CEN-CENELEC-ETSI Smart Grid Coordination Group

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CEN-CENELEC-ETSI Smart Grid Coordination Group

Smart Grid Reference Architecture

Contents

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History of document

Number	Date	Content
v0.5	24/01/2012	First TR external version for SG-CG “Sanity Check”
v1.0	02/03/2012	First Interim TR draft for official comments
v2.0	31/07/2012	Second interim TR draft for official comments
v3.0	**08/11/2012**	**Final TR for adoption by M/490**

Main changes in this version

The adoption of the SG-CG report template has induced a reordering and renumbering of most of the sections and annexes.

The changes between version 2.0 and 3.0 have been kept minimal, considering that this version was not to be reviewed.

However, Annex C has been largely changed. A lot of new work has been done within SG-CG/RA between TR2.0 and TR3.0 on the Conceptual Model. Considering that is was useful to the readers, even if it could not be introduced in the main section of the report because of the many uncommented changes, it has been decided to present it as an informative reference.

In addition, Annex F (Communication Architecture) has been largely changed and is provided as a separate document, as in the previous versions of this report.

Foreword

Based on the content of the M/490 EU Mandate, 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 promote continuous innovation.

The expected framework will consist of a set of deliverables. The deliverable addressed in this document is:

> "A technical reference architecture, which will represent the functional information data flows between the main domains and integrate several systems and subsystems architectures."

The development of this technical Reference Architecture, under the form of a Technical Report (TR), is the main responsibility of the Reference Architecture Working Group (SG-CG/RA), working under the Smart Grid Coordination Group (SG-CG) established by CEN, CENELEC and ETSI in order to fulfill the tasks laid down the Mandate M/490 of the European Commission.

The members of the Reference Architecture WG have been nominated, following an official call for experts. They have met since June 2011 in order to produce the various versions of the Technical Report. A Work Programme has been set-up that involves the production of several versions of the TR until final completion.

A first version v0.5 has been circulated in January 2012 for "Sanity check" within the SG-CG, to get guidance on the main aspects of the report.

The version v1.0 was the first Interim Report. It was a first solid step towards the Reference Architecture and has initiated a discussion about the architectural model proposed as well as its different viewpoints and dimensions.

The version v2.0 was the second Interim Report. It has been developed on the basis of the feedback (over 340 comments) received on v1.0 and on new contributions from the SG-CG/RA team.

The version v3.0 (this document) is the final version of the report within the current iteration of the M/490 mandate. It will be handed over to the European Commission in November 2012 and sent for approval by CEN, CENELEC and ETSI.

Further work on this report is expected in a subsequent iteration of the M/490 mandate, still to be decided.

1 Scope

This document is prepared by the Smart Grid Coordination Group (SG-CG) Reference Architecture Working Group (SG-CG/RA) and addresses the M/490 mandate's deliverable regarding the technical reference architecture.

This report is the final report due at the end of 2012.

1.1 How to use the document

The overall content of this document is as follows.

Chapter 1 (this chapter) introduces the approach chosen by the SG-CG/RA to address a complex problem space and the corresponding choices to define the scope of work. It outlines the main outcome expected at the end of the work and clarifies what is the main (but by far not the only) audience for the report. It also briefly outlines what is not in the scope of the SG-CG/RA work.

Chapters 2, 3 and 4 provide background information to the report (References, etc.) whenever they are not common to all SG-CG Reports.

Chapter 5 is an Executive Summary which is reproduced as such in the overall M/490 Framework Document.

Chapter 6 provides the European view of the Smart Grids Conceptual Model and an overview of the general elements of a Reference Architecture. It introduces the viewpoints chosen as target of the SG-CG/RA work.

Chapter 7 introduces the Smart Grids Architecture Model (SGAM) framework. The SGAM introduces interoperability aspects and how they are taken into account via a domain, zone and layer based approach. It finally introduces the methodology associated with the SGAM. Taking into account the interoperability dimension, the SGAM is a method to fully assign and categorize processes, products and utility operations and align standards to them.

Chapter 8 outlines the main elements of the different architectural viewpoints chosen for development by the SG-CG/RA, i.e. the Business, Functional, Information and Communication Architectures. Additional material or more detailed presentations of these architectures are provided in Annexes (that can be separate documents if their size requires it).

Chapter 1 lists the work items that SG-CG/RA may address in view of the next iteration of the M/490 mandate.

Annex A is grouping all the background work that serves as a foundation to the SG-CG/RA Report but was deemed not essential to the understanding of the Reference Architecture principles.

Annex B provides an overview how the SG-CG Sustainable Processes Work Group's Use Cases can be applied alongside the SGAM model, providing a holistic architectural view comprising the most important aspects for Smart Grid operations. In particular, it contains a detailed example regarding the application of the SGAM Methodology to a generic Smart Grid use case.

Annexes C to F provide details of the Reference Architecture viewpoints.

1.2 Approach to the problem domain

Considering that the overall scope of an architectural description can be quite large, the SG-CG/RA has chosen to focus on the following aspects of the reference architecture:

- Means to communicate on a common view and language about a system context, not only in the SG-CG but also with industry, customers and regulators;
- Integration of various existing state-of-the-art approaches into one model with additional European aspects;
- Methods to serve as a basis to analyze and evaluate alternative implementations of an architecture;
- Support for planning for transition from an existing legacy architecture to a new smart grid-driven architecture;
- Criteria for properly assessing conformance with identified standards and given interoperability requirements.

This has led the SG-CG/RA to address three major objectives:

- Ensuring that the main elements of the architectural model be able to represent the Smart Grid domain in an abstract manner with all the major stakeholders. Such a model should be coherent with already existing comparable models worldwide.
- Define an architectural framework that would support a variety of different approaches corresponding to different stakeholders' requirements and make it in a timeframe that would force to choose a limited set of such approaches.
- Providing a methodology that would allow the users of the architectural model to apply it to a large variety of use cases so that, in particular, it would provide a guide to analyze potential implementation scenarios, identify areas of possible lack of interoperability (e.g. missing Standards), etc.

Regarding the first objective, the NIST Conceptual Model [NIST 2009] was considered as a first essential input, though it required adaptation to the European context and some of its specific requirements (identified by prior work of the European Smart Grid Task Force).

Completion of the second objective required a careful selection of the architecture viewpoints to be developed. In general, reference architectures aim at providing a thorough view of many aspects of a system viewed by the different participating stakeholders throughout the overall system lifecycle. This means that, on a complex system like the Smart Grid, it is not always possible to cover all viewpoints and choices had to be made.

In particular, the viewpoints had to be chosen in order to allow for a meaningful description of relevant and essential aspects of the system (e.g. intended use and environment, principles, assumptions and constraints to guide future change, points of flexibility or limitations), documenting architectural decisions with their rationales, limitations and implications.

The third objective was reached through the provision of a model that would make the link between the different architecture viewpoints and that could be used in a systematic manner, thus leading to the provision of a methodology.

1.3 Outcome: an architecture framework and a mapping methodology

This report addresses the technical reference architecture part of mandate M/490 and provides the main results below:

- European Conceptual Model. It is an evolution of the NIST model in order to take into account some specific requirements of the EU context that the NIST model did not address. The major one is the integration of “Distributed Energy Resources” (DER).

- Architecture Viewpoints. They represent a limited set of ways to represent abstractions of different stakeholders' views of a Smart Grid system. The viewpoints selected are the Business, Functional, Information, Communication viewpoints.

- Smart Grids Architecture Model (SGAM) Framework. The architecture framework takes into account already identified relevant aspects [JWG-SG 2010] like interoperability (e.g. the

GridWise Architecture Council (GWAC) Stack), multi-viewpoints (SGAM Layers). Additionally, a functional classification, overview on needed and existing data models, interfaces and communication layers and requirements is provided to the First Set of Standards Work Group (FSSWG).

This framework can be applied, as a mapping methodology, to document smart grid use cases (developed by the Sustainable Processes Work Group - SG-CG/SP) from a technical, business, standardization and security point-of-view (as developed with the Smart Grids Information Security Work Group - SG-CG/SGIS) and identify standards gap.

1.4 Main target audience: Standardization Technical Committees

The target audience of the reference architecture is mainly standardization bodies and technical groups which can use the architectural framework, the methodological guidelines as well as the mappings of existing architectures (developed in the report annexes) to guide their work.

The SGAM provides a holistic view on the most important existing standards and architectures from different SDOs, making this deliverable a valuable document for members of standardization dealing with Smart Grid standards.

1.5 What is not in the scope of this document

For a variety of reasons, the work of SG-CG/RA shall not address notably the following domains:

- Standards development; Certification
- Market Models
- Regulation issues
- Home Automation, Building, …
- Gas

2 References

Smart Grids Coordination Group 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 (this document)
[SG-CG/D] SG-CG/M490/D_Smart Grid Information Security
[SG-CG/E] SG-CG/M490/E_Smart Grid Use Case Management Process

References made in the main part of this document

[ENTSO-E 2011] The Harmonized Electricity Market Role Model (December 2011), ENTSO-E, online: https://www.entsoe.eu/fileadmin/user_upload/edi/library/role/role-model-v2011-01.pdf.

[ENTSO-E 2012] ‘Modular Development Plan of the Pan-European Transmission System 2050’ of the e-HIGHWAY2050 Project Consortium: https://www.entsoe.eu/system-development/2050-electricity-highways/

[GWAC2008] GridWise Interoperability Context-Setting Framework (March 2008), GridWise Architecture Council, online: www.gridwiseac.org/pdfs/.

[IEEE2030-2011] IEEE Guide for Smart Grid Interoperability of Energy Technology and Information Technology Operation, with the Electric Power System (EPS), End-Use Applications, and Loads, IEEE Std. 2030 (2011).

[IEC61850-2010] IEC 61850, Communication networks and systems for power utility automation, 2010.

[IEC62357-2011] IEC 62357-1, TR Ed.1: Reference architecture for power system information exchange, 2011.

[IEC62559-2008] IEC 62559, PAS Ed.1: Intelligrid Methodology for developing requirements for Energy Systems

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

[ISO/IEC42010] ISO/IEC 42010: Systems Engineering – Architecture description, 2011

[JWG-SG 2011] JWG Smart grids: Final report: JWG report on standards for smart grids – V1.1

[NIST2009] NIST Framework and Roadmap for Smart Grid Interoperability, Interoperability Standards Release 1.0 (2009), Office of the National Coordinator for Smart Grid Interoperability, National Institute of Standards and Technology, U.S. Department of Commerce. Online: www.nist.gov/public_affairs/releases/smartgrid_interoperability.pdf

[NIST 2012] Framework and Roadmap for Smart Grid Interoperability, Interoperability Standards Release 1.0 (2009), Office of the National Coordinator for Smart Grid Interoperability, National Institute of Standards and Technology, U.S. Department of Commerce. Online: www.nist.gov/public_affairs/releases/smartgrid_interoperability.pdf

References made in the Annexes of this document

It should be noted that the SG-CG First Set of Standards Work Group report [SG-CG/B] provides a list of references that may include most of the references below. In case of doubt on the applicable referenced documents, the [SG-CG/B] list prevails.

The following references are made in Annex E:

- Mapping of IEC 61850 Common Data Classes on IEC 60870-5-104 (IEC 61850-80-1 TS)
- OASIS EMIX
- UN/CEFACT CCTS
- EN 60870-6-802:2002 + A1:2005, *Telecontrol equipment and systems – Part 6-802: Telecontrol protocols compatible with ISO standards and ITU-T recommendations – TASE.2 Object models*
- EN 60870-5-1:1993, *Telecontrol equipment and systems – Part 5: Transmission protocols – Section 1: Transmission frame formats*
- EN 60870-5-3:1992, *Telecontrol equipment and systems – Part 5: Transmission protocols – Section 3: General structure of application data*
- IEC 61850-7-410 Ed. 1.0, *Communication networks and systems for power utility automation – Part 7-410: 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 61400-25-2, *Communications for monitoring and control of wind power plants – Part 25-2: Information models*
- IEC 61400-25-3, *Communications for monitoring and control of wind power plants – Part 25-3: Information exchange models*
- IEC 61400-25-6, *Communications for monitoring and control of wind power plants – Part 25-6 Communications for monitoring and control of wind power plants: Logical node classes and data classes for condition monitoring*
- IEC 62056 series, *Electricity metering – Data exchange for meter reading, tariff and load control*, Parts 21, 31, 41, 42, 46, 47, 51, 52, 53, 61, 62
- IEC 61334, *Distribution automation using distribution line carrier systems* – Part 4 Sections 32, 511, 512, Part 5 Section 1
- EN 61970-301:2004, *Energy management system application program interface (EMS-API) – Part 301: Common information model (CIM) base*
- EN 61970-402:2008 Ed. 1.0, *Energy management system application program interface (EMS- API) – Part 402: Component interface specification (CIS) – Common services*
- EN 61970-403:2007, *Energy management system application interface (EMS- API) – Part 403: Component Interface Specification (CIS) – Generic Data Access*
- EN 61970-404:2007, *Energy management system application program interface (EMS-API) – Part 404: High Speed Data Access (HSDA))*
- EN 61970-405:2007, *Energy management system application program interface (EMS-API) – Part 405: Generic eventing and subscription (GES)*
- EN 61970-407:2007, *Energy management system application program interface (EMS-API) – Part 407: Time series data access (TSDA)*
- EN 61970-453:2008, *Energy management system application interface (EMS- API) – Part 453: CIM based graphics exchange*
- EN 61970-501:2006, *Energy management system application interface (EMS- API) – Part 501: Common information model resource description framework (CIM RDF) Schema*
- EN 61968-:2004, Application integration at electric utilities – System interfaces for distribution management – Part 3: Interface for network operations
- EN 61968-4:2007, Application integration at electric utilities – System interfaces for distribution management – Part 4: Interfaces for records and asset management
- EN 61968-9:2009, System Interfaces For Distribution Management – Part 9: Interface Standard for Meter Reading and Control
- FprEN 61968-11:2010, System Interfaces for Distribution Management – Part 11: Distribution Information Exchange Model
- EN 61968-13:2008, System Interfaces for distribution management – CIM RDF Model Exchange Format for Distribution

- IEC 61850-5 Ed. 1.0, *Communication networks and systems in substations – Part 5: Communication requirements for functions and device models*
- IEC 61850-6 Ed. 1.0, *Communication networks and systems in substations – Part 6: Configuration description language for communication in electrical substations related to IEDs*
- IEC 61850-7-1 Ed. 1.0, *Communication networks and systems in substations – Part 7-1: Basic communication structure for substation and feeder equipment – Principles and models*
- IEC 61850-7-2 Ed. 1.0, *Communication networks and systems in substations – Part 7-2: Basic communication structure for substation and feeder equipment – Abstract communication service interface (ACSI)*
- IEC 61850-7-3 Ed. 1.0, *Communication networks and systems in substations – Part 7-3: Basic communication structure for substation and feeder equipment – Common data classes*
- IEC 61850-7-4 Ed. 1.0, *Communication networks and systems in substations – Part 7-4: Basic communication structure for substation and feeder equipment – Compatible logical node classes and data classes*
- IEC 62325-301 Ed.1.0 : Common Information Model Market Extensions
- IEC 62325-501 Framework for energy market communications - Part 501: General guidelines for use of ebXML
- IEC 62325-351 Framework for energy market communications - Part 351: CIM European Market Model Exchange Profile
- IEC 62325-502 Framework for energy market communications - Part 502: Profile of ebXML

Other references pertaining to Communication Architecture are made in Annex F.

3 Terms and definitions

Architecture
Fundamental concepts or properties of a system in its environment embodied in its elements, relationships, and in the principles of its design and evolution [ISO/IEC42010].

Architecture Framework
Conventions, principles and practices for the description of architectures established within a specific domain of application and/or community of stakeholders [ISO/IEC42010].

Conceptual Model
The Smart Grid is a complex system of systems for which a common understanding of its major building blocks and how they interrelate must be broadly shared. NIST has developed a *conceptual architectural reference model* to facilitate this shared view. This model provides a means to analyze use cases, identify interfaces for which interoperability standards are needed, and to facilitate development of a cyber security strategy. [NIST2009]

Interoperability
Interoperability refers to the ability of two or more devices from the same vendor, or different vendors, to exchange information and use that information for correct co-operation [IEC61850-2010].

Reference Architecture
A Reference Architecture describes the *structure* of a system with its element types and their structures, as well as their *interaction* types, among each other and with their environment. Describing this, a Reference Architecture defines restrictions for an instantiation (concrete architecture). Through abstraction from individual details, a Reference Architecture is universally valid within a specific domain. Further architectures with the same functional requirements can be

constructed based on the reference architecture. Along with *reference* architectures comes a *recommendation*, based on experiences from existing developments as well as from a wide acceptance and recognition by its users or per definition. [ISO/IEC42010]

SGAM Interoperability Layer
In order to allow a clear presentation and simple handling of the architecture model, the interoperability categories described in the GridWise Architecture model are aggregated in SGAM into five abstract interoperability layers: Business, Function, Information, Communication and Component.

SGAM Smart Grid Plane
The Smart Grid Plane is defined from the application to the Smart Grid Conceptual Model of the principle of separating the Electrical Process viewpoint (partitioning into the physical domains of the electrical energy conversion chain) and the Information Management viewpoint (partitioning into the hierarchical zones (or levels) for the management of the electrical process. [IEC62357-2011, IEC 62264-2003]

SGAM Domain
One dimension of the *Smart Grid Plane* covers the complete electrical energy conversion chain, partitioned into 5 domains: Bulk Generation, Transmission, Distribution, DER and Customers Premises.

SGAM Zone
One dimension of the *Smart Grid Plane* represents the hierarchical levels of power system management, partitioned into 6 zones: Process, Field, Station, Operation, Enterprise and Market [IEC62357-2011].

4 Symbols and abbreviations

Acronyms

3GPP	3rd Generation Partnership Project
6LoWPAN	IPv6 over Low power Wireless Personal Area Networks
ADSL	Asymmetric digital subscriber line
AN	Access Network
ANSI	American National Standard Institute
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning
BCM	Business Capability Model
CEN	Comité Européen de Normalisation.
CENELEC	Comité Européen de Normalisation Electrotechnique
CIM	Common Information Model
DER	Distributed Energy Resources
DSO	Distribution System Operator
eBIX	(European forum for) energy Business Information Exchange
EGx	EU Smart Grid Task Force Expert Group x (1 to 3)
ENTSO-E	European Network of Transmission System Operators for Electricity
ESCO	Energy Service Company
eTOM	extended Telecom Operations Map
ETSI	European Telecommunications Standard Institute
EV	Electrical Vehicle
EVO	Electrical Vehicle Operator
FACTS	Flexible Alternating Current Transmission Systems
FLISR	Fault Location Isolation and Service Recovery
GSM	Global System for Mobile
GWAC	GridWise Architecture Council
HAN	Home Area Network

HDSL	High-bit-rate digital subscriber line
HSPA	High Speed Packet Access
ICT	Information & Communication Technology
IEEE	Institute of Electrical and Electronics Engineers
IETF	Internet Engineering Task Force
IP	Internet Protocol
IPv6	Internet Protocol Version 6
ISO	International Organization for Standardization
ITU-T:	International Telecommunications Union for the Telecommunication Standardization Sector
JWG	Joint Working Report for Standards for the Smart Grids
KNX	EN 50090 (was Konnex)
L2TP	Layer 2 Tunneling Protocol
LR WPAN	Low Rate Wireless Personal Area Network
LTE	Long Term Evolution
MAC	Media Access Control
MPLS	Multiprotocol Label Switching
MPLS-TP	MPLS Transport Profile
NAN	Neighborhood Area Network
NAT	Network Address Translator
OSI:	Open System Interconnection
OTN	Optical Transport Network
PLC	Power Line Carrier
PLC	Power Line Communication
PON	Passive Optical Network
QoS	Quality of Service
RPL	Routing Protocol for Low power and lossy networks (LLN)
SDH	Synchronous Optical Networking
SDO	Standards Developing Organization
SG-CG	Smart Grids Coordination Group
SG-CG/FSS	SG-CG First Set of Standards Work Group
SG-CG/RA	SG-CG Reference Architecture Work Group
SG-CG/SP	SG-CG Sustainable Processes Work Group
SLA	Service Level Agreement
TDM	Time Division Multiplexing
TMF	TeleManagement Forum
TOGAF	The Open Group Architecture Framework
TSO	Transmission System Operator
UMTS	Universal Mobile Telecommunications System
WAN	Wide Area Network
WAMS	Wide Area Management Systems
WAN	Wide Area Network
WASA	Wide Area Situation Awareness
WPAN	Wireless Personal Area Network
xDSL	Digital Subscriber Line
XG-PON	10G PON

5 Executive Summary

The "SG-CG/M490/C_ Smart Grid Reference Architecture" report prepared by the Reference Architecture Working Group (SG-CG/RA) addresses the M/490 mandate deliverable regarding the development of a Technical Reference Architecture.

The Reference Architecture challenge

The CEN/CENELEC/ETSI Joint Working Group report on standards for smart grids has defined the context for the development of the Smart Grids Reference Architecture (RA):

> "It is reasonable to view [the Smart Grid] as an evolution of the current grid to take into account new requirements, to develop new applications and to integrate new state-of-the-art technologies, in particular Information and Communication Technologies (ICT). Integration of ICT into smart grids will provide extended applications management capabilities over an integrated secure, reliable and high-performance network.
>
> This will result in a new architecture with multiple stakeholders, multiple applications, multiple networks that need to interoperate: this can only be achieved if those who will develop the smart grid (and in particular its standards) can rely on an agreed set of models allowing description and prescription: these models are referred to in this paragraph as Reference Architecture."

To develop a coherent and useful Reference Architecture, two main issues have been addressed:

- Clarification of the requirements for the reference architecture and description of its major elements. Reuse of existing results has been considered essential to a fast progress. In particular, the Reference Architecture elements are positioned with respect to existing models (e.g. NIST) and architectural frameworks (GWAC, TOGAF, etc.). Extensions have been limited and, in general, focused on addressing the European specificities.

- Coherence of the RA with respect to the overall Smart Grids standardization process. Notably, the work of SG-CG/RA has been aligned with the other SG-CG Work Groups.
  - Using upstream results of SG-CG/SP on (generic) use cases and the flexibility concept;
  - Providing results to SG-CG/FSS regarding the identification of useful standards and a method to support standards gap analysis;
  - Clarifying the alignment with SG-CG/SGIS regarding the representation of the Security viewpoint in the RA and providing a method to analyze Information Security use cases.

  In addition, alignment with existing initiatives from other organizations (e.g. NIST, ENTSO-E, EU Task Force Experts Groups …) has been a constant objective.

Main elements of the Reference Architecture

The main components of the Reference Architecture are now in place. The most important are described below.

<u>European Conceptual Model</u>
The National Institute of Standards and Technology (NIST) has introduced the Smart Grid Conceptual Model which provides a high-level framework for the Smart Grid that defines seven high-level domains and shows all the communications and energy/electricity flows connecting each domain and how they are interrelated.

Though the NIST model is a sound and recognized basis, it has been necessary to adapt it in order to take into account some specific requirements of the EU context that the NIST model did not address. Two main elements are introduced to create the EU Conceptual Model. The first one is the Distributed Energy Resource (DER) domain that allows addressing the very important role that

DER plays in the European objectives. The second one is the Flexibility concept (developed in SG-CG/SP) that group consumption, production and storage together in a flexibility entity.

The EU Conceptual Model is a top layer model (or master model) and will also act as a bridge between the underlying models in the different viewpoints of the Reference Architecture.

During the course of this first iteration of the M/490 mandate, a constant discussion has taken place with NIST SGIP/SGAC to ensure optimal alignment on the Conceptual Model. The model that is presented in the main part of the SG-CG/RA report is reflecting these discussions.

Smart Grids Architecture Model (SGAM) Framework

The SGAM Framework aims at offering a support for the design of smart grids use cases with an architectural approach allowing for a representation of interoperability viewpoints in a technology neutral manner, both for current implementation of the electrical grid and future implementations of the smart grid.

It is a three dimensional model that is merging the dimension of five *interoperability layers* (Business, Function, Information, Communication and Component) with the two dimensions of the Smart Grid Plane, i.e. *zones* (representing the hierarchical levels of power system management: Process, Field, Station, Operation, Enterprise and Market) and *domains* (covering the complete electrical energy conversion chain: Bulk Generation, Transmission, Distribution, DER and Customers Premises).

SGAM Methodology

This SGAM Framework can be used by the SGAM *Methodology* for assessing smart grid use cases and how they are supported by standards, thus allowing standards *gap analysis*. The model has largely evolved in v2.0, with clearer basic definitions, more detailed presentation of the elements (zones, domains, etc.), a clarification of the methodology and a complete detailed example.

Architecture Viewpoints

They represent a limited set of ways to represent abstractions of different stakeholders' views of a Smart Grid system. Four viewpoints have been selected by the SG-CG/RA: Business, Functional, Information and Communication, with associated architectures:

- The Business Architecture is addressed from a methodology point of view, in order to ensure that whatever market or business models are selected, the correct business services and underlying architectures are developed in a consistent and coherent way;
- The Functional Architecture provides a meta-model to describe functional architectures and gives an architectural overview of typical *functional groups* of Smart Grids (intended to support the high-level services that were addressed in the Smart Grids Task Force EG1);
- The Information Architecture addresses the notions of data modeling and interfaces and how they are applicable in the SGAM model. Furthermore, it introduces the concept of "*logical interfaces*" which is aimed at simplifying the development of interface specifications especially in case of multiple actors with relationships across domains;
- The Communication Architecture deals with communication aspects of the Smart Grid, considering generic Smart Grid use cases to derive requirements and to consider their adequacy to existing communications standards in order to identify communication standards gaps. It provides a set of recommendations for standardization work as well as a view of how profiling and interoperability specifications could be done.

How to use the Reference Architecture

Given the large span of the Reference Architecture components described above, the Reference Architecture can be used in a variety of ways, amongst which:

- Adaption of common models and meta-models to allow easier information sharing between different stakeholders in pre-standardization (e.g. research projects) and standardization;

- Analysis of Smart Grids use cases via the SGAM methodology. This is a way to support, via an easier analysis of different architectural alternatives, the work of those who are going to implement those use cases;
- Gap analysis: analysis of generic use cases in order to identify areas where appropriate standards are missing and should be developed in standardization;
- …

Outlook

The current version of the Reference Architecture document is the result of the work done by the SG-CG/RA Working Group during the first iteration of the M/490 Mandate.

The final version (v3.0) of this report addresses the comments made on v2.0 and clarifies some of the remaining issues, such as the handling of Security aspects in the Architecture and in SGAM, an (SG-CG) agreed functional meta-model, or the respective role of markets and business viewpoints.

However, there are still areas where the document can be completed such as a role-based definition of the European Conceptual Model (developed but still to be validated), expansion of the Functional Architecture, more in-depth exploration of the communication profiles, etc. This work could be addressed if the extension of the M/490 Mandate for a second iteration is decided.

6 Conceptual Model and Reference Architecture Principles

6.1 Motivation for Conceptual Model and Reference Architecture

Smart Grids standardization is not a green field. It is largely relying on previous work done at national, regional (in particular European) and international level, both on standardization (largely focused on the identification of the existing set of standards that are applicable to the Smart Grid) and on pilot and research project (that validate early ideas that may be brought to standardization).

The work of the Reference Architecture WG will, in particular, use significant existing material such as the NIST Conceptual Model [NIST 2009], the GridWise Architecture Council Stack interoperability categories [GWAC 2008], architecture standards like TOGAF and Archimate [Jonkers 2010].

The development of the SG-CG framework (as already noted above in section 5) addresses 'continuous standard enhancement and development in the field of Smart Grids, while maintaining transverse consistency and promote continuous innovation'.

To achieve consistency and gradual integration of innovation in an incremental manner, two elements are deemed essential, that are both addressed by the SG-CG/RA:

- An overall high-level model that describes the main actors of the Smart Grid and their main interactions. This is captured by the Conceptual Model. The approach taken by the SG-CG/RA, considering the need to reuse existing models whenever possible, has been to take into account the NIST Conceptual Model, analyze which differences a European approach would need to bring to it and further reduce these differences as much as possible;
- A set of universal presentation schema that allow for the presentation of the Smart Grid according to a variety of viewpoints that can cope with
    - The variety of Smart Grid stakeholders,
    - The need to combine power system management requirements with expanded interoperability requirements, and
    - The possibility to allow for various levels of description from the top-level down to more detailed views.

  This is captured in the Reference Architecture that should be seen as the aggregation of several architectures (e.g. functional, communication, etc.) into a common framework.

The motivation for the creation and utilization of reference architectures can be to have a blueprint for the development of future systems and components, providing the possibility to identify gaps in a product portfolio. It can also be used to structure a certain Smart Grid domain and provide a foundation for communication about it to other domains which need to interoperate. Furthermore, it can be used to document decisions which have been taken during the development process of an infrastructure.

An additional – and important - motivation for the SG-CG/RA was to ensure that the Reference architecture could help, by providing an appropriate methodology to identify where standardization gaps may exist.

It is also important to finally point out a very essential motivation for the Reference Architecture work: reuse as much of the existing work as possible and not re-invent the wheel. This has guided both the Conceptual Model (as noted above) as well as the Reference Architecture.

6.2 Requirements for the M/490 Reference Architecture

The reference architecture has to be very much in consistency with the following aspects and requirements already outlined in this report.

It must support the work of Smart Grids standardization over a long period of time:

- Be able to **represent the current situation** (snapshot of already installed basis and reference architectures)
- Be able to **map future concepts** (migration and gap analysis)
- Achieve a **common understanding of stakeholders**
- **Fulfill the demand for systematic coordination of Smart Grid standardization** from an **architectural perspective**
- **Provide a top-level perspective encompassing entire smart grid but enabling enlargements to details**
- Be able to be represented using established and state-of-the art System Engineering technology and methodologies (e.g. lifecycle model, architecture standards and methods)
- Take into account Standardization activities (regional, Europe, international)
- Be able to reflect European Pilot and research projects (regional, Europe, international)

More specifically, the Reference Architecture must be able to address the complexity of the Smart Grid in a coherent manner:

- Be **consistent with the M/490 conceptual model**;
- **Fulfill the need for an universal presentation schema – a model**, allowing to map stakeholder specific prospective in a common view
- Being able to **represent the views of different stakeholders (not only SDOs)** in an universal way , e.g. provide some of the following viewpoints in an abstract way:
    - **Enterprise** viewpoint,
    - **Information** viewpoint,
    - **Computational** viewpoint,
    - **Engineering** viewpoint,
    - **Technology** Viewpoint (RM-ODP, ISO/IEC 10746)
    - **Business Architecture** viewpoint,
    - **Application Architecture** viewpoint,
    - **Data Architecture** viewpoint,
    - **Technology Architecture** viewpoint
- Be **consistent with established interoperability categories and experiences**
- Provide an **abstract view on SG specific structures** (domains, zones, layers)
- **Fulfill the need for an universal presentation schema – a model**, allowing to map stakeholder specific prospective in a common view

6.3 Conceptual Model

This section will present the Conceptual Model practically unchanged since the draft version 2.0 of the Reference Architecture report.

Nevertheless, a lot of new work has been done within SG-CG/RA between TR2.0 and TR3.0 on the Conceptual Model, in order to better support the flexibility concept and to take into account the comments made on version 2.0. A new version of this section has been produced but it could not be introduced in the main section of the report because of the many uncommented changes. Consequently, it has been decided to present it as an informative reference in Annex C, section C.1. It is expected that this new section will be introduced in the subsequent versions of this report, should the new M/490 iteration be decided.

6.3.1 Introduction

The electrical energy system is currently undergoing a paradigm change, that has been affected by a change from the classical centralistic and top down energy production chain "Generation", "Transmission", "Distribution" and "Consumption" to a more decentralized system, in which the participants change their roles dynamically and interact cooperative. The development of the concepts and architectures for a European Smart Grid is not a simple task, because there are various concepts and architectures, representing individual stakeholders' viewpoints.

The National Institute of Standards and Technology (NIST) has introduced the Smart Grid Conceptual Model which provides a high-level framework for the Smart Grid that defines seven high-level domains (Bulk Generation, Transmission, Distribution, Customers, Operations, Markets and Service Providers) and shows all the communications and energy/electricity flows connecting each domain and how they are interrelated. Each individual domain is itself comprised of important smart grid elements (actors and applications) that are connected to each other through two-way communications and energy/electricity paths. The NIST Conceptual Model helps stakeholders to understand the building blocks of an end-to-end smart grid system, from Generation to (and from) Customers, and explores the interrelation between these smart grid segments.

In order to develop the different viewpoints in an aligned and consistent manner, the EU Conceptual Model is introduced. It is based on the NIST Model which is used with some customizations and extensions regarding the general European requirements. This EU Conceptual Model forms the top layer model or master model and it is therefore the bridge between models from different viewpoints. Its task is to form a bracket over all sub models.

6.3.2 Approach and Requirements

The electrical power grid in the European Union is based on a big number of heterogeneous participants; that are hierarchically and next to each other connected. Every participant of the electrical power grid builds and operates its part of the network in its own manner; and at the same time they have to work together. So the EU Conceptual Model has to deal with different levels of decentralization (see Figure 1). The figure shows still another effect. Regarding to the history of electrical power supply systems, the electrical power supply started more than a century ago with decentralized isolated networks and developed to an European centralized mixed network. With the beginning of the 21st century, more and more decentralized energy systems are coming into the network again, so future architectures will have to support both centralized and decentralized concepts. Consequently requirements for distributed and centralized concepts and applications need to be considered. . From this follows the requirement to the EU conceptual model to allow to model different levels of decentralization between the two extremes: “Fully Centralized Energy System” and “Fully Decentralized Energy System”.

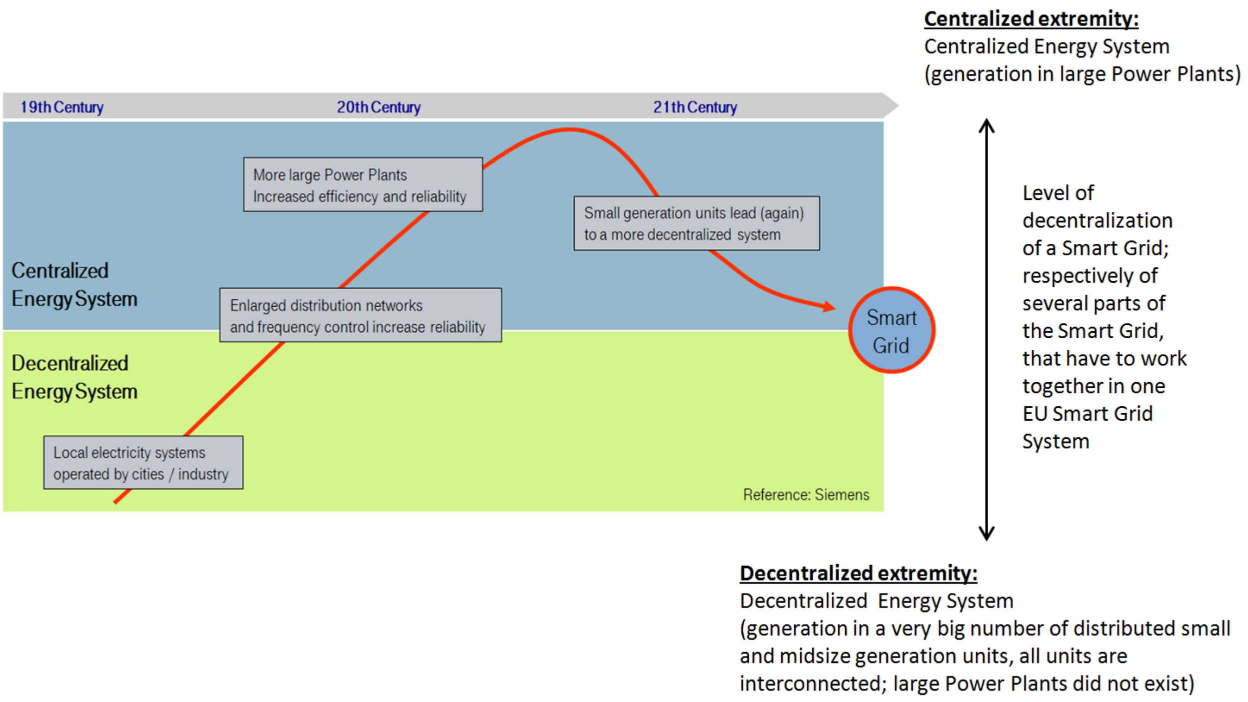

Figure 1: Different levels of decentralization

6.3.3 An EU extension of the NIST Model

To integrate the "Distributed Energy Resources" (DER) into the NIST Model, it will be extended by a new "Distributed Energy Resources" Domain, which is (in terms of electricity and communications) connected with the other NIST Domains shown in Figure 2.

The extension of the NIST Model with a new DER Domain is necessary for the following reasons:

- Distributed Energy Resources require a new class of use cases
- In order to comply to future anticipated regulation and legislation explicit distinction of Distributed Energy Resources will be required
- Distributed Energy Resources represent the current situation
- A consistent model requires clear criteria to separate the new DER Domain from the existing Domains, especially from Bulk Generation and the Customer Domain. Initial criteria are given in Table 1: Separation criteria for the DER-Domain.
    - "Control" The generation units in the Customer Domain can not be remote controlled by an operator. The generation units in the DER and Bulk Generation Domain are under control of an operator, (approximately comparably with the controllability of bulk generation units today).
    - "Connection point". The generation units in the bulk generation domain are predominantly connected to the high voltage level. The generation units in the DER Domain are predominantly connected to the medium voltage level (in some cases also to the low voltage level) and the generation units in the customer domain to the low voltage level.

Table 1: Separation criteria for the DER-Domain

Criteria / Domain	Bulk Generation	Distributed Energy Resources	Consumer
Control	Direct	direct	indirect
Connection Point	high voltage	medium voltage / low voltage	low voltage

One can uniquely model the two extremes as shown in Figure 1 ("Centralized Energy System" and "Decentralized Energy System") and the space between them as follows:

- "Fully Centralized Energy System"
  At the extreme point of "Centralized Energy System", no distributed energy resources exist and "Distributed Energy Resources" Domain is not needed.

- "Fully Decentralized Energy System"
  At the extreme point of "Decentralized Energy System", no bulk generation systems exist and the "Bulk Generation" Domain is not needed. The power generation is realized by a large number of distributed and interconnected power generation units. The generation power of the distributed generation units are aggregated by the distribution network to the transmission network. Areas with power reserve can supply areas with power demand. Due to the constantly changing weather situation over Europe the mix of the regions will permanently change.

- A level of decentralization between both turning points.
  This case will correspond to reality, which shows that the trend here is towards an increasing degree of decentralization. Furthermore, it is assumed that both extreme positions will not be reached, they are only theoretical. The mixture of 'bulk generation' and 'distributed energy generation' (which includes a significant proportion of volatile energy generating units) will effect an increase of volatility in the operation of classical generating units. This is primarily the case in countries, where legislations determine the feed-in of energy from renewable sources.

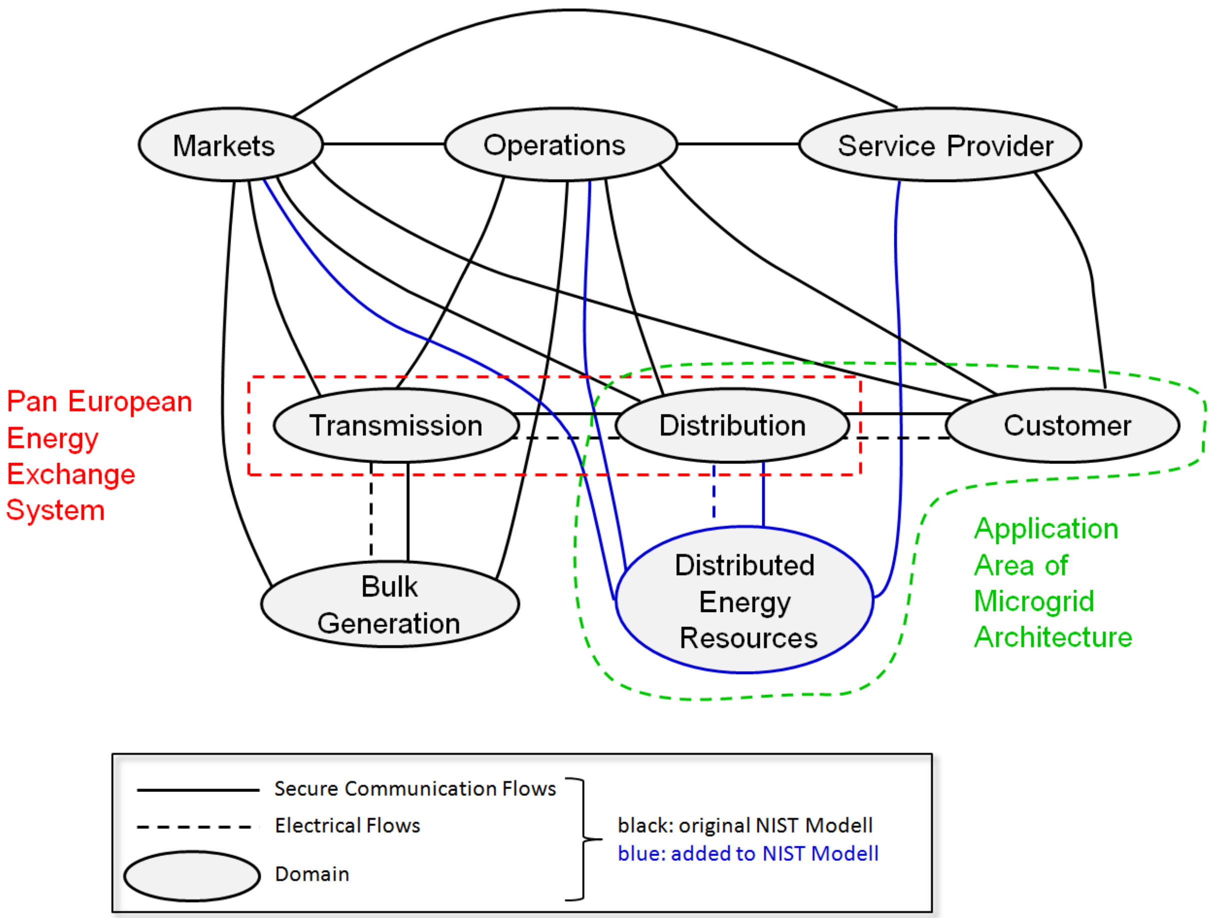

Figure 2: EU extension of the NIST Model

Figure 2 also defines the scope of PAN European Energy Exchange System and application area of a microgrid architecture:

- The application area of the hierarchical mesh cell architectures (microgrids) includes the Customer, Distribution, and Distributed Energy Resources domains. One objective is to find a balance between production and consumption as locally as possible in order to avoid transmission losses and increase transmission reliability through ancillary services such as reserves volt/var support, and frequency support .For other objectives for microgrids see also use case WGSP-0400 The Pan European Energy Exchange System (PEEES), which includes technologies in the transport network for low-loss wide-area power transmission systems (e. g. high-voltage direct current transmission, HVDC), better realizing the large-scale energy balance between the regions, which is essential due to the constantly changing weather situation, which has a significant influence on the power generation capacity of different regions.
  In version 3.0 examples of microgrids and a PAN European Energy Exchange System will be given.

One should not forget that the customer domain in a Smart Grid has the ability to control their energy consumption within certain limits. In the future, the smart grid will have two adjustment possibilities: generation and power consumption (load)) and a large number of new degrees of freedom to control the power balance (frequency stability).

6.3.4 The Flexibility Concept

As a result of ongoing work in the M490 Working Groups (SG-CG/RA and SG-CG/SP), the flexibility concept has been introduced and is discussed. In this model, consumption, production and storage are grouped together in a flexibility entity (next to the entities Grid, and Markets). It is believed that this concept creates much more the required flexibility to support future demand response use cases then the more rigid classification given in table 1. In version 3.0 of this document the existing conceptual model will be re-represented in a way that it supports the flexibility concept and also that it enables maximum re-use of results and standards derived from the existing conceptual model.

Initial ideas on this are given in table 2 below.

Table 2 (for further study)

CM Domains/Flexibility entities	Market	Grids	Flexibility
Markets	+		
Bulk Generation			+
DER			+
Customer			+
Transmission		+	
Distribution		+	
Operations	+	+	+
Service Provider	+	+	+

6.3.5 Conclusion

The EU Conceptual Model corresponds for the most part with the NIST Model and extends it with a new DER Domain to fulfill the specific European requirements. It is a future-oriented model, because it allows the description of a totally centralized grid, a totally decentralized grid and a mixture between both extreme points on a defined level. The application area of the hierarchical mesh cell architectures will allow in future the description of microgrid architecture and local energy management systems, that are integrated in the future European Smart Grid system.

6.4 Reference Architecture Viewpoints

The report of the Joint Working Group (JWG) for Standards for the Smart Grids [JWG-SG 2011] had outlined some of the potential viewpoints that the work of M/490 might have to deal with:

- Conceptual Architecture. A high-level presentation of the major stakeholders or the major (business) domains in the system and their interactions.
- Functional Architecture. An arrangement of functions and their sub-functions and interfaces (internal and external) that defines the execution sequencing, the conditions for control or data flow, and the performance requirements to satisfy the requirements baseline. (IEEE 1220)
- Communication Architecture. A specialization of the former focusing on connectivity.
- Information Security Architecture. A detailed description of all aspects of the system that relate to information security, along with a set of principles to guide the design. A security architecture describes how the system is put together to satisfy the security requirements.
- Information Architecture. An abstract but formal representation of entities including their properties, relationships and the operations that can be performed on them.

As such, these viewpoints could be very much targeting the Information and Communication Technology (ICT) aspects of the Smart Grid. However, this aspect – though an essential element of the Smart Grid – cannot be seen in isolation of the other essential aspect of the Smart Grid: the Power Technology. The choice of the appropriate viewpoints and their level of granularity are therefore very important. This is addressed by the section below.

Considering the JWG recommendations and the requirements defined in section 6.2, the following viewpoints have been selected as the most appropriate to represent the different aspects of Smart Grids systems:

- Business Architecture
- Functional Architecture
- Information Architecture
- Communication Architecture

The ‘Information Security Architecture’ listed in the JWG list above has been handled separately from the SG-CG/RA work by the SG-CG/SGIS. However, alignment of work of both WGs is deemed essential. At this stage, first elements of this alignment can be found in 7.2.7.

7 The Smart Grid Architecture Model (SGAM) Framework

7.1 Interoperability in the context of the Smart Grid

7.1.1 General

Interoperability is seen as the key enabler of smart grid. Consequently the proposed SGAM framework needs to inherently address interoperability. For the understanding on interoperability in the context of smart grid and architectural models, a definition and requirements for achieving interoperability are given.

7.1.2 Definition

A prominent definition describes interoperability as the ability of two or more devices from the same vendor, or different vendors, to exchange information and use that information for correct co-operation [IEC61850-2010].
In other words, two or more systems (devices or components) are interoperable, if the two or more systems are able to perform cooperatively a specific function by using information which is exchanged. This concept is illustrated in Figure 3.

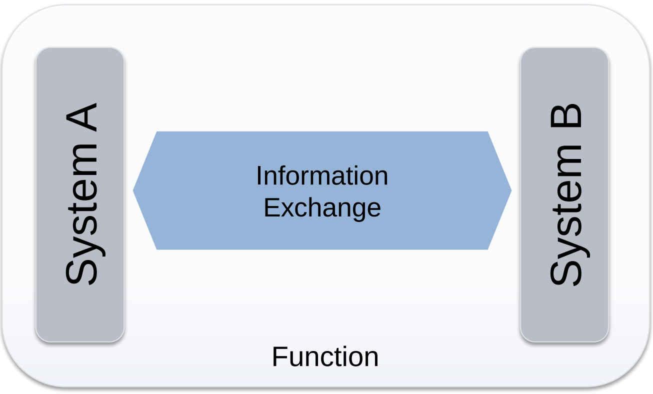

Figure 3: Definition of interoperability – interoperable systems performing a function

Being formulated in a general way, the definition is valid to the entire smart grid.

7.1.3 Interoperability Categories

The interoperability categories introduced by the GridWise Architecture Council [GWAC2008] represent a widely accepted methodology to describe requirements to achieve interoperability between systems or components (Figure 4).

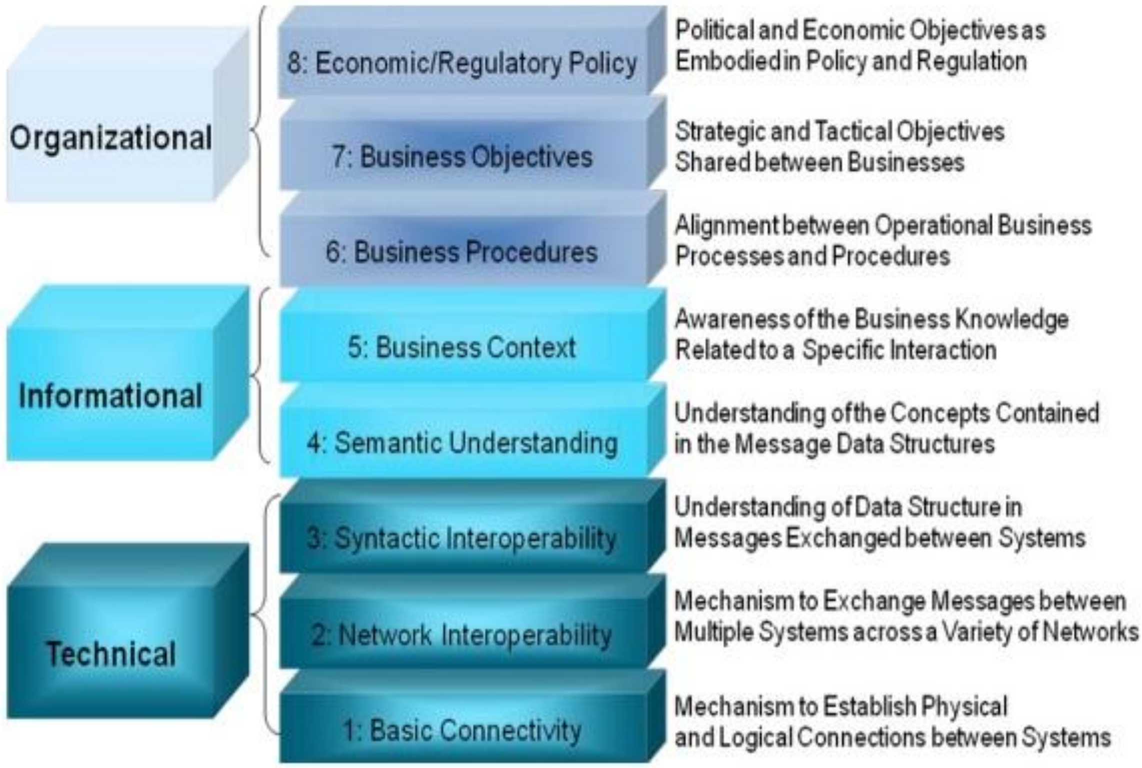

Figure 4: Interoperability Categories defined by GWAC [GWAC2008]

The individual categories are divided among the three drivers “Technical”, “Informational” and “Organizational”. These interoperability categories underline the definition of interoperability in the previous section 7.1.2. Hence for the realization of an interoperable function, all categories have to be covered, by means of standards or specifications.

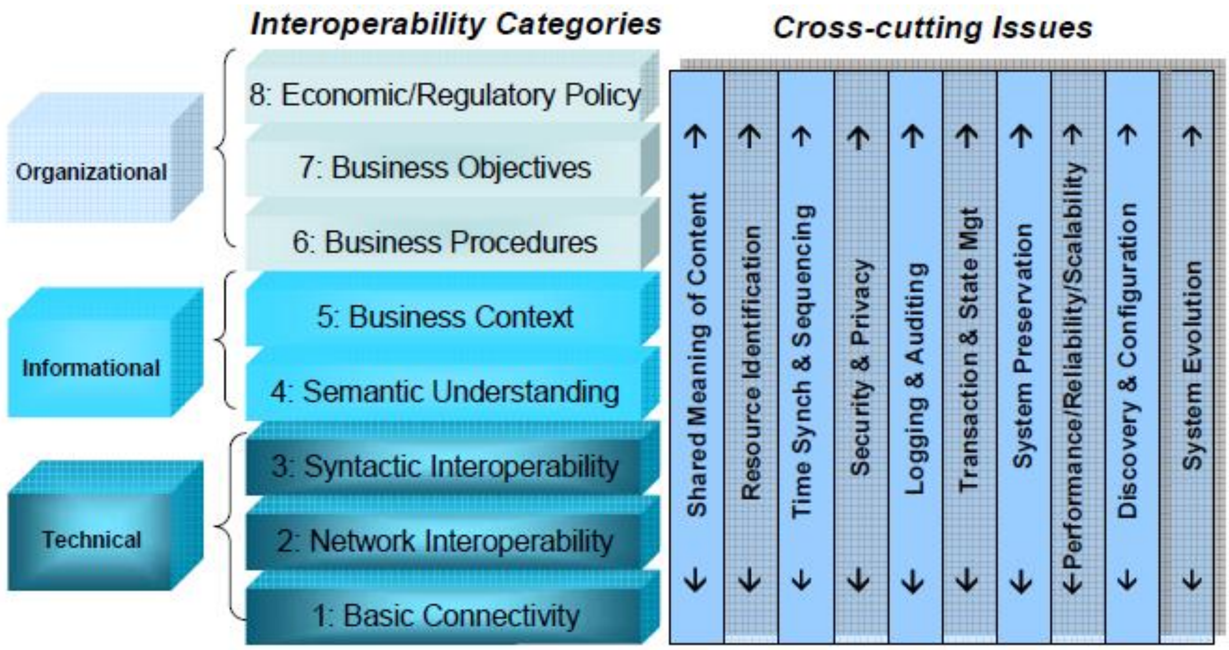

Figure 5: Interoperability Categories and Cross-Cutting Issues [GWAC2008]

Cross-cutting issues are topics which need to be considered and agreed on when achieving interoperability [GWAC 2008]. These topics may affect several or all categories to some extent. Typical cross-cutting issues are cyber security, engineering, configuration, energy efficiency, performance and others.

7.2 SGAM Framework Elements

7.2.1 General

The SGAM framework and its methodology are intended to present the design of smart grid use cases in an architectural viewpoint allowing it both- specific but also neutral regarding solution and technology. In accordance to the present scope of the M/490 program, the SGAM framework allows the validation of smart grid use cases and their support by standards.

The SGAM framework consists of five layers representing business objectives and processes, functions, information exchange and models, communication protocols and components. These five layers represent an abstract and condensed version of the interoperability categories introduced in section 7.1.3. Each layer covers the smart grid plane, which is spanned by electrical domains and information management zones (section 7.2.3). The intention of this model is to represent on which zones of information management interactions between domains take place. It allows the presentation of the current state of implementations in the electrical grid, but furthermore to depict the evolution to future smart grid scenarios by supporting the principles universality, localization, consistency, flexibility and interoperability.

7.2.2 SGAM Interoperability Layers

In order to allow a clear presentation and simple handling of the architecture model, the interoperability categories described in section 7.1.3 are aggregated into five abstract interoperability layers (refer to Figure 6). However in case of a detailed analysis of interoperability aspects, the abstraction can be unfolded.

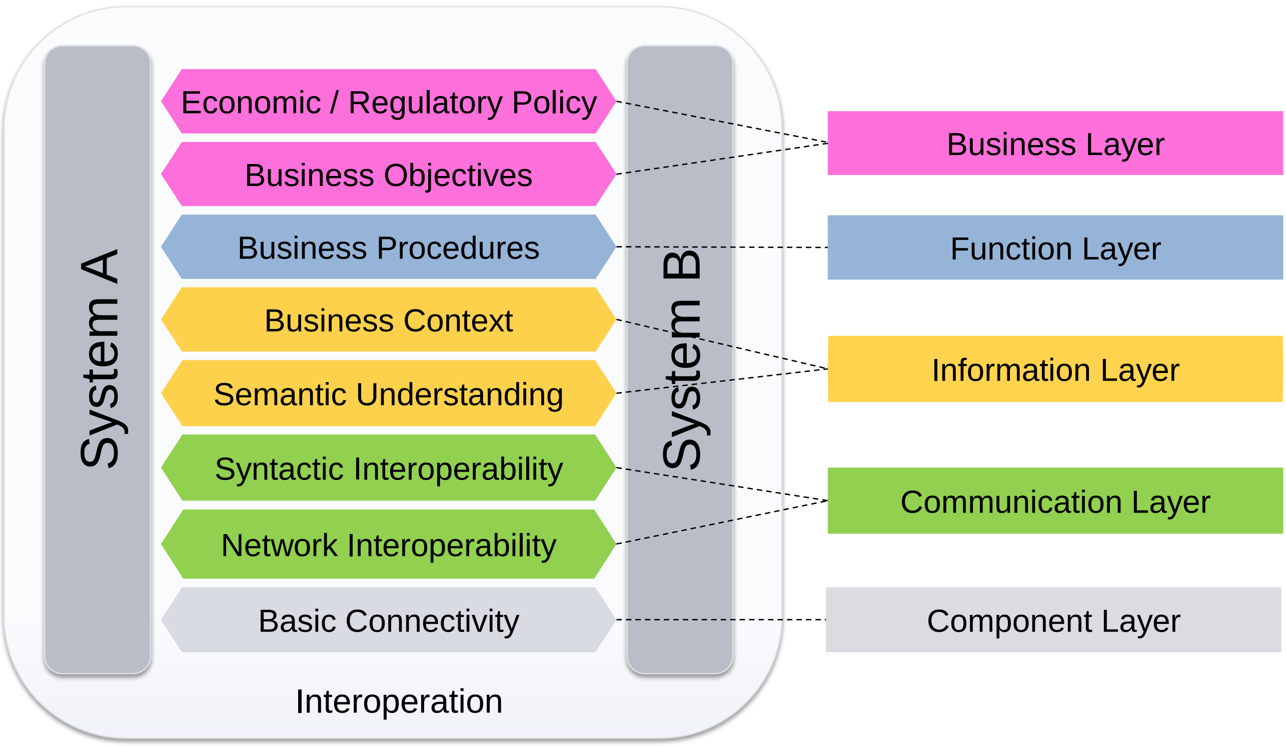

Figure 6: Grouping into interoperability layers

7.2.2.1 Business Layer

The business layer represents the business view on the information exchange related to smart grids. SGAM can be used to map regulatory and economic (market) structures and policies, business models, business portfolios (products & services) of market parties involved. Also business capabilities and business processes can be represented in this layer. In this way it supports business executives in decision making related to (new) business models and specific business projects (business case) as well as regulators in defining new market models. The Business layer is addressed in more detail in paragraph 8.1.

7.2.2.2 Function Layer

The function layer describes functions and services including their relationships from an architectural viewpoint. The functions are represented independent from actors and physical implementations in applications, systems and components. The functions are derived by extracting the use case functionality which is independent from actors.

7.2.2.3 Information Layer

The information layer describes the information that is being used and exchanged between functions, services and components. It contains information objects and the underlying canonical data models. These information objects and canonical data models represent the common semantics for functions and services in order to allow an interoperable information exchange via communication means.

7.2.2.4 Communication Layer

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.

7.2.2.5 Component Layer

The emphasis of the component layer is the physical distribution of all participating components in the smart grid context. This includes system actors, applications, power system equipment (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.

7.2.3 SGAM - Smart Grid Plane

In general power system management distinguishes between electrical process and information management viewpoints. These viewpoints can be partitioned into the physical domains of the electrical energy conversion chain and the hierarchical zones (or levels) for the management of the electrical process (refer to [IEC62357-2011, IEC 62264-2003]). Applying this concept to the smart grid conceptual model introduced in section 6.3 allows the foundation of the *Smart Grid Plane* (see Figure 7.). This smart grid plane enables the representation on which levels (hierarchical zones) of power system management interactions between domains take place.

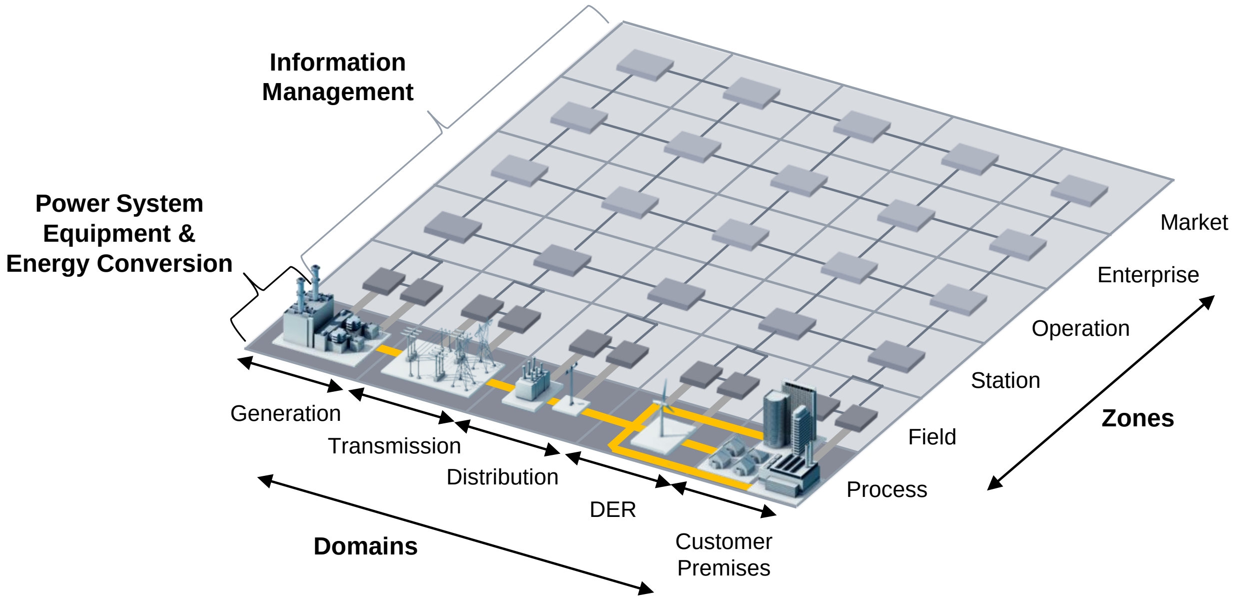

Figure 7: Smart Grid plane - domains and hierarchical zones

According to this concept those domains, which are physically related to the electrical grid (Bulk Generation, Transmission, Distribution, DER, Customer Premises) are arranged according to the electrical energy conversion chain. The conceptual domains Operations and Market are part of the information management and represent specific hierarchical zones. The conceptual domain Service Provider represents a group of actors which has universal role in the context of smart grid. This means that a Service Provider can be located at any segment of the smart grid plane according to the role he has in a specific case.

7.2.4 SGAM Domains

The *Smart Grid Plane* covers the complete electrical energy conversion chain. This includes the domains listed in Table 2:

Table 2: SGAM Domains

Domain	Description
Bulk Generation	Representing generation of electrical energy in bulk quantities, such as by fossil, nuclear and hydro power plants, off-shore wind farms, large scale solar power plant (i.e. PV, CSP)– typically connected to the transmission system
Transmission	Representing the infrastructure and organization which transports electricity over long distances
Distribution	Representing the infrastructure and organization which distributes electricity to customers
DER	Representing distributed electrical resources directly connected to the public distribution grid, applying small-scale power generation technologies (typically in the range of 3 kW to 10.000 kW). These distributed electrical resources may be directly controlled by DSO
Customer Premises	Hosting both - end users of electricity, also 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… are hosted

7.2.5 SGAM Zones

The SGAM zones represent the hierarchical levels of power system management [IEC62357-2011]. These zones reflect a hierarchical model which 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 which was adopted by IEC 62264-1 standard for “enterprise-control system integration” [IEC 62264-2003]. This model was also applied to power system management. This is described in IEC 62357 “Reference architecture for object models services” [IEC 62357-2003, IEC 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, several bays form a substation; multiple DER form a plant station, 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 considering user philosophies. Real-time functions are typically in the field and station zone (metering, protection, phasor-measurement, automation…). Functions which cover an area, multiple substations or plants, city districts are usually located in 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 3.

Table 3: 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	Includes 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 and procurement…
Market	Reflecting the market operations possible along the energy conversion chain, e.g. energy trading, mass market, retail market..

In general organizations can have actors in several domains and zones. In the smart grid plane the areas of the activity of these actors can be shown. E.g. according to the business area of a transmission utility it is likely that the utility covers all segments of the transmission domain, from process to market.

A service provider offering weather forecast information for distribution system operators and DER operators could be located to the market zone interacting with the operation zone in the distribution and DER domain.

7.2.6 SGAM Framework

The SGAM framework is established by merging the concept of the interoperability layers defined in section 7.2.2 with the previous introduced smart grid plane. This merge results in a model (see Figure 8) which spans three dimensions:

- Domain
- Interoperability (Layer)
- Zone

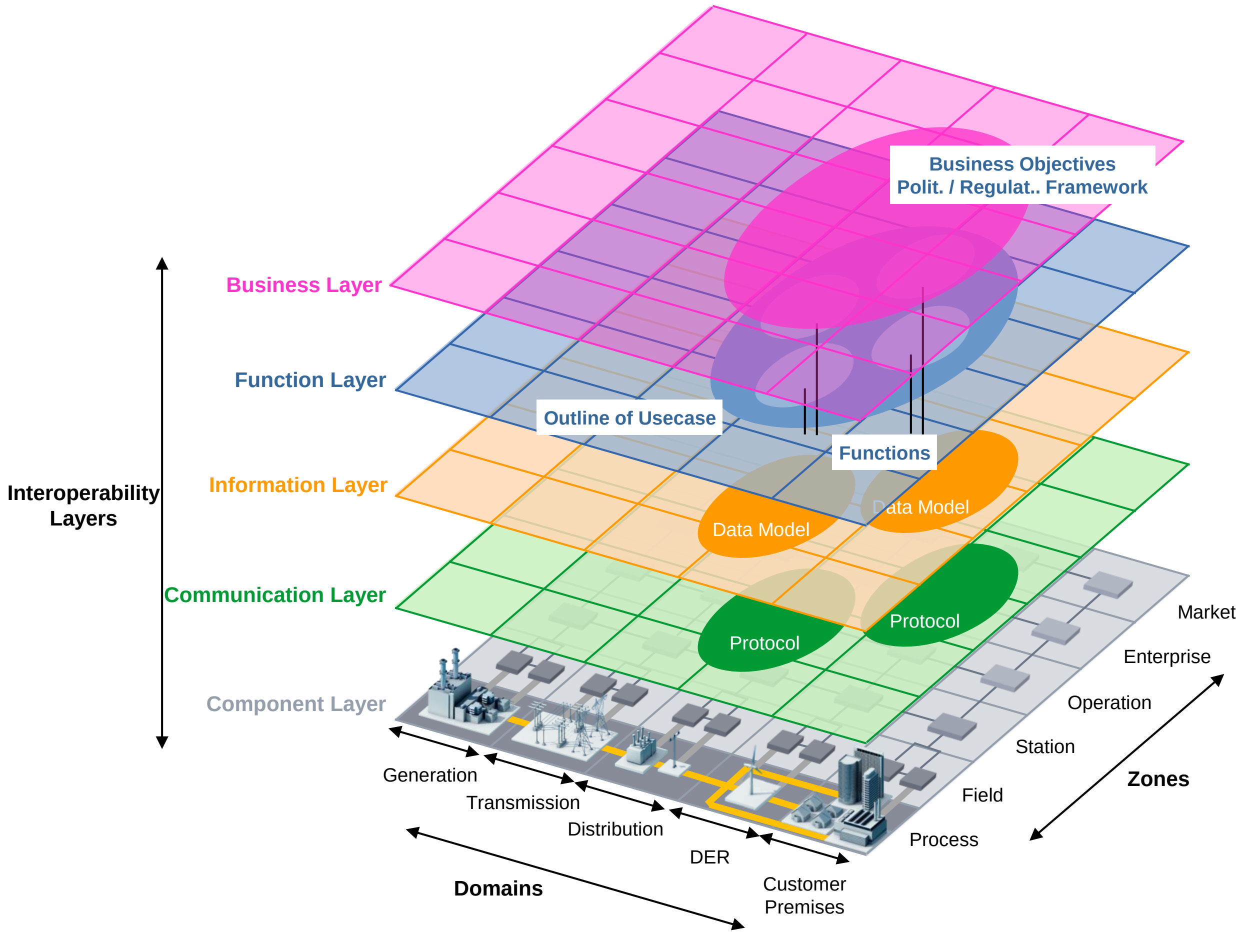

Figure 8: SGAM framework

Consisting of the five interoperability layers the SGAM framework allows the representation of entities and their relationships in the context of smart grid domains, information management hierarchies and in consideration of interoperability aspects.

7.2.7 Cross-cutting Issues and SGAM

7.2.7.1 Application to SGAM interoperability layers

According to the adopting of the concept of interoperability categories, which was introduced in section 7.1.3, cross-cutting issues apply in the same manner to the abstract interoperability layers. Figure 9 shows the relation of cross-cutting issues to the five abstracted interoperability layers.

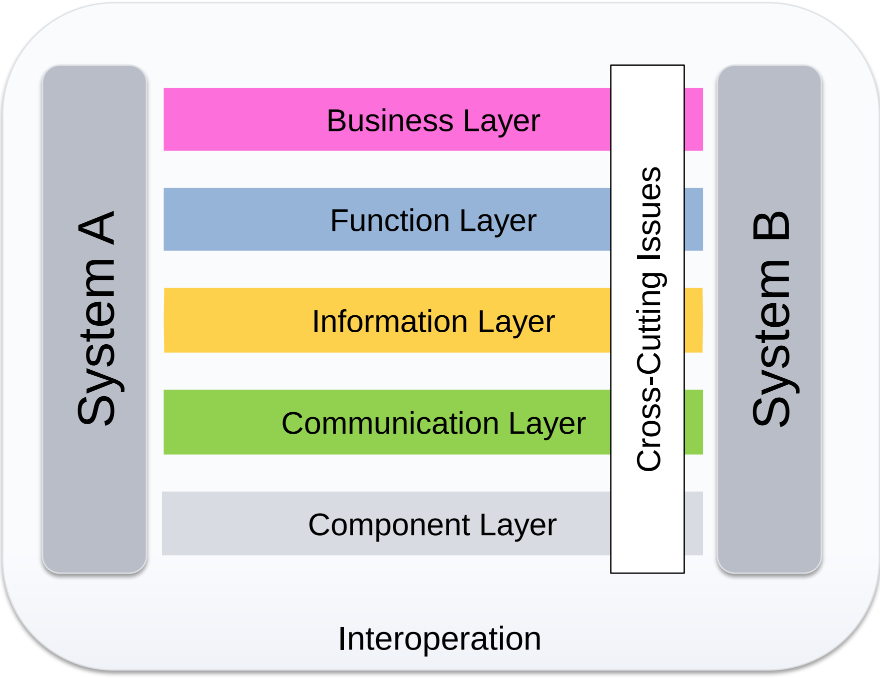

Figure 9: Interoperability layers and cross-cutting issues

Figure 10 depicts the impact of crosscutting issues to the individual interoperability layers from the overall SGAM framework prospective.

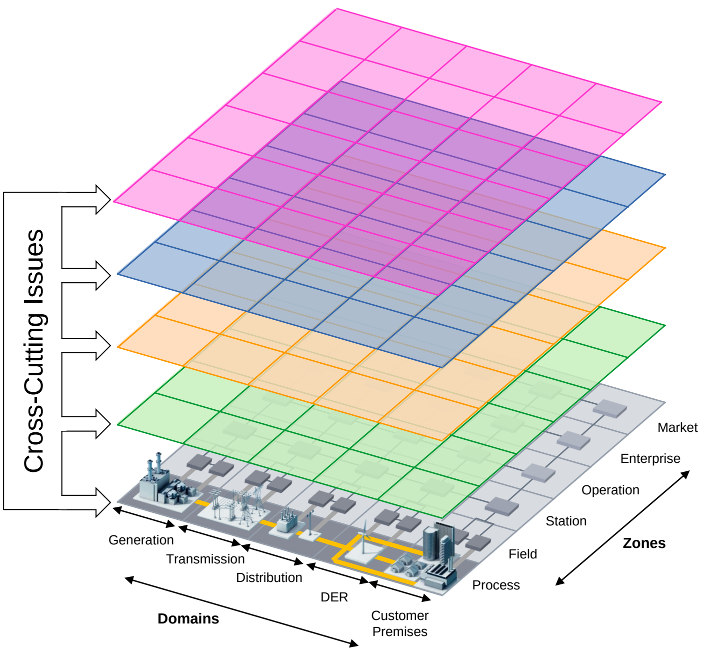

Figure 10: Impact of cross-cutting issues on SGAM interoperability layers

7.2.7.2 Example cyber security

Information Security in Smart Grid is an integral part of the Reference Architecture. The incorporation of the security aspects is the task of the Smart Grid Information Security Work Group (SG-CG/SGIS) investigating into existing security standards and their feasibility in a smart grid environment. A commonly agreed view of SG-CG/RA and SG-CG/SGIS is that security is a consistent process and has to be addressed upfront, both from a functional and non functional perspective.

The question has been addressed in two angles:

- How to benefit from the SGAM Methodology to address Security Use Cases
- How to represent the Information Security viewpoint within SGAM.

Regarding the first question, the SGAM Methodology based on a Use Case analysis as depicted in Figure 12 can be directly used for dedicated security functions. Security specific interactions can be shown on different SGAM layers showing the involved entities, their functional interface in terms of protocols and information models and also the relating business case. This has been shown on the example of Role-based Access Control, where SGAM allowed depicting the security specifics on each layer.

Regarding the representation of security within SGAM, it has been discussed (between SG-CG/RA and SG-CG/SGIS) to provide a “security view per layer” emphasizing that security is a cross functional topic, which has to be obeyed in each of the SGAM layers and has been depicted in that way by the SG-CG/SGIS. This can even more underlined as security is actually to be obeyed per layer, per domain, and per zone and thus basically per SGAM cell. To allow for the consideration of security aspects in that detail the SG-CG/SGIS has provided a toolbox, supporting the analysis and determination of security risks on a per use case base, following the SGAM methodology.

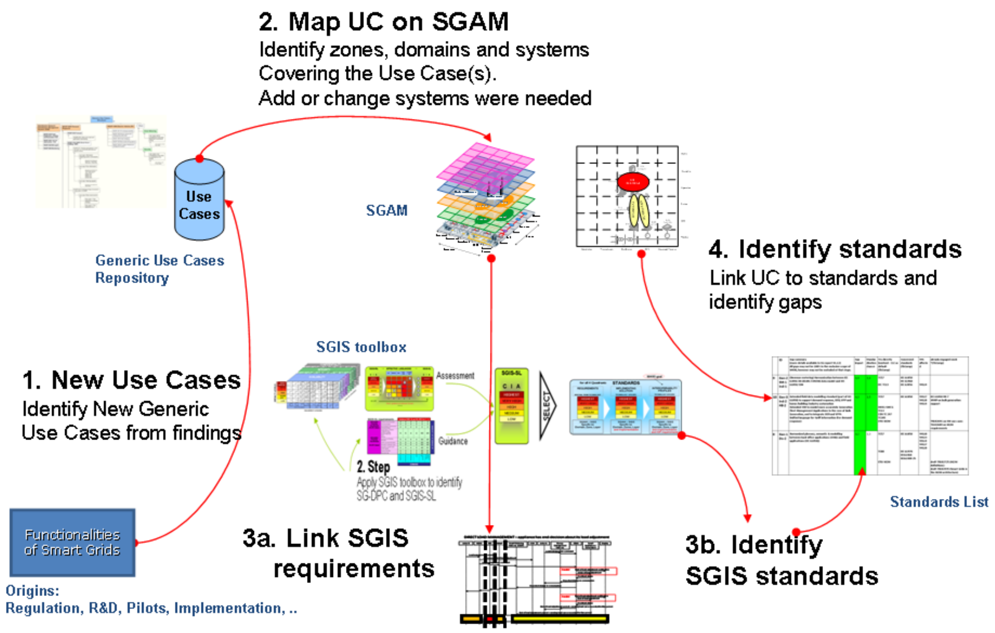

Figure 11: Using the SGIS Toolbox

Moreover, using the toolbox allows identifying available standards, applicable in dedicated use cases and also to identify gaps, for which further work is has to be done. This approach completes the SGAM methodology with inherent security considerations.

7.3 The SGAM methodology

7.3.1 General

This section introduces the methodology of the SGAM framework. It is intended to provide users an understanding on its principles and a guideline how to use the SGAM framework.

7.3.2 Principles

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

7.3.2.1 Universality

The SGAM is intended as a model to represent smart grid architectures in a common and neutral view. For the M/490 objectives it is essential to provide a solution and technology agnostic model, which also gives no preferences to existing architectures.

7.3.2.2 Localization

The fundamental idea of the SGAM is to place entities to the appropriate location in the smart grid plane and layer respectively. With this principle an entity and its relation to other entities can be clearly represented in a comprehensive and systematic view. E.g. a given smart grid use case can be described from an architectural viewpoint. This includes its entities (business processes, functions, information exchange, data objects, protocols, components) in affected and appropriate domains, zones and layers.

7.3.2.3 Consistency

A consistent mapping of a given use case or function means that all SGAM layers are covered with an appropriate entity. If a layer remains open, this implies that there is no specification (data model, protocol) or component available to support the use case or function. This inconsistency shows that there is the need for specification or standard in order to realize the given use case or function. When all five layers are consistently covered, the use case or function can be implemented with the given specifications / standards and components.

7.3.2.4 Flexibility

In order to allow alternative designs and implementations of use cases, functions or services, the principle of flexibility can be applied to any layer of SGAM. This principle is essential to enable future mappings as smart grid use cases, functions and services evolve. Furthermore the principle of flexibility allows to map extensibility, scalability and upgradability of a given smart grid architecture.

Flexibility includes the following methods:

- Use cases, functions or services are in general independent of the zone. E.g. a centralized Distribution Management System (DMS) function can be placed in operation zone; a distributed DMS function can be placed in field zone.
- Functions or services can be nested in different components case by case.
- A given use case, function or service can be mapped to information and communication layer in many different ways in order to address specific functional and non-functional requirements. E.g. the information exchange between control centers and substations can be realized with IEC 61850 over IP networks or with IEC 60870-5-101 over SDH (Synchronous Digital Hierarchy) communication networks.

7.3.2.5 Scalability

The SGAM encompasses the entire smart grid from a top level view. An enlargement to specific domains and zones is possible in order to detail given use cases, functions and services. E.g. the SGAM could be scaled and detailed focusing on microgrid scenarios only.

7.3.2.6 Extensibility

The SGAM reflects domains and zones of organizations which are seen from the current state. In the evolution of the smart grid there might be a need to extend the SGAM by adding new domains and zones.

7.3.2.7 Interoperability

Picking up the GWAC Stack methodology [GWAC2008], the SGAM represents a kind of a three-dimensional, abstract aggregation of the GWAC Stack interoperability categories to the smart grid plane. By doing this, the interaction between actors, applications, systems and components (component layer) is indicated by their connections or associations via information exchange and data models (information layer), protocols (communication layer) ,function or service (function layer) and business constraints (business layer). Generally the connection between entities (components, protocols, data models) is established by interfaces. In other words the consistency of an interoperable interaction can be represented by a consistent chain of entities, interfaces and connections in the *SGAM* layers.

The principles of *Consistency* and *Interoperability* constitute the coherency of the SGAM. Consistency ensures that the five layers are unambiguously linked; interoperability ensures that the conditions for interaction (interfaces, specifications, standards) are met within each layer. Both principles need to be fulfilled for a given use case, function or service to be realized.

7.3.3 Mapping of use cases to SGAM framework

This section describes the basic process to map use cases to the SGAM framework. A detailed example can be found in annex B.2.4.

The mapping process can be applied to the following tasks, which are considered relevant for the present mandate M/490:

- Mapping of use cases in order to validate the support by standards
- Identifying gaps in respect to standards
- Mapping of existing architectures into a general view
- Developing smart grid architectures.

On overview of the process and its steps is depicted in Figure 12.

Depending on the task the process can be carried out iteratively.

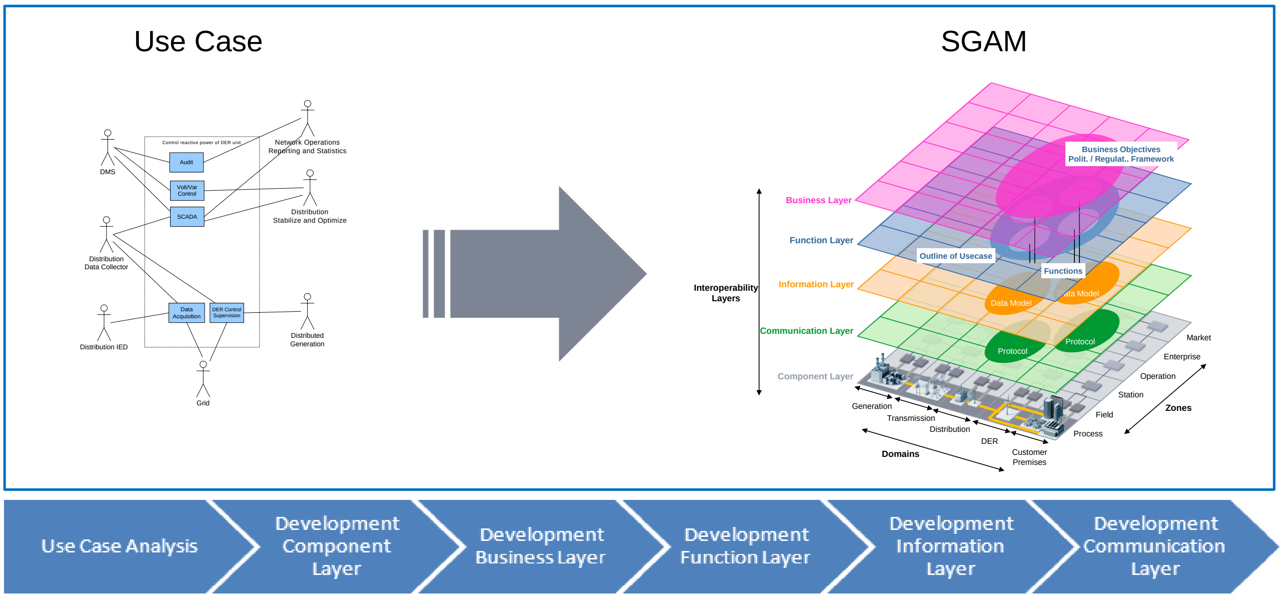

Figure 12: Use case mapping process to SGAM

7.3.3.1 Use Case Analysis

The starting point is an analysis of the use case to be mapped. It needs to be verified that a use case description provides the sufficient information which is necessary for the mapping. This information includes:

- Name, scope and objective
- Use case diagram
- Actor names, types
- Preconditions, assumptions, post conditions
- Use case steps
- Information which is exchanged among actors
- Functional and non-functional requirements.

The use case template considered by M/490 Sustainable Process WG provides the required information.
It is crucial that hard constraints are identified from a use case description. These constraints may have impact on the sequence of steps carried out for the mapping process.

7.3.3.2 Development of the Component Layer

The content of the component layer is derived from the use case information on actors. As actors can be of type devices, applications, persons and organizations, these can be associated to domains relevant for the underlying use case. In the same manner the hierarchical zones can be identified indicating where individual actors reside.

7.3.3.3 Development of the Business Layer

The business layer is intended to host the business processes, services and organizations which are linked to the use case to be mapped. This includes also the business objectives, economic and regulatory constraints underlying to the use case. These business entities are located to the appropriate domain and zone.

7.3.3.4 Development of the Function Layer

The function layer is intended to represent functions and their interrelations in respect to domains and zones. Functions are derived from the use case by extracting its functionality. Typically a use case consists of several sub use cases with specific relationships. These sub use case can be transformed to functions when formulating them in an abstract and actor independent way.

7.3.3.5 Development of the Information Layer

The information layer describes the information that is being used and exchanged between functions, services and components. The information objects which are exchanged between actors are derived from the use case description in form of use case steps and sequence diagrams. Underlying canonical data models are identified by analysis of available standards if these provide support for the exchanged information objects. Information objects and canonical data models are located to the appropriate domain and zone being used.

7.3.3.6 Development of the Communication Layer

The emphasis of the communication layer is to describe protocols and mechanisms for the interoperable exchange of information between the use case actors. Appropriate protocols and mechanisms are identified on the basis of the information objects and canonical data models and by consideration of non-functional requirements of the use case. Protocols and mechanisms are located to the appropriate domain and zone being used.

7.3.4 Mapping the business layer with the lower SGAM layers

This is a crucial phase of the methodology. Some guidelines below can be applied.

7.3.4.1 European market structure alignment

Guideline
Define architectural elements on the business layer in accordance to business roles that are identifiable within the European electricity market.

Rationale
In order to have business architectures derived from this reference architecture match the situation in all European countries, the roles used in the business interactions must be defined and agreed upon, or otherwise the responsibilities carried out by those roles are inconsistent and the interactions (and consequently the interfaces) between roles are unclear. This results in a system that is not interoperable.

Currently, the Harmonized Electricity Market Role Model by ENTSO-E, EFET and ebIX [ENTSO-E] is the best candidate, since it is harmonized and fits on all European electricity markets. Note that this model only represents the current EU situation, based on the current regulations, and that this might not fit future developments. Any deviation from this model should be documented and preferably discussed and agreed upon with the creators of the model and/or regulators (e.g. through Expert Group 3 of the European Commission's Task Force on Smart Grids).

Approach
Use the HEM-RM of ENTSO-E, EFET and ebIX (freely downloadable from the ebIX website at http://www.ebix.org/content.aspx?ContentId=1117&SelectedMenu=8) as a guidance to select and define your business roles and their interactions.

7.3.4.2 Consistency with the business layer

Guideline
Ensure consistent association between roles identified on the business layer and architectural elements identified on other layers, such as functions, applications, databases, or power system elements. Make sure there is a 1-to-n mapping from a single role to one or more architectural elements in the other layers, mitigating ambiguity of responsibilities for architectural elements.

Rationale
when a clear mapping is made between the roles in the business layer and the architectural elements in the other layers of SGAM (functions, interfaces, information, communication infrastructure, components …), one automatically knows which role is responsible for an architectural element and which business interfaces exist between these roles.

For example: the functional layer provides a list of functions required for the execution of a business process in the business layer. Due to the role mapping it is clear which roles are responsible for a specific function. Consequently none of the functions (and in lower layers information, interfaces and components) is omitted when realizing the business process and ownership/responsibility is clear.

Approach

once the architectural elements of the layer under work are defined, one needs to check how these map to the business roles from the roles defined on the business layer. If one cannot map an element onto a single role from the role model, the responsibility on that element is unclear and needs further investigation before continuing.

8 Reference Architecture Elements

The Conceptual Model (as defined in 6.3) consists of several domains, each of which contain applications and actors that are connected by associations through interfaces.

The Conceptual Model can be regarded as the basis from which regulation, business models, ICT architectures, standards etc. can be derived. Since it forms the common starting point for all these activities, it has the potential to ensure consistency between all these mentioned perspectives / viewpoints.

8.1 Business Architecture

It is commonly understood that ICT solutions are meant to support business processes, and that business processes of an organization produce products or services (in the service industry). Products and/or services are offered by that organization to its customers (residential of business) on a market. These markets may be subject to regulation in order to ensure a level playing field. Some markets/ products /services may even be fully regulated (e.g. unbundling).

Therefore it is essential that in creating ICT standards for inter-operability, the relation to markets, products and processes as described here, is well understood and aligned. Only then ICT solutions really support the business. This logic is well presented in the SGAM, showing the business layer as the top layer of the SGAM frame work.

Although standardization of market models and business models itself is out of scope of M/490, good interoperability is essential in order to create well-functioning markets. This requires standardized business services and interfaces, and this is in scope of M/490.

In this paragraph the business architecture is addressed from a methodology point of view, with the objective to ensure that whatever market or business models are selected, the correct business services and underlying architectures are developed in a consistent and coherent way. The business architectures are modeled in the business layer of the SGAM, and comprise the markets and enterprise zone of the SGAM layer, thereby also coping with regulatory aspects of markets and business objectives ate enterprise level.

The basis for alignment between organizations, roles & responsibilities, and application & information architectures, is created by the use of the meta-model, as shown in Figure 13 (source TOGAF 9.1).

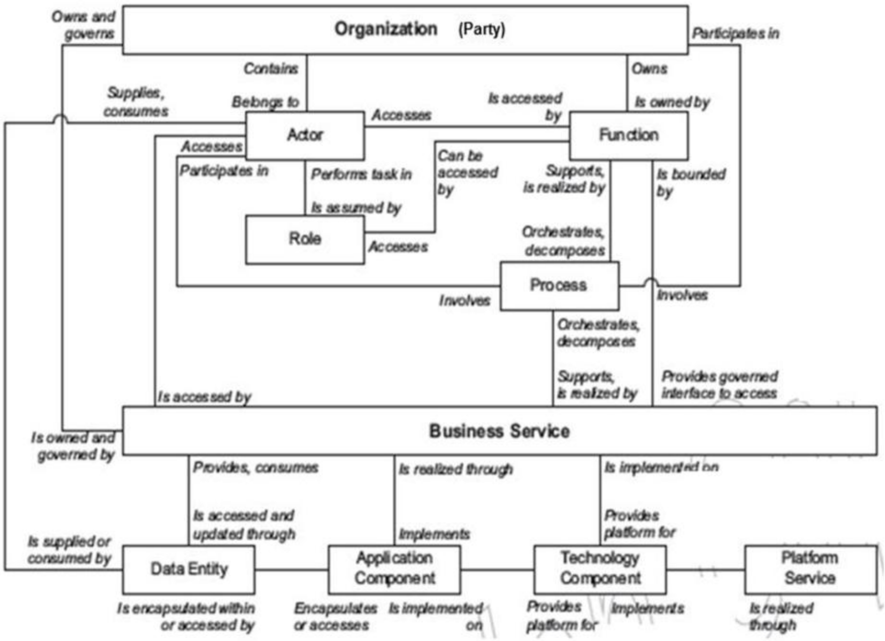

Figure 13: Meta model (TOGAF 9.1)

The use of this model also ensures alignment between the work of the M/490 working groups SG-CG/SP (Sustainable Processes WG), SG-CG/RA (Reference Architecture WG), and the development of a generic market model by the EU taskforce smart grids (EG3).

Figure 14 defines the relation between the metamodel and the SGAM framework, and it specifies more in detail what artifacts/deliverables should come out of the business architecture layer. The data entity corresponds with the information layer, the application component with the functional layer, and the technology component and platform services with the communication and component layer.

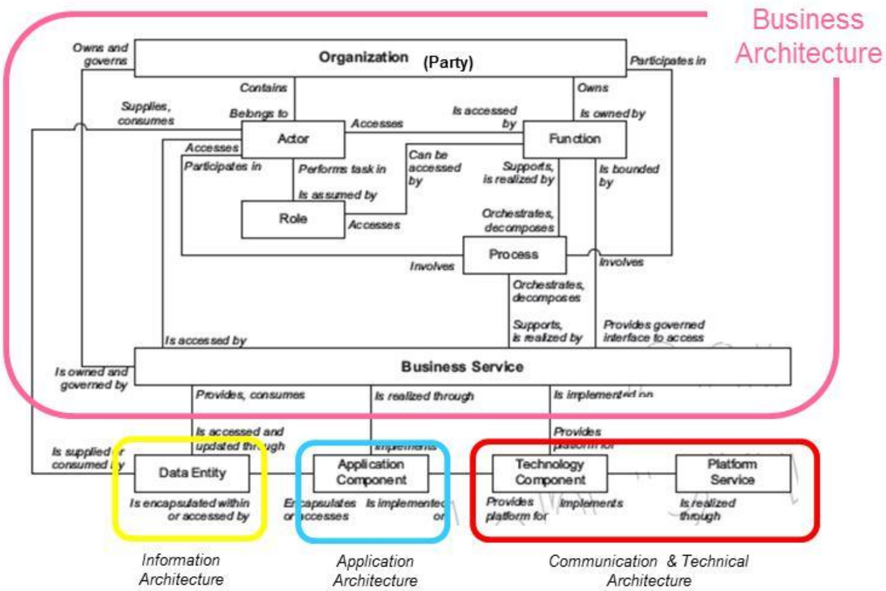

Figure 14: Relation Meta-model to SGAM

In the business architecture layer, the definition and overview (listing) of the following deliverables are foreseen:

- Roles & actors
- Business functions (or business function model)
- Business services
- Business processes (or business process model)

8.1.1 Roles & actors

In a market model in the business layer, roles are defined. These roles are mainly defined in terms of responsibility (ref. ENTSO-E/eBIX, see also Annex H). Then these roles are allocated to market parties. A party hereby is defined as a legal entity performing one or more roles (ref.[NIST 2009]).

This role-allocation to parties may be subject to regulation / legislation.

A role represents the external intended behavior of a party. A party cannot share a role. Businesses carry out their activities by performing roles (e.g. System Operator, Trader). Roles describe external business transaction with other parties in relation to the goal of a given business transaction.

The concept of an “Actor” is very general and can cover People (their roles or jobs), systems, databases, organizations, and devices.

Roughly actors, as identified by SG-CG/SP, might be divided into system actors and business actors (Ref. IEC TC8).

- System actors are covering functions or devices which for example are defined in the Interface Reference Model (IEC 61968-1). A system actor will perform a task under a specific role.
- A business actor specifies in fact a « Role » and will correspond 1:1 with roles defined in the eBIX harmonized role model (possibly some new roles will be required and added to the eBIX model).

An actor represents a party that participates in a business transaction. Within a given business transaction an actor assumes a specific role or a set of roles.

For example with respect to unbundling in Europe, the market models define what activities are regulated and what activities are allowed in the commercial market;
In that respect smart grid parties (DSO, TSO) and smart market parties (suppliers, Energy Service Companies (ESCOs), traders, customers, etc.) are defined.

The energy transition will require an update of existing market models, which differ today, even in different EU member states. It is the ambition of the EU to harmonize existing market models and to develop a generic EU market model.

With respect to mandate M/490, work on the definition of a EU generic market models is out of scope but work on components which are to be used for defining a market model (roles & business services) is in scope. Therefore, strong alignment between M/490 (especially SG-CG/SP) and EG3 of the EU Smart Grid Task Force is necessary, to guarantee use of the same definition and overview (listing) of roles & business services.

Only then EU work on market model development and the M/490 work on standards are in sync.

8.1.2 Business Functions

A business function delivers business capabilities closely aligned to an organization, but not necessarily governed by the organization (ref. TOGAF 9.1)

8.1.3 Business Services

A business service supports a business function through an explicitly defined interface and is explicitly governed by an organization (ref. TOGAF 9.1).

Actors in the conceptual model are connected by associations. Where these actors are represented by applications, information is exchanged via application interfaces. Where these interfaces cross boundaries between market parties, we define the information exchanged as business services. Through these business services market parties will interact.

The definition of business services via which regulated and unregulated market parties will interact, will be subject or part of regulation/legislation in order to create a level playing field in the smart market.

The 'physical" energy product, being an energy "end user proposition" from a commercial market party or an energy transport product (underlying) from a regulated market party, is defined as a business product. Associations between business products and business services are foreseen (e.g. a business transaction service related to EV charging). In order to fully facilitate "smart markets" by "smart grids", it is expected that business services (interfaces) between regulated and unregulated environments will be prioritized.

A Smart Market hereby is defined as an unregulated environment where energy products and energy related services are freely produced, traded, sold and consumed between many market actors.

A Smart Grid is defined a regulated environment where energy is transported and distributed via energy networks, and which provides relevant data & functionality to facilitate envisioned market functioning (e.g. switching customers, providing metering data).

8.1.4 Business Processes

In order to realize business services between markets parties, it is important to have a good insight in the underlying business processes. Furthermore the business processes drive the requirements for the functional and information architectures.

Creating a Utility common Business process model, (to be derived via a business function model) contributes to EU economy of scale with respect to application development and can lead to an "eco -system" of interconnected applications; It contributes to M490 interoperability objectives that go beyond 2 systems interfacing, leading to the realization of defined and specified use cases.

Today, a generic process model for utilities does not exist (for example, in contrast to the telecom sector where the eTOM reference model of TMF is internationally widely accepted and used).

Related work, leading a smart grid/ smart market high level process model is considered to be in scope of M490. Input for this work could come from:

- ENTSO-E/eBIX where processes/interactions between actors are described.
- Cooperation between ENTSO-E/eBIX and IEC related to the HMM and CIM model
- IEC standards (e.g. 61850) in which also processes/functions entities are described
- Work from relevant EU research programs
- The SG-CG/SP on sustainable processes is working on use case and generic use cases.

All these results will be input, next to other contributions and existing material for drafting an initial business capability and process model. This is for further study, input is welcome.

8.1.5 Methodology/ Process

In order to reach and maintain alignment between market model developments and ICT architecture & services development, the process that needs to be followed is:

1. The definition of a market model which includes defining and allocating clear roles and responsibilities to market parties. EG3 defines the roles, building on the existing ENTSO-E/eBIX Harmonized Role Model. EG3 and maps these roles to all market parties and DSO's. An initial mapping of existing roles is given in annex H. New roles may come out of analysis of uses cases (SG-CG/SP) as well as market model discussions (EG3)
2. M/490 (SG-CG/SP) derives from the use cases, the actors, and maps these actors onto the roles used by EG3.
3. M/490 (SG-CG/SP) is identifying the information exchange between actors from the use cases, and since actors are allocated to roles, this also defines the information exchange between roles. As roles are also allocated to market parties it consequently also defines the information exchange between market parties, thereby defining the basis for the standard business services.
4. From the business services defined, the process model, the information, application, communication & technical architecture should be derived.

This process is shown in Figure 15.

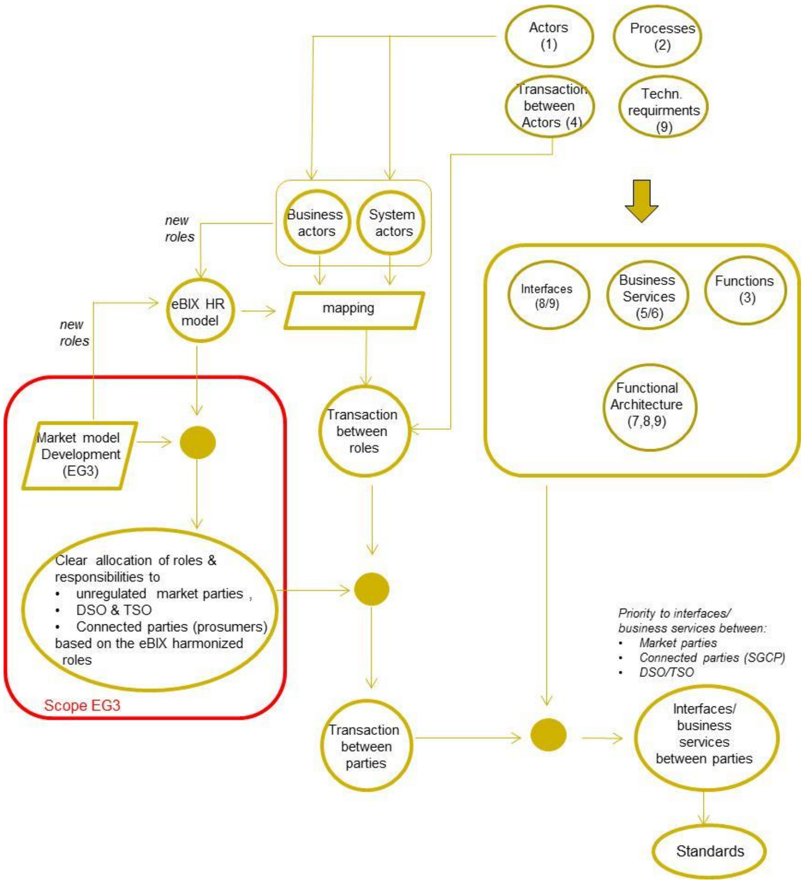

Figure 15: Alignment process between market model developments and ICT architecture & services development

It is envisaged that, at the end of 2012, the EU commission in its revision of mandate M490 will prioritize business services that will be necessary between connected parties (SGCP), market parties and DSO's. So, these business services should be addressed with priority, leading to a first set of standardized interfaces and business services, also required for implementation of the flexibility concept.

8.2 Functional Architecture

8.2.1 General

A functional architecture is intended to describe the functional elements of a system and their relationship independent from physical implementation, applied technology or assigned actor. In the context of Smart Grid a functional architecture consists of functions that enable Smart Grid use cases. The functional layer of the SGAM model hosts functional architectures of Smart Grids.

This section provides the concept of a meta-model to describe functional architectures and gives an architectural overview of typical functional groups of Smart Grids.

8.2.2 Functional Architecture Meta-model

8.2.2.1 Concept

The objective of this section is to introduce a meta-model, which describes Smart Grid functions and their relationship from an architectural viewpoint. The basic concept for the description of functional architectures for Smart Grid is adopted from the M/441 Smart Metering Reference Architecture [CEN CLC ETSI TR 50572:2011].

Figure 1Figure 16 shows the meta-model concept for the description of functional architectures for Smart Grid.

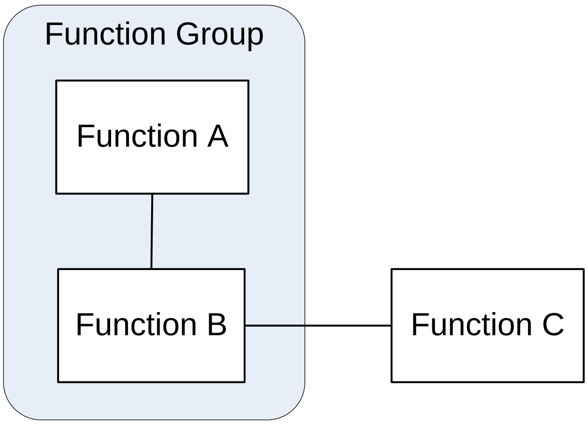

Figure 16: Functional architecture meta-model

Table 4: Terms of functional architecture meta-model

Term	Description
Function	Represents a logical entity which performs a dedicated function. Being a logical entity, a function can be physically implemented in various ways.
Function Group	Is a logical aggregation of one or more functions. A function group may also contain one or more function groups.
interaction	An “interaction” of two or more functions is indicated by a connecting line between these functions. Interaction is realized by information exchange via the interfaces of functions and communication means..
Functional architecture	Identifies the functional elements of a system and relates them to each other.

Figure 16 shows a function group containing the functions A and B that mutually interact. Function C interacting with function B, is not contained by any function group.

An example for a functional architecture is given for the use case “control of reactive power in section B.2.4.

8.2.2.2 Flexibility

Being able to describe functional elements of a system and their relationship independent from physical implementation, applied technology or assigned actor, allows an abstract and flexible development and use of functional architectures. In terms of SGAM this means, that functions or function groups can be assigned and shifted over the segments of the SGAM smart grid plane.

The example in Figure 17 illustrates the flexible assignment of functions to SGAM segments.

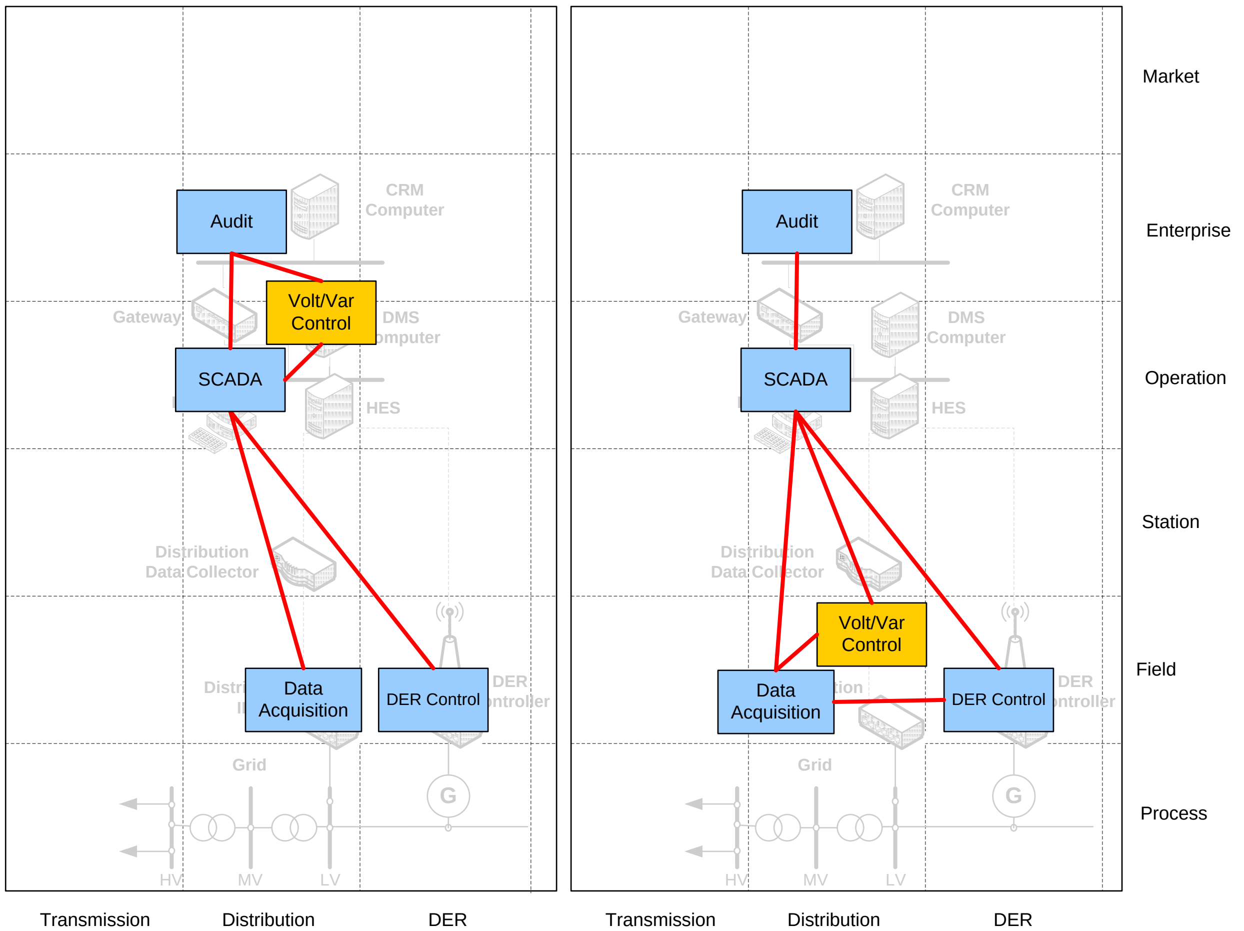

Figure 17: Flexibility for assignment of function “Volt/Var Control” to SGAM segments, case A - in operation zone, case B - in field zone

In case A, the function “Volt/Var Control” is assigned in the operation zone. This is a typical functional architecture in centralized DMS systems. In case B, the function is located in the field zone representing a local or decentralized concept. Both scenarios have specific impact on the other SGAM layers in terms of information exchange, canonical data models, communication protocols and component capabilities (see example in section B.2.4).

8.2.3 Smart Grid Functional Architecture

8.2.3.1 General

This section provides an overview on function groups that are derived from the Smart Grid systems introduced by SGCG/FSS [SG-CG/B]. Moreover these function groups are intended to support the high-level services, which were addressed in the Smart Grids Task Force EG1 report:

- Enabling the network to integrate users with new requirements
- Enhancing efficiency in day-to-day grid operation
- Ensuring network security, system control and quality of supply
- Enabling better planning of future network investment
- Improving market functioning and customer service
- Enabling and encouraging stronger and more direct involvement of consumers in their energy usage and management

8.2.3.2 Smart Grid Function Groups

The smart grid systems cover all five SGAM interoperability layers. Consequently the systems have specific content in the functional architecture viewpoint. Figure 18 shows the functional groups of the Smart Grid systems mapped to the Smart Grid domains and zones.

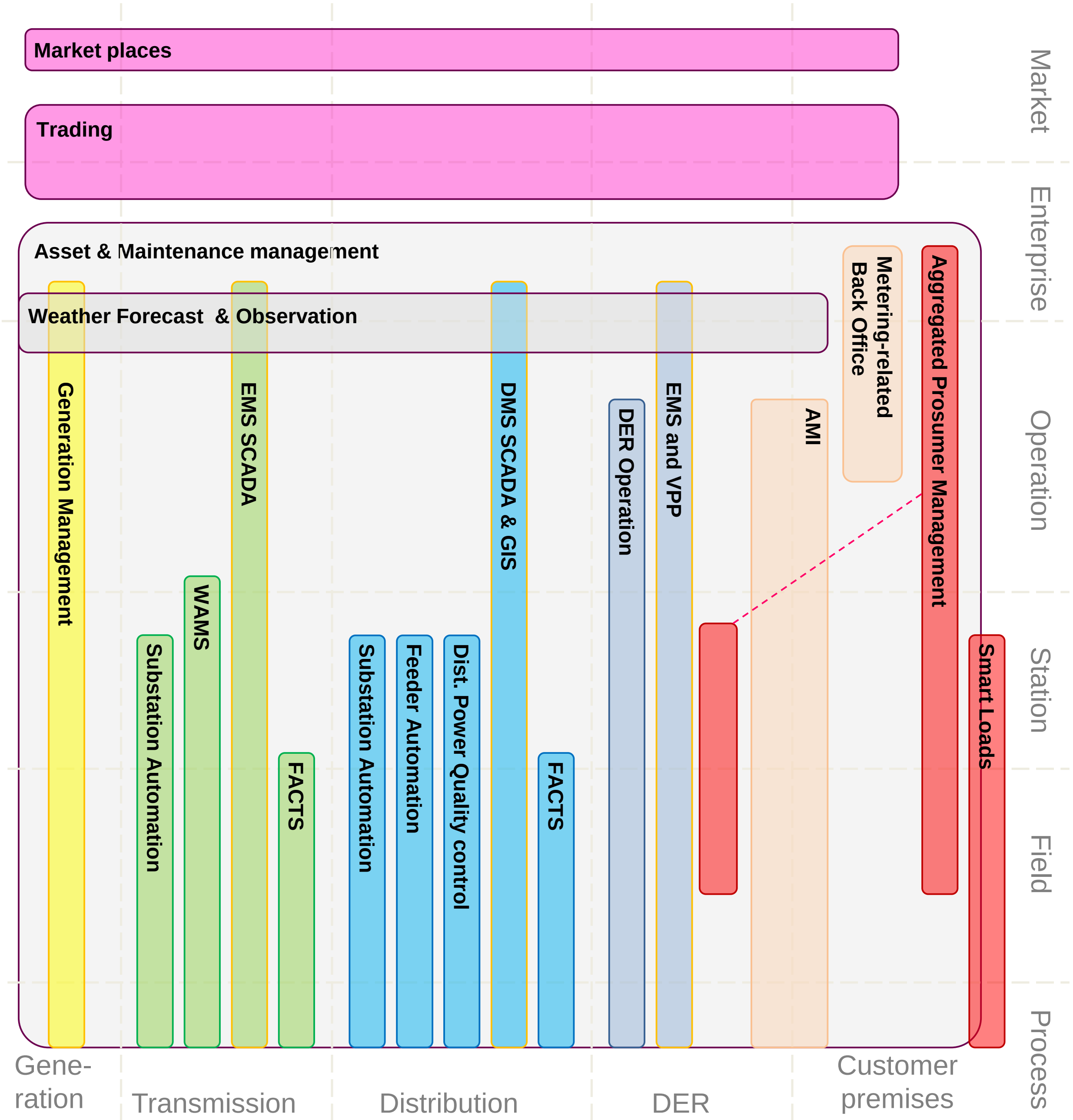

Figure 18: Overview on Smart Grid function groups derived from Smart Grid Systems

A description and further details on the smart grid systems is given in [SG-CG/B].

From a functional prospective the function groups of the individual systems contain further function groups or function of smaller granularity. E.g. the function group “Substation Automation” can be decomposed into the function groups “protection”, “control”, “monitoring”, “data acquisition”… which themselves can be break down in further functions or function groups. The key idea is to identify basic functions which can be seen as reusable building blocks for complex functions. By the help of these basic functions different functional layouts can be studied and compared (see section 8.2.2.2).

8.3 Information Architecture

8.3.1 General

This section of the report focuses of the overview of the most important concepts for the representation and management of the needed information for the Smart grid elements. An Information Architecture is an abstract but formal representation of entities including their properties, relationships and the operations that can be performed on them. Important aspects which are addressed are data management, integration concepts and the interfaces needed. For those main aspects, the Smart Grid JWG report has already provided a thorough overview what has be considered state-of-the-art from the viewpoints of standardization bodies. In order to distinguish between those three aspects in the SGAM, the integration aspects must be seen as a link between either two or more layers and between one or more fields at plane level. Data models are typically focusing on the information layer and can be mapped easily onto the SGAM planes.

The following paragraphs focus on the three very aspects of the information architecture in more detail. Furthermore the concept of “logical interfaces” is introduced which is dedicated to simplify the development of interface specifications especially in case of multiple actors with relationships across domains.

8.3.2 Integration technology

While systems and applications in the past were often operated separately, today business requires interactions between multiple systems and applications to operate effectively. To do so, a coupling of former separated and heterogeneous systems is necessary. This requires solutions to integrate those systems in a way their functionality is still available and can be adapted to changing need. The establishment of a common information model that is to be used throughout many applications and systems requires solutions to cope with different data sources from the various actors.

To allow the recombination of different data sources and the establishment of new interfaces between those systems, syntactic and semantic interoperability is required. Different than in data or function integration, the implementation of the original systems is not affected by this enterprise application integration approach.

Usually, the integration will be realized through integration platforms that allow the implementation of required interfaces – Middleware is often the layer where this integration effort takes place. Often times the middleware is message-based, meaning components exchange data defined in messages which are sent from one component to another. XML is then used for various purposes, like message description and interchange. By shifting the intelligence to interfaces in conjunction with intelligent routing, publish/subscribe and event mechanisms, it is possible to define efficient systems spanning across multiple organizations and actors. In general this approach is labeled as EAI.

SOA goes one step further with the integration approach as well as with the organizational embedding, but also share the technological concepts of EAI. A SOA requires specific features according to the service paradigm from the applications to be coupled in order to allow for successful process integration. The smallest units in SOAs are services that provide a defined set of functionality, being so fine-grained that they provide units for reuse.

However, what exactly a service is and its level of granularity is in many cases defined different. The term service is often considered from a certain perspective from a particular stakeholder group, for instance, regarding the structuring of the business or the IT, as being stated by TOGAF. Different approaches to describe SOAs and to classify their services are further mentioned in [Uslar et al 2012].

Services, both business and technical, are self-contained, have a contract assigned that specifies their functionality and how to access it, and produce predictable results. In contrast to the sizing of applications and their functionality, services are designed to be used with other services in terms of composition and orchestration. This level of granularity adds more flexibility to business processes, as they may defined and executed using the services. Services are characterized by loose coupling and will usually be provided in specific directories where they can be found by third parties or process engines. Technical services are mostly realized as Web Services using the WS* technology stack from W3C. The service localization is then realized with Universal Description, Discovery and Integration (UDDI) that provides standardized way to locate those services. Besides the possibility of direct coupling, the usage of a platform providing the required functionality to orchestrate and compose services is highly important and can be realized in SOA middleware.

The features that middleware for this application area usually offers can for example be data transformation, connection to data sources, automation technology, logging, reporting as well as filtering and transformation. Such complex middleware is often named ESB. A platform like this can serve as a focal point for data, but it can also become a bottleneck for the decentralized arranged services. Therefore, it is beneficial to have a redundant middleware infrastructure that is scalable. In case a part of the IT infrastructure is not operated by a company itself but by another provider, the provided infrastructure becomes more and more abstract and blurred, meaning it appears as to be surrounded by a cloud.

By turning from a central IT to more decentralized systems in the energy sector, more efforts on system integration have to be spent. The mentioned integration paradigms are very valuable for Smart Grids, as they can be applied for the integration of decentralized systems, comprising producers, storage, consumers and other data sources. Here, the integration paradigms of EAI and SOA may be used for communication, automation as well as for secondary and primary IT. Internationally standardized solutions already exist to simplify this, like for instance the IEC 62357 SIA, which can be realized using a SOA, or the IEC 62541 OPC Unified Architecture as a SOA-based approach for data exchange. Nevertheless, there are still gaps that require harmonization between semantic and syntactic interfaces.

8.3.3 Data Models

According to literature, a data model in software engineering is an abstract model that documents and organizes the business data for communication between team members and is used as a plan for developing applications, specifically how data is stored and accessed. If the abstract level is higher, usually, business functions implemented and exchanged in processes are represented in a data model, focusing on the data in terms of payloads between stakeholders being exchanged.

Data modeling and description languages are typical “system enablers” transversal to use cases and should be seen in priority from a top-down approach. It may conflict with the traditional bottom-up approaches. However, there are many benefits of proceeding top-down starting with the data models:

- Avoiding useless translators, which increase the complexity of the deployment of smart grids, increase its costs, reduce its overall reliability, reduce flexibility in the future and finally speed down the over all market acceptance.
- Avoid misunderstanding between stakeholders from different domains involved in the system development, and increase the global reliability and interoperability of the system.

- Increase the flexibility of the system.
- Increase the speed of spreading the smart grid, by reducing the amount of engineering time per additional point of connection of IEDs.
- Providing harmonized data model and description language leads to think ”transverse” to be efficient, with the constraint not only to define an “ultimate” target but also the migration path from the existing situation.
- Harmonization between various data models takes place before the actual system development and might lead to a better seamless integration.

In the utility domain, several data models in context with the different aspects for the corresponding SGAM plane “Information layer” exist and have been thoroughly documented.

Annex 6.2 of the JWG-SG Report on Smart Grid Standardization provides a thorough overview on the most important data models which have to be seen in context with the smart grid standardization. As most reports point out, the CIM (IEC 61968, 61970 and 62325) and the IEC 61850 data model are the most prominent data models [Uslar et al 2012]. Fortunately, there are strong initiatives started by the SG-CG FSSWG group to harmonize the most important data models for smart grids. Therefore, we assume for a future version of the SGAM, seamless integration of data model at the information plane between the domains and zones can be reached.
This report does not recommend (apart from the obvious standards form the JWG reports) any data model standards but leaves this for the final report of the first set of standards group which will cover, based on the SGAM methodology described in this report, individual standards to be included in the M/490 First list of Standards focusing on meaningful data model standards for the Smart Grid. Additionally, the identified gaps between those data models are identified and will be addressed by the final report of the first set of standards group, e.g. IEC 61850 and CIM harmonization. Additionally, the SGAM method and EA techniques applied like TOGAF and Archimate provide for a meaningful integration and identification of needed date models in a context.

8.3.4 Interfaces

Most of the interfaces are normally seen between the domains and zones on the information plane. However, also interfaces between the planes must exist. Data like measurements and control signals are to be exchanged between those layers. The SGAM principles were created to make sure that both data models and interfaces for technical standardization could be mapped and properly addressed for standards.

As most utility standards were developed with the focus on the separation of concerns, interfaces are usually specified technology independent (ETSI M2M, IEC 61850 ACSI, CIM profiles (in RDF, OPC UA) and CIS/IRM) and can therefore be assumed somehow fix for a reference architecture as the semantics and syntax usually stays stable over the system’s lifecycle.

The generic basic interfaces can be supplied by literally unlimited numbers of technology mappings) most of the time, a vast number already exists because of the different use cases the standards have), however standardization most of the time recommends some of them only. Choosing the appropriate technology mapping for an interface depends on the functional and non-functional requirements of a use case and on the given context. This aspect is similar for the communications architecture plane. The non-functional aspects of an interface and data model are addressed by the IEC PAS 62559 IntelliGrid template and its extensions by the WG SP of the mandate. In a Use case, the interfaces and data models which will be mapped onto the SGAM for structuring can be identified from a pre-filled template and easily be annotated for the later system development.

The SGAM focuses on the possibility to model different types of uses for interfaces on plane and layer level, making it easier to distinguish between the interfaces which cover different domains of the conceptual models, different roles (e.g. at market or unbundling level) and of course technical systems.

8.3.5 Logical interfaces

The concept of logical interfaces is intended to provide a methodology for a systematic development of interface specifications. The resulting interface specification includes the information to be exchanged via the interface. This method offers advantages especially when multiple actors interoperate among different domains. Focusing on logical relationships, this method is independent from physical implementations of interfaces making it well applicable in concept studies e.g. in standardization.

Figure 19 illustrates the concept of logical interfaces in the context of SGAM domains and zones.

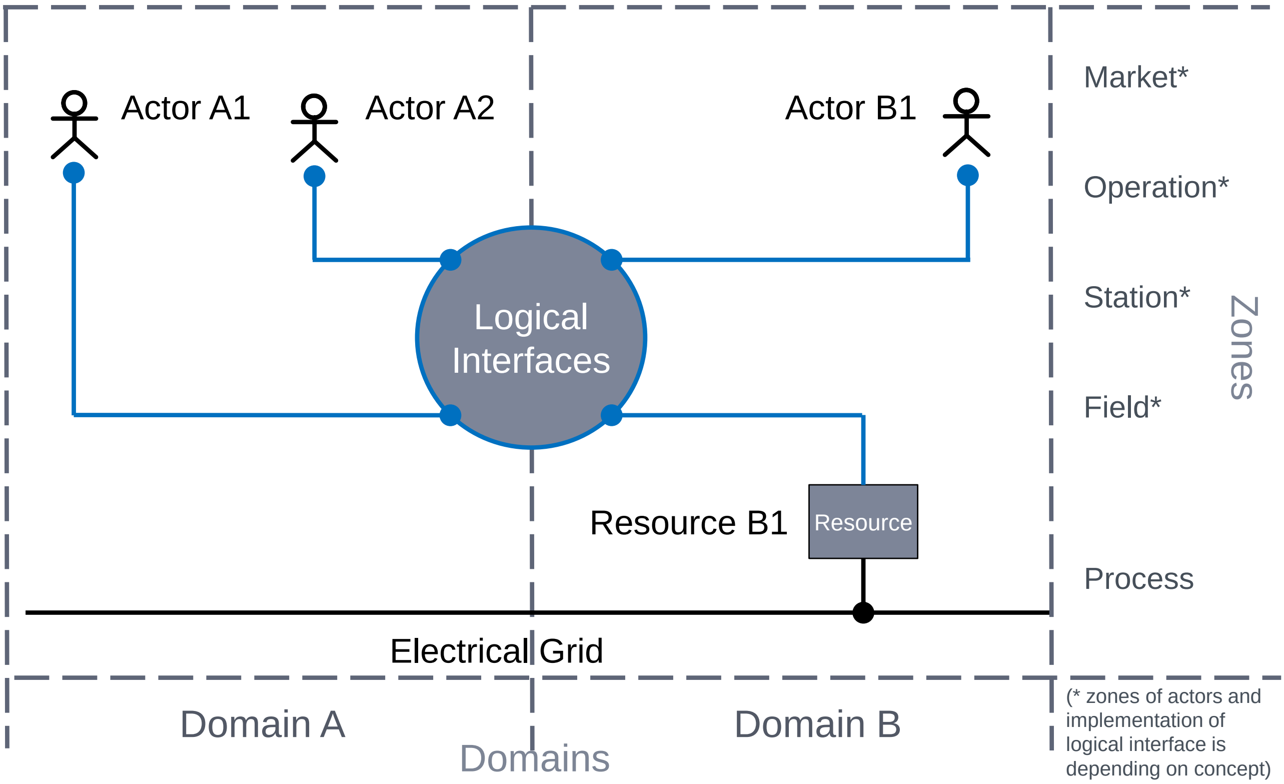

Figure 19: Concept of logical interfaces in the context of domains and zones

The generic example consists of business actors (A1, A2, B1) and a system actor (resource B1) assigned to domains A and B. In this example resource B is connected to the electrical grid and might be assigned to process zone. The business actors can be assigned to any zone, depending on the type of actor and the specific use case.

All actors may interact with other actors across the domain boundary but also within domains, e.g. actor A1 interacts with resource B1, actor A2 interacts with actor B2, actor B1 interacts with resource B1. The logical interfaces, indicated by the dots on the circle line at the domain boundary, manage the information exchange among all connected actors. For doing this, all actors have to provide the information in quality and quantity which is expected by the other actors. This idea of logical information exchange is independent from physical implementation, which can be realized with computers, dedicated gateways, and interface components (e.g. integrated in resource B1). This makes this concept flexible providing the necessary interface specifications required for implementation.

For the systematic development of interface specifications the information which is available in use case descriptions can be used. The necessary steps can be summarized as follows:

- Sorting use cases to logical interfaces
  - The use case actors are mapped to the appropriate domains and zones
  - The logical interfaces result from crossing through the circle of the connection between interacting actors
- Identification of exchanged information per logical interface
  - The exchanged information is assigned to the respective logical interfaces (dot on circle line)
  - This is done for all use cases
- Merging of interfaces specifications
  - The result is a list of information for each logical interface
  - Duplicates can be identified and removed

In conclusion this concept can be used for the development of information specifications

- For the analysis if standards are available which provide necessary support by data models
- For the extension of data model standards for new use cases
- Used in R&D and customer projects.

8.4 Communication Architecture

The Communication Architecture document (see Annex F) deals with communication aspects of the Smart Grid. The main objective of the study on Smart Grid communications is to identify gaps that need to be addressed in standardization organizations. This work considered generic Smart Grid use cases to derive the requirements and to consider the adequacy of those requirements to the existing communications standards in order to identify communication standards gaps. It was found that there are no specific standardization gaps for Layer 1 to Layer 4 standards (according to OSI model) mandating the immediate need for evolution of existing standards.

However, there is an immediate need to develop profiling and interoperability specifications based on the existing communications standards. The profiling work is the task of the SDOs. However, for the purpose of explaining our vision of such a profiling, a draft profile is proposed as an example of Smart Grid sub-network architecture.

The first section of the document provides a set of recommendations for standardization work as well as a mapping of the communication technologies to Smart Grid communication sub-networks that are listed in the section below.

The remaining part of the document provides:

- An overview of the Communication standards applicable to Smart Grid communications.
- A description of generic Smart Grid use cases, their communication requirements, along with recommendations on how to setup the communication networks to address these requirements.
- An example of profile and some interoperability considerations.

8.4.1 Recommendations

8.4.1.1 Recommendation 1

Examining the communication needs of different Smart Grid use cases, it appears that there are cases that have very stringent communications requirements (PMU, Tele-protection, etc.). However, all these requirements can be addressed using existing communications standards with sufficient engineering guidelines (see Recommendation 2). There is already a large set of communication standards for each network segment identified and no gaps mandating the need for new communication standards have been identified.

8.4.1.2 Recommendation 2

Communication network performance including QoS, reliability, and security must be managed so as to achieve the smart grid communications requirements. This mandates the need to develop communication profiles on "how to use" the current communication standards for Smart Grids. IEC in collaboration with bodies such as IETF, IEEE, ETSI, CEN and CENELEC is the right place to develop such profiles. A profile is defined as a description of how to use the different options and capabilities within a set of standards for a particular use.

8.4.1.3 Recommendation 3

There is a need to develop a standardized Service Level Specification (i.e. the technical part of a Service Level Agreement: availability, resiliency, DoS, etc.) that allows a utility network or application to rely on predictable network performance when communication is provided by a shared communication infrastructure.

8.4.1.4 Recommendation 4

Deployment constraints mandate the need for both wireline and wireless communications. Utility access to wireless network resources is necessary. Where spectrum is allocated for use by utility networks, this will help progress the Smart Grid deployments ensuring the standard work and products take into account the allocated spectrum for utilities.

8.4.1.5 Recommendation 5

Given the plethora of L1 and L2 technologies (according to OSI) used in the different communication standards (as well as the upcoming ones), IP shall be the recommended L3 technology to ensure communications are future proof and avoid the unnecessary need for interworking gateways in different parts of the Smart Grid communication networks.

8.4.1.6 Recommendation 6

This Communication Architecture document recommends a list of applicable communication technologies as well as their applicability statement to different sub-networks of the communications architecture. The choice of a technology for a sub-network is left to implementations, which need to take into account a variety of deployment constraints.

8.4.1.7 Recommendation 7

Profiles (see Recommendation 2) should be used as a basis for building interoperability test specifications. When interoperability test specifications / suites exist, those should be leveraged for building test specifications for the communication profiles.

8.4.1.8 Recommendation 8

ESOs should consider the approval of their specifications applicable to Smart Grid as ENs.

Recognizing the role of consortia in providing & developing specifications for communications and considering the fact that these consortia adopt an open standards approach (i.e. IEEE, IETF, W3C) the European Commission should endorse the importance of their specifications in building communications network, including for Smart Grid. There are globally recognized technologies & deployments for communications that use a selection of open specifications from ESOs, global SDOs and these consortia. The endorsement of the specifications into ENs, may not be reasonable in defined timeframe or achievable.

8.4.2 Smart Grid sub-networks

We are identifying the different networks that play a role in the overall communication architecture and we are representing their scope using the SGAM model (see Figure 8).

The following networks could be defined, see figure 3-2 below where these terms are used:

- **(A) Subscriber Access Network**

Network that is not part of the utility infrastructure but involve devices and systems that interact significantly with the utility such as responsive loads in residences and commercial/industrial facilities, etc.

- **(B) Neighborhood network**

Network at the distribution level between distribution substations and end users. It is 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) Field Area Network**

Network 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**

Network 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 –**

Network that interconnects 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) Enterprise Network**

Enterprise or campus network, as well as inter-control center network. Since utilities typically have multiple control centers and multiple campuses that are widely separated geographically.

- **(I) Balancing Network**

Network that interconnects generation operators and independent power producers with balancing authorities, and network which interconnects balancing authorities with each other. In some emerging cases, balancing authorities may also dispatch retail level distributed energy resources or responsive load.

- **(J) Interchange network**

Network that interconnects regional reliability coordinators with operators such as transmission operators and power producers, as well as network that connects wholesale electricity markets to market operators, providers, retailers, and traders. In some cases, the bulk markets are being opened up to small consumers, so that they have a retail-like aspect that impacts networking for the involved entities.

- **(K) Trans-Regional / Trans-National network**

Network that interconnects synchronous grids for power interchange, as well as emerging national or even continental scale networks for grid monitoring, inter-tie power flow management, and national or continental scale renewable energy markets. Such networks are just beginning to be developed.

- **(L) Wide and Metropolitan Area Network**[1]

Network that can use public or private infrastructures. They inter-connect network devices over a wide area (region or country) and are defined through SLAs (Service Level Agreement).

- **(M) Industrial Fieldbus Area Network**

Networks that interconnect process control equipment mainly in power generation (bulk or distributed) in the scope of smart grids.

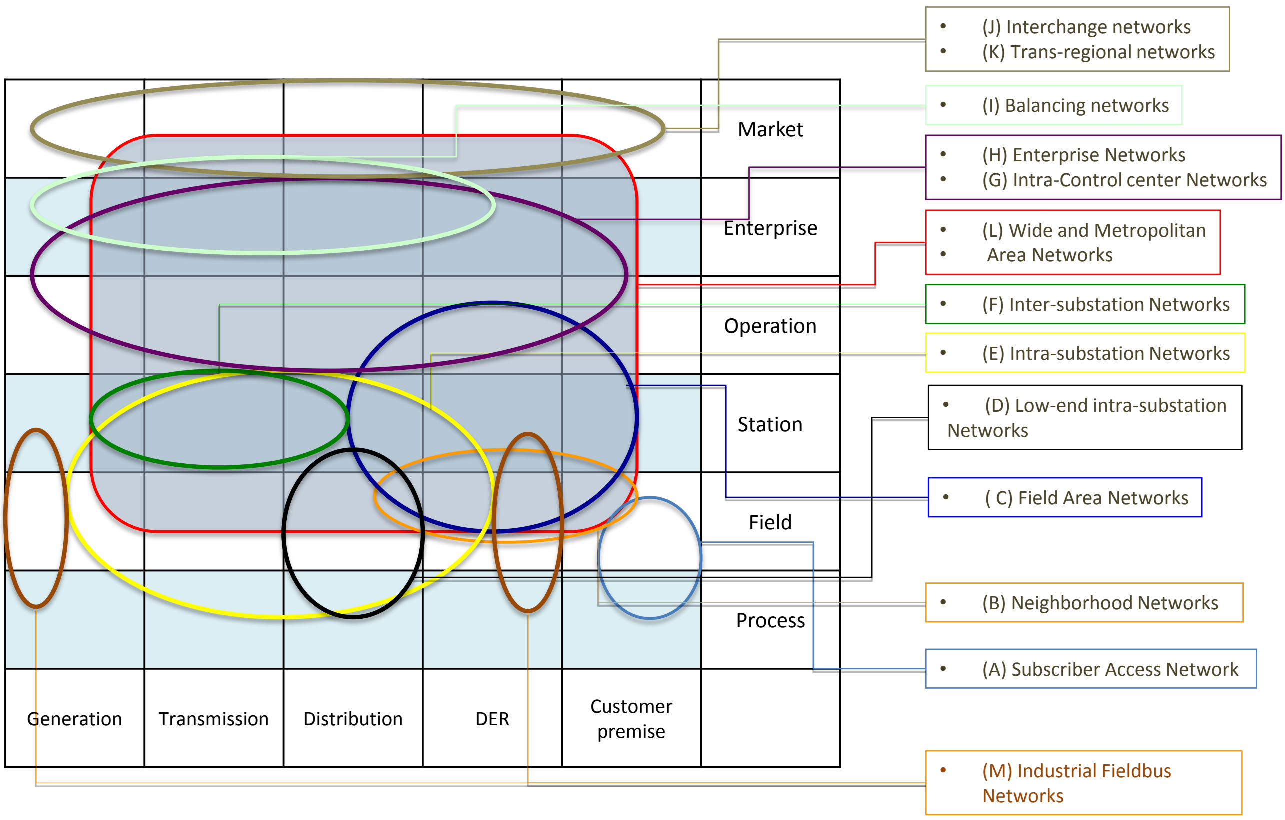

Figure 20: Mapping of communication networks on SGAM Communication Layer

Note 1 These areas of responsibility are an example mapping and cannot be normative to all business models.

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[1] Several of the shown networks could be based on WAN technologies. However since those networks

A. can be run / managed by different stakeholders,

B. could provide different level of security or different SLAs

they are depicted separately. It should be noted however that this is a logical view and that in practice multiple logical networks can be implemented using a single WAN technology. Implementation design choices are beyond the scope of this report

Note 2 It is assumed that 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.

8.4.3 Applicability statement of the Communication Technologies to the Smart Grid Sub-networks

The following table provides an applicability statement indicating the standardized communication technologies to the Smart Grid sub-networks depicted in the previous sub-clause. As per Recommendation 6, the choice of a technology for a sub-network is left to implementations, which need to take into account a variety of deployment constraints.

Note This report addresses communication technologies related to smart grid deployment. It includes communication architecture and protocols that could be used in smart metering deployments as well as other use cases (like feeder automation, FLISR etc.). For AMI only specific standards, please refer to CEN/CLC/ETSI TR 50572 and other future deliverables as listed in SMCG_Sec0025_DC_V0.3 Work Program Document.

Table 5: Applicability statement of the communication technologies to the smart grid sub-networks

	Subscriber access network	Neighbourhood Network	Field area	Low-end intra substation	Intra-substation	Inter-substation	Intra control centre	intra data centre	Enterprise	Balancing	Interchange	Trans regional	Trans national	WAN	Industrial Fieldbus
	A	B	C	D	E	F	G		H	I	J	K		L	M
Narrow band PLC (Medium and Low voltage)	x	x	x												
Narrow band PLC (High and very High voltage)					x	x									
Broadband PLC	x	x													
IEEE 802.15.4	x	x	x												
IEEE 802.11	x	x		x	x										
IEEE 802.3/1				x	x		x	x	x						x
IEEE 802.16	x	x	x												
ETSI TS 102 887		x	x												
IPv4	x	x	x	x	x	x	x	x	x	x	x	x	x	x	
IPv6	x	x	x	x	x	x	x	x	x	x	x	x	x	x	
RPL / 6LowPan	x	x	x												
IEC 61850		x	x	x	x	x								x	
IEC 60870-5				x	x	x								x	
GSM / GPRS / EDGE	x	x												x	
3G / WCDMA / UMTS / HSPA	x	x					x	x	x	x	x	x	x	x	
LTE/LTE-A	x	x	x	x		x	x	x	x	x	x	x	x	x	
SDH/OTN	x	x	x	x	x	x	x	x	x	x	x	x	x	x	
IP MPLS / MPLS TP	x	x	x	x	x	x	x	x	x	x	x	x	x	x	
EN 13757		x													
DSL/PON [2]	x	x				x								x	

[2] **IEEE GEPON and EPON are considered to be part of DSL/PON line**

Annex A
Background Architecture Work

A.1 Objectives of this annex

This annex is dealing with the main principles for architecture management which have been applied developing both the SGAM and the Reference Architecture.

A.1.1 Aspects of a Common View: evolvability, simplicity and reuse of building blocks

For the understanding of the term Reference Architecture in the context of this document, various definitions have to be taken into account. Different relevant terms and definitions exist for architectures. The paragraphs provides and overview on how the term is used in context of this document and the ISO 42010.

One relevant ISO/IEC definition can be found in the ISO/IEC FDIS 42010 (2011): “Systems and software engineering — Architecture description”

Architecture

Fundamental concepts or properties of a system in its environment embodied in its elements, relationships, and in the principles of its design and evolution.

Architecting

Process of conceiving, defining, expressing, documenting, communicating, certifying proper implementation of, maintaining and improving an architecture throughout a system’s life cycle.

Architecture Framework

Conventions, principles and practices for the description of architectures established within a specific domain of application and/or community of stakeholders.

Reference Architecture

A Reference *Architecture* describes the *structure* of a system with its element types and their structures, as well as their *interaction* types, among each other and with their environment. Describing this, a Reference Architecture defines restrictions for an instantiation (concrete architecture). Through abstraction from individual details, a Reference Architecture is universally valid within a specific domain. Further architectures with the same functional requirements can be constructed based on the reference architecture. Along with *reference* architectures comes a *recommendation*, based on experiences from existing developments as well as from a wide acceptance and recognition by its users or per definition.

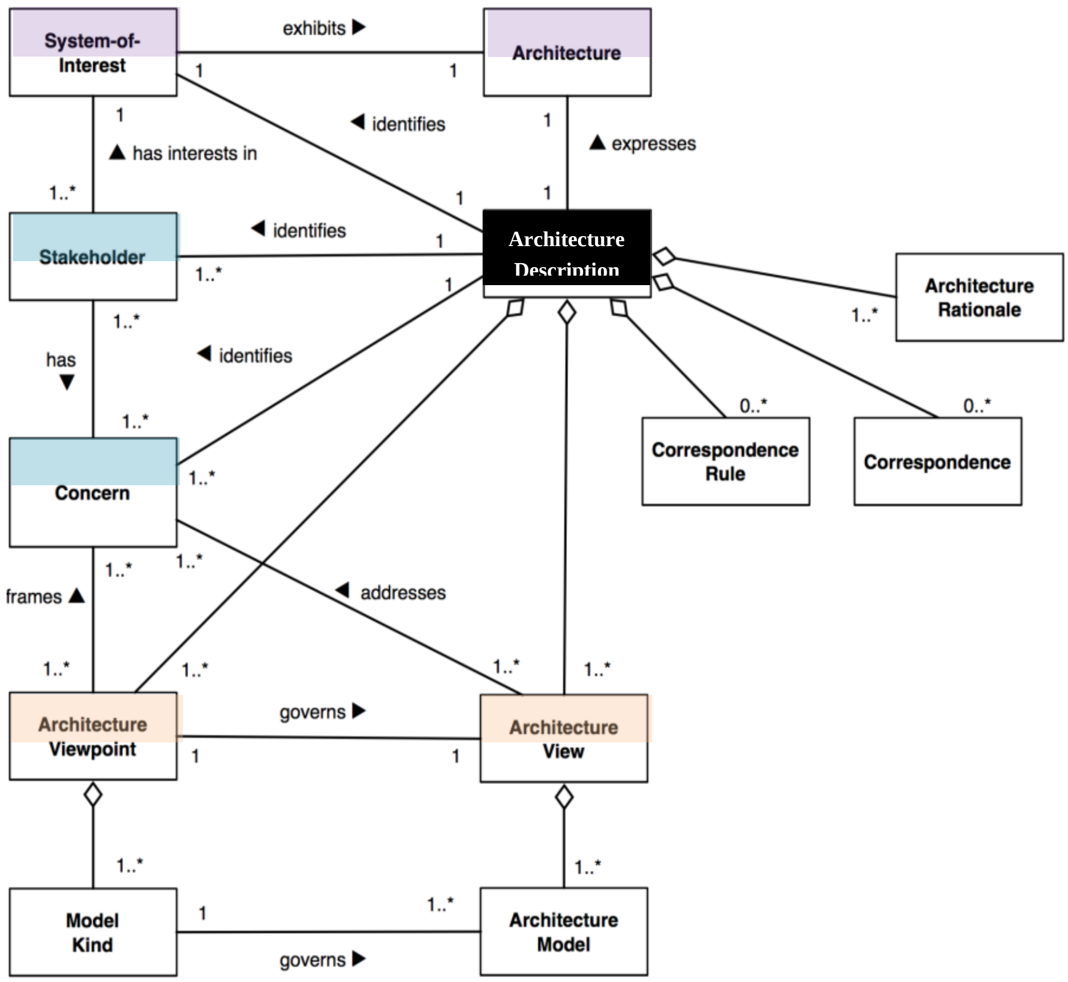

Figure 21: Metamodel of ISO/IEC 42010

What characterizes a Reference Architecture can be seen in the following list and overview of typical attributes which are covered by it:

- Recommendation character
- Declared by author
- Acceptance and recognition by users
- Generality
- Abstracts from specific characteristics
- Universal validity just possible within a specific domain or in relation to a set of use cases

In general, an architecture description is a work product used to express an architecture (of a system). Its content varies depending on the architecture. Stakeholders and their concerns and the Architecture Description usually depict the relevant stakeholders concerns.

Different Architecture Views are used to express architecture and to cover the stakeholder's concerns. Architecture Viewpoints are used to describe (relevant) architecture views; those Viewpoints describe stakeholders, concerns, notations, etc.

A.1.2 Clarification of views: power vs. communication; applications vs. services

When developing a Reference Architecture, it is important to know which aspects and view-points should be addressed in order to keep the model as simple as possible and not to introduce to much un-needed complexity. Often, those viewpoints differ in granularity, depending on the covered concerns. Typical possible viewpoints are:

- **Enterprise** viewpoint,
- **Information** viewpoint,
- **Computational** viewpoint,
- **Engineering** viewpoint,
- **Technology** Viewpoint (RM-ODP, ISO/IEC 10746)
- **Business Architecture** viewpoint,
- **Application Architecture** viewpoint,
- **Data Architecture** viewpoint,
- **Technology Architecture** viewpoint

With regard to methodologies like The Open Group Architecture Framework (TOGAF) or Zachman some of those viewpoints should always be addressed in context because they are inseparable. As for the SGAM, section 7 of this document will show the addressed viewpoints at zones, planes and layers.

A.2 Relationship to existing Architectures

As this is not the first architecture to be developed, most SDOs and their TCs already have created certain reference models and different viewpoints which are already used all around the world. As the overall project time to create the RA for the M490 process was limited, existing work was taken into account. The following (non-exhaustive) list contains already existing work whose principles and ideas were used by the RWAG:

- IEC SIA (TC 57 and SMB SG 3)
- GridWise
- Intelligrid Framework
- NIST Conceptual Model
- eTom/SID/Frameworx
- Electrinet
- OASIS, ebIX, ENTSO-E
- SG-CG First Set of Standards and Security Work Groups key issues

As for the SGAM, section 7 of this document outlines which aspects of those models were incorporated into the SGAM and which were not. Annex B of this document provides conceptual mappings to the SGAM layers for several of the aforementioned frameworks, making an alignment of SGAM use cases with those models possible.

A.3 Overview of one possible RA lifecycle-model

The possible lifecycle for the creation and maintenance of a reference architecture depicted in Figure 22 can be easily adopted by M/490 processes.

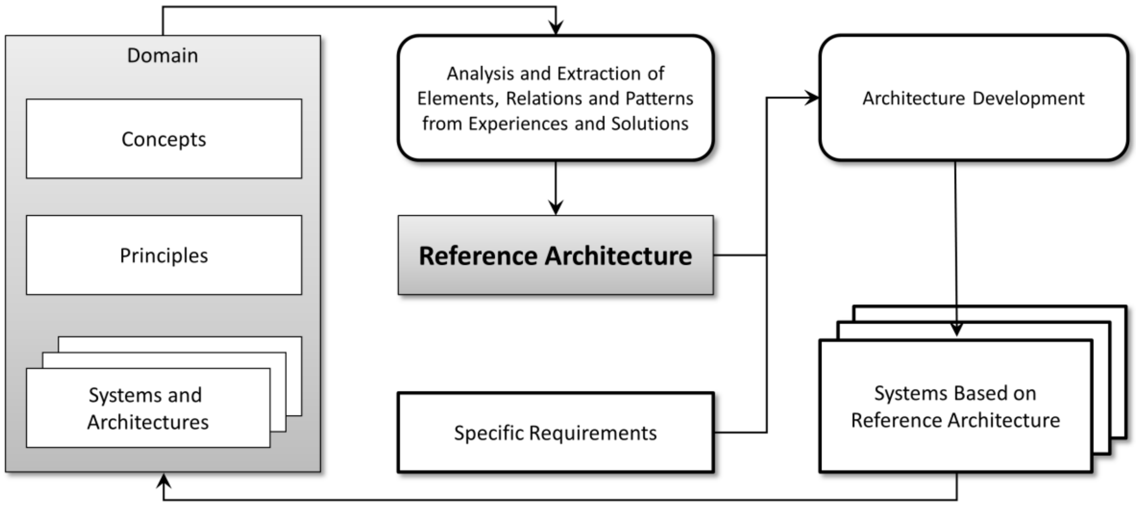

Figure 22: General Lifecycle for a reference architecture model

Firstly, the existing systems and architecture, principles and concepts of a domain, some relevant elements, relations and patterns are extracted, This step was performed by the SG-CG/RA members, taking into account exiting work and EGx and JWG reports. A first version of the reference architecture, the SGAM has been developed. However, as it is applied in practice, special requirements which are not covered by the general model can occur and must be instantiated. They must be incorporated in the architecture development and will be fulfilled by the systems which are instance-based on the reference architecture form the domain. Again, the knowledge gathered about the domain and application of the reference architecture is brought back in the process to build a new version of the reference architecture. It is strongly suggested to use this model when first experiences with the SGAM in practice are gained to create a new version 2.0 of the SGAM.

Annex B
Model mappings

B.1 Conceptual Model

This section will be completed in a subsequent version.

B.2 SGAM Framework

B.2.1 Quality of interoperability

The quality of interoperability can be measured by integration effort. When systems are to be integrated to fulfill a function cooperatively, all interoperability categories need to be covered. Here standards help to increase the quality of interoperability by reducing the integration effort.

Figure 23 shows the relationship between integration efforts and system complexity in respect to the use of standards. A standard is designated

- "rich", when the standard covers several interoperability categories (e.g. IEC 61850, covering the categories from basic connectivity up to semantic understanding, even including aspects of business context)
- "simple", when the standard covers a single or few interoperability categories (e.g. Ethernet, covering aspects of basic connectivity, syntactic and network interoperability)

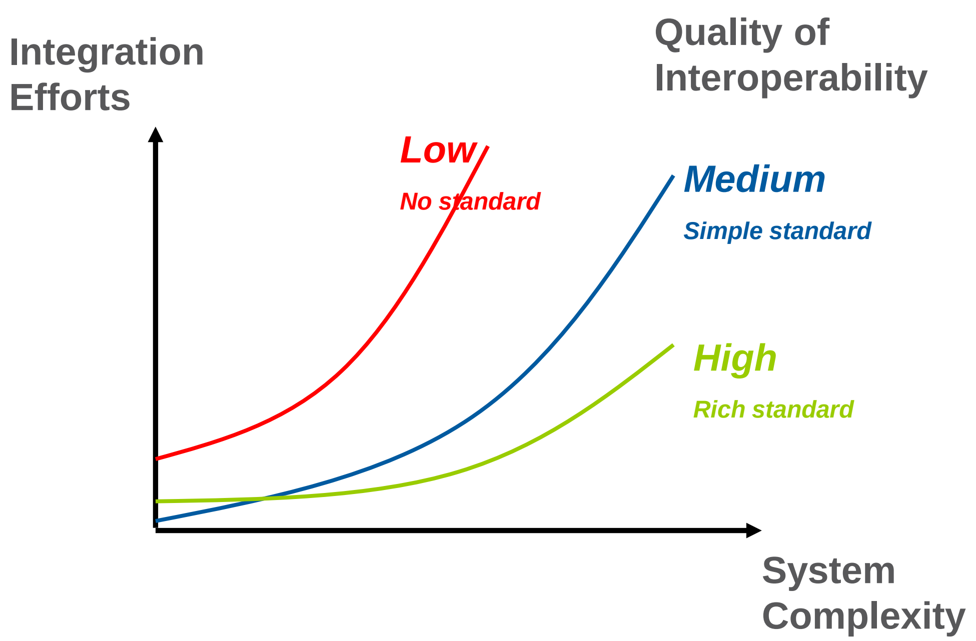

Figure 23: Quality of interoperability

Generally the integration effort to achieve full interoperability increases by system complexity. Having rich standards available (for a given integration task), which provide specifications for the required interoperability categories (e.g. standardized connectors, communication protocols, semantic data models, standardized functions), will ease the integration work. Having simple or even no standards applicable for the integration task may result in higher efforts due to project specific adaptions.

Consequently “rich” standards bridging as many interoperability categories as possible are to be preferred for smart grid interoperability.

B.2.2 Specific qualities of interoperability: “Plug-and-play” and “Interchangeability”

In the discussion about the meaning of interoperability, the terms “plug-and-play” and “exchangeability” are quite common. Rather than synonyms for interoperability, these terms represent a specific quality of interoperability.

Plug-and-play

Plug-and-play can be described as the ability to add a new component to a system and have it work automatically without having to do any technical analysis or manual configuration. In other words this includes the automatic configuration of specific settings necessary for the integration for systems. In respect to the interoperability categories, the concept of automatic configuration complements standards and specifications with mechanisms and procedures to simplify system integration. At best these mechanisms and procedures are standardized.

Interchangeability

Interchangeability is defined as “*the ability to replace a device supplied by one manufacturer with a device supplied by another manufacturer, without making changes to the other elements in the system”* [IEC61850-2010]. This means that interchangeability represents “hot plug” capability of a system or component. For this purpose the system requires a well-defined behavior in respect of function and information exchange, in other words the full specification of all interoperability categories. This full specification can be achieved by using standard profiles (see 2.2.6).

For a given system or component, the *Plug-and-play* (auto configuration) capability is not necessary for the support of interchangeability, since pre-configuration is sufficient.

B.2.3 Standard profiles – a measure to increase the quality of interoperability

Generally a profile defines a subset of an entity (e.g. standard or specification). Profiles can be used to reduce the complexity of a given integration task by selecting or restricting standards to the essentially required content. A standard profile may contain a selection of data models, communication services applicable for a specific use case. Furthermore a profile may define instances (e.g. specific device types) and procedures (e.g. programmable logics, message sequences) in order to support interchangeability.

B.2.4 SGAM Mapping Example

The following example illustrates how a use case can is mapped to the SGAM framework. For this example the process which is described in section 7.3.3 is applied. The sample use case “*Control reactive power of DER unit”* is a typical use case, which falls under the area of the distribution management.

This example also illustrates that a use case can be represented with existing devices, infrastructures, functions, communication and information standards and business objective and constraints. Consistency of the layers in respect to the use case is provided by standards, which are applicable for the implementation of the use case.

B.2.4.1 Use Case Analysis

Starting point is an analysis of the use case to be mapped. It needs to be verified that a use case description provides the sufficient information which is necessary for the mapping.

For this mapping example the required information is taken from

- Name, scope and objective (Table 6)
- Use case diagram (Figure 24)
- Actor names, types (Table 7)
- Preconditions, assumptions, post conditions (Table 8)
- Use case steps (Table 9)
- Information which is exchanged among actors (Table 10)

The underlying business objective of the use case is the operation of the distribution system in order to deliver electrical energy to customers under consideration of specific constraints. These constraints are typically economic and regulatory oriented, such as e.g. grid codes (incl. technical and non-technical requirements), security of supply, system stability, quality standards, company processes, etc.

Table 6: Scope and Objective

Scope and Objectives of Use Case	
Related business case	Operation of distribution grid
Scope	Monitor voltage level in distribution grid, control reactive power of DER unit, volt/var control of distribution grid,
Objective	Monitor and control voltage level of distribution grid in tolerated limits

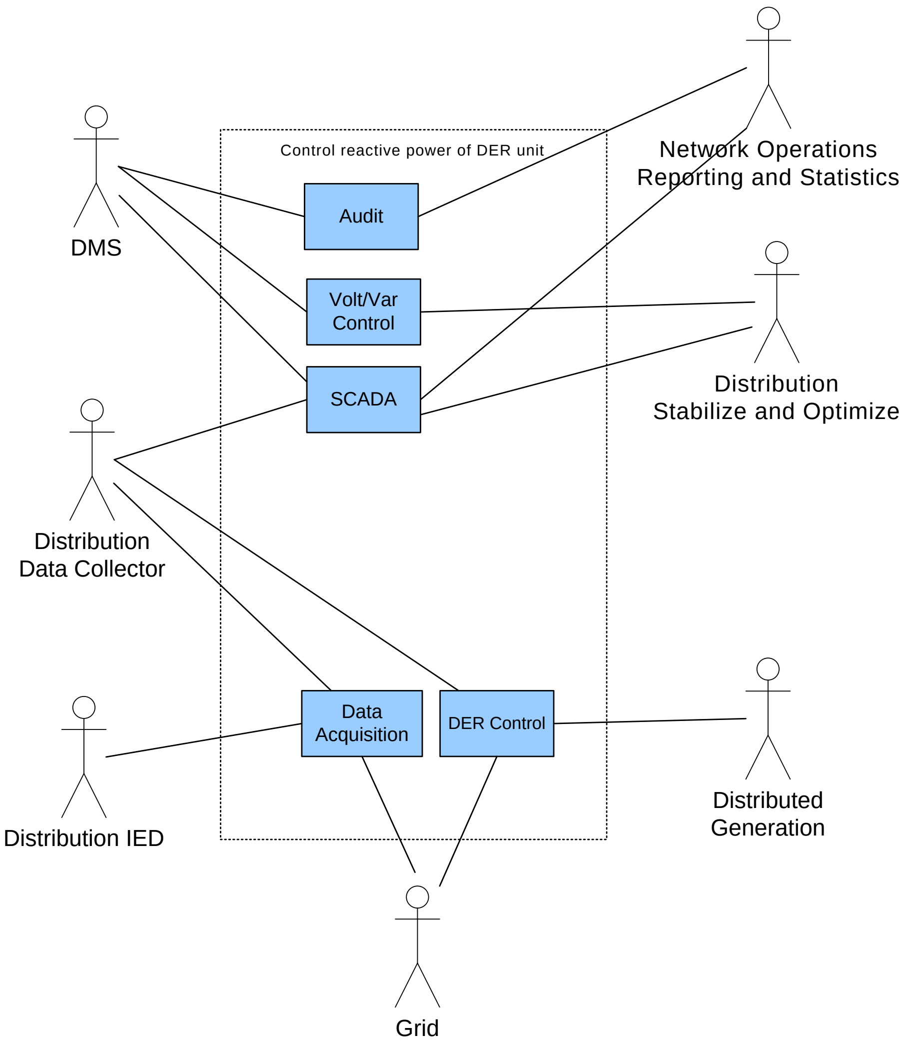

Figure 24: Use Case Diagram for "*Control reactive power of DER unit*"

214 **Table 7: Actor List “*Control reactive power of DER unit*”**

Actors			
Grouping (Community)		***Group Description***	
Actor Name *see Actor List*	***Actor Type*** *see Actor List*	***Actor Description*** *see Actor List*	***Further information specific to this Use Case***
Grid	System	Power Distribution system	
Distribution-IED	Device	Intelligent Electric Device (IED) is a communications-enabled controller to monitor and control automated devices in distribution which communicates with Distribution SCADA or other monitoring/control applications, as well as distributed capabilities for automatic operations in a localized area based on local information and on data exchange between members of the group. Operations such as such as tripping circuit breakers if they sense voltage, current, or frequency anomalies.	
Distributed Generation	Device	Distributed Generation, also called Distributed Energy Resources (DER), includes small-scale generation or storage of whatever form. This is in contrast to centralized or bulk generation and/or storage of electricity. These generation facilities are part of Demand/Reponse programs and may be dispatchable resources. The primary distictions between Distributed Generation (DG) and Bulk Generation is: Bulk Generation is attached via Transmission facilities, output is sold in wholesale markets, provides base load; DG is sited on a Customer permises attached to the Distribution grid, output is Retail (unless sold via an aggregator), can provide ancillary services. These generation facilities include but are not limited to Photvoltaic panel (PV), micro-hydro, mindmill, Plug-in Hybrid/Electric Cars (PHEV), and potentially Fuel cells. These facilites are usually not scheduled but can be dispatched.	
Distribution Data Collector	Device	A data concentrator bringing data from multiple sources and putting it into different form factors.	
Distribution Stabilize and Optimize	Application	Performed by actors to ensure the network is operating within appropriate tolerances across the system. They gather information for control decisions that ensure reliable, proper operations (stability) and more efficient operations (optimization). Measurement and control form a feedback loop that allows grid operators to stabilize the flow of energy across the electric network or safely increase the load on a transmission path.	
Distribution Management	Application	A suite of application software that	

System		monitors and controls the distribution system equipment based on computer-aided applications, market information, and operator control decisions.	
Network Operations Reporting and Statistics	Application	Operational Statistics and Reporting actors archive on-line data and to perform feedback analysis about system efficiency and reliability.	

Table 8: Preconditions, Assumptions, Post condition "*Control reactive power of DER unit*"

Use Case Conditions			
Actor/System/Information/Contract	***Triggering Event***	***Pre-conditions***	***Assumption***
Distribution Management System		• The Grid is continuously monitored • The Grid topology is known and reflects the real topology • The Grid energy path is known and reflects the real path (effective status of remote monitored and controllable switches)	
Distribution-IED		The device is up and running	
Distributed Generation		The DER is connected to the grid and injects active and reactive power	
Distribution Data Collector		The device is up and running	
Distribution Stabilize and Optimize		The application is up and running	
Distribution Management System		The application is up and running	
Network Operations Reporting and Statistics		The application is up and running	

Table 9: Step by Step Analysis of Use Case "*Control reactive power of DER unit*"

Scenario Conditions					
No.	**Scenario Name**	**Primary Actor**	**Triggering Event**	**Pre-Condition**	**Post-Condition**
4.1	Data Acquisition	Distribution IED	Periodically		
4.2	SCADA	DMS	Periodically		
4.3	Voltage/Var Control	Distribution Stabilize and Optimize	Voltage Measurement exceeded threshold		
4.4	DER Control	DMS	Control value, equipment id, received		
4.5	Audit	DMS	Control action		

221 **Table 10: Use Case Steps "*Control reactive power of DER unit*"**

Step #	***Triggering Event***	***Actor*** *What actor, either primary or secondary is responsible for the activity in this step?*	***Description of the activity*** *Describe the actions that take place in this step including the information to be exchanged. The step should be described in active, present tense*	***Information producer***	***Information Receiver***	***Information exchanged***	***Additional Notes*** *Elaborate on any additional description or value of the step to help support the descriptions. Short notes on architecture challenges, etc. may also be noted in this column*
Data Acquisition"							
1a	Periodically	Distribution IED	Distribution IED acquires analogue voltage measurement	Grid	Distribution IED	Analogue Voltage Measurement	
2	Periodically	Distribution IED	Distribution IED transmits voltage measurement	Distribution IED	Distribution Data Collector	Voltage Measurement	
3	Periodically	Distribution Data Collector	Distribution Data Collector transmits voltage measurement to DMS system.	Distribution Data Collector	DMS	Voltage Measurement	
Scada							
4	Periodically	DMS	The DMS System collects data from the grid, reformates the data and complements it with additional relevant information , distributes the data to DMS applications	DMS	Network Operations Reporting & Statistics, Distribution Stabilize and Optimize	Voltage Measurement, location, topology information	
Voltage/Var Control							
5	Voltage Measurement exceeded threshold	Distribution Stabilize and Optimize	Distribution Stabilize and Optimize application detects a threshold violation of voltage	Distribution Stabilize and Optimize	Distribution Stabilize and Optimize	Violation information	
6	Threshold Violation	Distribution Stabilize and Optimize	Distribution Stabilize and Optimize application starts Voltage/Var calculation	Distribution Stabilize and Optimize	Distribution Stabilize and Optimize	Start of voltage/Var calculation	
7	Start voltage Var calculation	Distribution Stabilize and Optimize	Distribution Stabilize and Optimize application calculates control value and identifies equipment to be controlled and transmits value to DMS	Distribution Stabilize and Optimize	DMS	Control value, equipment id	

Step #	Triggering Event	Actor *What actor, either primary or secondary is responsible for the activity in this step?*	Description of the activity *Describe the actions that take place in this step including the information to be exchanged. The step should be described in active, present tense*	Information producer	Information Receiver	Information exchanged	Additional Notes *Elaborate on any additional description or value of the step to help support the descriptions. Short notes on architecture challenges, etc. may also be noted in this column*
DER Control							
8	Control value, equipment id, received	DMS	DMS reformats control value and equipment id and transmits controllable setpoint to Distribution Data Collector	DMS	Distribution Data Collector	Controllable setpoint	
9	Controllable setpoint received	Distribution Data Collector	Distribution Data Collector device forwards information to Distributed Generation device	Distribution Data Collector	Distributed Generation	Controllable setpoint	
10	Controllable setpoint received	Distributed Generation	Distributed Generation device updates its operation parameters according to setpoint	Distributed Generation	Distributed Generation	Operation parameter	
11	Operation parameter update	Distributed Generation	Distributed Generation device verifies updated operation mode and acknowledges parameter change	Distributed Generation	Distribution Data Collector	Acknowledge information	
12	Acknowledge information received	Distribution Data Collector	Distribution Data Collector device forwards information to DMS	Distribution Data Collector	DMS	Acknowledge information	
Audit							
13	Control action	DMS	DMS application posts control action to Network Operations Reporting & Statistics application	DMS	Network Operations Reporting & Statistics	Control action	
14	Control action	Network Operations Reporting & Statistics	Network Operations Reporting & Statistics application documents control action	Network Operations Reporting & Statistics	Network Operations Reporting & Statistics	Control action	

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B.2.4.2 Development of the Component Layer

The content of the component layer is derived from the use case information on actors. In this example the actors are of type devices, applications and system. These actors are located to the appropriate domain and zone (Figure 25).

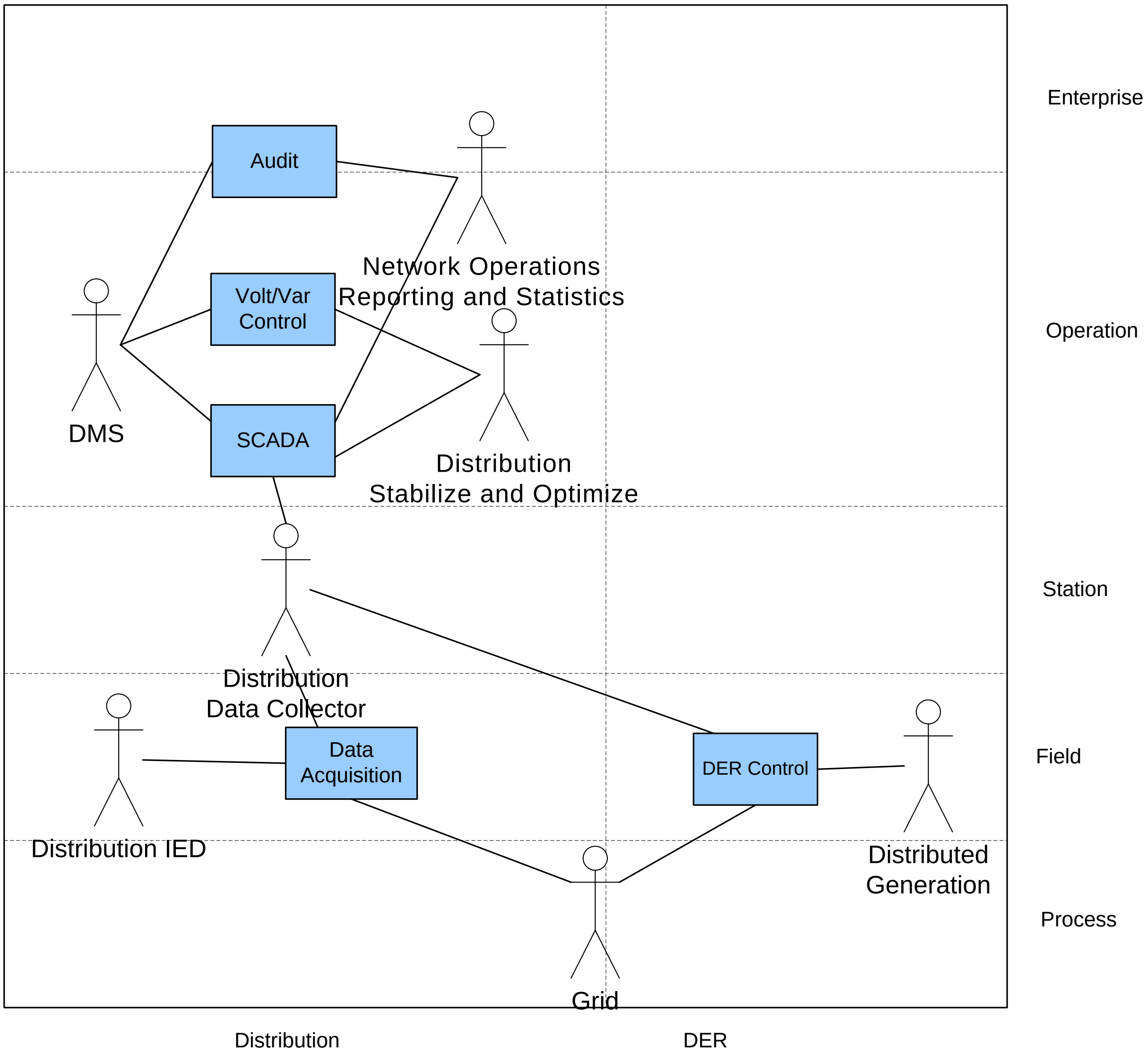


Figure 25: Actors and sub use cases mapped to domains and zones, "*Control reactive power of DER unit*"

The actors "DMS", "Network Operations, Reporting and Statistics" and "Distribution Stabilize and Optimize" typically reside in the distribution domain. DMS and Distribution Stabilize and Optimize" are on operation zone, whereas "Network Operations, Reporting and Statistics" can be in enterprise zone. "Distribution Data Collector" is depicted in distribution domain and station zone, "Distribution IED" in distribution domain and field zone. "Distributed Generation" is consequently located at DER domain and Field zone. The actor "Grid" is valid in both distribution and DER domain in the process zone.

In the next step, the mapped use case diagram is transformed to a technical configuration representation by using typical technical symbols (Figure 26)

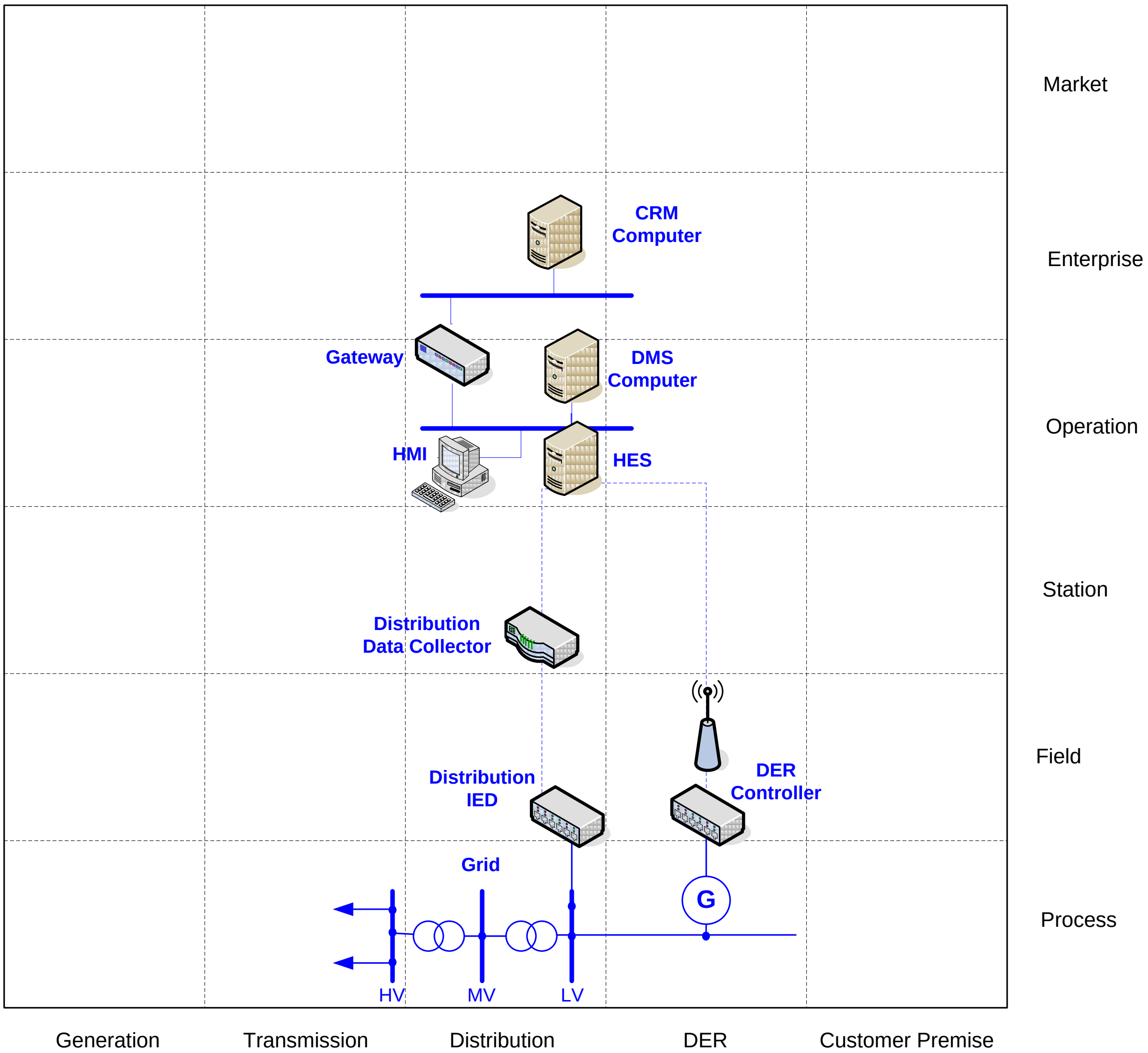


Figure 26: Component Layer "*Control reactive power of DER unit*"

The component layer (Figure 26) depicts the use case actors in form of hardware which is used to provide the intended use case functionality. In this example these are computers in the enterprise and operation zones which host the application type actors, dedicated automation devices in field and station zones, and nevertheless the grid is depicted with power system equipment (lines, bus bars, transformers, generators …). To complete this view the typical communication infrastructure is added. This configuration is a sample application, thus various scenarios are possible

B.2.4.3 Development of the Business Layer

The business layer is intended to host the business processes, services and organizations which are linked to the use case to be mapped. This includes also the business objectives, economic and regulatory constraints underlying to the use case. These business entities are located to the appropriate domain and zone.

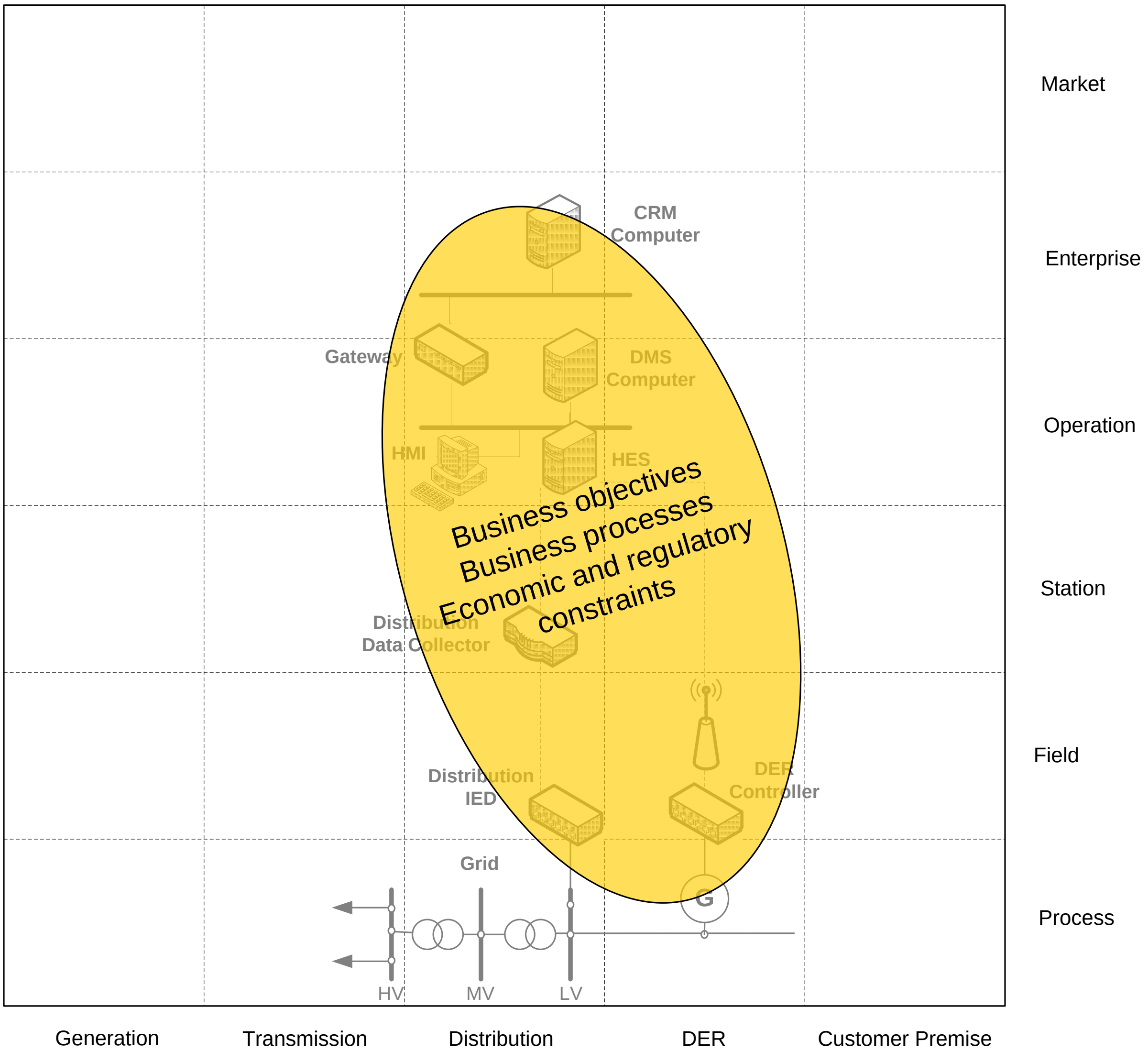


Figure 27: Business Layer "*Control reactive power of DER unit*"

The business layer (Figure 27) shows the area which is affected by the use case and consequently influenced by underlying business objectives and economic and regulatory constraints. This means that this objectives and constraints need to be taken into account as non-functional requirements for implementations.

B.2.4.4 Development of the Function Layer

The function layer is intended to represent functions and their interrelations in respect to domains and zones. Functions are derived from the use case by extracting its functionality. In this example the step-by-step analysis provides the functions of the uses case (Figure 28). The interrelation between functions is implicitly derived from the exchanged information documented in the use case steps (Table 10).

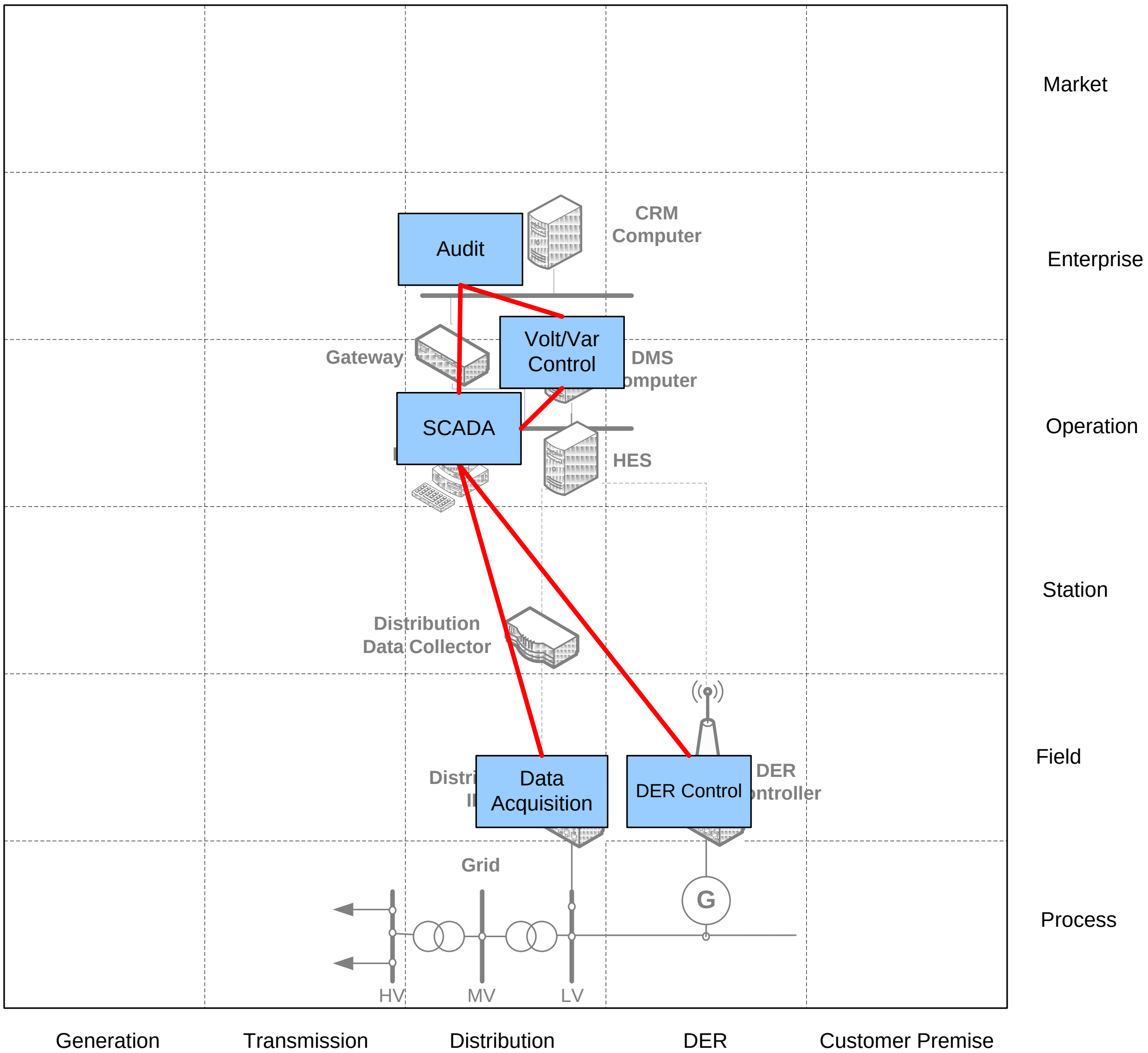


Figure 28: Function Layer "*Control reactive power of DER unit*"

The functions "Volt/Var Control" and "SCADA" typically reside in Distribution/Operation. The function "Audit" is located in Distribution/Enterprise. The functions "Data Acquisition" and "DER Control" are located to Distribution/Field and DER/Field, respectively.

B.2.4.5 Development of the Information Layer

The information layer describes the information that is being used and exchanged between functions, services and components. The information objects which are exchanged between actors are derived from the use case step description (Table 10). Figure 29 shows the result of the mapping of the exchanged information to the components that represent the use case actors.

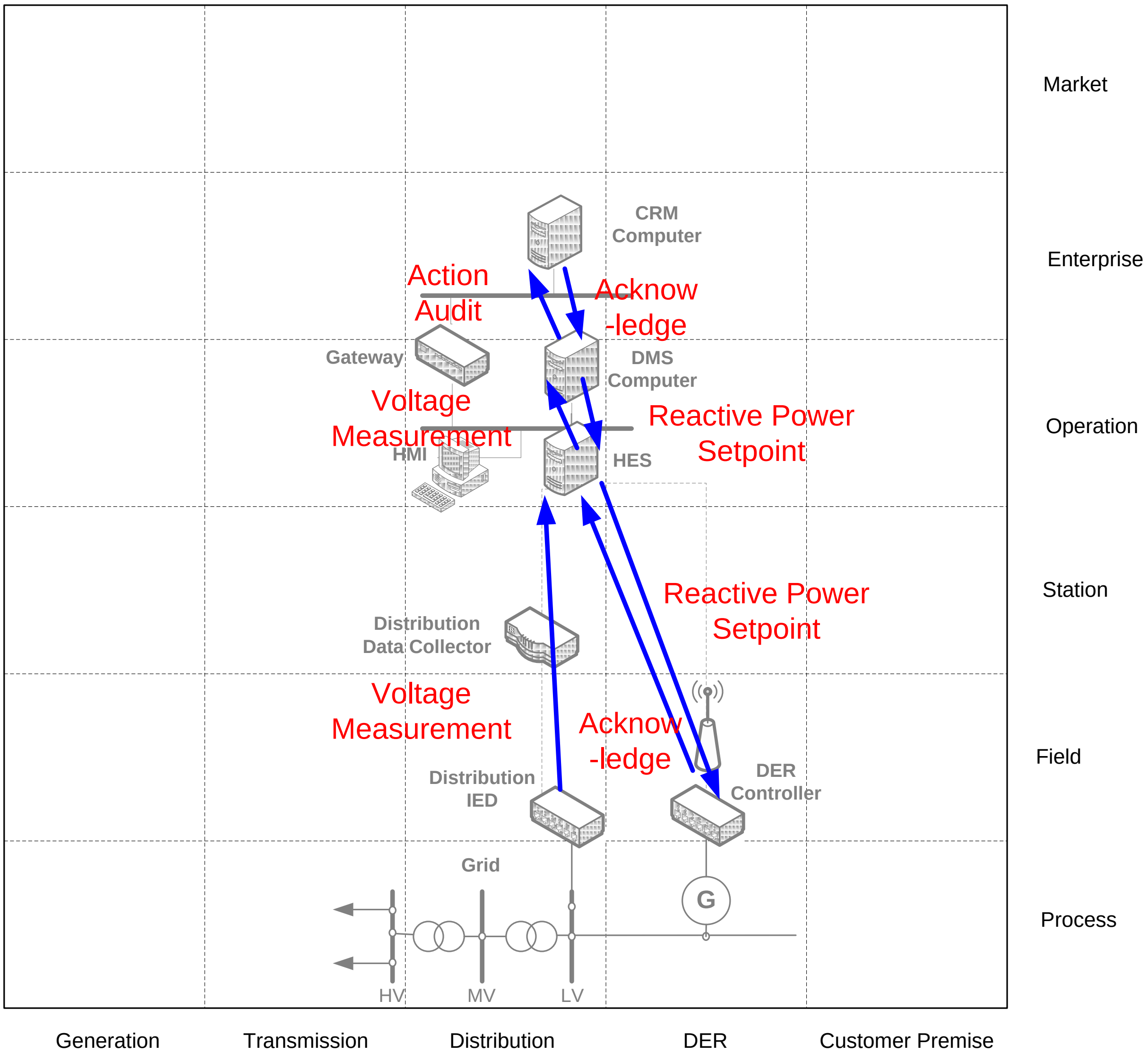


Figure 29: Information Layer / Business Context view, "*Control reactive power of DER unit*"

The Canonical Data Model view (Figure 30) of the information layer is intended to show underlying canonical data model standards which are able to provide information objects. In other words for the implementation of the present use case, instances of data objects according to the standards are required. In the present example CIM standard (IEC 61968-4) is an appropriate basis for exchanging information objects in the enterprise and operation zones. From field to operation zone, data objects according IEC 61850-7-4 (Compatible logical node classes and data object classes) and IEC 61850-7-420 (Distributed energy resources logical nodes) are applied.

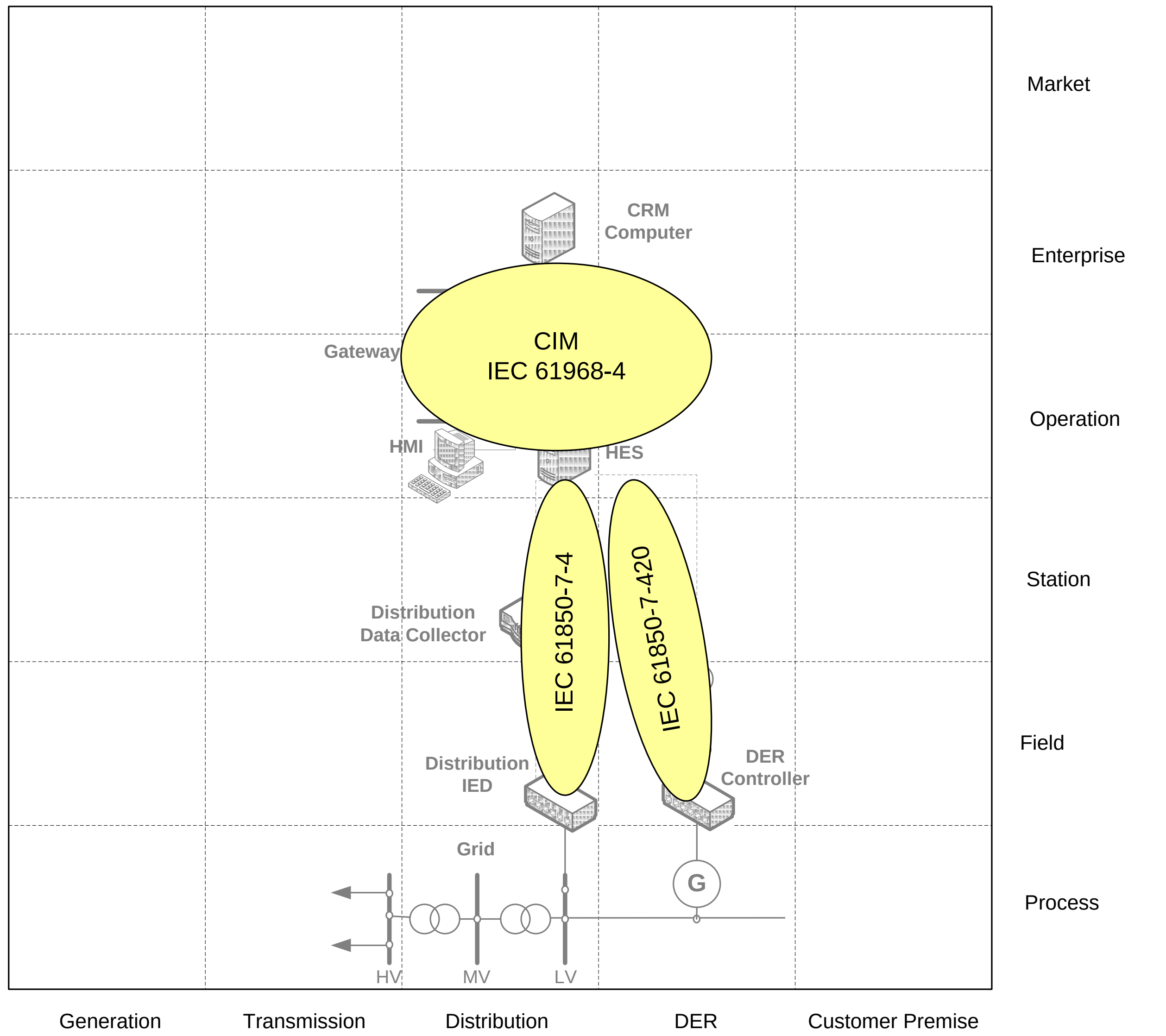


Figure 30: Information Layer / Canonical Data Model view, "*Control reactive power of DER unit*"

B.2.4.6 Development of the Communication Layer

The emphasis of the communication layer is to describe protocols and mechanisms for the interoperable exchange of information between the use case actors. Appropriate protocols and mechanisms are identified on the basis of the information objects and canonical data models and by consideration of non-functional requirements of the use case. The communication layer (Figure 31) presents the communication protocols for the data exchange of the necessary information between the components

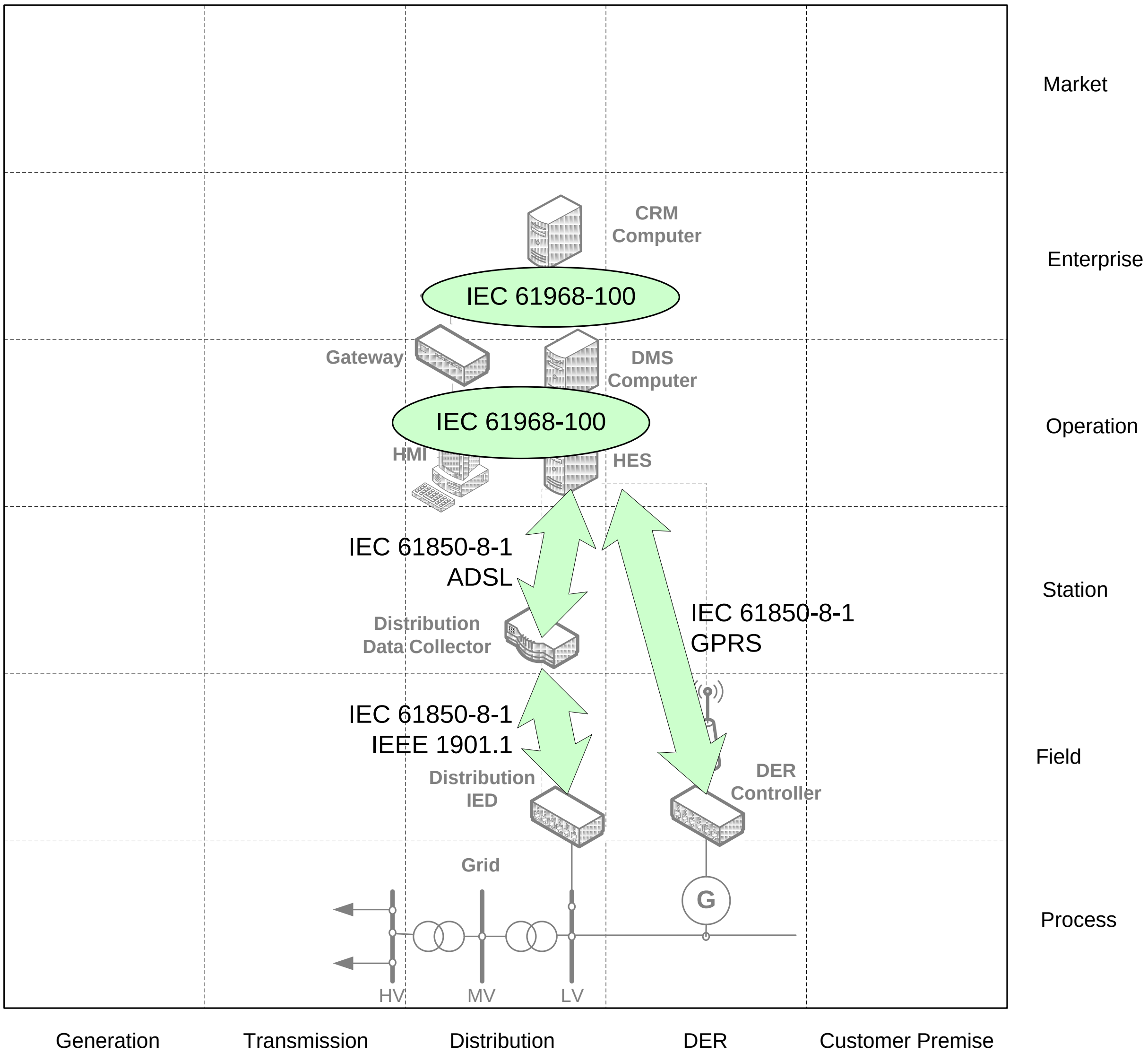


Figure 31: Communication Layer "*Control reactive power of DER unit*"

In the enterprise and operation zone IEC 61980-100 is an option for the exchange of CIM data objects. In the field to operation zones there are options of communication standards. IEC 61850 is the state-of-the-art communication protocol in power system automation. This standard can be mapped to different lower layers, such as Ethernet, PLC or wireless communications.

B.2.5 Relation of SGAM framework to Architecture Standards

The SGAM framework has been developed with the focus on supporting the very needs of standardization experts and architects in the utility domain. The focus grew originally out of the need of the conceptual model described in section 6 of this document to be put in context with the very existing smart grid architectures from the view of standardization.

Section B.2.6 "Examples and Mappings of existing solutions" provides the most relevant examples of how the existing meta-models on reference frameworks to been seen in context with smart grid standardization can be mapped onto the SGAM model itself. However, this section focuses on the need form the domain perspective developed in Utilities by engineers for primary technology, communication technology and standardization engineers. Another possible view towards the smart grid architecture can be given from the point of a non-domain oriented software engineer.

In the very context of documenting software architectures, different standards or methodologies have evolved. One of the most prominent standards is the ISO/IEC 42010: Systems Engineering – Architecture description. It focuses on the tool-independent way of conceptualizing architectures for systems, which may be hybrid (e.g. hardware, communications and software). The scope is further detailed as followed [ISO/IEC 42010].

The complexity of systems has grown to an unprecedented level. This has led to new opportunities, but also to increased challenges for the organizations that create and utilize systems. Concepts, principles and procedures of architecting are increasingly applied to help manage the complexity faced by stakeholders of systems.

Conceptualization of a system's architecture, as expressed in an architecture description, assists the understanding of the system's essence and key properties pertaining to its behavior, composition and evolution, which in turn affect concerns such as the feasibility, utility and maintainability of the system.

Architecture descriptions are used by the parties that create, utilize and manage modern systems to improve communication and co-operation; enabling them to work in an integrated, coherent fashion. Architecture frameworks and architecture description languages are being created as assets that codify the conventions and common practices of architecting and the description of architectures within different communities and domains of application.

The ISO/IEC 42010 addresses the creation, analysis and sustainment of architectures of systems through the use of architecture descriptions. It provides a core ontology for the description of architectures. The provisions of this International Standard serve to enforce desired properties of architecture descriptions, also specifying provisions that enforce desired properties of architecture frameworks and architecture description languages (ADLs), in order to usefully support the development and use of architecture descriptions. ISO/IEC 42010 provides a basis on which to compare and integrate architecture frameworks and ADLs by providing a common ontology for specifying their contents and can be used to establish a coherent practice for developing architecture descriptions, architecture frameworks and architecture description languages within the context of a life cycle and its processes (which have to be defined outside the standard). This International Standard can further be used to assess conformance of an architecture description, of an architecture framework, of an architecture description language, or of an architecture viewpoint to its provisions.

One particular way of implementing the ISO/IEC 42010 based ideas proven in industry, addressing the aspect of operationalizing the ideas from the meta-model [Jonkers 2010] are the standards from the Open Group TOGAF and Archimate.

A major strength of the TOGAF method is its ability to stress the importance of stakeholder concerns for each enterprise architecture development phase: creation, change, and governance. This ability may suggest that TOGAF also describes how an architect should address these concerns. This, however, is not the case. What TOGAF actually offers is a sort of "open interface" for the declaration of a "concern". The actual specification of the concern is left to any suitable modeling language which is capable of capturing such concerns and is compliant with the ISO/IEC 42010:2007 standard like ArchiMate.

ArchiMate is a modeling standard following the definitions and relationships of the concepts of concern, viewpoint, and view proposed by the ISO/IEC 42010:2007 standard for architecture descriptions. The ArchiMate framework is capable of defining stakeholder concerns in viewpoints, while the ArchiMate language is capable of addressing these with corresponding views showing the right aspects of the architecture conforming to defined viewpoints.

The core of TOGAF is basically a process, the so-called Architecture Development Method (ADM) describing viewpoints, techniques, and reference models, but not a complete formal language. ArchiMate describes viewpoints and provides a formal modeling language, including a (graphical) notation.

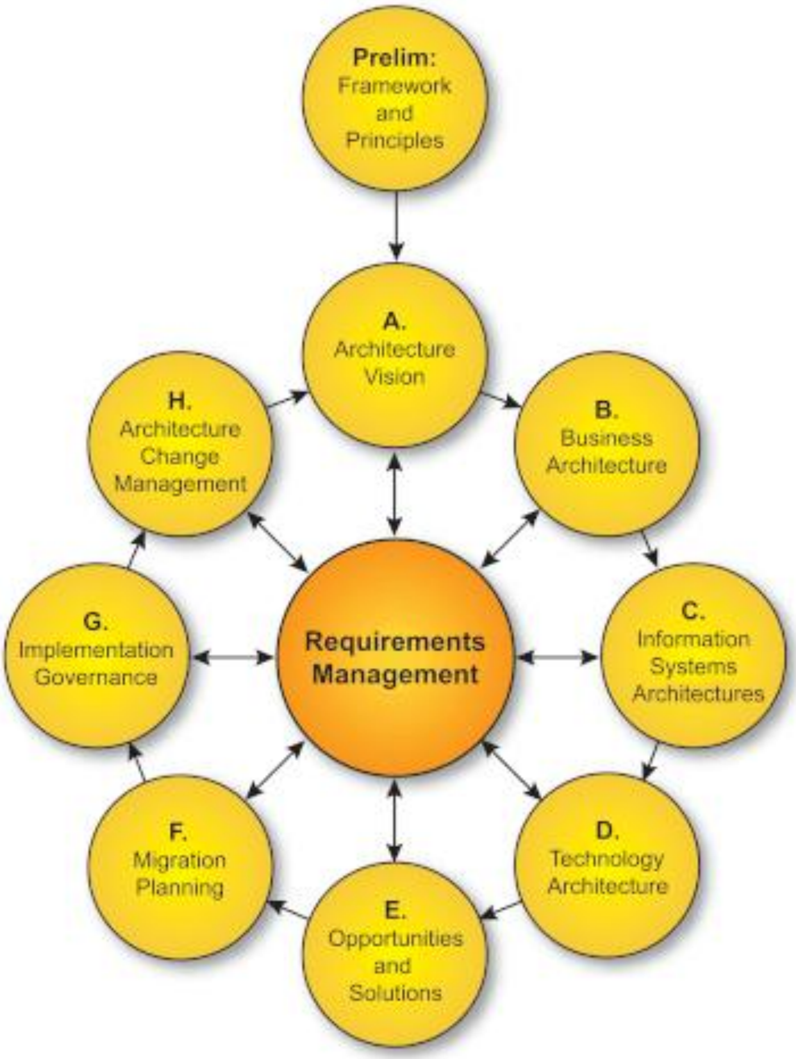


Figure 32: TOGAF ADM model

TOGAF and ArchiMate overlap in their use of viewpoints, and the concept of an underlying common repository of architectural artifacts and models; i.e., they have a firm common foundation. Both complement each other with respect to the definition of an architecture development process and the definition of an enterprise architecture modeling language.

ArchiMate 1.0 chiefly supports modeling of the architectures in Phases B, C, and D of the TOGAF Architecture Development Method (ADM). The resulting models are used as input for the subsequent ADM phases. However, modeling concepts specifically aimed at the other phases are still missing in the language.

Those three main standards (ISO/IEC 42010, TOGAF and Archimate) which are domain independent can also be used to express the SG-CG/RA work's group for the M/490 mandate. However, this method has a major drawback of using Software and system engineering specific vocabulary and a new specification language most standardization members are not familiar with. Therefore, we suggest the use of the architecture related, non-domain specific standards is possible but suggest fort his document to adhere to the known principles and provide and example in the how to use the three standards for a Smart grid Use Case in the annex.

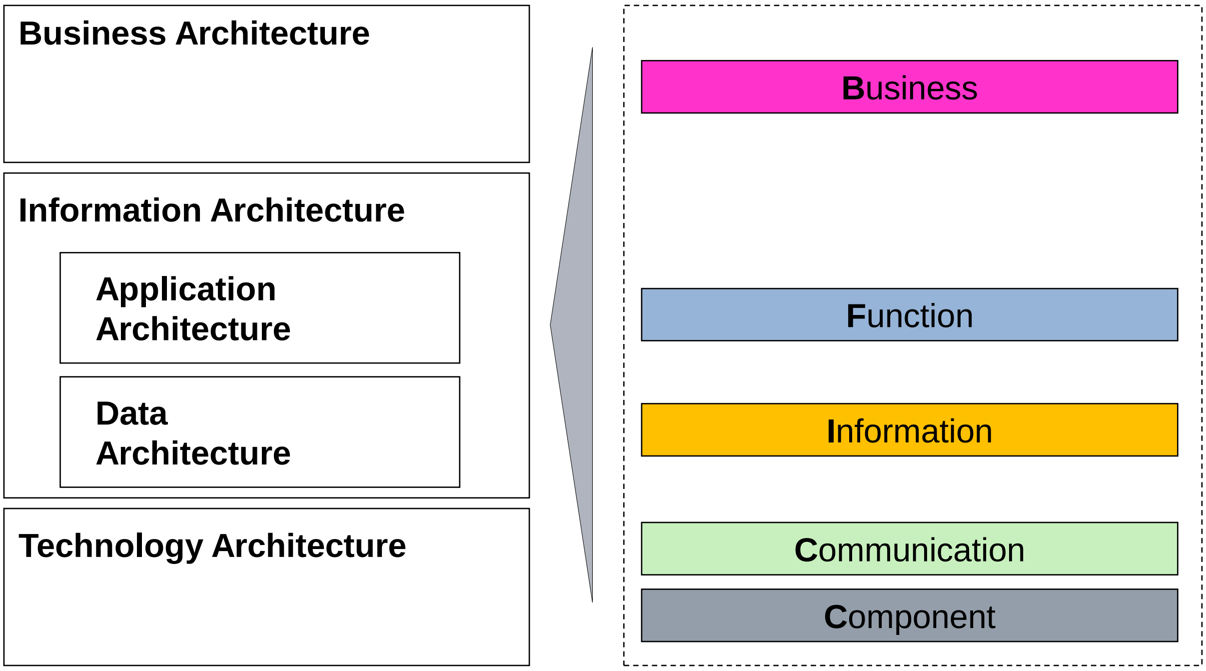


Figure 33: Mapping of GWAC dimensions onto Archimate

Figure 33 provides a representation of the different aspects form the GWAC stack and dimension onto the Archimate view for a reference architecture model. Figure 34 shows that additionally to the three main dimensions, finer viewpoints addressing more precise objects exist. Figure 35 shows how the model can be applied in a multi-dimensional view if e.g. an unbundled European utility must be modeled. This approach shows that existing, non-domain related views and methodologies can be applied in conjunction with the SGAM and its views.

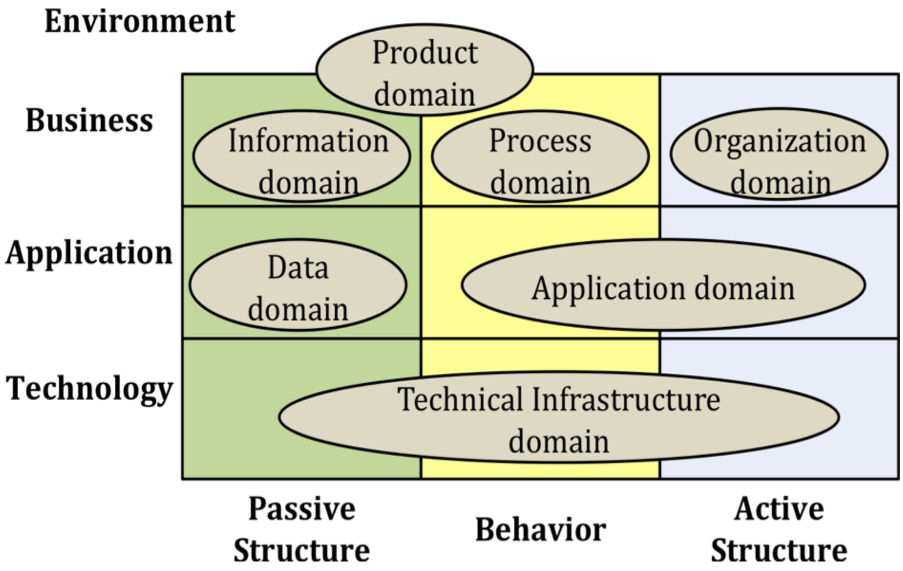


Figure 34: Archimate representation of the architectural viewpoints

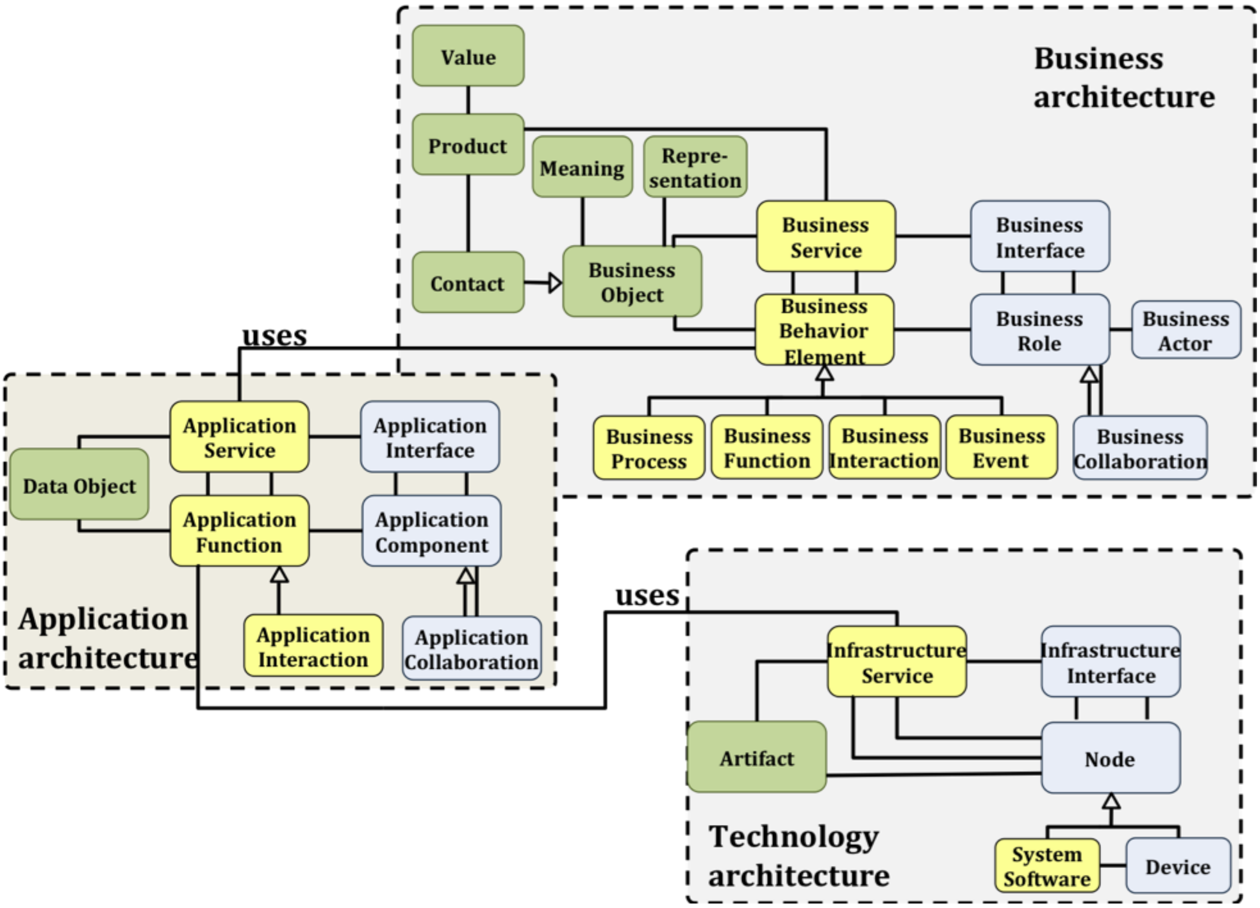


Figure 35: interdependencies between the three most important dimensions with Archimate

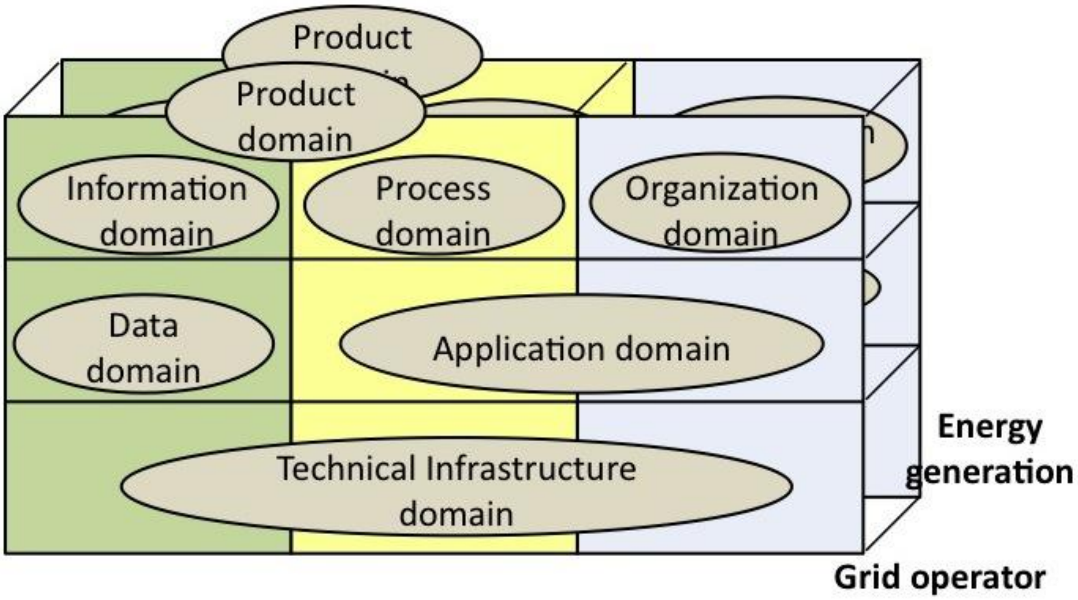


Figure 36: Multi-dimensional view for unbundled utility

B.2.6 Examples and Mappings of existing solutions

Possible examples on how the *SGAM* model can be applied to existing solutions and meta-models from ETSI or IEC can be seen in the following graphics. A mapping was made with respect to the existing models; in case of gaps - these need to be fixed or addressed in general.

B.2.6.1 Example: ETSI "M2M Architecture"

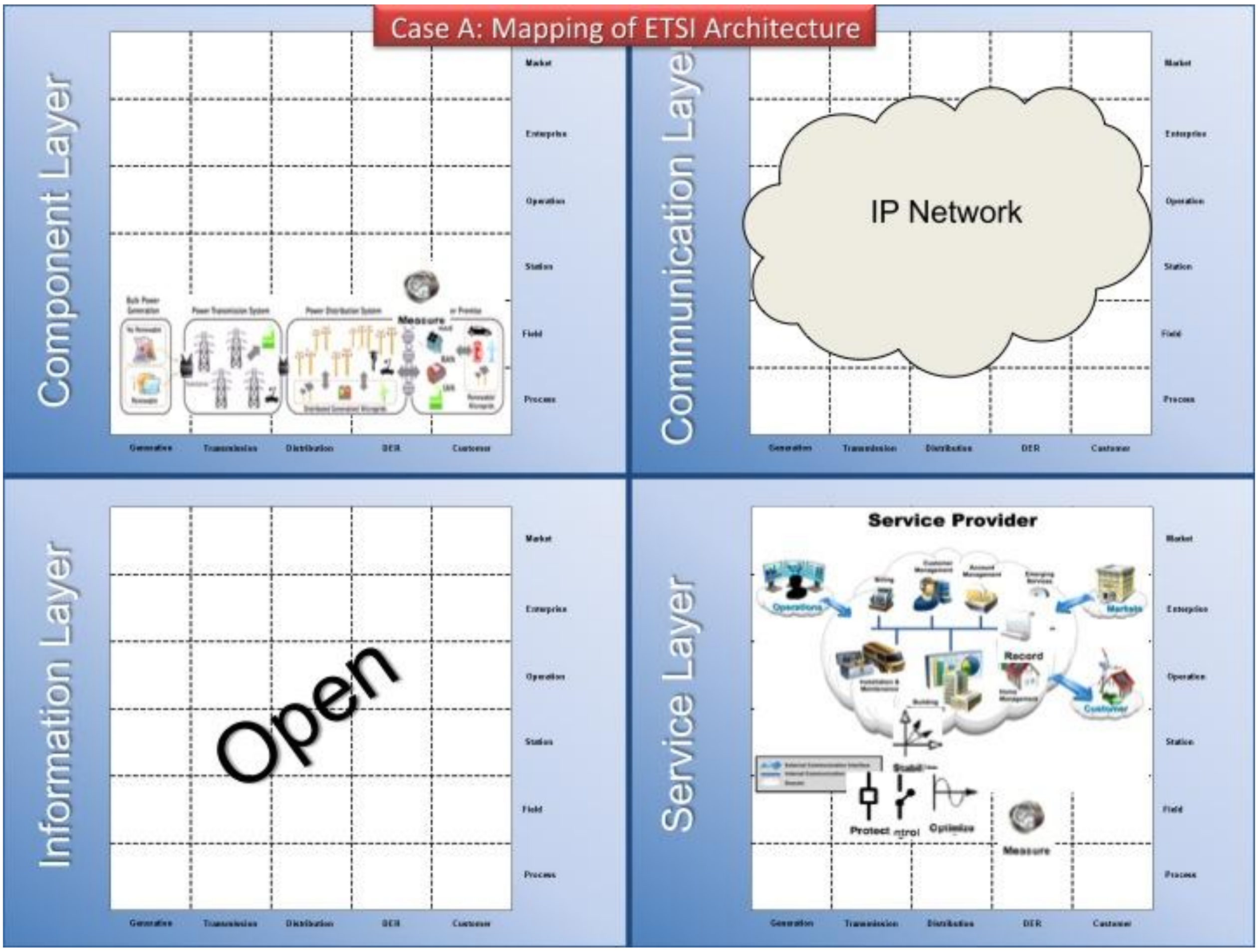


Figure 37: SGAM Mapping of ETSI M2M Architecture

Most of the issues could be directly addressed; a direct mapping for the information model was not possible.

B.2.6.2 Example: IEC SG3 "Mapping Chart"

Case B from the IEC SG 3 addresses the existing model from the IEC SG group which is also covered in the IEC roadmap and the standards mapping tool for smart grid solutions.

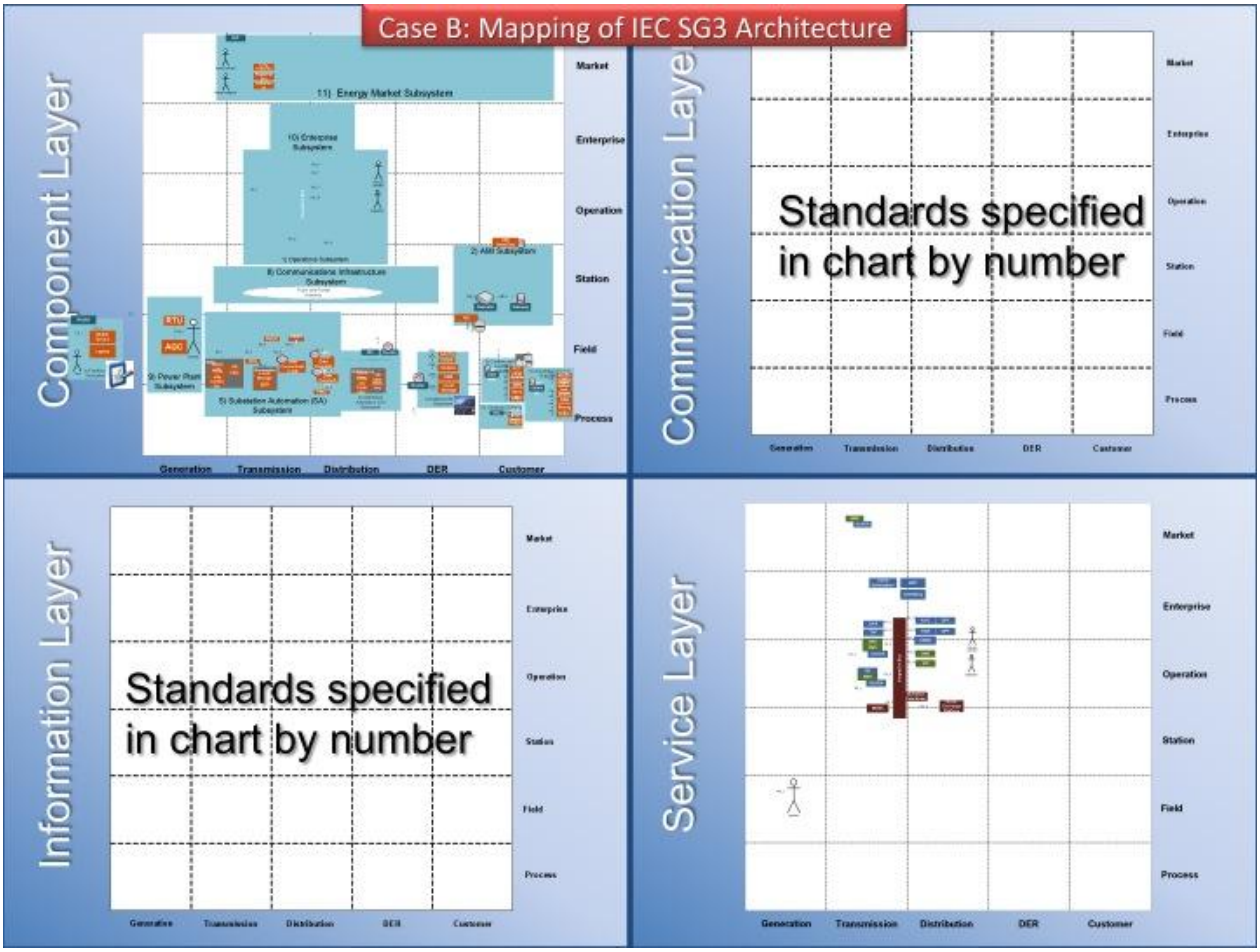


Figure 38: SGAM Mapping of IEC SG3 Mapping Chart

This example also shows that even information layers and their corresponding standards can be mapped if the original meta-model addresses the *SGAM* relevant viewpoint. The model is sliced just as the ETSI model; therefore, needed viewpoint for the different stakeholders (e.g. communications parts of existing models) can be easier identified.

B.2.6.3 Example: IEC TC57 “RA for Power System Information Exchange”

Last example is the existing seamless integration architecture (SIA) from the IEC TC 57 which covers all the relevant smart grid standards form TC 57 in a layered architecture and links to other relevant standards from TCs outside 57.

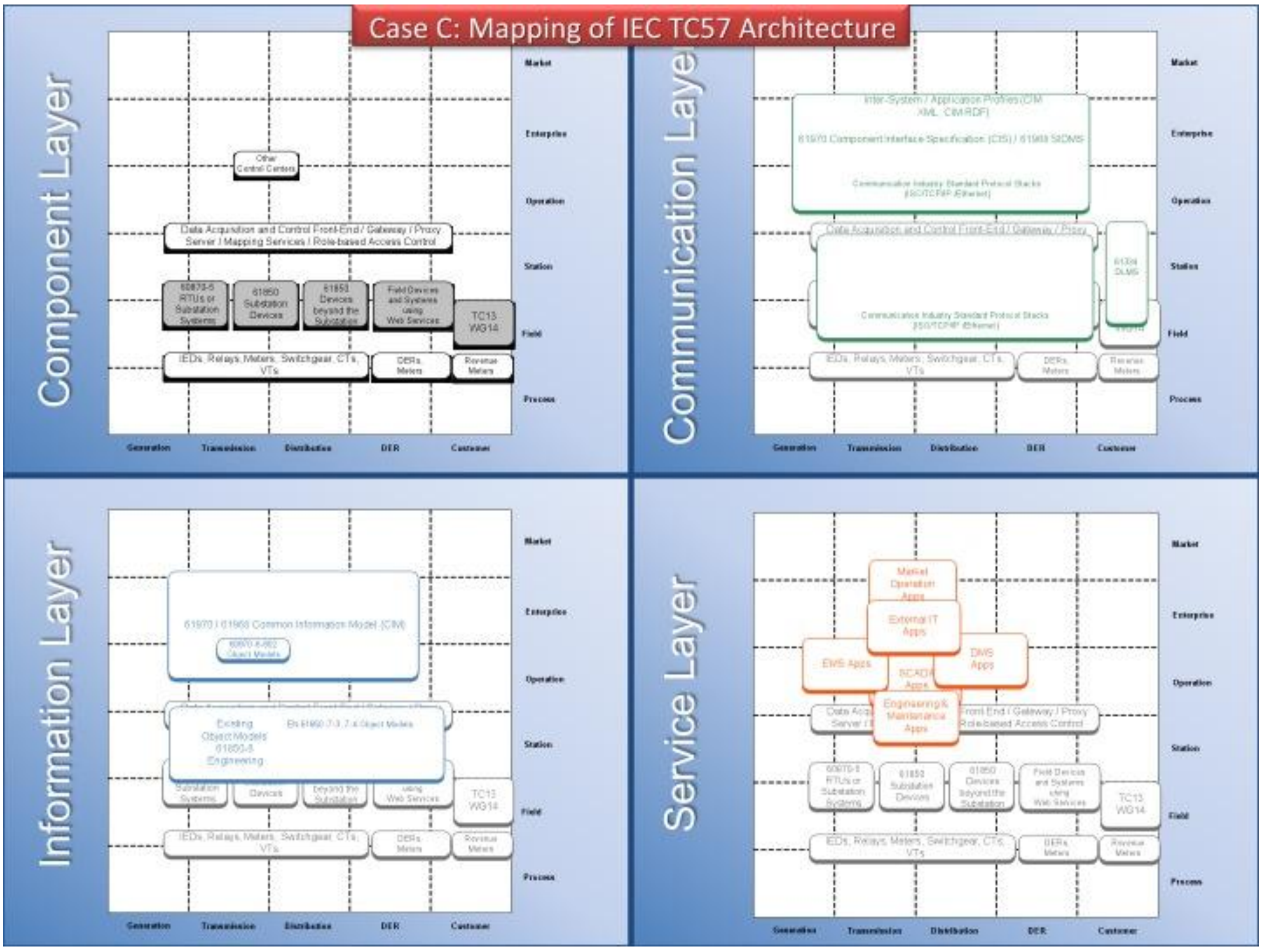


Figure 39: SGAM Mapping of IEC TC57 Reference Architecture for Power System Information Exchange

The SIA has taken most of the SGAM architectural viewpoints into account and provides for easy mapping onto SGAM.

B.2.7 Findings

As those, from an European perspective main relevant examples clearly show, is that the *SGAM* meta model with its viewpoints provides a proper way to represent existing solutions which have been developed by the various standardization bodies and stakeholder groups. One important additional conceptual model which should be taken into account fort his *SGAM* document is the NIST Conceptual model as international alignment of initiatives is of high interest. A future version will address this model.

The *SGAM* model provides, additionally, a good way of both categorizing existing models and identifying gaps. Categorizing in terms of finding out what the specific scope of an existing model is and, using this, finding out about is proper application and on the other hand, finding out what is missing and might need to be addressed.

B.2.8 Mapping of business transactions

Architectures in general provide services and functionality which is addressed by the corresponding technical or business processes. For the reference architecture, use cases with systems within this architecture are of highest importance. Starting at the function layer, the processes are mapped onto the *SGAM*, sub-functions are then distributed and things are drilled down to components, information and communication model. Using this, not only existing processes and use cases can be mapped onto the *SGAM* but also onto the existing reference architectures from IEC or ETSI and the *SGAM* can be used as alignment ontology for the processes and use cases between those models like common semantic mediator.

Annex C
Business Architecture and Conceptual Model

This Annex is introducing informative reference on the following elements:

- The new version of the European Smart Grids Conceptual Model that has been developed by the SG-CG/RA Work Group to take into account the comments on the previous version (v2.0) of this report as well as the need to address the Flexibility Concept. This version has not been introduced in the main section of this report for reasons explained in 6.3.5
- The European Harmonized Electricity Market Role Model and the list of Actors involved.
- A clarification of the relationship between the domains of the European Smart Grids Conceptual Model and the European Harmonized Electricity Market Role Model.

C.1 Conceptual Model

C.1.1 Introduction

The electrical energy system is currently undergoing a paradigm change, that has been affected by a change from the classical centralistic and top down energy production chain "Generation", "Transmission", "Distribution" and "Consumption" to a more decentralized system, in which the participants change their roles dynamically and interact cooperative. In the future decentralized energy system, distributed energy resources and consumers produces will become key elements. The development of the concepts and architectures for an European Smart Grid is not a simple task, because there are various concepts and architectures, representing individual stakeholders viewpoints. To imagine the paradigm change from the current situation to future situation, both situations are described below:

The current situation can best be described as:

- Supply follows demand
- One-way energy flow in the grid:
  bulk generation => transmission => distribution => consumption.
- Capacity in distribution networks is dimensioned on peak (copper plate), resulting in (almost) no network congestion
- Capacity required in the lower voltage range is predictable, since it is only based on energy usage.

The future situation can best be described as:

- Demand follows supply, due to the insertion of renewables, which are by nature of intermittent character
- Electrification of society in order to meet 202020 objectives, which will lead to a further growth of electricity demand
- Two way energy flow in the grid: consumers will also produce (e.g. by means of a photovoltaic cells, micro combined heat and power installations, etc.) and supply their surplus to the grid
- A future grid will need to support:
  - Multiple producing consumers, that will aggregate their electrical surplus to an Virtual Power Plant.
  - Electrical cars, in such a way that the grid won't fail when they want to charge simultaneously or use their batteries for energy storage to use in situations with high consumption or high production.
  - The integration of all kinds of distributed energy resources (wind, solar, …)

- A grid which will have to fulfill these requirements, not only by expanding grid capacity (which might become very costly due to the expected increase of peaks), but also by implementing smartness via ICT solutions, in a way that it will fully support current and future market processes.
- Furthermore a future grid will need the Smart Grid functions, described in the EG1 report of the CEN/CENELEC/ETSI Joint Working Group.

In the future situation it will have more and very different dynamics in the grid, as in the current situation, because the dynamics results from the distributed (renewable) energy resources, that behavior are difficult to predict. These increased dynamics will require a much more flexible (and intelligent) approach towards the management of electricity supply and demand. Furthermore, the future situation should also allow for new market models and let all kinds of customers participate in the trade of electricity energy.

Flexibility, thus, will be key. Where until today in the current “supply follows demand” model, flexibility was offered in bulk generation, in the future in the “demand follows supply” model the flexibility must be equivalent offered on both sides (generation (centralized and decentralized) and consumption (e.g. demand side management)).

Therefore the ICT infrastructure and ICT solutions, which enables the required flexibility on demand and supply side in a fully interchangeable way, becomes a key component of the smart grid and therefore it will be become part of the smart grid eco system.

This paragraph defines the conceptual model of the European smart grid. This conceptual model should be regarded as the initial “umbrella” model from which all future frameworks, architectures and standards could be derived from, and from which also existing standards could be (re) positioned. This conceptual model should also be able to act as a basis for future market models and related regulation, in order to guarantee that market models are supported by the right architectures and standards.

The Reference Architecture for the Smart Grid must support several stakeholders in building the European smart grid, and each stakeholder today has a different view on this smart grid. The more and more decentralized energy production requires new methods to guarantee the stable operation of the electrical part of the smart grid.

The development of the future smart grid requires the collaboration of different stakeholders. The future smart gird technology is the equivalent integration of power system management technology and information and communication technology (IT/OT convergence).

The conceptual model attempts to be the common framework, thereby enabling this convergence and facilitating the dialog between all these stakeholders, resulting in an aligned and consistent smart grid.

It is the basis of a common dictionary, necessary to talk the same language. The Conceptual Model will be this common dictionary and describe the key concepts in the European smart grid.

C.1.2 Historical context

A starting point for the development of a European conceptual model was the reuse of existing know-how to avoid redundant work and to build up on it. This led in the previous version of this report initially to the full adoption of the US conceptual model, defined by NIST. This model provides a high-level framework for the Smart Grid that defines seven high-level domains (Bulk Generation, Transmission, Distribution, Customers, Operations, Markets and Service Providers).

The NIST model shows all the communications and energy/electricity flows connecting each domain and how they are interrelated. Each individual domain is itself comprised of important smart grid elements (actors and applications) that are connected to each other through two-way communications and energy/electricity paths.

Due to strong European focus on decentralized energy generation, the original NIST model was extended by a new “Distributed Energy Resources” Domain (see 0), for the following reasons:

- Distributed Energy Resources require a new class of use cases
- In order to comply to future anticipated regulation and legislation explicit distinction of Distributed Energy Resources will be required
- Distributed Energy Resources represent the current situation

Consistent and clear criteria to separate the new DER Domain from the existing Domains, especially from Bulk Generation and the Customer Domain were identified.

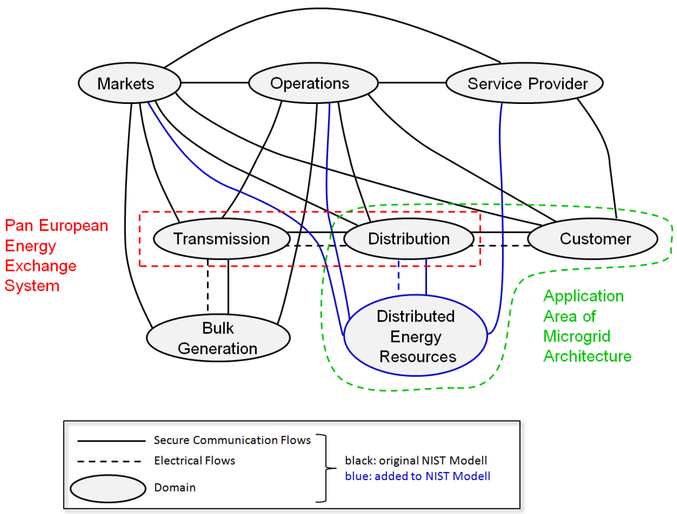


Figure 40: EU extension of the NIST Model

Review comments and discussion on the M490 report version 2.0 led to the insight that a rigid separation of the DER domain from the customers domain, would actually create complexity and would rule out required flexibility that emerges in the energy transition from customers both consuming and producing energy.

As a result of these discussions it was decided that the European conceptual model should incorporate/ enable the flexibility concept that was defined by SG-CG/SP.

<u>The European Flexibility Concept</u>

The objective of the flexibility concept, shown in Figure 41, is to describe the flexibility (demand and generation) methods for technical and commercial operations.

Figure 41: Flexibility concept (result of WGSP)

In the flexibility concept the management (control) of flexible demand and supply is fully interchangeable at the Smart Grid Connection Point (SGCP); in principle any connected party (Smart Customer) with flexible generation, consumption and/or storage.

In the elaboration of the flexibility model commercial and technical flexibilities are identified, leading to commercial flexibilities for interaction with the market (e.g. contracts, pricing) and technical flexibilities (control signals, technical information exchange) for interaction with grid operations. This is shown in Figure 42.

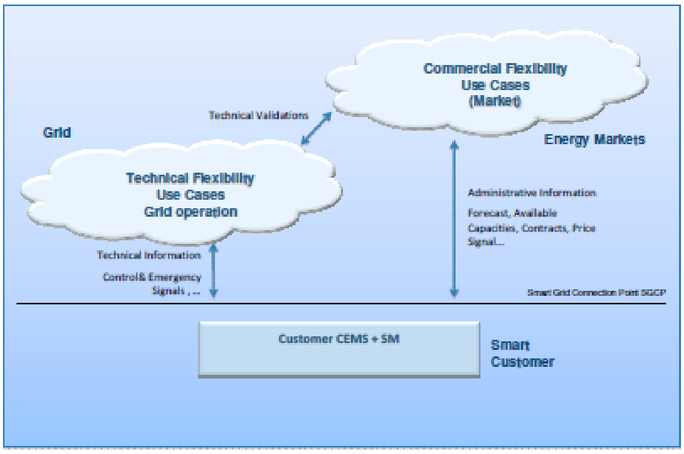


Figure 42: Technical & commercial flexibilities

With the historical background in mind, as described above, this led to the formulation of starting principles and to a clear definition of an (evolved) European Conceptual Model, addressing all stakeholders' interests.

C.1.3 Starting Principles

Defining a European conceptual model, from which architectures and standards can be derived, requires explicit starting principles, to be used as acceptance criteria for the Conceptual Model. These starting principles are described in this paragraph.

The evolution of the European Conceptual Model in a way that it is aligned with the rather technical aspects of the extended NIST Model and with the rather future energy markets aspects of the SG-

CG/SP Flexibility Concept is guaranteed by the following approach and procedure, which is based on the 5 principles below.

Approach

Domains are a grouping of roles and actors. So roles and actors in the domains of both models can be used as a fix point for the alignment of the models. To identify the same roles and actors in the domains of both models, the European harmonized electricity market role model will be used. The alignment is based in detail on the following 5 principles, which form the basis for the development of the EU Conceptual Model (described in C.1.4).

Principle 1: Extract business roles and system actors from the EU extended NIST conceptual model

The EU extension of the NIST conceptual model is organized in domains. These domains group business roles and thereby system actors which perform tasks in these roles as shown in Figure 43. This figure illustrates the meta-model used for the European conceptual model for Smart Grids.

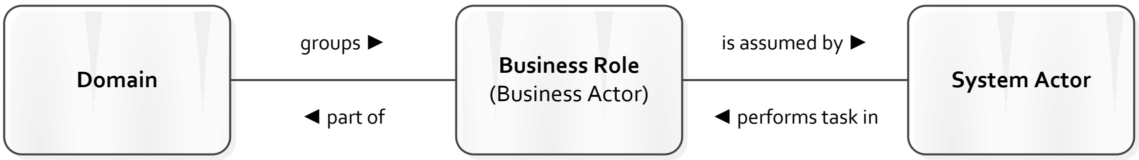


Figure 43: Meta-model for the European conceptual model for Smart Grids

The approach to model the conceptual model based on business roles and related system actors ensures ‘compatibility’ between market and technologies/standards. Section 6.1 provides a more detailed description of this approach.

Principle 2: Alignment with the European electricity market

In the WGSP flexibility model, the business roles are based on the European harmonized electricity market role model, developed by ENTSO-E, ebIX and EFET and defined in [ENTSO-E 2011]. This ensures alignment of technologies/standards which are developed from this model with the European electricity market. The grouping of roles of the harmonized electricity market role model into the domains of the WGSP flexibility model supports initial understanding of the European electricity market (at a higher level of abstraction than the 36 roles identified in [ENTSO-E 2011]).

Principle 3: Support central and distributed power system deployments

The EU conceptual model (described in the next part) must support fully centralized, fully distributed and hybrid deployments of the power system. Energy resources connected to all levels of the grid are relevant in Smart Grids, ranging from bulk generation and industrial loads down to distributed energy resources and domestic loads. Also support for grids outside the traditional public infrastructure should be supported, as e.g. analyzed in the use cases of the workgroup on sustainable processes from the SG-CG. Examples include (non-public) grids used in local energy cooperatives, ranging from industrial areas (sea- and airports) to agricultural areas (e.g. in the greenhouse sector).

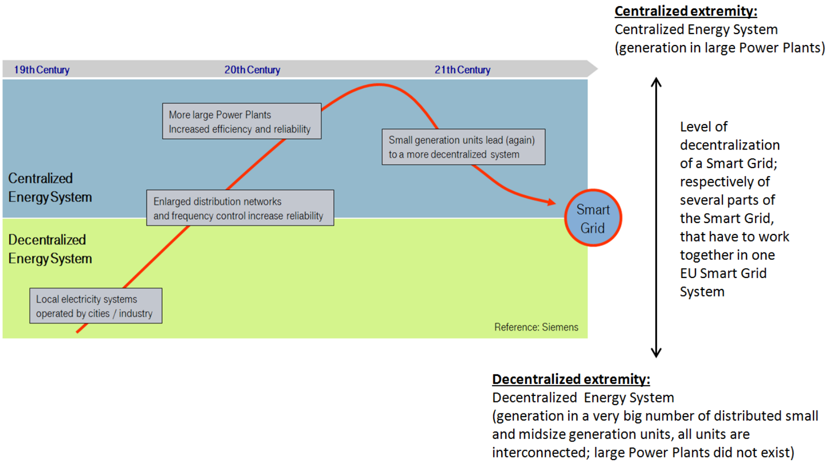


Figure 44: Evolution of centralized/ decentralized power systems deployments

Principle 4: Support micro grids and a Pan European Energy Exchange System (PEEES)

The objective of micro grids is to start the optimization of the grid as locally as possible, e.g. to find a balance between production and consumption, in order to avoid transmission losses and increase transmission reliability through ancillary services such as reserves volt/var support, and frequency support. For other objectives to be met for micro grids see also use case WGSP-0400.

PEEES are essential to realizing the large-scale energy balance between regions with a low-loss wide-area power transmission.

The Pan European Energy Exchange System (PEEES), includes technologies in the transport network for low-loss wide-area power transmission systems (e. g. high-voltage direct current transmission, HVDC), better realizing the large-scale energy balance between the regions, which is essential due to the constantly changing weather situation, which has a significant influence on the power generation capacity of different regions.

The PEEES is here to be understood as a abstract model for further discussions to cover the concepts for low-loss wide-area power transmission systems. As an example of this, the "Modular Development Plan of the Pan-European Transmission System 2050" of the e-HIGHWAY2050 Project Consortium can be mentioned here. [ENTSO-E 2012]

Principle 5: Support providing flexibility in electricity supply and demand

Providing flexibility in electricity supply and demand – on all levels in the power system – is paramount for integration of renewable energy sources in the Smart Grid. The EU conceptual model must support the use cases identified by the workgroup on sustainable processes on providing and using flexibility.

C.1.4 European Conceptual Model of Smart Grids

The definition of the European conceptual model of Smart Grids is defined through grouping of (European harmonized) roles and system actors, in line with the European electricity market. Figure 45 depicts the European conceptual model for the Smart Grid. The model consists of four main domains, *Operations*, *Grid Users, Markets, and Energy Services*.

Each of these domains contains one or more subdomains which group roles which can be identified in the European electricity market. For this the European harmonized electricity market role model developed by ENTSO-E, ebIX and EFET is used as defined in [ENTSO-E 2011] and introduced in C.2. Detailed definitions of the domains of the European conceptual model for the Smart Grid and the relationship to the role model used is provided annex C.2

Operations and *Grid Users* are domains which are directly involved in the physical processes of the power system: electricity generation, transport/distribution and electricity usage. Also, these domains include (embedded) ICT enabled system actors. The *Markets* and *Energy Services* domains are defined by roles and (system) actors and their activities in trade of electricity products and services (markets), and the participation in the processes of trade and system operations representing grid users (energy services).

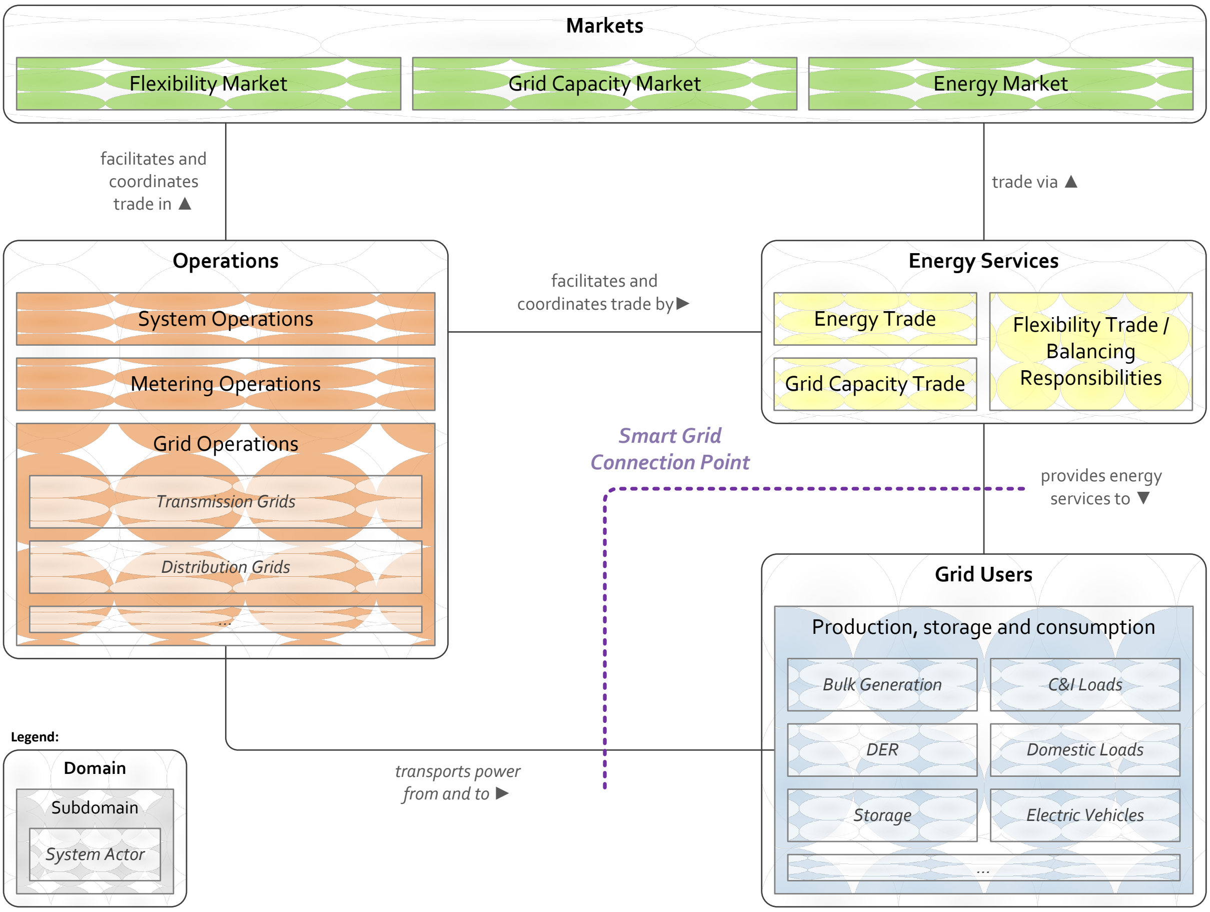


Figure 45: European Conceptual Model for the Smart Grid

Operations
The *Operations* domain is defined by roles and actors related to the stable and safe operations of the power system; the domain ensures the usage of the grid is within its constraints and facilitates the activities in the market. *Grid Operations*, *System Operations* and *Metering Operations* are identified as sub-domains in the *Operations* domain. System actors in this domain include grid assets such as transformers, switchgear, etc. in *Transmission* and *Distribution Grids*, metering systems and control centre systems.

Grid Users
The *Grid Users* domain is defined by roles and actors involved in the generation, usage and possibly storage of electricity; from bulk generation and commercial and industrial loads down to distributed energy resources, domestic loads, etc. The roles and actors in this domain use the grid to transmit and distribute power from generation to the loads. Apart from roles related to the

generation, load and storage assets, the *Grid Users* domain includes system actors such as (customer) energy management and process control systems.

Energy Services

The *Energy Services* domain is defined by roles and actors involved in providing energy services to the *Grid Users* domain. These services include trading in the electricity generated, used or stored by the *Grid Users* domain, and ensuring that the activities in the Grid Users domain are coordinated in e.g. the system balancing mechanisms and CIS systems.

Through the *Energy Services* domain the *Grid Users* domain is connected to activities such as trade and system balancing. From the *Grid Users* domain, flexibility in power supply and demand is provided. This flexibility is used for system balancing (through e.g. ancillary services, demand response, etc.) and trading on the market. Also roles are included which are related to trade in grid capacity (as currently is traded on the transmission level).

Example (system) actors in this domain include systems for customer relationship management, and billing, trading systems, etc.

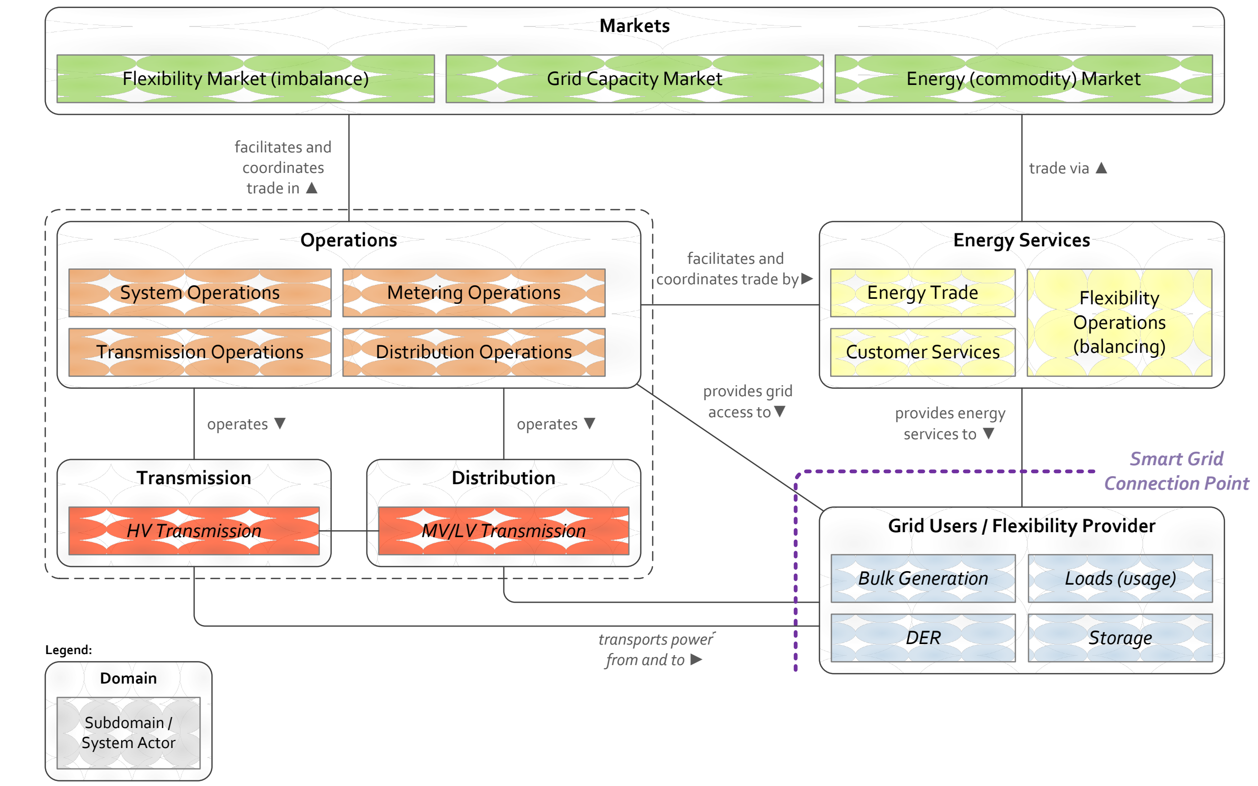
I.e. the roles and actors from the *Energy Services* domain facilitate participation in the electricity system, by representing the *Grid Users* domain in operations (e.g. balance responsibility) and markets (trading).

Markets

The *Market* domain is defined by roles and actors which support the trade in electricity (e.g. on day ahead power exchanges) and other electricity products (e.g. grid capacity, ancillary services). Sub domains which are identified in this domain are: *Energy Market, Grid Capacity Market*, and *Flexibility Market*. Activities in the *Market* domain are coordinated by the *Operations* domain to ensure the stable and safe operation of the power system. Example (system) actors in this domain are trading platforms.

C.1.4.1 Alternative Figure: European Conceptual Model for the Smart Grid

The figure below is provided as a possible alternative for Figure 45*. The main difference is in presentation: 1) in the grouping of grid assets (by introducing the transmission and distribution domains which only contains system actors) and 2) in different naming of the domains* Grid Users *and* Energy Services*. This is to be discussed in the next meeting of the architecture workgroup in Bilbao. The essence is the same as the figure above, however for commitment a graphical representation is chosen to accommodate more were we are coming from.*



Alternative Figure: European Conceptual Model for the Smart Grid

The table below shows which domains contain business actors and which contain system actors in this alternative figure.

Table C-1: Mapping of domains to roles and actors

Domain	*ENTSO-E role*	*Business Actor*	*System Actor*
Market	+	+	+
Operations	+	+	+
Service Provider	+	+	+
Flexibility Provider	+	+	+
Transmission	*n/a*		+
Distribution	*n/a*		+

C.1.5 Alignment

This paragraph identifies and describes the required alignment with other relevant initiatives/ activities that are required for building a smart grid based on standards and common reference architectures.

C.1.5.1 Alignment with the EU flexibility concept

In the energy transition, Europe is focusing on managing flexibility of demand and supply. This concept of flexibility is elaborated in the M490 WGSP, resulting in several related use cases. These use cases on ‘providing flexibility’ concern control/management of flexible demand & supply.

Flexibility in demand and supply is provided by ‘smart customers. In the conceptual model as described in paragraph C.1.4 this is reflected by the *Grid Users* domain, which provides flexibility. This flexibility is used by parties related to grid/power system management and electricity markets.

Operating this flexibility is performed by an actor ‘Flexibility Operator’. In annex xx this use case is analyzed in the context of the European Harmonized Electricity Market Role Model (HEM-RM) which underpins the European conceptual model for Smart Grids. The Flexibility Operator relates to one of various roles in the *Energy Services* domain. Depending on the type of interaction with the ‘smart customers’ in the use cases of WGSP, the Flexibility Operator acts in the *Resource Provider*, *Balance Responsible Party, Balance Supplier* or *Grid Access Provider* role from [ENTSO 2011].

In the flexibility market flexibility in demand and supply (interchangeable) will be traded, by services providers with balance responsibilities that have access to this (wholesale) market.

C.1.5.2 Alignment with SG-CG/SP on Sustainable Processes

The SG-CG/SP Work Group on Sustainable Processes, in collecting use cases, has defined generic use cases. The deliverables coming from WG SP from these uses cases are:

- Actors (business actors and system actors)
- Identification and interaction between actors
- Processes
- Technical requirements

Based on these deliverables, SG-CG/RA is able to identify existing standards via the SGAM framework (see 7.2), to be possible modified and used in the smart grid standards. In future work a more refined functional architecture with well-defined interfaces and services definitions between market parties will be defined. Since actors and transaction between actors will form the basis for this reference architecture, alignment is guaranteed.

In the future smart grid eco system a well-defined interaction between the capacity market and the energy market will be crucial. The traffic light concept as defined by WGSP will form the basis for this. This interaction will be modeled between roles (and subsequently parties) as identified in the EU Harmonized Electricity Market Role Model, leading to required information exchange on the Smart Grid Connection Point (SGCP), being the information interface between the grid users’ domain and the other domains.

C.1.5.3 Alignment with NIST, SGIP, SGAC

Since market models in US and EU differ, it is important to derive standards which are, as much as possible, market model independent. Also the Harmonized Electricity Market Role Model as defined by ENTSO-E/ebIX/EFET is currently not used in the US. Alignment therefore is created and maintained on the basis of common actor list and interactions between actors, driven from use case analysis. From this common International standards can be derived and interoperability is achieved. There for even if the market models and the conceptual model differ (grouping of roles and actors), the same standards may be applicable (although priorities may differ). (The alignment of actor lists and interactions between actors is currently on going work extended into 2013).

C.1.5.4 Alignment with Harmonized Electricity Market Role Model

The Harmonized Electricity Market role model has been picked up for use, both by WGSP as WGRA, leading to a consistent and solid approach for all future modeling exercises. From discussion within the M490 groups, as well in market model discussions (EG3) new roles in this model may become necessary. It therefore will be required to come to working arrangements with ENTSO-E on this, in order to establish adequate version control of the Harmonized Electricity Market Role Model.

C.1.5.5 Alignment with EU market model developments (EG3)

In the EU standardization activities, the Harmonized Electricity Market Role Model (HEM-RM) is promoted to be used to map responsibilities of market parties to the harmonized roles. This means that the interaction between actors, as defined by WGSP and translated to interaction between roles, can define the interaction between market parties.

The task force smart grid (EG3) recommended the EU commission that in the market model discussions, whatever the outcome will be, the roles & responsibilities of market parties, related to the market models, will be mapped onto the HEM-RM roles. In this way interaction between actors and roles can be translated tot interaction between market parties.

In this way it becomes clear which standards on interfaces and business services are required, and is alignment between market model development and M490 standards.

C.1.6 Conclusions

As a conclusion from the above:

- The conceptual model is solid and well defined, based on roles and actors
- It accommodates the flexibility concept
- It bridges the 2 approaches/cultures coming from power system management and IT technology; it forms a common ground for cooperation.
- It accommodates alignment between M/490 Standardization activities and market model discussions
- It identifies the way alignment should be reached with US (NIST, SGIP, SGAC)

C.2 The European Harmonized Electricity Market Role Model

The text in this section is an excerpt taken from the [ENTSO-E 2011] Harmonized Electricity Market Role Model, and included for informational purpose. Please refer to the original document for more detailed information on this role model.

A “Role Model” provides a common definition of the roles and domains employed in the electricity market which enables people to use a common language in the development of information interchange.

A party on the market may play several roles, for example a TSO frequently plays both the role of System Operator and the role of Imbalance Settlement Responsible. However two different roles have been defined since these roles are not always played by the same party. Even in a large organisation the roles may not be played by the same business unit. Consequently it is necessary to clearly define the roles in order to be in a position to correctly use them as required. It is important to differentiate between the roles that can be found on a given marketplace and the parties that can play such roles. ENTSO-E and the associated organisations have identified a given role whenever it has been found necessary to distinguish it in an information interchange process.

The model consequently identifies all the roles that intervene in the exchange of information in the electricity market. These roles define the external interfaces managed by a party for given processes. It also identifies the different domains that are necessary in the electricity market for information interchange. A domain represents a grouping of entities with common characteristics.

The objective of decomposing the electricity market into a set of autonomous roles and domains is to enable the construction of business processes where the relevant role *participates to satisfy a specific transaction. Business processes should be designed to satisfy the requirements of the roles and not of the parties.*

C.2.1 Role model – role definitions

The table below quotes the definitions from [ENTSO-E 2011] of all the roles in the European harmonized electricity market role model.

Role	Description
Balance Responsible Party	A party that has a contract proving financial security and identifying balance responsibility with the Imbalance Settlement Responsible of the Market Balance Area entitling the party to operate in the market. This is the only role allowing a party to nominate energy on a wholesale level. *Additional information*: The meaning of the word "balance" in this context signifies that that the quantity contracted to provide or to consume must be equal to the quantity really provided or consumed. Equivalent to "Program responsible party" in the Netherlands. Equivalent to "Balance group manager" in Germany. Equivalent to "market agent" in Spain.
Balance Supplier	A party that markets the difference between actual metered energy consumption and the energy bought with firm energy contracts by the Party Connected to the Grid. In addition the Balance Supplier markets any difference with the firm energy contract (of the Party Connected to the Grid) and the metered production. *Additional information*: There is only one Balance Supplier for each Accounting Point.
Billing Agent	The party responsible for invoicing a concerned party.
Block Energy Trader	A party that is selling or buying energy on a firm basis (a fixed volume per market time period).
Capacity Coordinator	A party, acting on behalf of the System Operators involved, responsible for establishing a coordinated Offered Capacity and/or NTC and/or ATC between several Market Balance Areas.
Capacity Trader	A party that has a contract to participate in the Capacity Market to acquire capacity through a Transmission Capacity Allocator. *Note*: The capacity may be acquired on behalf of an Interconnection Trade Responsible or for sale on secondary capacity markets.
Consumer	A party that consumes electricity. *Additional information*: This is a Type of Party Connected to the Grid.

Role	Description
Consumption Responsible Party	A party who can be brought to rights, legally and financially, for any imbalance between energy nominated and consumed for all associated Accounting Points. *Additional information*: This is a type of Balance Responsible Party.
Control Area Operator	Responsible for : 1. The coordination of exchange programs between its related Market Balance Areas and for the exchanges between its associated Control Areas. 2. The load frequency control for its own area. 3. The coordination of the correction of time deviations.
Control Block Operator	Responsible for : 1. The coordination of exchanges between its associated Control Blocks and the organisation of the coordination of exchange programs between its related Control Areas. 2. The load frequency control within its own block and ensuring that its Control Areas respect their obligations in respect to load frequency control and time deviation. 3. The organisation of the settlement and/or compensation between its Control Areas.
Coordination Center Operator	Responsible for : 1. The coordination of exchange programs between its related Control Blocks and for the exchanges between its associated Coordination Center Zones. 2. Ensuring that its Control Blocks respect their obligations in respect to load frequency control. 3. Calculating the time deviation in cooperation with the associated coordination centers. 4. Carrying out the settlement and/or compensation between its Control Blocks and against the other Coordination Center Zones.
Grid Access Provider	A party responsible for providing access to the grid through an Accounting Point and its use for energy consumption or production to the Party Connected to the Grid.
Grid Operator	A party that operates one or more grids.
Imbalance Settlement Responsible	A party that is responsible for settlement of the difference between the contracted quantities and the realised quantities of energy products for the Balance Responsible Parties in a Market Balance Area. *Note*: The Imbalance Settlement Responsible has not the responsibility to invoice. The Imbalance Settlement Responsible may delegate the invoicing responsibility to a more generic role such as a Billing Agent.

Role	**Description**
Interconnection Trade Responsible	Is a Balance Responsible Party or depends on one. He is recognised by the Nomination Validator for the nomination of already allocated capacity. *Additional information*: This is a type of Balance Responsible Party.
Market Information Aggregator	A party that provides market related information that has been compiled from the figures supplied by different actors in the market. This information may also be published or distributed for general use. *Note*: The Market Information Aggregator may receive information from any market participant that is relevant for publication or distribution.
Market Operator	The unique power exchange of trades for the actual delivery of energy that receives the bids from the Balance Responsible Parties that have a contract to bid. The Market Operator determines the market energy price for the Market Balance Area after applying technical constraints from the System Operator. It may also establish the price for the reconciliation within a Metering Grid Area.
Meter Administrator	A party responsible for keeping a database of meters.
Meter Operator	A party responsible for installing, maintaining, testing, certifying and decommissioning physical meters.
Metered Data Aggregator	A party responsible for meter reading and quality control of the reading.
Metered Data Collector	A party responsible for the establishment and validation of metered data based on the collected data received from the Metered Data Collector. The party is responsible for the history of metered data for a Metering Point.
Metered Data Responsible	A party responsible for the establishment and qualification of metered data from the Metered Data Responsible. This data is aggregated according to a defined set of market rules.
Metering Point Administrator	A party responsible for registering the parties linked to the metering points in a Metering Grid Area. He is also responsible for maintaining the Metering Point technical specifications. He is responsible for creating and terminating metering points.
Merit Order List (MOL) Responsible	Responsible for the management of the available tenders for all Acquiring System Operators to establish the order of the reserve capacity that can be activated.

Role	**Description**
Nomination Validator	Has the responsibility of ensuring that all capacity nominated is within the allowed limits and confirming all valid nominations to all involved parties. He informs the Interconnection Trade Responsible of the maximum nominated capacity allowed. Depending on market rules for a given interconnection the corresponding System Operators may appoint one Nomination Validator.
Party Connected to the Grid	A party that contracts for the right to consume or produce electricity at an Accounting Point.
Producer	A party that produces electricity. *Additional information*: This is a type of Party Connected to the Grid.
Production Responsible Party	A party who can be brought to rights, legally and financially, for any imbalance between energy nominated and produced for all associated Accounting Points. *Additional information*: This is a type of Balance Responsible Party.
Reconciliation Accountable	A party that is financially accountable for the reconciled volume of energy products for a profiled Accounting Point.
Reconciliation Responsible	A party that is responsible for reconciling, within a Metering Grid Area, the volumes used in the imbalance settlement process for profiled Accounting Points and the actual metered quantities. *Note*: The Reconciliation Responsible may delegate the invoicing responsibility to a more generic role such as a Billing Agent.
Reserve Allocator	Informs the market of reserve requirements, receives tenders against the requirements and in compliance with the prequalification criteria, determines what tenders meet requirements and assigns tenders.
Resource Provider	A role that manages a resource object and provides the schedules for it.
Scheduling Coordinator	A party that is responsible for the schedule information and its exchange on behalf of a Balance Responsible Party. For example in the Polish market a Scheduling Coordinator is responsible for information interchange for scheduling and settlement.

Role	Description
System Operator	A party that is responsible for a stable power system operation (including the organization of physical balance) through a transmission grid in a geographical area. The System Operator will also determine and be responsible for cross border capacity and exchanges. If necessary he may reduce allocated capacity to ensure operational stability. Transmission as mentioned above means “the transport of electricity on the extra high or high voltage network with a view to its delivery to final customers or to distributors. Operation of transmission includes as well the tasks of system operation concerning its management of energy flows, reliability of the system and availability of all necessary system services”. (Definition taken from the ENTSO-E RGCE Operation handbook Glossary). *Note*: additional obligations may be imposed through local market rules.
Trade Responsible Party	A party who can be brought to rights, legally and financially, for any imbalance between energy nominated and consumed for all associated Accounting Points. *Note*: A power exchange without any privileged responsibilities acts as a Trade Responsible Party. *Additional information*: This is a type of Balance Responsible Party.
Transmission Capacity Allocator	Manages the allocation of transmission capacity for an Allocated Capacity Area. For explicit auctions: The Transmission Capacity Allocator manages, on behalf of the System Operators, the allocation of available transmission capacity for an Allocated capacity Area. He offers the available transmission capacity to the market, allocates the available transmission capacity to individual Capacity Traders and calculates the billing amount of already allocated capacities to the Capacity Traders.

C.3 Relationship between the domains of the conceptual model and the European harmonized electricity market role model

Figure 46 below shows the relationship between the domains of the conceptual model and the European harmonized electricity market role model.

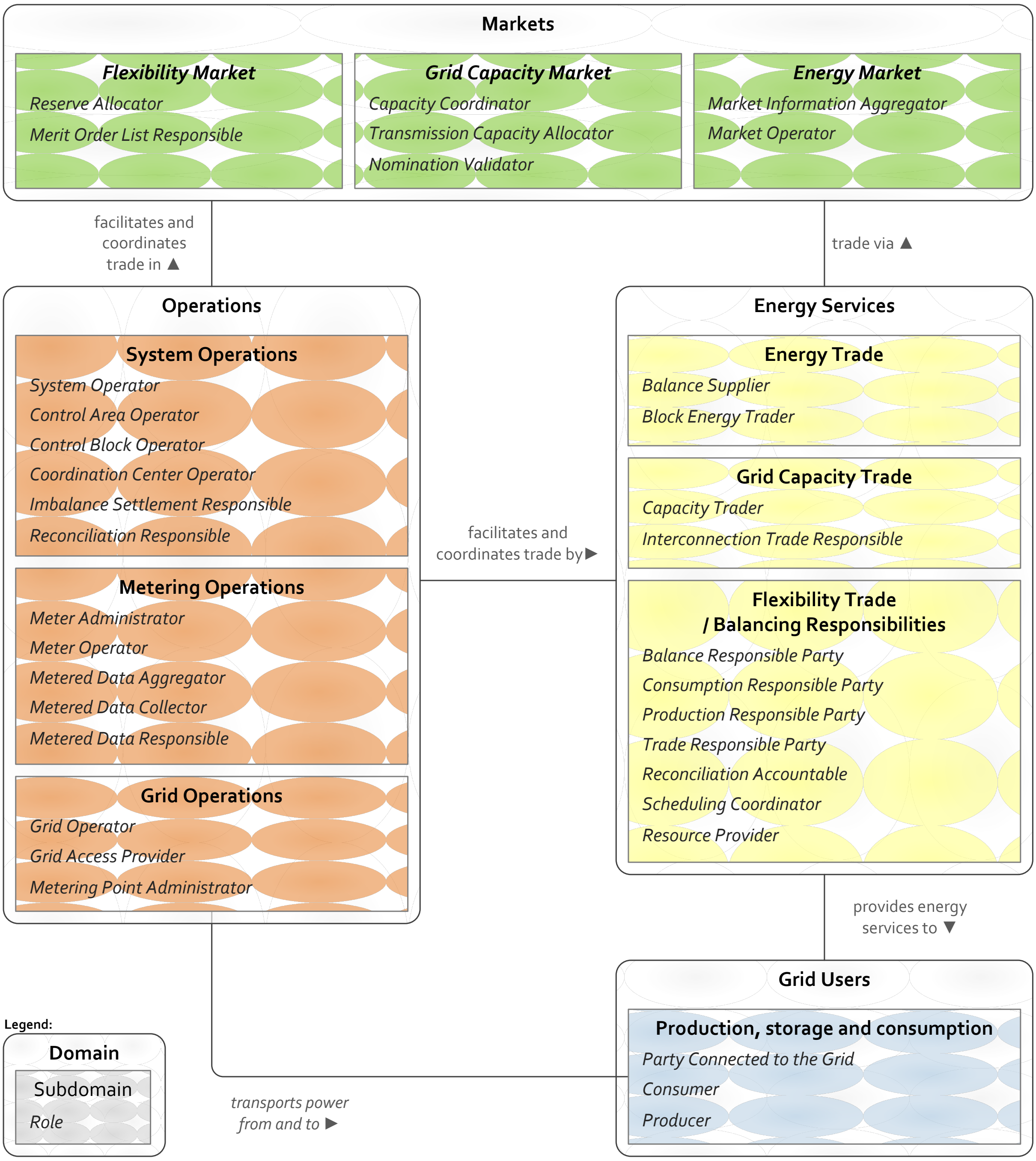


Figure 46: Relationship between the domains of the conceptual model and the European harmonized electricity market role model

Note that in the figure above, the Billing Agent role is not included in the relationship between domains of the conceptual model and the harmonized electricity market roles due to its generic nature. In [ENTSO-E 2011] the Billing Agent role is not associated to any other role.

C.4 Relation between the flexibility operator actor and the European harmonized electricity market role model

The use cases identified by the SG-CG/SP Sustainable Processes Work Group on 'providing flexibility' concerns control/management of flexible demand & supply. In these use case, flexibility in demand and supply is provided by ‘smart customers’, for usage in use cases related to e.g. system balancing, network constraint management, voltage / var optimization, network restoration and black start, power flow stabilization, market balancing.

I.e. the flexibility is used by parties related to grid / power system management and/or electricity markets. Pooling of this flexibility is performed by a so called ‘Flexibility Operator’. The flexibility use cases cover several means of interacting with ‘smart customers’, including:

- Communication of price signals, tariffs and other economic incentives
- Explicit trade in flexibility in demand and/or supply
- Direct control of demand and/or supply

Although analyzed in combination in the flexibility use case, distinguishing between these approaches allows for better analysis in relation to the European electricity market. Below, each of these approaches is analyzed further in relationship to the organizational structure of the European electricity market.

The figures used throughout the analysis below show roles and their associations from the European harmonized electricity market role model and how they relate to actors and their associations from the use case. This is graphically represented according to the legend as shown in Figure 47.

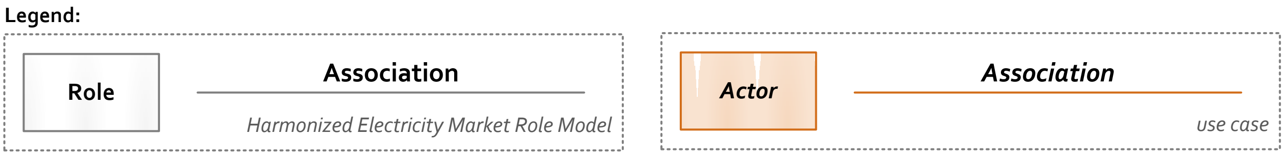


Figure 47: Legend used in analysis of relation between the flexibility operator actor and the European harmonized electricity market role model

C.4.1 Communication of price signals, tariffs and other economic incentives

Economic incentives can be given to parties connected to the grid, primarily based on state of the grid or market. Within [ENTSO-E 2011], parties connected to the grid are ‘associated’ to the market through the Balance Supplier role and connect to grid operations through the Grid Access Provider role. Figure 48 provides a visualization of this mapping.

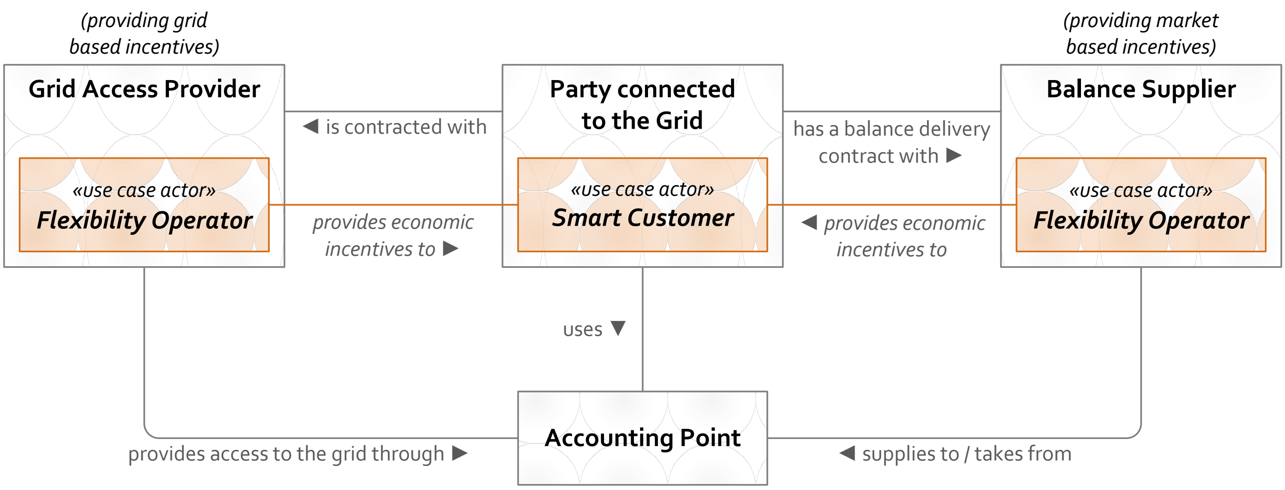


Figure 48: Economic incentives in the flexibility use cases in relation to European electricity market

C.4.2 Explicit trade in flexibility in demand and/or supply

The explicit trade in flexibility is closely related to the mapping of the use case wherein the Flexibility Operator performs direct control; with the major differences that the ‘smart customer’ moves in the value chain in the sense that it now takes the Resource Provider role itself instead of the Flexibility Operator. This mapping is visualized in Figure 49.

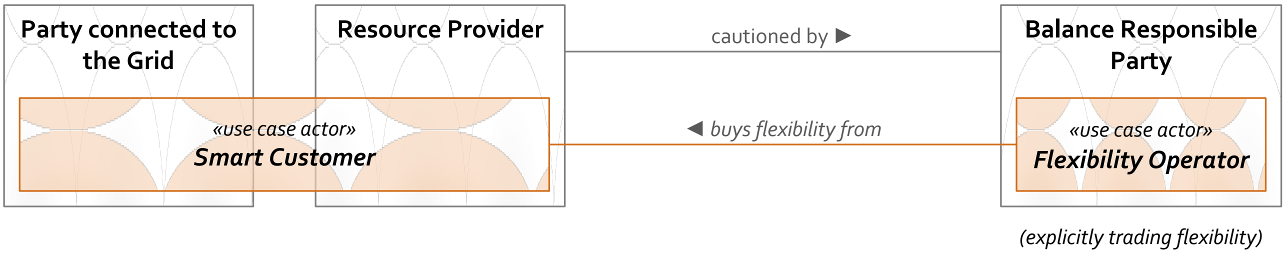


Figure 49: Explicit trade in flexibility in relation to European electricity market

C.4.3 Direct control of demand and/or supply

Within [ENTSO-E 2011] the role of Resource Provider is identified, actors with this role take part in system operations by providing reserve (balancing) services, by up/down regulation of ‘resource (or reserve) objects’ under its control. In case of direct control, the Flexibility Operator can be considered performing the Resource Provider role. The mapping of this use case to the roles of [ENTSO-E 2011] is visualized in Figure 50.

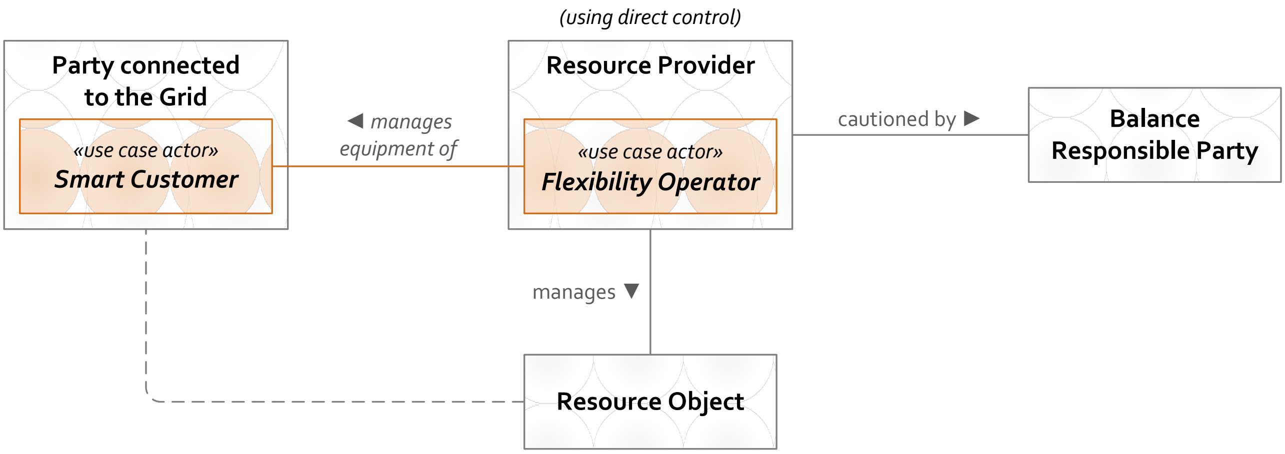


Figure 50: Direct control of demand and/or supply use case in relation to European electricity market

Note: the relationship between Party connected to the Grid and Resource Provider is not defined in [ENTSO-E 2011]. The relationship between Resource Object (a domain from [ENTSO 2012], not to be mistaken with the organizational domains of the European conceptual model) and the Party connected to the Grid is assumed.

Note: the Flexibility Operator in its role of Resource Provider connects to power system management and the market via another party (or by itself) performing the Balance Responsible Party role.

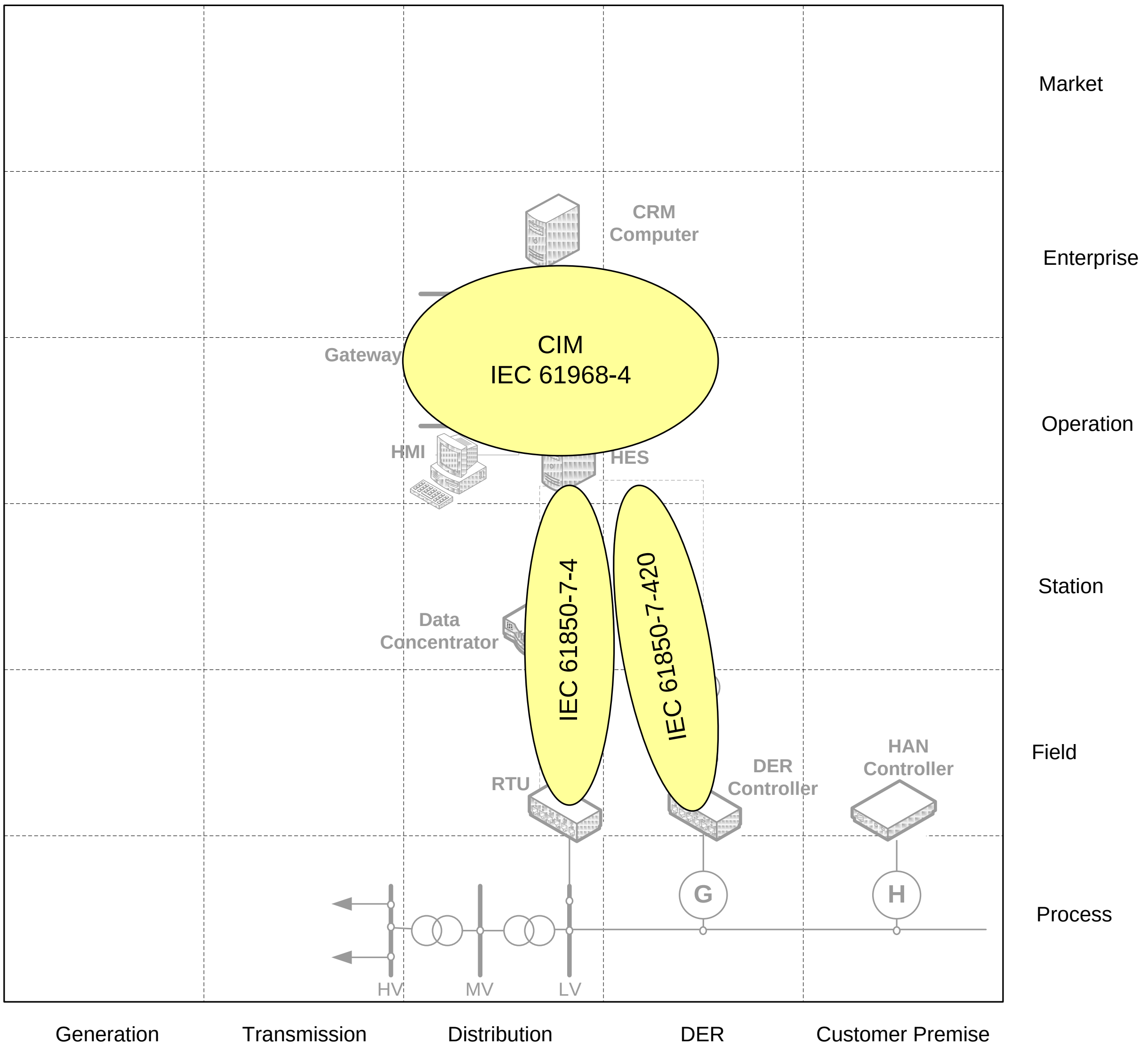
Annex D
Functional Architecture

969 This section will be filled if applicable or necessary.

Annex E
Information Architecture

Within the SGAM, one particular aspects of the layer is the level of data exchanged between the various layers. The particular focus of the layer within the SGAM is the meaningful representation and localization of the data models, abstract communication system interfaces towards the communication layer and the functional (system) layers implementing the logics and the smart grid component using standards and data models.

The Information layer is intended to show data models that are used by the sub-functions in order to fulfill the use case. Within section 5 of this document, the SGAM use case has already outlined the application of the mapping as depicted in the next graphic.



In addition to the standards already used and depicted, the JWG report form CEN/CENELEC and ETSI [3] and its annex 6 have already outlined the needed data model standards which will also be

[3] JWG report on standards for smart grids, version 1.0

evaluated from the view of the first set of standards group. Harmonization on the view of data integration technology vs. system/sub-system taxonomy of FSS 2.0 report is envisioned for version 3 of this SG-CG/RA report.

For this version of the report, relevant data models already identified are the following ones which will be mapped onto the SGAM domain/zones plane (note: subject to further extension):

- Mapping of IEC 61850 Common Data Classes on IEC 60870-5-104 (IEC 61850-80-1 TS)
- OASIS EMIX
- UN/CEFACT CCTS
- EN 60870-6-802:2002 + A1:2005, *Telecontrol equipment and systems – Part 6-802: Telecontrol protocols compatible with ISO standards and ITU-T recommendations – TASE.2 Object models*
- EN 60870-5-1:1993, *Telecontrol equipment and systems – Part 5: Transmission protocols – Section 1: Transmission frame formats*
- EN 60870-5-3:1992, *Telecontrol equipment and systems – Part 5: Transmission protocols – Section 3: General structure of application data*
- IEC 61850-7-410 Ed. 1.0, *Communication networks and systems for power utility automation – Part 7-410: 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 61400-25-2, *Communications for monitoring and control of wind power plants – Part 25-2: Information models*
- IEC 61400-25-3, *Communications for monitoring and control of wind power plants – Part 25-3: Information exchange models*
- IEC 61400-25-6, *Communications for monitoring and control of wind power plants – Part 25-6 Communications for monitoring and control of wind power plants: Logical node classes and data classes for condition monitoring*
- IEC 62056 series, *Electricity metering – Data exchange for meter reading, tariff and load control*, Parts 21, 31, 41, 42, 46, 47, 51, 52, 53, 61, 62
- IEC 61334, *Distribution automation using distribution line carrier systems* – Part 4 Sections 32, 511, 512, Part 5 Section 1
- EN 61970-301:2004, *Energy management system application program interface (EMS-API) – Part 301: Common information model (CIM) base*
- EN 61970-402:2008 Ed. 1.0, *Energy management system application program interface (EMS- API) – Part 402: Component interface specification (CIS) – Common services*
- EN 61970-403:2007, *Energy management system application interface (EMS- API) – Part 403: Component Interface Specification (CIS) – Generic Data Access*
- EN 61970-404:2007, *Energy management system application program interface (EMS-API) – Part 404: High Speed Data Access (HSDA))*
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Annex F
Communication Architecture

This section is provided as a separate document.

Annex G
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