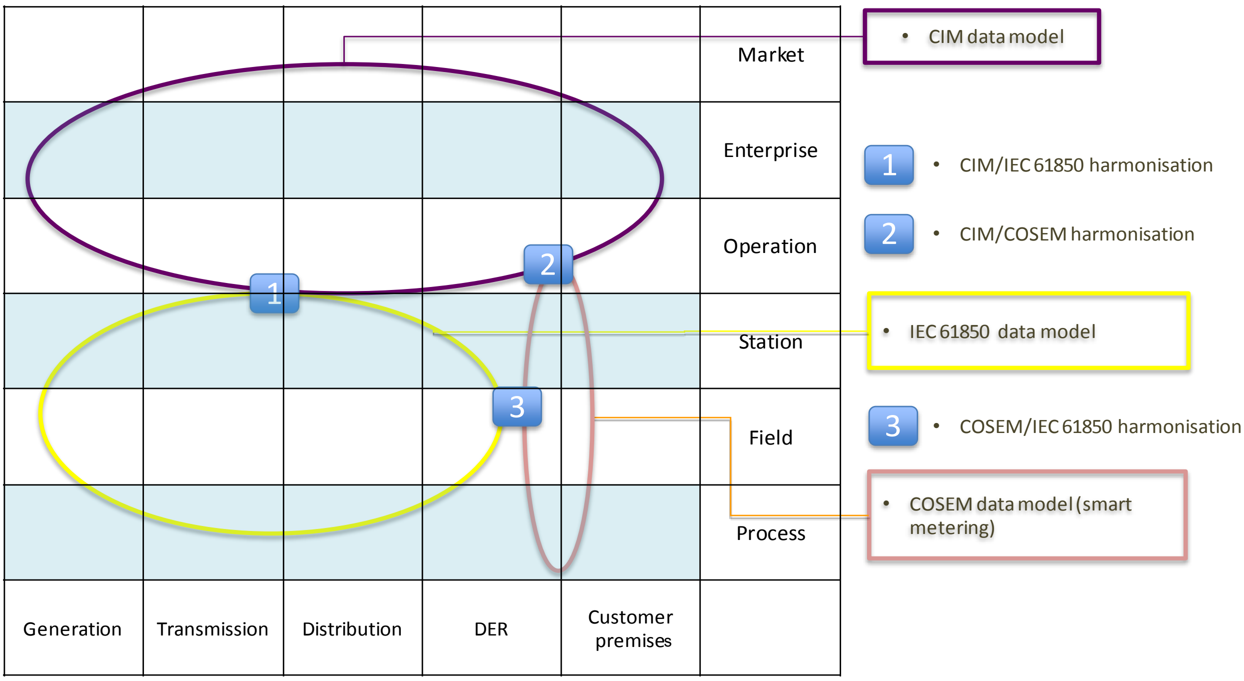


Figure 17 - Data modeling and harmonization work mapping

[9] CIM Common Information Model, IEC 61968, IEC 61970

[10] COSEM Companion Specification for Energy Metering, IEC 62056

8 Examples showing the use of the SGAM

8.1 Introduction

With the help of an example we like to validate the SGAM Methodology and justify the following key points:

- The SGAM analysis pattern provides a valuable scheme to analysis, visualize and compare Smart Grid use cases from high-level to detailed specifications.
- A Use Case Concept with its short template is a simple way to document general ideas in an easy manner. It provides abstract information on all SGAM layers, allows alternatives and leaves room for the experts to specify the details.
- The mapping of the use case to the Smart Grid plane is a simple way to compare, cluster/group and harmonize several use cases.

In the following sub-sections we discuss use cases related to "*Monitoring"* on very different levels of abstraction. We will start with a high-level use case taken from the previous work done in [SG-CG/E] and analyze it as a use case concept on all SGAM layers in an abstract manner. Further detailing will be done for selected, more detailed use cases and different views – business as well as technical / system. Figure 18 shows an overview of the different examples outlined in the following sections, where each description provides information on the related SGAM layers with the defined level of abstraction.

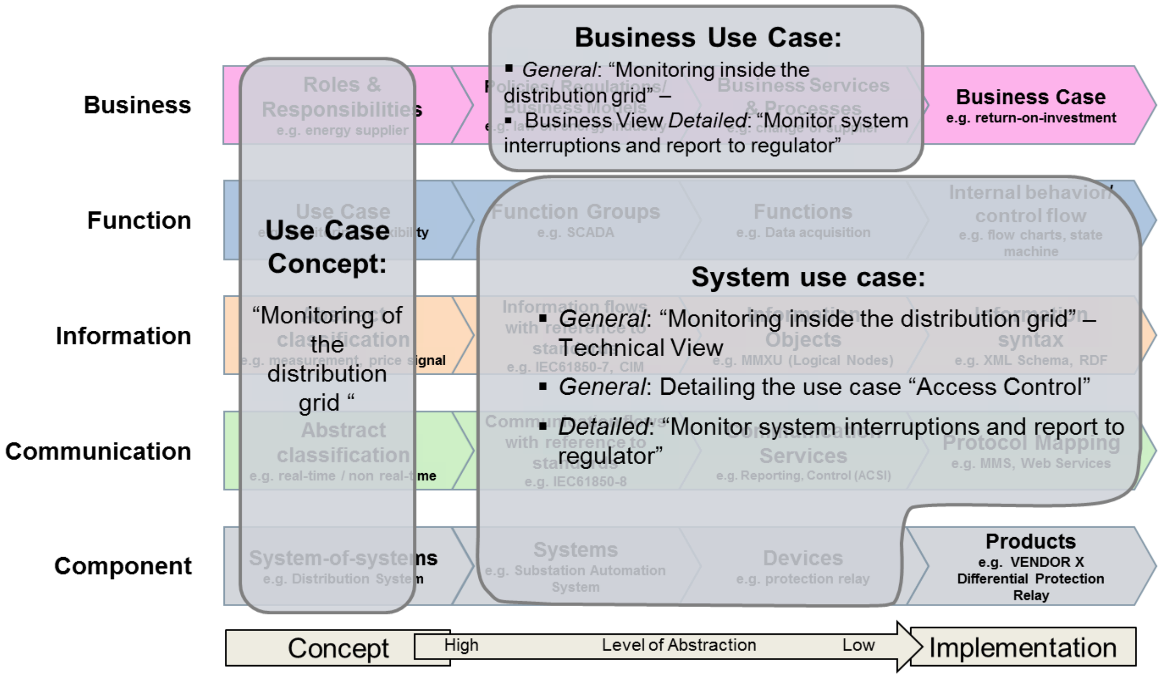


Figure 18: Overview of examples presented

8.2 Example #1: Monitoring of the distribution grid (SG-CG WGSP-0600)

- WGSP-0600 use case description is used as an example of the **Use Case Concept / High-level Use Case.**
- Several sources for monitoring data and different roles are involved, e.g. sensors, meters, DERs, CEMSs.
- A mapping of the use case to the SGAM Smart Grid Plane plus involved market roles is depicted in Figure 20.

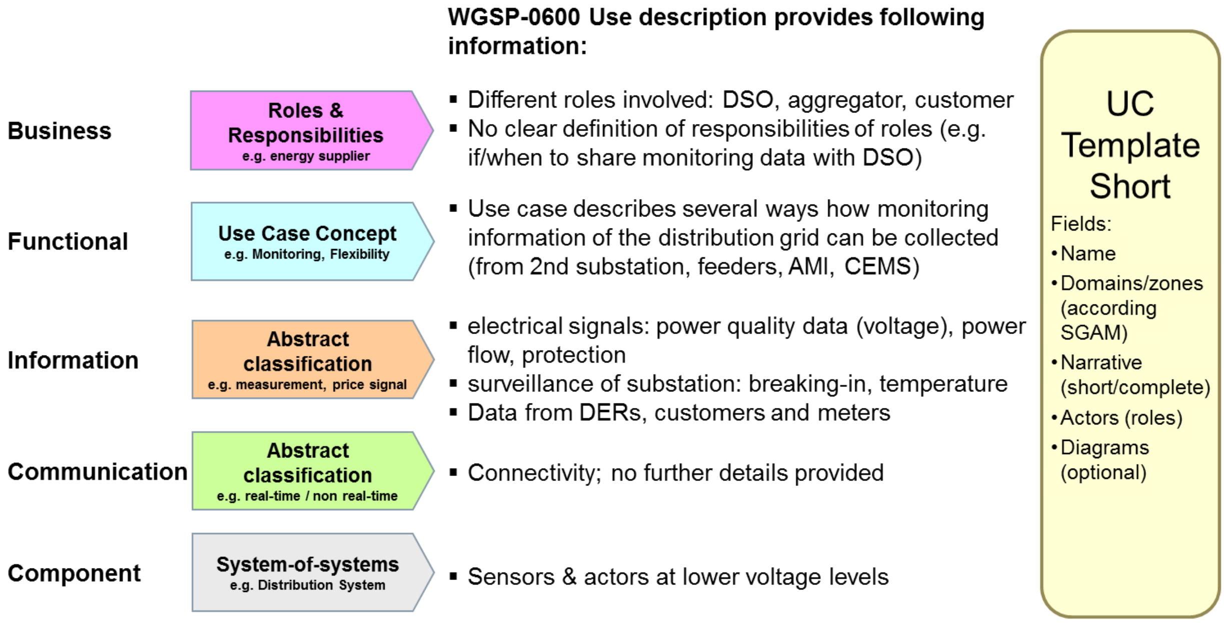


Figure 19: Mapping of the use case "Monitoring of the distribution grid"

To reach the next level of detail primary use cases needs to be defined

Primary use cases

- Monitoring inside the distribution grid
- Monitoring of DERs by the DSO
- …

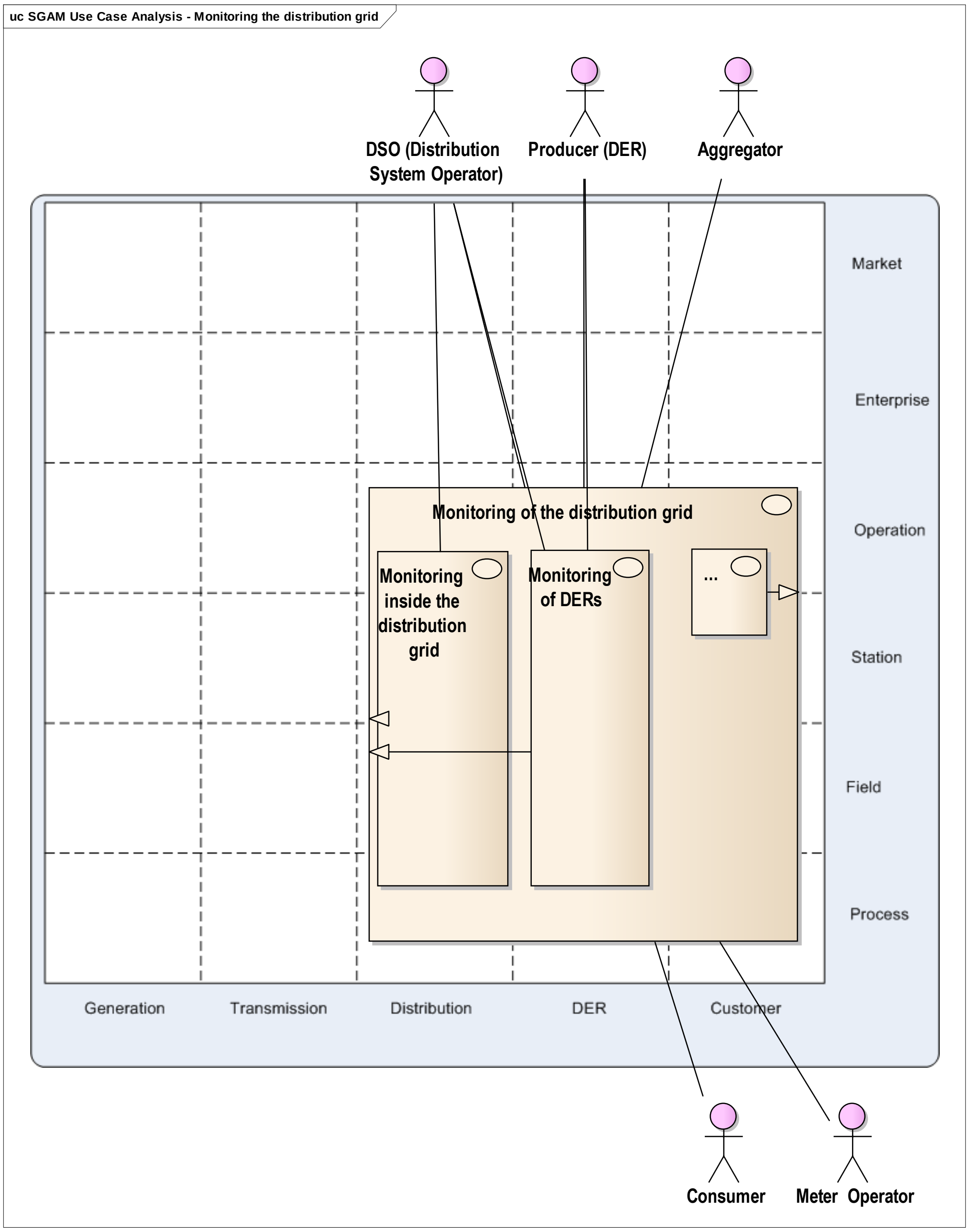


Figure 20: Primary use cases for "Monitoring the distribution grid"

8.3 Example #1.1: "Monitoring inside the distribution grid" (Business Use Case)

Roles & Responsibilities

- Use case includes a role with a clear responsibility. According to HRM the following role is a grouped role (refer to [SG-CG/J])
- From EG1: **Distribution System Operator (DSO)**: according to the Article 2.6 of the Directive: "*a natural or legal person responsible for operating, ensuring the maintenance of and, if necessary, developing the distribution system in a given area and, where applicable, its interconnections with other systems and for ensuring the long-term ability of the system to meet reasonable demands for the distribution of electricity". Moreover, the DSO is responsible for regional grid access and grid stability, integration of renewables at the distribution level and regional*

Policies/ Regulation/ Business Models
e.g. law on energy industry

load balancing.

- Monitoring information is the basis for several other use cases, e.g. FLISR, Volt/VAr control.
- These use cases ensure the stable operation of the distribution grid and improve performance indexes like SAIDI (System Average Interruption Duration Index) and SAIFI (System Average Interruption Frequency Index).
- The business value of this use case has to be evaluated together with the use cases it enables.
- Security requirements: Regulative, e.g.: NERC CIP; Information Security Management: ISO 27001/02/19; from guidelines: NIST IR 7628, BDEW White Paper)

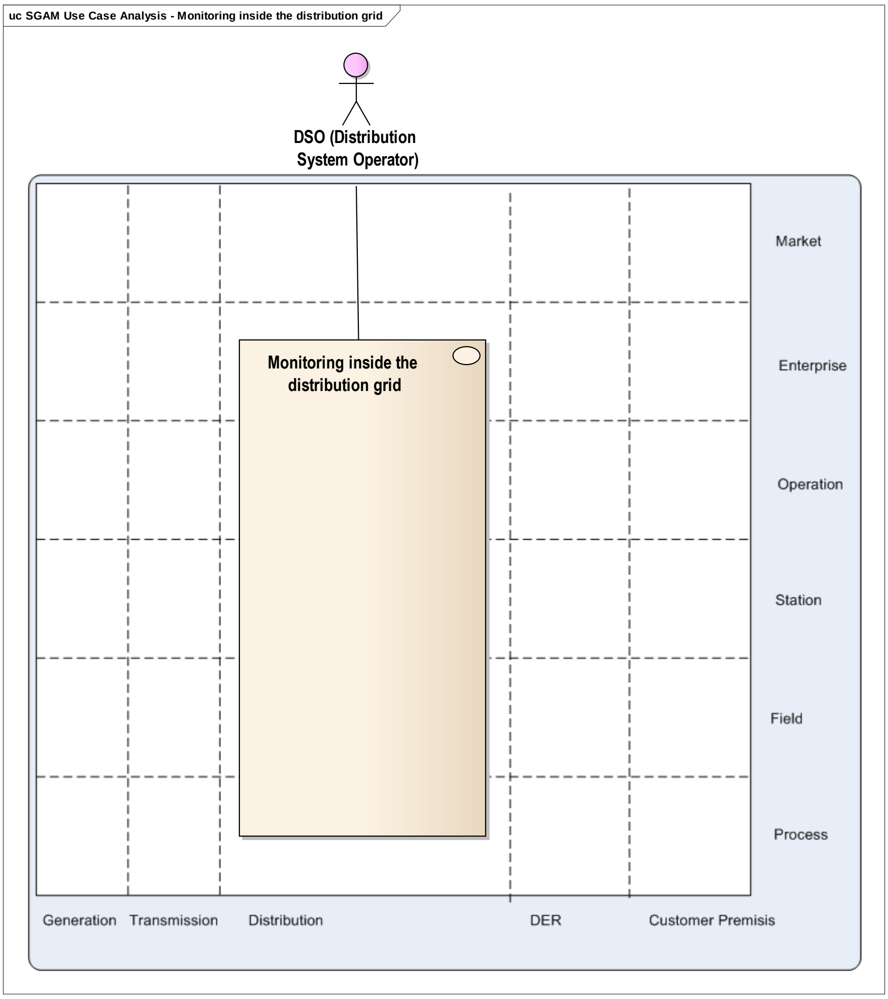


Figure 21: Mapping of "Monitoring inside the distribution grid" on SGAM plane

8.4 Example #1.2: "Monitoring inside the distribution grid" (Device/system use case)

A rich monitoring functionality is the prerequisite to determine the state and performance of the distribution grid. Monitoring has to provide:

- Measurements of the grid at field level,

- Data concentration and access control at the station level,
- SCADA system to process, visualize, archive etc. the monitoring information.

Data to be collected are e.g. voltage, current, frequency, phase angle, active and reactive power, and state of the control elements. These data need different monitoring approaches depending on their time horizons. A measurement of these quantities could be time-critical and partially need high sample rates.

Further measurements are sent only when they exceed thresholds or every time a state change occurs. The task is to optimize data collection ,finding a compromise between getting precise enough system states and not overloading the monitoring network.

The monitoring protocols have to support all timescales with high reliability. All information collected should be stored in an archive for further processing.

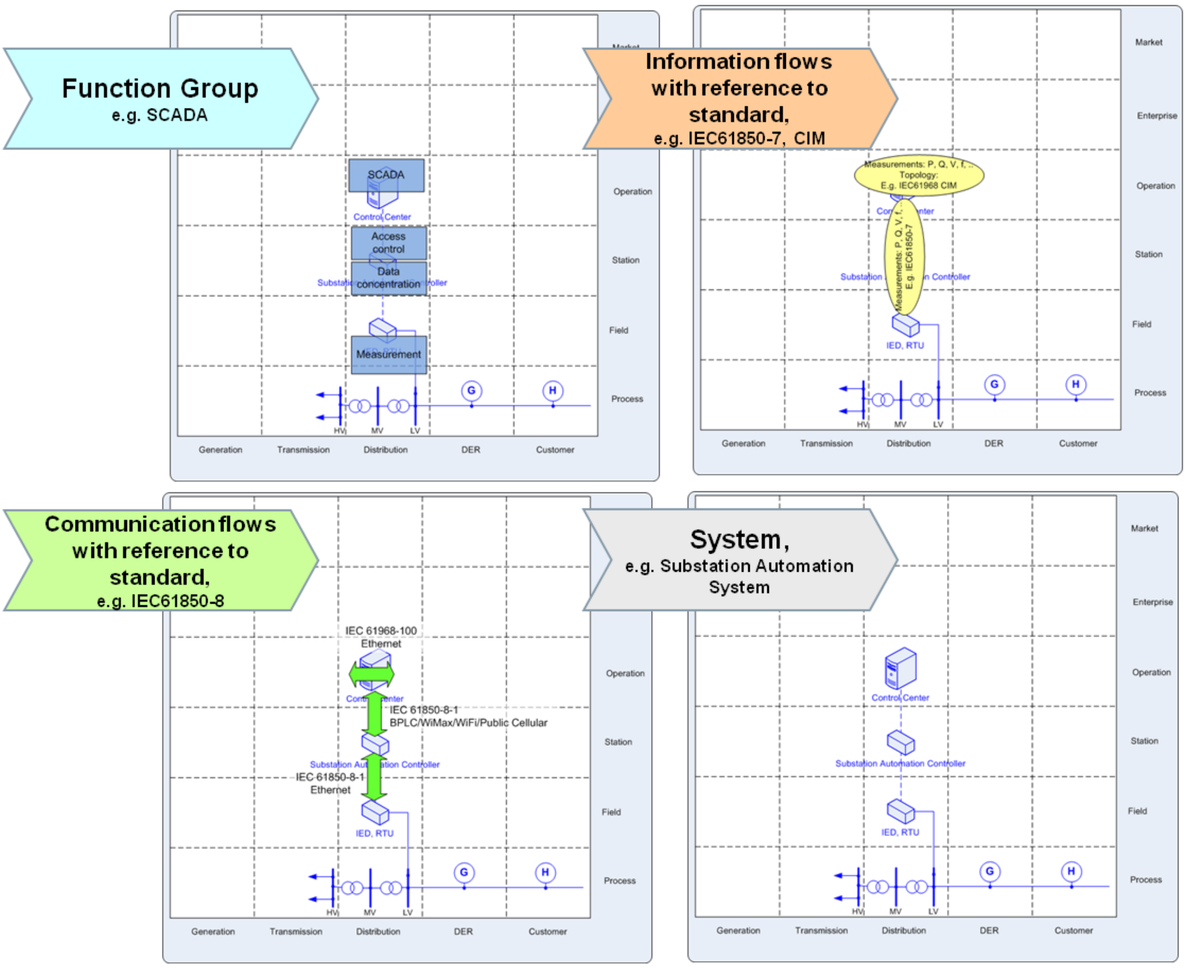
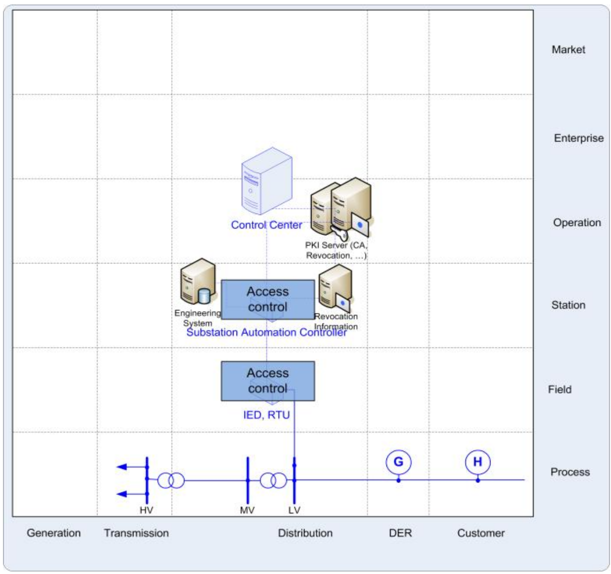


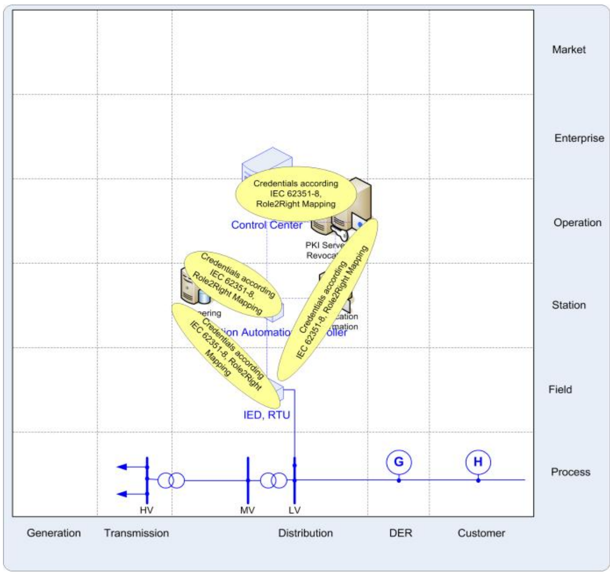
Figure 22: SGAM analysis for “Monitoring inside the distribution grid”

8.5 Example #1.1.1: Detailing the secondary use case “Access Control”

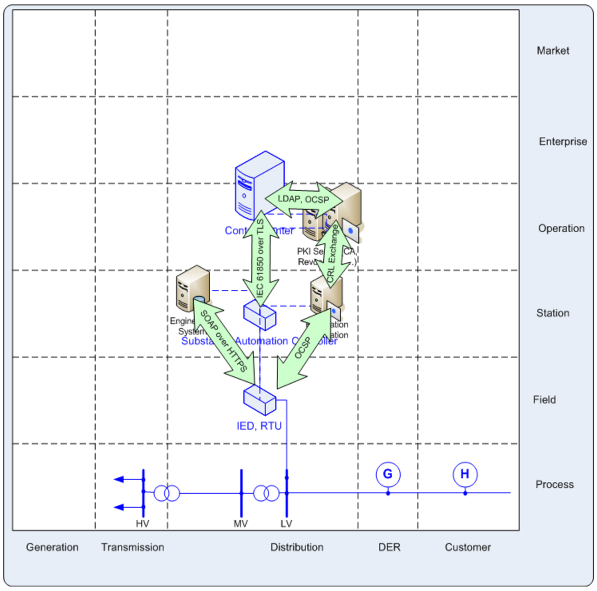
Access control as depicted as secondary use case in Figure 22 is often required for the operation of critical infrastructures. This is being requested by regulation and also by standards and guidelines addressing Smart Grid as mentioned in the business use case description in Section “8.3 Example #1.1: “Monitoring inside the distribution grid” (Business Use Case)”. In the following, SGAM is used to identify the detailed requirements to support Role-Based Access Control (RBAC) by mapping a technical solution to the SGAM function, information, communication and component layers.



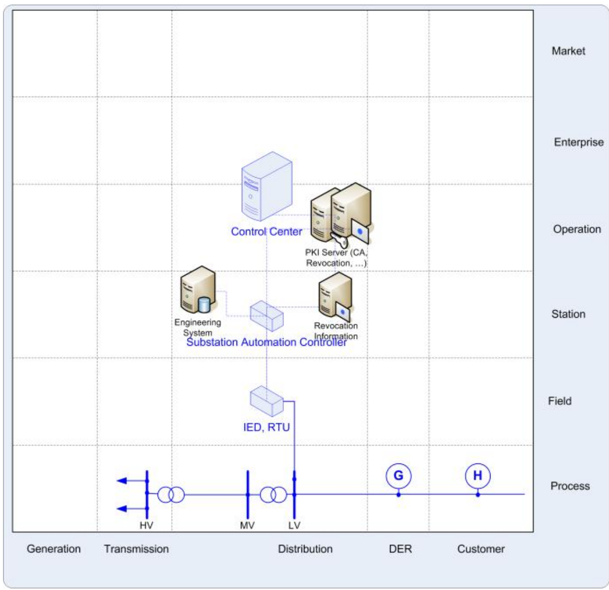
a) Function Layer



b) Information Layer



c) Communication Layer



d) Component Layer

Figure 23: SGAM Analysis of Role-based Access Control

Based on the requirements stemming from the business layer in Section 0, the functional layer reflects the functional security requirements for role-based access control related to dedicated zones and domains. Through mapping to different zones, one can already distinguish between local and remote access. The function layer comprises access control to components but also command execution authentication and authorization control as functional requirements. Functional requirements are typically related to an existing functional architecture during the design of an appropriate security architecture addressing discovered potential security risks (e.g. according to a risk assessment based on use cases).

The SGAM analysis for the information and communication layers shows the application of [IEC 62351-8] in the context of Smart Grid systems applying protocols like IEC 61850 or IEC 60870-5-104. It has been chosen here to provide an example of the application of SGAM in the context of identifying security requirements as well as mapping special solutions to these requirements. IEC 62351-8 addresses the integration of role-based access control to ease the burden of access management in power systems. It enables verification of authorization before command execution, e.g. in substation automation in terms of who is authorized to perform a specific switching command. This information can be required e.g. for auditing purposes. The roles[11] are bound to different credentials as defined in [IEC 62351-8]. The standard distinguishes between:

- Public Key (Identity) certificate with included role information;
- attribute certificate bound to an identity certificate;
- software token (HMAC-protected structure, Kerberos like).

The standard IEC 62351-8 describes merely the token providing the role information as well as a set of mandatory roles (and associated rights):

- VIEWER;
- OPERATOR;
- ENGINEER;
- INSTALLER;
- SECADM (Security Administrator);
- SECAUD (Security Auditor);
- RBACMNT (Role-based Access Management).

This list of roles and associated rights can be extended with own specific roles and rights information. The predefined list above is intended for interoperability between different components. It is expected that all enhancements are installed on the entities involved, to facilitate interoperability.

The information layer requires RBAC credential specification and also mapping of entities to roles. As stated, IEC 62351-8 provides predefined roles and associated rights. Nevertheless, these role definitions and rights associations can be enhanced according to deployment needs.

On the communication layer, roles are transmitted bound to credentials within IEC protocols. IEC 62351-6 defines the structure of the RBAC token and also guidance how to transmit this token as part of utilized protocols. One example is the application of X.509 attribute certificates bound to X.509 Public Key certificates. The communication layer in this example includes the following protocols:

- IEC 61850 protected through IEC 62351-3/4: Here TLS is used to protect the communication on transport layer. Within TLS X.509 certificates are used to support mutual authentication. The X.509 certificates may be enhanced directly with role information allowing for RBAC. Alternatively an attribute certificate can be bound to the X.509 ID certificate to enable a short-term binding.
- SOAP (Simple Object Access Protocol) over HTTPS: Engineering using web services transported over HTTPS, which is protected by TLS. Here again, X.509 certificates may be used for mutual authentication and thus also allow for realizing RBAC based on mechanisms described in IEC 62351-8.
- LDAP (Lightweight Directory Access Protocol): Protocol used to access directory services to retrieve certificates. May be used using TLS.
- OCSP (Online Certificate Status Protocol): Protocol to retrieve fresh revocation information for single certificates. Avoids storing certificate revocation list (CRLs) on single field devices

[11] The understanding of roles in this standard is similar as described in [SG-CG/J], but these roles are not related to the HRM. Here they are related to different responsibilities and access rights as explained.

- CRL retrieval: Protocols used to request a CRL from a Certification Authority (CA). These protocols may be FTP, SSH, or HTTP. Unsecure protocols should be protected e.g. by using an underlying security protocol like TLS. The CRL is protected by itself, as it is signed by the CA.

The component layer comprises additional components for credential handling like the generation or revocation of X.509 key material. This task is commonly performed by a Public Key Infrastructure (PKI). The additional components needed here comprise a Certification Authority issuing the X.509 certificates including the role information and also a repository for querying the RBAC information. A component is also needed for storing revocation information for the case when a RBAC credential is revoked before its validity period has ended.

As shown above, IEC 62351-8 can be used to support RBAC for the discussed use case and in general for Smart Grid Systems. Nevertheless, regarding IEC 62351-8 there are also gaps, which can be identified:

- for interoperability reasons a mandatory profile for RBAC support is necessary. The standard currently defines three different profiles, without requiring concrete support for at least one. This would be necessary to ensure interoperability and avoid a full implementation of this standard;
- transport profiles also for other protocols than TCP/IP (e.g. application for UDP/IP or even Ethernet based communication) may be outlined. The current standard only takes TLS as concrete example for application. Nevertheless, there are other standards utilizing X.509 certificates for authentication on transport but also on (OSI) application layer. They may leverage the approach of enhancing either the X.509 public key certificate with the role information (as an extension) or by providing an attribute certificate containing the role information for a holder of a dedicated X.509 public key certificate.

8.6 Example #1.1.2: “Monitor system interruptions and report to regulator”

As outlined in the previous sections the *Monitoring use case* supports a wide range of other use cases. For the short and general descriptions of the *Monitoring use case* it was not necessarily required to define how the monitoring data is used. This allows us to consolidate a set of monitoring use cases into a single harmonized description. However, to derive a primary use case description providing all information on all levels of details as depicted in [Cockburn], we have to define the goal of the use case precisely. Hence, we outline in this section a specialized use case that monitors system interruptions in the distribution grid and reports them to the regulator. The use case was chosen because measures for reliability are reported for many years in various countries. Thus, the required information for the use case description is based on existing sources and not derived completely new. Regulatory rules differ from country to country including also the guidelines for reporting system interruptions. In the following we focus on the regulations in Germany without any intention beyond demonstrating the SGAM methodology.

As defined in Germany in the law of energy industry EnWG §52, system operators including DSOs have the obligation to report system interruptions on a yearly basis to the German Federal Network Agency (Bundesnetzagentur (BNetzA)). Furthermore, the German Federal Network Agency has the right to specify formal guidelines for reporting[12].

Business View:

- BNetzA has the right to define the guidelines for reporting
- Two types of reporting are defined:
  - Web form for manual input
  - XML-based report using web services

[12] As specified on the website of the German Federal Network Agency (in German only): http://www.bundesnetzagentur.de/cln_1932/DE/Sachgebiete/ElektrizitaetundGas/Unternehmen_Institutionen/Versorgungssicherheit/Stromnetze/stromnetze-node.html

Technical View:

Functions
e.g. Data acquisition

- Functions in control center include e.g.
    - Data acquisition
    - Archiving
    - Reporting to regulatory body

Semantic information model profiles
e.g. MMXU (Logical Nodes)

- Basic data set which has to be reported for each interruption include e.g.
    - Start (date, time)
    - Duration (minutes)
    - Type of the interruption (e.g. planned, unplanned)
    - Reason for interruption (e.g. force majeure)

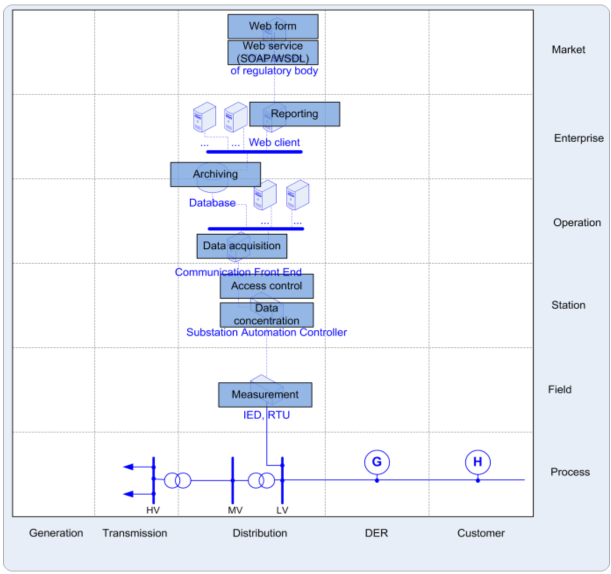
Communication Services
e.g. Reporting, Control (ACSI)

- Communication services for submitting the report include e.g.
    - Start/close/abort transaction
    - Send network data
    - Report interruptions

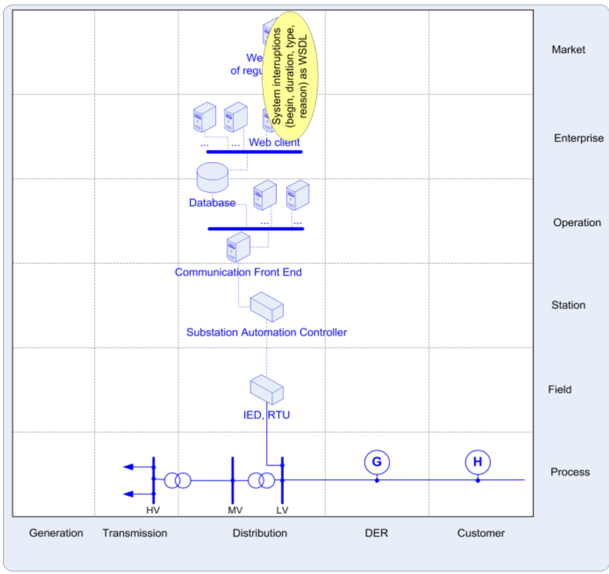
Devices
e.g. protection relay

- The control center can be detailed including e.g. the following components
    - Communication Front End
    - Database
    - Web client

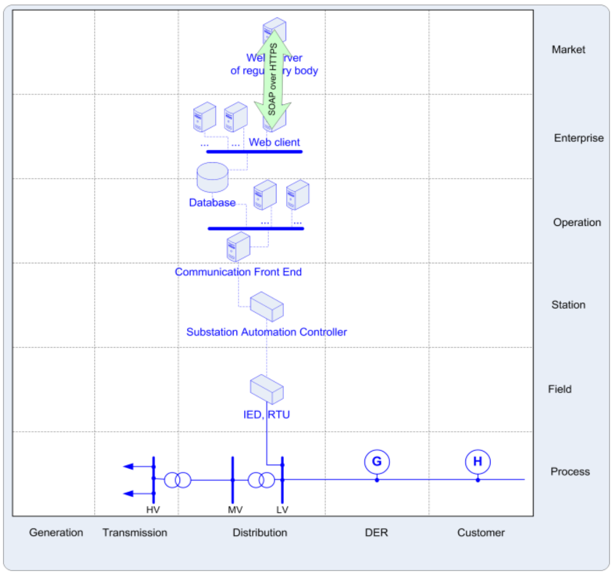
Figure 24 depicts the SGAM analysis for this use case with a special focus on the interaction between components of the DSO and the regulator.



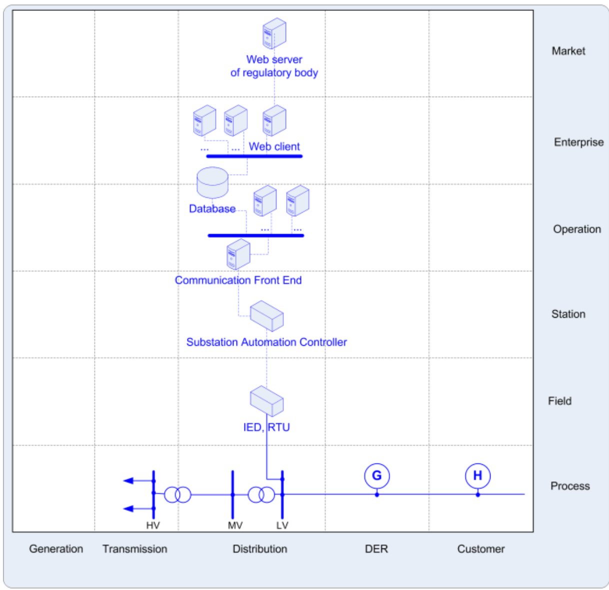
e) Function Layer



f) Information Layer



g) Communication Layer



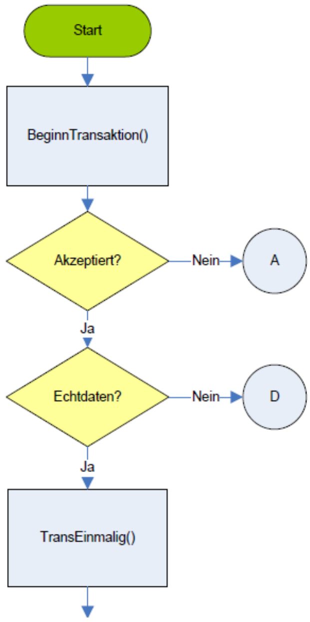
h) Component Layer

Figure 24: SGAM Analysis “Monitoring system interruptions and report to regulator”

According to Figure 3 “SGAM Analysis Pattern”, the function, information and communication layer can be further detailed to specify flow charts, the information syntax and the communication protocols, respectively. The following provides an example for the lowest level of detail.

Flow charts
e.g. CFC

- BNetzA defines flow charts for reporting system interruptions
- Following excerpt is provided as example:



Information syntax
e.g. XML Schema, RDF

- BNetzA uses WSDL to provide the service description for reporting system interruptions with web services (which is available online[13])
- Following excerpt is provided as example:


```
- <wsdl:definitions targetNamespace="https://app.bundesnetzagentur.de/WsVersorgUnterbrStrom">
    <wsdl:documentation>Version 2.0.1.3 vom 15.09.2009</wsdl:documentation>
  - <wsdl:types>
    - <s:schema elementFormDefault="qualified" targetNamespace="https://app.bundesnetzagentur.de/WsVersorgUnterbrStrom">
      - <s:element name="BeginnTransaktion">
        - <s:complexType>
          - <s:sequence>
              <s:element minOccurs="1" maxOccurs="1" name="betriebsNummerBT" type="s:int"/>
              <s:element minOccurs="0" maxOccurs="1" name="kontrollNummerBT" type="s:string"/>
              <s:element minOccurs="1" maxOccurs="1" name="netznummerBT" type="s:int"/>
              <s:element minOccurs="1" maxOccurs="1" name="berichtsJahrBT" type="s:int"/>
              <s:element minOccurs="1" maxOccurs="1" name="leermeldungBT" type="s:boolean"/>
              <s:element minOccurs="1" maxOccurs="1" name="paketeGesamtBT" type="s:int"/>
              <s:element minOccurs="1" maxOccurs="1" name="anzahlUntGesamtBT" type="s:int"/>
              <s:element minOccurs="1" maxOccurs="1" name="anzahlUntInPaketBT" type="s:int"/>
              <s:element minOccurs="1" maxOccurs="1" name="tranArtBT" type="tns:TransBeginnArtEnum"/>
            </s:sequence>
          </s:complexType>
        </s:element>
      - <s:simpleType name="TransBeginnArtEnum">
        - <s:restriction base="s:string">
            <s:enumeration value="EchtDaten"/>
            <s:enumeration value="TestVerweigert"/>
            <s:enumeration value="TestGesperrt"/>
            <s:enumeration value="TestAusserBetrieb"/>
            <s:enumeration value="TestAkzeptiert"/>
            <s:enumeration value="TestNichtAkzeptiert"/>
            <s:enumeration value="TestFehler"/>
          </s:restriction>
        </s:simpleType>
      - <s:element name="BeginnTransaktionResponse">
        - <s:complexType>
          - <s:sequence>
              <s:element minOccurs="0" maxOccurs="1" name="BeginnTransaktionResult" type="tns:BeginnTranAntwort"/>
            </s:sequence>
          </s:complexType>
        </s:element>
      - <s:complexType name="BeginnTranAntwort">
        - <s:complexContent mixed="false">
          - <s:extension base="tns:TranAntwort">
            - <s:sequence>
                <s:element minOccurs="0" maxOccurs="1" name="Transaktionsnummer" type="s:string"/>
```


13 https://app.bundesnetzagentur.de/WsVersorgUnterbrStrom/WsVersUnterbrechungenStrom.asmx?WSDL

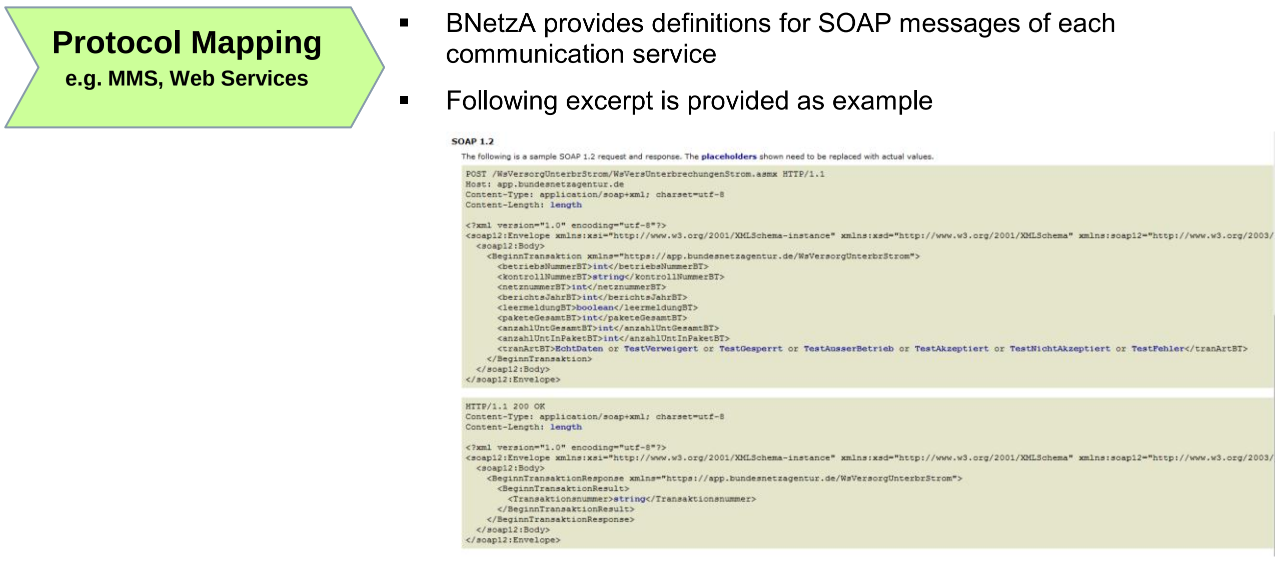


Figure 25: SGAM Analysis on the detailed level

In summary, this section outlines a SGAM analysis from a use case concept to a detailed description on all layers. It shows how different use case descriptions provide information for the SGAM layers with different level of abstraction. The SGAM analysis pattern depicted in Figure 3 can be used as guideline to derive high quality descriptions of use cases providing information on all interoperability layers of the SGAM framework.

9 Further example use cases to test the SGAM

9.1 Overview

The following use case, which had been considered in the Sustainable Processes workgroup and was already in the use case repository, has been identified and is proposed as suitable for this purpose. It relates to the internal automation function of the *customer* role for optimizations according to the preferences of the customer, based on signals from outside and internal flexibilities.

In this example, a demand response approach uses variable tariffs to motivate the customer to shift consumption in a different time horizon (i.e. load shifting). On customer side the signals are automatically evaluated according to preset customer preferences like cost optimization or CO2 savings and appropriate functions of one or more connected devices are initiated.

9.2 High level use case WGSP-2135 Inter-CEMS energy trading

Co-ordination of distributed generation and loads at neighborhood level based upon peer-to-peer communication between several Central Energy Management Systems, and brokerage within a multi-agent system

Within this high level use case, two primary use cases can be identified:

- The first primary use case (WGSP-2136) describes how flexibility is offered to other neighborhood CEMSs. An example of such a scenario would be peer-to-peer co-ordination of local energy trading involving extra PV energy (not used in-house) that can be stored or used by other homes in the neighborhood.
- The second primary use case (WGSP-2137) describes how flexibility is requested from other neighborhood CEMSs. An example of such a scenario would be peer-to-peer co-ordination for

voltage control i.e. how distributed generation resources can be utilized for voltage stability control purposes based on distributed intelligence.

The use cases are described in more detail in appendix A.

The following generic functional architecture for flexibility has been used as a basis in considering these use cases.

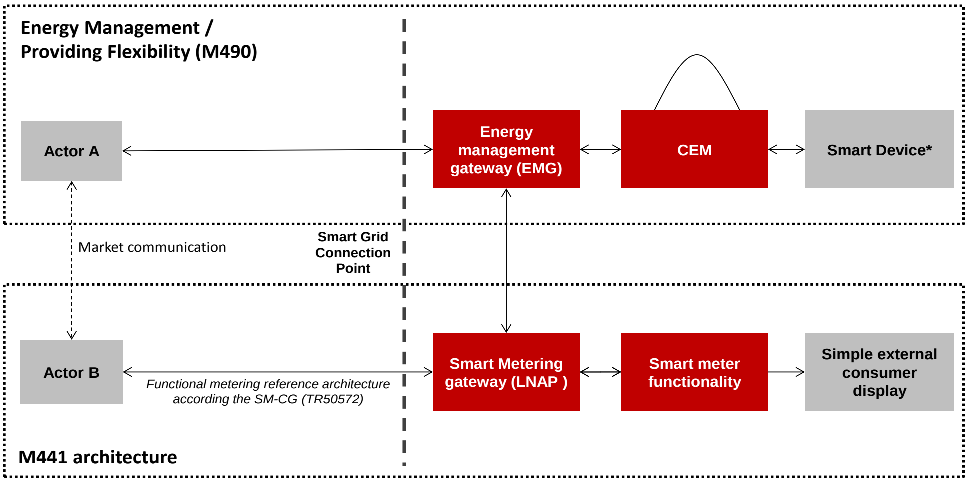


Figure 26: SGAM Analysis "Generic functional description"

Note that the actors in the above architectural diagram are functional entities, which means that some of them may be part of the same physical device (e.g. CEM functionality may be part of a smart device, the smart meter might also encompass the smart metering gateway and CEM, etc.)

The interfaces between the entities shown in the diagram are the subject of current standardization activities overseen by the Smart Grid Co-ordination Group, with those involving the AMI delegated to the Smart Meter Co-ordination Group.

9.3 Consideration of use cases against the SGAM

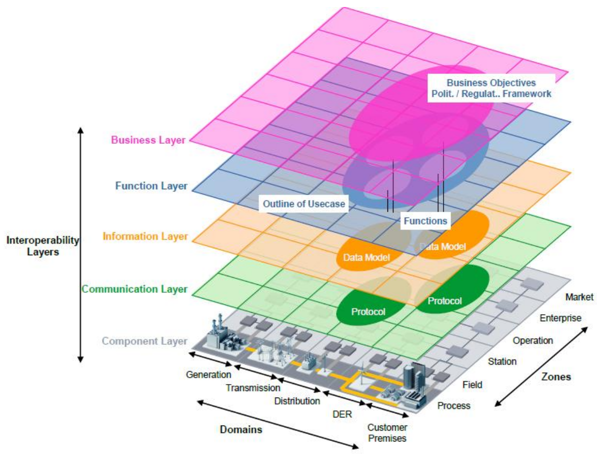


Figure 27: SGAM

<u>Domains and Zones</u>

Looking at the SGAM framework, we have seen that the activity envisaged in the selected use cases both involve peer-to-peer communications between CEMSs within a community.

In the case of WGSP-2136, the community would be at the most local level, within a few dwellings or buildings within a neighborhood. That ‘community’ of CEMs would manage their own flexibility as far as possible independently of the distribution system, acting as a kind of local ‘clearing house’ for flexibility. The wider smart grid would only ‘see’ the net result of that local activity if there were any residual flexibility needs or offerings after the local community had managed their individual flexibility in the way they had agreed upon, e.g. by having made optimum use of their local generation resources.

Thus in SGAM terms the peer-to-peer activity for WGSP-2136 is essentially localized to the DER and Customer Premises domains and the Process zone, with communications feeding back to the supplier (for billing purposes. The relevant communications would be via the energy management gateway or smart meter gateway. Given that the supplier will be receiving data and perhaps also managing the allocation process, communications would most probably make use of the protocols already defined for demand and production (generation) flexibility systems and in particular aggregated prosumers management systems.

In the case of WGSP-2137, the need for injection would be evident within the distribution domain and field zone, and as noted earlier, there would be some interaction between these zones and the peer-to-peer activity described. These communications would most probably make use of the protocols already defined for distributed power quality control systems.

Appendix A of the current document illustrate the detailed mapping of each of the use cases using the format adopted in the First Set of Standards work for the component, communication, information and function layers. This mapping is essentially the same as that for aggregated prosumers management systems and distributed power quality control systems, with the addition of a peer-to-peer element.

9.4 Implications of above analysis for the SGAM

The above analysis does not indicate that peer-to-peer communications as envisaged in the two use cases considered necessitate modification of the SGAM. Peer-to-peer communications can follow whatever protocols may be agreed upon locally.

However in the activity envisaged in WGSP-2136, residual flexibility arrangements (after local optimization) would need to be managed with the supplier/utility. Such communications would thus most probably make use of the protocols already defined for aggregated prosumers management systems. Indeed in overall terms WGSP-2136 can be seen as a refinement of the existing flexibility use case, with the addition of the peer-to-peer element.

Similarly, in the case of WGSP-2137, communications with the distribution domain would most probably make use of the protocols already defined for distributed power quality control systems.

9.5 Conclusions of the work to date

At a general and strategic level, the above analysis shows the value of the SGAM and the approach to mapping of use cases against the SGAM. It demonstrates how new use cases can be considered and incorporated within the present SGAM framework, using the tools developed by the SG-CG. It also shows how potential standardization gaps resulting from a new use case can be identified. This should be of value to future smart grid-related work by Technical Committees.

The analysis also shows that as use cases become more detailed, they increasingly reflect national and industry circumstances. However detailed use cases can be readily fitted into the SGAM methodology and framework. The value of the methodology is that it provides Member States, Technical Committees and others with a common approach and analytical language for such activity.

The analysis of the new use cases demonstrates is that there is no lack of European standards for the two use cases considered. The main challenge presented by the possibility of peer-to-peer communications as envisaged relates to the market, industry, legal and regulatory framework for such activity. Member States and others wishing to develop the concept at national level are exploring what arrangements would be required, and it may be necessary to review this preliminary conclusion in the light of such national use cases.

Finally the work demonstrates the need for ready access to the use case repository and to the templates and examples of use case descriptions, such as those shown in Appendix A below. This is necessary if those with potential new or more detailed use cases are to be able to check the relationship of such use cases to what has already been developed and to integrate them with previous work.

The work also shows the desirability of ready access to the detailed mapping tools used in presentation of the SGAM, as illustrated in Appendix A of the current document.

Appendix A

Use case descriptions and mapping to SGAM

A.1Introduction into the Appendix

This appendix sets out the detailed mapping of two use cases as examples originally considered in the Sustainable Processes workgroup and appearing in the use case repository. They relate to the internal automation function of the customer role for optimizations according to the preferences of the customer, based on signals from outside and internal flexibilities.

The use cases are included here to illustrate how the methodology in this report can be applied to novel use cases, considering the analysis of each use case, their detailed mapping to the SGAM at the component, communication and information layers.

A.2 Primary use case WGSP-2136

A2.1 Description

To illustrate the first primary use case WGSP-2136, the agent of the “PV house” may offer its energy (as a proposal) while the broker agents of the other homes evaluate the proposal knowing their own upcoming loading schedule, the habits of the house, the storage capacity, its own generation capacity and other relevant information. Accepting the energy offer would lead to a load increase and effectively a temporary switch of energy provider in the homes that accepted the energy offer. Hence, the energy produced by the PV would be locally absorbed. Various schemes of energy allocation within the neighborhood can be thought of, leading to different required billing approaches. This dynamic matching may result in nothing being perceived at the distribution substation, no load increment, no injection increment.

WGSP-2136: Inter-CEM flexibility offerings

Scenario Name	Primary Actor	Triggering Event	Pre-Condition	Post-Condition
Inter-CEM flexibility offering	CEM-1	CEM_1 is (made) aware of one or more potential flexible loads / production	CEM_1 is configured to create flexibility offerings CEM_1 is configured for inter-CEM communication The potential flexible load does not fall into a constraint set by the end-user	CEM_xyz is aware that flexibility has been assigned

Typical steps

Step No.	***Event***	***Name of Process/ Activity***	***Description of Process/ Activity***	***Information Producer (Actor)***	***Information Receiver (Actor)***	***Information Exchanged***
1	CEM_1 is (made) aware of one	Send flexibility	CEM_1 creates flexibility offering and sends this to	CEM_1	CEM_2-n	Flexibility Offer

	or more potential flexible loads / production	offer	connected neighborhood CEM's			
2	Neighbor-hood CEM's receive the flexibility offer	Reply to flexibility offer	Neighborhood CEM's reply, indicating the conditions under which they are willing to accept the flexibility offer	CEM_2-n	CEM_1	Flexibility Offer Reply
3	CEM_1 receives reply from interested neighbor-hood CEM's	Assign flexibility	CEM_1 determines the "winners", the final amount of power for each and sends an assignment to the "winning" neighborhood CEM's	CEM_1	CEM_xyz	Flexibility Offer Assignment

A2.2 Implications: WGSP-2136

Considering the selected use case WGSP-2136 more deeply, it is evident that this peer-to-peer clearing activity is only worthwhile in practice if suitable commercial and regulatory arrangements are in place. It has to be cheaper for the community to act together in this way than if the dwellings concerned engaged individually in offering their own flexibility to the grid at whatever price their supplier/utility was offering. Thus the dwelling with its own generation would have to get a better price by making it available to the local community than the price that would be obtained if the power were exported to the wider grid; similarly the customers in that community needing electricity would have to get it at a better price than the retail price available from their supplier.

A number of approaches are possible to achieve this, and all would probably require changes to the industry model operating in the member state concerned. However, one way is that the community could in effect act as a group customer, aggregating energy requirements / pooling generation resources, and entering into a supply (possibly wholesale?) contract with their chosen supplier for the balance of the community's needs. The community coordinator would keep a list of community energy resources up-to-date and indicate available resources and communicating community energy offers/needs to each energy management gateway (EMG). Customers would continue to be metered individually, but a community system of (dynamic) allocation would exist in parallel, with direct transactions set-up between different EMGs (e.g. via the internet). This need not involve the community coordinator. However the coordinator would take information from the various CEMSs on the outcome of the transactions and divide costs and benefits according to whatever methodology they might mutually agree.

For the latter to work, the community agreement would need to be registered with the supplier. Registration would entitle community members to receive a higher price (or other benefit) for locally produced and consumed energy than the normal export price, since the export price would normally take account of the distribution costs associated with injection of energy into the grid. Similarly members consuming locally produced power would receive a discount on the distribution element of the normal retail tariff to reflect their local consumption. NOTE this is simpler to achieve if all members of the community are customers of the same supplier.

A community coordinator (specific to the community or an Energy Service Provider acting on behalf of the community) could receive an aggregated bill on behalf of all members based on these special community prices and then allocate costs/income accordingly. Or the supplier, acting as the agent of the community and following the community's allocation rules in the registered agreement, could carry out the task.

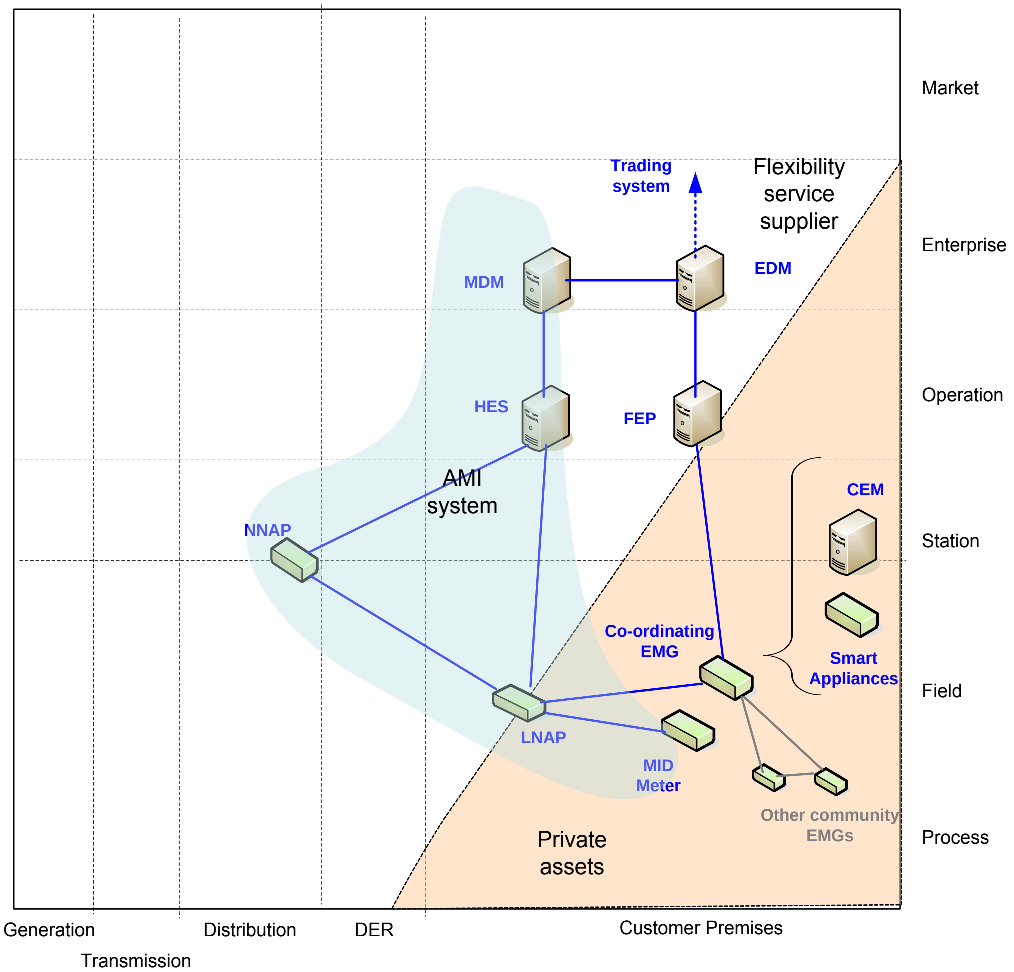
NOTE A direct peer-to-peer agreement between two individual parties seems unlikely to be able to be implemented without someone playing a coordinating role, serving as a community repository or acting as an aggregator on behalf of the community, and for this reason, the community coordinator is seen as a separate actor, even if the role is undertaken by one of the users in the community.

In terms of information flows, there would be a need to manage the aggregation and allocation process. This would require communications between individual community members (or more precisely the energy management gateways of the premises concerned) and the community coordinator, and potentially peer-to-peer communications between CEMSs via their energy management gateways also.

Since this use case is primarily concerned with achieving the optimal commercial outcome for the community, the coordinator would also communicate with the community's supplier, with the coordinator acting as either a community aggregator or a quasi-customer and dealing with the supplier for any surplus energy made available to the wider grid. Since the coordinator is in effect acting as a customer, communications with the supplier can be seen in the same way as when an individual customer is providing flexibility.

1181 ### A.2.3 Detailed mapping of WGSP-2136 to SGAM

1182 The following diagrams illustrate possible mapping of WGSP-2136 at the component, communication and
1183 information layers[14].



1184

1185 **Figure A- 1 : Mapping of WGSP-2136 to the SGAM Component Layer**

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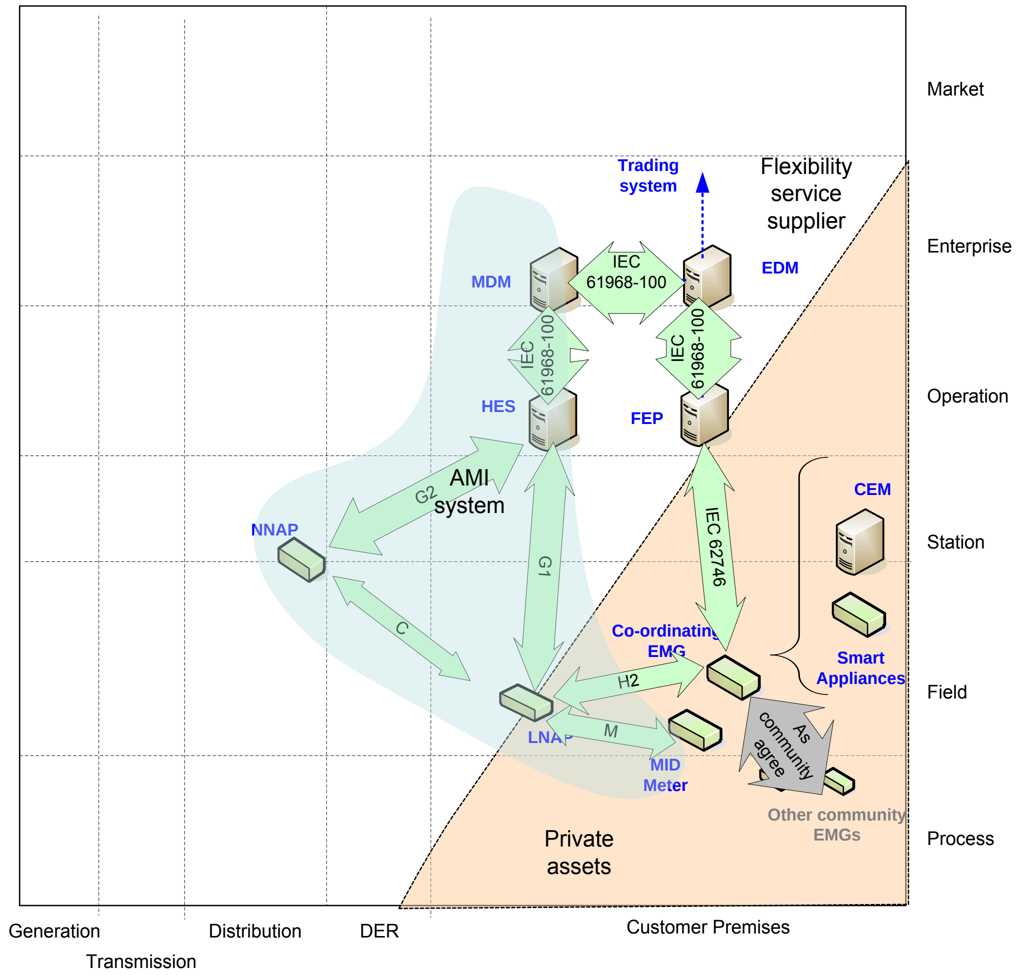
[14] Please that the following mappings are based on [SG-CG/G], abbreviations and symbols are explained in this report.



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1188 **Figure A- 2: Mapping of WGSP-2136 to the SGAM Communication Layer**

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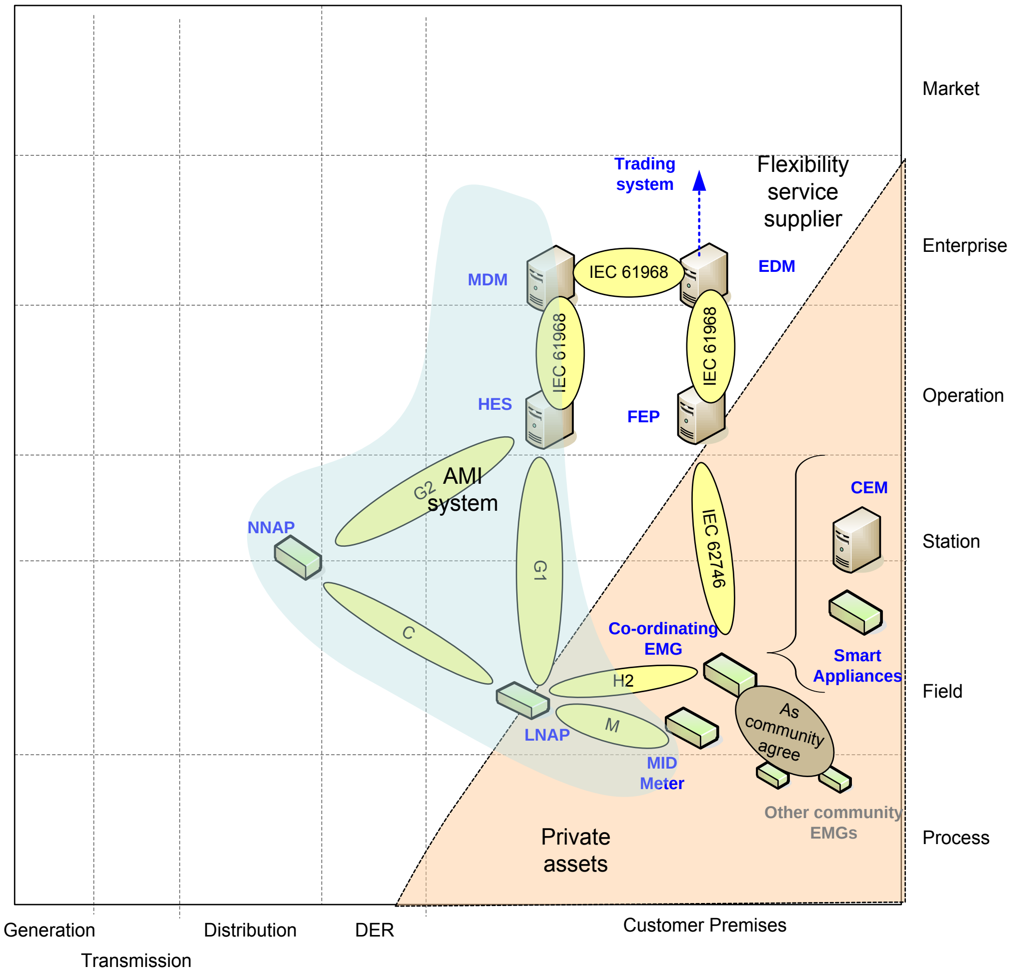

1190

1191 **Figure A- 3: Mapping of WGSP-2136 to the SGAM Information Layer**

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A.3 Primary use case WGSP-2137

A.3.1 Description

To illustrate the second primary use case WGSP-2137, consider a radial distribution network with distributed generation resources (producers). The producers can be used to support voltage by injection of power at the connection node. Each producer is monitored and controlled by a broker agent, which can detect the voltage violation. Each agent can behave as a broker to engage the other agents (and in practice their generators) in the voltage regulation. Note that each agent is capable of broker behavior, so this structure is not rigid. Each producer can contribute depending on its current operating conditions and “electrical position” in the network. Via his CEMS, the broker agent requests flexibility and, based on the current information and offers received from the other agents, decides a dispatch strategy.

In this use case, the broker agent is considered to be a part of the CEM and includes local monitoring and control capabilities as well as algorithms for brokerage including accounting. Since this use case describes communication between multiple CEMS, each CEM is assigned a number / an IP address.

<u>WGSP-2137: Inter-CEM flexibility request</u>

Scenario Name	**Primary Actor**	**Triggering Event**	**Pre-Condition**	**Post-Condition**
Inter-CEM flexibility request	CEM_1	CEM_1 is (made) aware of a flexibility need	CEM_1 is configured to request flexibility CEM_1 is configured for inter-CEM communication The potential flexible load does not fall into a constraint set by the end-user	CEM_xyz is aware that flexibility has been assigned

<u>Typical steps</u>

Step No.	***Event***	***Name of Process/ Activity***	***Description of Process/ Activity***	***Service***	***Information Producer (Actor)***	***Information Receiver (Actor)***	***Information Exchanged***
1	CEM_1 is (made) aware of a flexibility need	Send flexibility request	CEM_1 creates a flexibility request and sends this to connected neighborhood CEM’s		CEM_1	CEM_2-n	Flexibility Request
2	Neighbor-hood CEM’s receive the flexibility request	Reply to flexibility request	Neighborhood CEM’s reply, indicating the conditions under which they are willing to provide		CEM_2-n	CEM_1	Flexibility Request Reply

			flexibility				
3	CEM_1 receives reply from offering neighbor-hood CEM's	Assign flexibility	CEM_1 determines the "winners", the final amount of power for each and sends an assignment to the "winning" neighborhood CEM's		CEM_1	CEM_xyz	Flexibility Request Assignment

Information exchanged

Name of Information Exchanged	***Description of Information Exchanged***
Flexibility Offer	
Flexibility Offer Reply	Contains information on how much flexibility is the CEM willing to buy, what is the local impact and which is the sensitivity index value)
Flexibility Offer Assignment	
Flexibility Request	
Flexibility Request Reply	Contains information on how much flexibility is the CEM willing to offer, what is the local impact and which is the sensitivity index value)
Flexibility Request Assignment	

A.3.2 Implications: WGSP-2137

In WGSP-2137, there is in effect a 'community' of producers who are prepared to inject power as required by the local distribution company. This community may be virtual, rather than geographically delineated as in WGSP-2136, but in common with WGSP-2136, the list of individual premises involved in the process would probably be registered in some way, in this instance with the distribution company. While the need for power injection could be communicated to the producers in the community by the distribution company, this use case envisages an automatic process based on monitoring of the system by individual producers and peer-to-peer communications between them to determine optimal dispatching on a collective basis.

Since the purpose is to stabilize voltage within the wider distribution grid, no special community tariff arrangements would be required. Individual producers would be recompensed via the usual export tariffs for their part in the collective resolution of the need for injection. In common with WGSP-2136, peer-to-peer communication would be required, together with the existence of a community coordinator who would manage the community response in accordance with locally determined rules.

In terms of information flows at the local level, there would be a similar need for communications between individual community members (or rather the energy management gateways of the premises concerned) and the community coordinator, and potentially peer-to-peer communications between energy management gateways also. However since the use case is primarily concerned with achieving the optimal response by the community to a distribution problem, the coordinator would in this instance communicate with the distribution system operator. Again the coordinator is in effect acting as a customer, and communications from the distribution company can be seen as an emergency response use case.

A.3.3 Detailed mapping of WGSP-2137 to SGAM

The following diagrams illustrate possible mapping of WGSP-2137 at the component, communication and information layers.

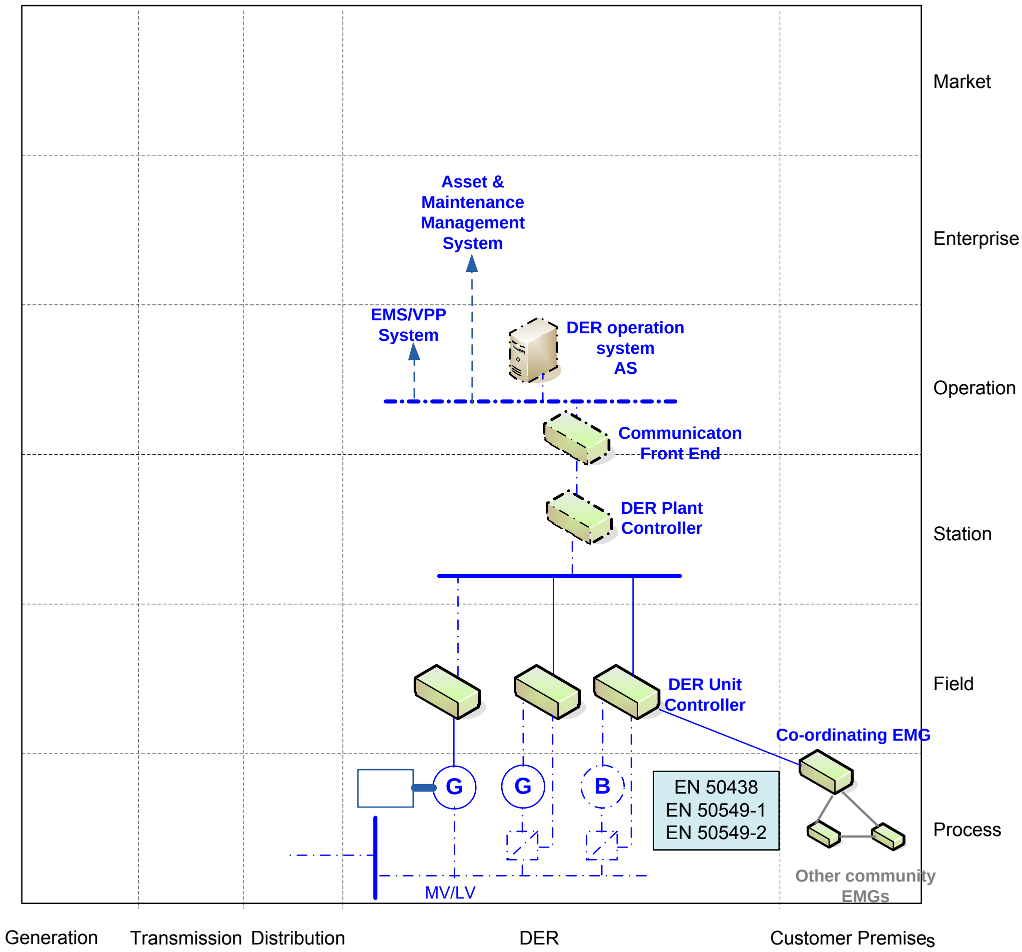

Figure A-4 : Mapping of WGSP-2137 to the SGAM Component Layer

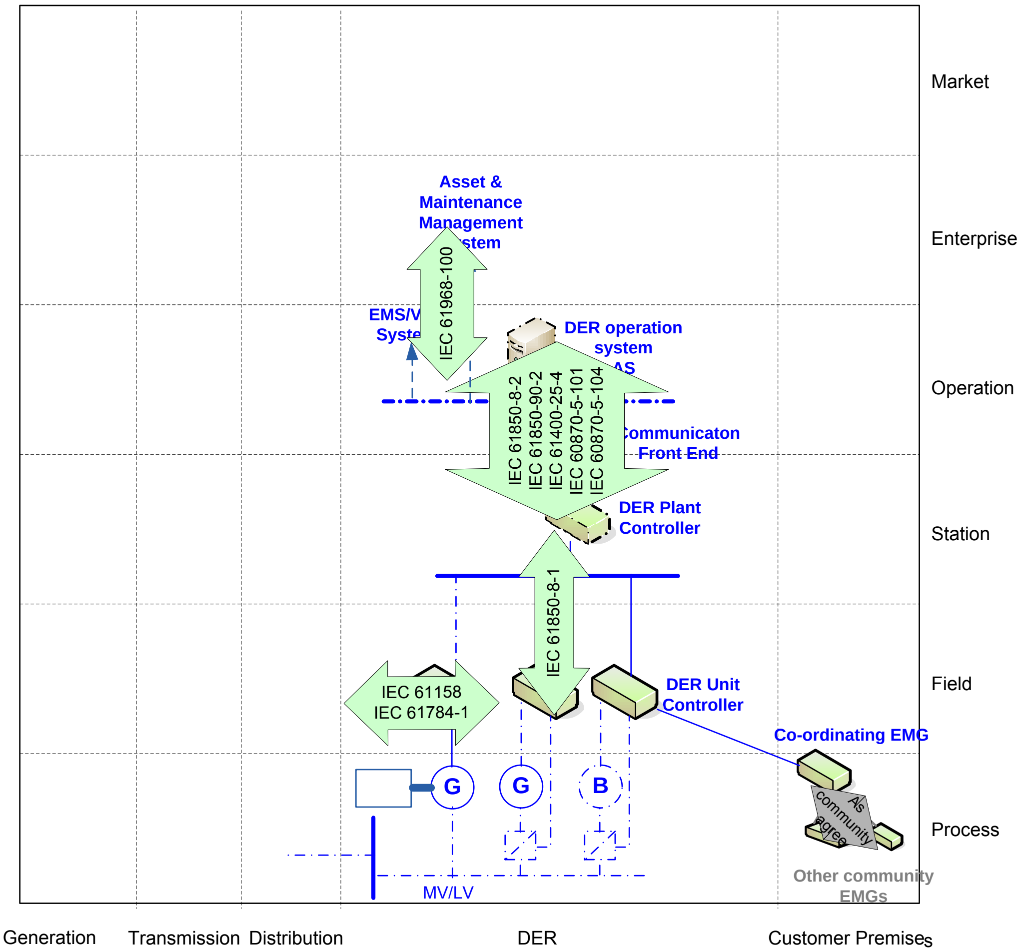

Figure A- 5: Mapping of WGSP-2137 to the SGAM Communication Layer

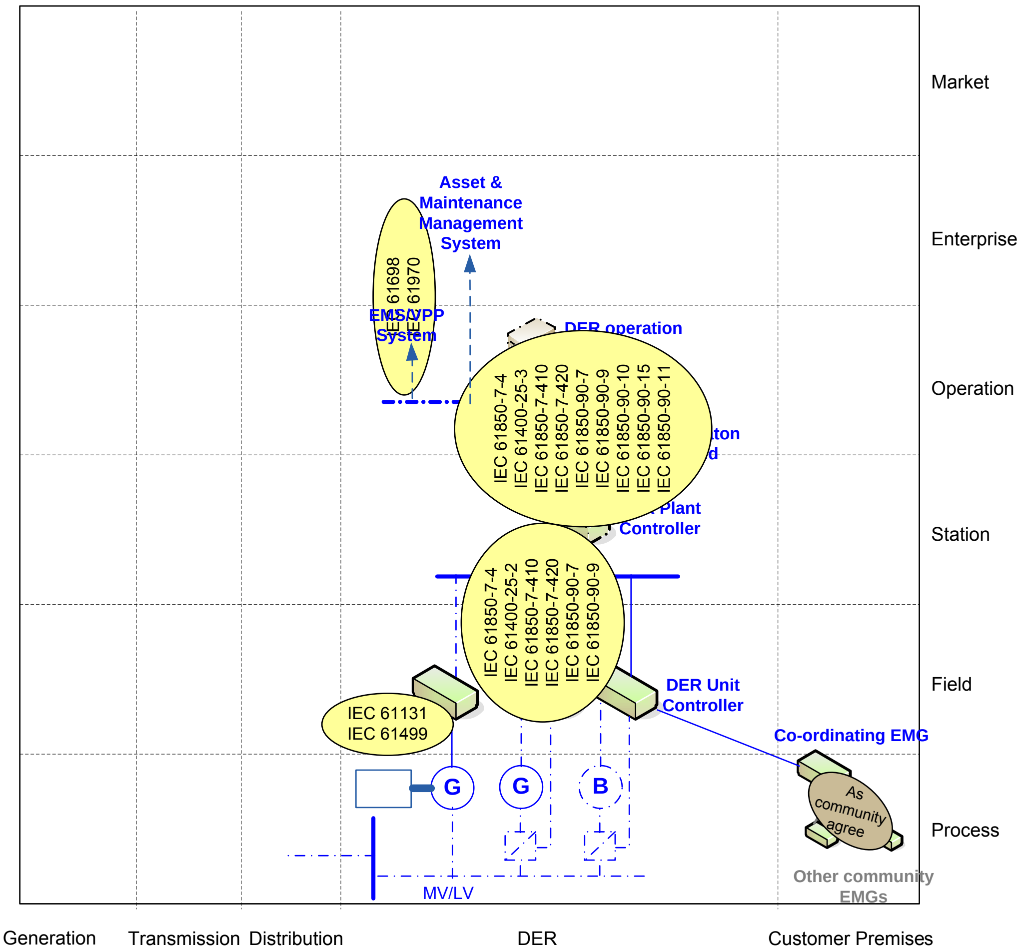

Figure A- 6: Mapping of WGSP-2137 to the SGAM Information Layer