PD IEC/TR 62357-1:2016

BSI Standards Publication

Power systems management and associated information exchange

Part 1: Reference architecture

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National foreword

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TECHNICAL REPORT

colour inside

Power systems management and associated information exchange – Part 1: Reference architecture

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CONTENTS

FOREWORD 7
1 Scope 9
2 Normative references 9
3 Terms, definitions and abbreviated terms 10
3.1 Terms 10
3.2 Abbreviated terms 12
4 Drivers and objectives for Reference Architecture 13
5 Overview 15
5.1 Standardisation context 15
5.2 Relevant business domains 16
5.3 Intended audience 19
5.3.1 General 19
5.3.2 Implementing actors 19
5.3.3 Standardization actors 20
5.4 Reference to relevant sources 20
6 Reference Architecture 21
6.1 Underlying methodology 21
6.1.1 General 21
6.1.2 The Smart Grids architectural methodology 22
6.1.3 SGAM levels of abstraction 24
6.1.4 The use case methodology 25
6.1.5 Data modelling 27
6.1.6 Profiling methodology 28
6.2 Reference Architecture overview 29
6.3 Elements of Reference Architecture 30
6.3.1 General 30
6.3.2 Elements as Interface Reference Model abstract components 31
6.3.3 Elements as some typical Smart Grids Systems 33
6.3.4 Elements as 61850 Intelligent Electronic Devices 34
6.4 Relationships of Reference Architecture 35
6.4.1 General 35
6.4.2 Communication inside substation 37
6.4.3 Communication between substations 38
6.4.4 Communication to support distributed automation along the feeder 39
6.4.5 Communication between substation and control centres and between control centres 39
6.4.6 Communication at the enterprise level 42
6.4.7 Communication to connect DERs (see Figure 26) 43
6.4.8 Communication to or within power plants (hydro, gas, thermal, wind) (see Figure 27) 44
6.5 Security standard landscape for Reference Architecture 45
6.5.1 General 45
6.5.2 Evolving security requirements for power system management 47
6.5.3 Resilience and security measures for power system operations 48
6.5.4 Overview and correlations of IEC 62351 security standards 50
6.6 Relationships applied to telecommunication 52

AVA Documents
Document Sharing Hub

6.6.1 General ... 52
6.6.2 Applicability statement of communication technologies to the Smart Grids sub-networks ... 54
6.7 Interoperability ... 56
7 Use of Reference Architecture ... 56
7.1 General ... 56
7.2 Development of Enterprise Architecture ... 56
7.2.1 General ... 56
7.2.2 Model Driven Architecture ... 57
7.2.3 The Open Group Architecture Framework ... 57
7.3 How to evolve from a Present User Architecture to Reference Architecture ... 58
7.4 Example: how to map a use case using Reference Architecture ... 58
7.5 Development of information exchange specification ... 67
7.6 Integrating security in Reference Architecture ... 68
7.6.1 General ... 68
7.6.2 Identification of security requirements ... 69
7.6.3 Mapping of security to power system domains ... 70
7.6.4 Security controls ... 71
8 Main areas of future standardisation work ... 73
8.1 General ... 73
8.2 Increase standard usage efficiency through digitalisation ... 73
8.3 Harmonise data modelling ... 73
8.4 Other future topics ... 74
9 Conclusion ... 74
Annex A (informative) SGAM Layer description ... 75
Annex B (informative) Elements examples ... 76
B.1 Example of control centre distribution systems ... 76
B.2 Example of a system, the case of network model management system ... 76
B.3 Example of a power flow component ... 77
Annex C (informative) Relationship examples ... 79
C.1 General ... 79
C.2 Data transformation via gateways and adapters ... 79
C.3 Example of a Message Exchange ... 80
Annex D (informative) TC 57 standards descriptions and roadmaps ... 84
D.1 TC 57 Working Group 03 ... 84
D.2 TC 57 Working Group 10 ... 85
D.2.1 General ... 85
D.2.2 IEC 61850 standard overview ... 85
D.3 TC 57 Working Group 13 ... 87
D.3.1 General ... 87
D.3.2 IEC 61970 standard overview ... 87
D.4 TC 57 Working Group 14 ... 89
D.4.1 General ... 89
D.4.2 IEC 61968 standard overview ... 89
D.5 TC 57 Working Group 15 ... 91
D.5.1 General ... 91
D.5.2 IEC 62351 standard overview ... 91
D.6 TC 57 Working Group 16 ... 100

AVA Documents
Document Sharing Hub
Full document details: PD IEC/TR 62357-1:2016

D.6.1 General ... 100
D.6.2 IEC 62325 standard overview ... 100
D.7 TC 57 Working Group 17 ... 105
D.8 TC 57 Working Group 18 ... 105
D.9 TC 57 Working Group 19 ... 106
D.9.1 General ... 106
D.9.2 IEC 62357 and IEC 62361 related standard overview ... 106
D.10 TC 57 Working Group 20 ... 107
D.11 TC 57 Working Group 21 ... 108
D.11.1 General ... 108
D.11.2 IEC 62746 related standard overview ... 108
D.12 Supplemental standards developed by the IEC and other bodies ... 109
Bibliography ... 110

Figure 1 – Core domain of Reference Architecture ... 16
Figure 2 – IEC TS 62913 conceptual model ... 17
Figure 3 – Two infrastructures (OT/IT) must be designed, operated, and secured ... 18
Figure 4 – Relevant sources for IEC TR 62357-1:2016 ... 21
Figure 5 – SGAM plane ... 22
Figure 6 – SGAM Model ... 23
Figure 7 – SGAM levels of abstraction ... 24
Figure 8 – Interactions between the Business and Function layers ... 27
Figure 9 – Data modelling and harmonization work mapping ... 28
Figure 10 – Information Models, Profiles and Messages ... 29
Figure 11 – Reference Architecture ... 30
Figure 12 – Power systems information related standards ... 31
Figure 13 – Distribution IRM Model ... 32
Figure 14 – Flexibility for assignment of element “Volt/Var Control” to SGAM segments (M490 C-Reference Architecture) ... 33
Figure 15 – SGCG/M490 Smart Grids systems on SGAM Plane ... 34
Figure 16 – IEC 61850 Data Modelling ... 35
Figure 17 – Functions of a substation automation system allocated logically on three different levels (station, bay/unit, or process) ... 36
Figure 18 – IEC 61850 related standards ... 37
Figure 19 – Communication inside substation ... 38
Figure 20 – Communication between substations ... 38
Figure 21 – IEC 61850 Telecontrol and control equipment and systems related standards ... 40
Figure 22 – Communication between substation and control centres ... 41
Figure 23 – Communication between control centre ... 41
Figure 24 – CIM Communication layer standards ... 42
Figure 25 – Communication from control centre / trading system to a market place ... 43
Figure 26 – Communication to connect DER ... 44
Figure 27 – Communication to/or within power plants ... 44
Figure 28 – Generic security architecture ... 45

AVA Documents
Document Sharing Hub
Full document details: PD IEC/TR 62357-1:2016

Figure 29 – Architecture of key power system management security standards and guidelines 46
Figure 30 – Typical cyber security requirements, threats, and possible attack techniques 48
Figure 31 – Interrelationships between IEC communication standards and IEC 62351 security standards 51
Figure 32 – Mapping of communication networks on SGAM 54
Figure 33 – Use of Reference Architecture in TOGAF 58
Figure 34 – CIM circuit breaker application view 59
Figure 35 – Real world devices 61
Figure 36 – Operate a circuit breaker with IEC 61850 62
Figure 37 – SCL for LNs 63
Figure 38 – SCL POS attribute 64
Figure 39 – ACSI service example 65
Figure 40 – Mapping of an ACSI service 66
Figure 41 – Hierarchical model for a circuit breaker 66
Figure 42 – SGAM analysis for the function “Monitoring inside the distribution grid” 67
Figure 43 – IEC mapping tool 68
Figure 44 – Security assessment types supporting Security Architecture design 69
Figure 45 – Security requirements and tasks per SGAM Layer depending on the abstraction layer 71
Figure 46 – Security Controls 72
Figure 47 – Addressing security requirements with security means of different strength 72
Figure 48 – RA through time 73
Figure A.1 – SGAM layer description 75
Figure B.1 – Example of control centre distribution system and relationships with other typical distribution systems 76
Figure B.2 – Network Model Management and other involved systems 77
Figure B.3 – Parts of a CIM network case 78
Figure C.1 – SCADA data interfaces 80
Figure C.2 – IEC 61968 associated communication technologies 81
Figure C.3 – XMPP architecture concept 82
Figure C.4 – Use of XMPP example 83
Figure D.1 – IEC 61850 standard series 85
Figure D.2 – IEC 61970 standard series 88
Figure D.3 – IEC 61968 standard series 90
Figure D.4 – NSM object models 94
Figure D.5 – RBAC concepts in IEC TS 62351-8 95
Figure D.6 – Architecture of IEC information exchange standards 96
Figure D.7 – Hierarchical architecture of DER system operations 98
Figure D.8 – IEC 62325 standard series 101
Figure D.9 – MADES overview 102
Figure D.10 – MADES scope 102
Figure D.11 – Interface Reference Model or the North American Style ISO/RTO market operations 104

AVA Documents
Document Sharing Hub
Full document details: PD IEC/TR 62357-1:2016

Figure D.12 – IEC 62361, IEC 62357 standard series 107
Figure D.13 – IEC 62746 standard series 109

Table 1 – Business and System Use Case 26
Table 2 – Standards Guidelines 47
Table 3 – Overview of IEC 62351 standards 50
Table 4 – Technologies covered by SDOs in function of SGAM Communications Sub-Networks 55
Table 5 – Message types 60
Table 6 – Information assets and their relation to system security 70

Documents
Document Sharing Hub

Full document details: PD IEC/TR 62357-1:2016

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POWER SYSTEMS MANAGEMENT AND ASSOCIATED INFORMATION EXCHANGE –

Part 1: Reference architecture

FOREWORD

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The main task of IEC technical committees is to prepare International Standards. However, a technical committee may propose the publication of a technical report when it has collected data of a different kind from that which is normally published as an International Standard, for example "state of the art".

IEC 62357-1, which is a technical report, has been prepared by IEC technical committee 57: Power systems management and associated information exchange.

This new edition cancels and replaces the first edition published in 2012 and constitutes a technical revision.

This edition includes the following significant technical changes with respect to the previous edition:

a) The new edition provides updates and defines layered Reference Architecture to help direct longer term goals and activities, specifically to ensure compatibility of all new

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standards developed in the IEC by benefitting from lessons learned during development of the current standards and their application to actual utility projects as well as through application of other internationally recognized architecture standards.

b) This edition reflects the progress recently achieved with the international Smart Grids (SG) initiatives and the CIGRE D2.24 large system architecture vision. It also leverages the work done by NIST-SGIP, CEN-CELELEC-ETSI SGCG M490, IEC SG3 Smart Grids Roadmap, and IEC SyC Smart Energy working groups.

The edition also reflects the most recent editions of the IEC standards relating to power systems management and associated information exchange, including the IEC 61850 series and the IEC 61968, IEC 61970 and IEC 62325 Common Information Model (CIM) standards.

The text of this technical report is based on the following documents:

Enquiry draft	Report on voting
57/1688/DTR	57/1745/RVC

Full information on the voting for the approval of this technical report can be found in the report on voting indicated in the above table.

This publication has been drafted in accordance with the ISO/IEC Directives, Part 2.

In this technical report, the following print types are used:

– *obligations: in italic underlined type.*

A list of all parts in the IEC 62357 series, published under the general title *Power systems management and associated information exchange*, can be found on the IEC website.

The committee has decided that the contents of this publication will remain unchanged until the stability date indicated on the IEC website under "http://webstore.iec.ch" in the data related to the specific publication. At this date, the publication will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

A bilingual version of this publication may be issued at a later date.

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POWER SYSTEMS MANAGEMENT AND ASSOCIATED INFORMATION EXCHANGE –

Part 1: Reference architecture

1 Scope

Electricity grids from generation to consumers, including transmission and distribution, as well as energy markets are facing many new challenges while integrating an increasing variety of digital computing and communication technologies, electrical architectures, associated processes and services. The new challenges lead very often to support an increasing level of interaction between involved actors, components and systems.

Thus, it is key for the IEC to propose a clear and comprehensive map of all standards which are contributing to support these interactions, in an open and interoperable way.

The purpose of this document is to provide such a map (as available in 2016), but also to bring the vision of the path which will be followed by the concerned IEC technical committees and working groups in the coming years, to improve the global efficiency, market relevancy and coverage of this series of standards.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60870-5 (all parts), *Telecontrol equipment and systems – Part 5: Transmission protocols*

IEC 60870-6 (all parts), *Telecontrol equipment and systems – Part 6: Telecontrol protocols compatible with ISO standards and ITU-T recommendations*

IEC 61850 (all parts), *Communication networks and systems for power utility automation*

IEC 61968 (all parts), *Application integration at electric utilities – System interfaces for distribution management*

IEC 61970 (all parts), *Energy Management System Application Program Interface (EMS-API)*

IEC 62325 (all parts), *Framework for energy market communications*

IEC 62351 (all parts), *Power systems management and associated information exchange – Data and communications security*

IEC TR 62357-200, *Power systems management and associated information exchange – Part 200: Guidelines for migration from Internet Protocol version 4 (IPv4) to Internet Protocol version 6 (IPv6)*

IEC 62361 (all parts), *Power systems management and associated information exchange – Interoperability in the long term*

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IEC 62746 (all parts), *Systems interface between customer energy management system and the power management system*

3 Terms, definitions and abbreviated terms

3.1 Terms

3.1.1 Architecture

The purpose of architecture is to define or improve systems. The architectural process encompasses understanding the scope of interest, understanding stakeholder requirements, and arriving at a design to satisfy those requirements.

The two word-senses in which architecture is used are:

- A set of models with the purpose of representing a system of interest.
- The activity and/or practice of creating the set of models representing a system.

Model Driven Architecture advocates the application of modelling to the architectural process and formalizes the resulting artefacts such that the realization or improvement of the system may be more actionable, less expensive and less risky.

3.1.2 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/IEC 42010]

3.1.3 System

A system is a collection of parts and relationships among these parts that may be organized to accomplish some purpose.

In Model Driven Architecture, the term ‘system’ can refer to an information processing system but it is also applied more generally. Thus a system may include anything: a system of hardware, software, and people, an enterprise, a federation of enterprises, a business process, some combination of parts of different systems, a federation of systems – each under separate control, a program in a computer, a system of programs, a single computer, a system of computers, a computer or system of computers embedded in some machine, etc.

One of the key strengths of modelling, and one that distinguishes it from implementation technologies like software source code, is that it is an excellent way to represent, understand and specify systems.

In Smart Grids Architecture Model (SGAM) a system is a boundary which include all layers of SGAM

3.1.4 Functional Architecture / Concept

- A “function” represents a logical entity which performs a dedicated function. Being a logical entity, a function can be physically implemented in various ways (in devices or applications).
- A “function group” is a logical aggregation of one or more functions.

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- 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.
- A “functional architecture” identifies the functional elements of a system and relates them to each other.

3.1.5 Service

This is the contract to perform a certain task, with certain deliverables (output) and other agreements on what is included (external view)

3.1.6 Function

This is when the service is carried out (internal view)

3.1.7 Application

This is the implementation of a service providing a certain functionality

3.1.8 Model

A model in the context of Model Driven Architecture (MDA) is information selectively representing some aspect of a system based on a specific set of concerns. The model is related to the system by an explicit or implicit mapping. A model should include the set of information about a system that is within scope, the integrity rules that apply to that system and the meaning of terms used.

A model may represent the business, domain, software, hardware, environment, and other domain-specific aspects of a system.

3.1.9 Modelling language

To be useful, any model needs to be expressed in a way that communicates information about a system among involved stakeholders that can be correctly interpreted by the stakeholders and supporting technologies. This requires that the model be expressed in a language understood by these stakeholders and their supporting technologies. Well-known modelling languages include Unified Modelling Language (UML), Structured Query Language (SQL), Business Process Model and Notation (BPMN, E/R, Ontology Web Language (OWL), EXtensible Mark-up Language (XML) Schema.

3.1.10 Elements

Elements are systems and a system may contain subsystems applications and devices. An element can also be a function or group of functions. An element can also be a service or group of services.

3.1.11 Profile

Generally a profile defines a subset of an entity (e.g. standard, specification or a suite of standards/specifications). Profiles enable interoperability and therefore can be used to reduce the complexity of a given integration task by:

- selecting or restricting standards to the essentially required content, e.g. removing options that are not used in the context of the profile
- setting specific values to defined parameters (frequency bands, metrics, etc.)

A standard profile for communications standards may contain a selection of communication capabilities applicable for specific deployment architecture. Furthermore a profile may define instances (e.g. specific device types) and procedures (e.g. programmable logics, message

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sequences) in order to support interoperability. It may also provide a set of engineering guidelines to ease the deployment of new technologies.

3.2 Abbreviated terms

AMM	Advanced Metering Manager
BPMN	Business Process Model and Notation
CEN/CENELEC	European Committee for Electrotechnical Standardization
CIGRE	Conseil International des Grands Réseaux Electriques
CIM	Common Information Model
COSEM	Companion Specification for Energy Metering
DER	Distributed Energy Resources
DR	Demand Response
DSO	Distribution System Operator
ebIX	European forum for energy Business Information eXchange
EFET	European Federation of Energy Traders
ENTSO-E	European Network of Transmission System Operators for Electricity
ETSI	European Telecommunications Standards Institute
EU	European Union
EV	Electric Vehicle
FERC	Federal Energy Regulatory Commission
GIS	Geographic Information System
ISO	International Standardization Organization
ITU	International Telecommunications Union
MDA	Model Driven Architecture
NERC	North American Electric Reliability Corporation
NIST	National Institute of Standards and Technology
OWL	Ontology Web Language
RA	Reference Architecture
RDF	Resource Description Framework
SCADA	Supervisory Control And Data Acquisition
SDO	Standards Development Organization
SG	Smart Grid
SGAC	Smart Grids Architecture Committee
SGAM	Smart Grids Architecture Model
SGIP	Smart Grids Interoperability Panel
SGTCC	Smart Grids Testing & Certification Committee
SNMP	Simple Network Management Protocol
SQL	Structured Query Language
TC	Technical Committees
TOGAF	The Open Group Architecture Framework
TSO	Transmission System Operator
UML	Unified Modelling Language
XML	Extensible Markup Language
XSD XML	Schema Definition

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4 Drivers and objectives for Reference Architecture

The Reference Architecture drivers are:

- Need to manage the increase of intermittent and distributed energy resources

The objective is to anticipate the new usage of electricity and support the new business models attached to these new usages.

Electricity paradigms are changing due to the introduction of intermittent distributed resources, as well as a higher and higher presence of active users, modifying their behaviour to make the most of electricity.

It is the role of the IEC to enable the emergence of these new ways of using electricity.

It shall enable meaningful data to flow freely across the system as the energy flows in various directions and ensure any information is available anywhere it is needed.

The Reference Architecture shall consider and represent the specifics of intermittent and distributed energy resources. It shall support meaningful information exchanges and communication within the power system and to external parties to facilitate their integration.

- Need for sustainable and efficient energy

The objective is to make the best of available energy and preserve natural resources

The contribution of the Reference Architecture is to facilitate and consider specific requirements for interactions between or within involved players, renewable energy producers, markets, utilities and consumers to reach such a goal.

The Reference Architecture must provide a means to leverage energy efficiency potentials.

- Need for safe, secure, and reliable energy to have a resilient power system

The objective is to support the needed functions to provide the expected quality to consumers such as voltage and frequency regulation and outage reduction

The objective is to provide a resilient power management system complying with the reliability objective of the utility

Cyber security supports the reliable operation of power systems coping with technical, physical, and organizational security requirements related to specific use cases. The derivation of security requirements is typically based on a threat and risk analysis. Further security requirements may also stem from regulation. The security counter measures need to be appropriate to address the security requirements.

The Reference Architecture provides a framework for identifying risk and providing security counter measures.

- Need for economic efficiency

The objective is to support flexibility while maximising the use of existing foundations

Architecture flexibility refers to its ability to adapt to dynamic changes mostly through incremental changes.

This may lead the architecture to add/remove/update services/functions/components at different level of depths.

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The market is requiring more and more flexibility and standardization should help the users in managing these needed evolutions.

Increasing flexibility through international standards will increase the value and the duration of concerned assets.

Backward compatibility with an easy migration from the existing appears among the main properties to consider reaching such an objective.

The objective is to support interoperability by design and offer multi-vendor system capabilities

It is one of the main properties of the Reference Architecture to support interoperable architecture enabling mixing components, sub-systems and systems coming from different vendors.

This also includes properties of the Reference Architecture to allow any market player to have an equal opportunity to participate in this architecture.

The needed property of such a Reference Architecture to meet this objective relies on the availability of common data model across a maximum number of levels of the architecture.

The Reference Architecture shall support the “customization” of standard usage – also known as “profiling” − if it helps to reach a better level of interoperability in a specific context.

It is important to recognize that the focus of the IEC in this domain is standards for interoperability among different utility organizations and/or different vendor products. Neither the IEC nor its working groups design or build applications, and the internals of applications are deliberately left open to competition and are not part of the IEC scope for standardization. The policy is to maximize opportunities for creativity by restricting standardization to points where exchange of information is required.

The objective is to maximise the re-use of off-the-shelf technologies, especially the technologies coming from the IT and communication domain

Offering capabilities to exchange data between components, sub-systems and systems requires the use of information and communication technologies.

Considering that the use of this technology is not specific to the electricity domain, it is the challenge of the Reference Architecture to maximize the re-use of opened transverse technologies which are used in other domains.

However it is also the challenge to pick from these the most open, sustained and used ones, and in any case to make the Reference Architecture resilient to changes in this domain, which is known as a fast moving one.

The objective is to reduce power management systems total costs around their life cycle

- Need to cope with faster changing context

The objective is to support assets agility while preserving the existing ones

Agility means the ability to support a new user’s objectives driven by internal (new user’s company objectives) or external pressures (technological change, regulatory changes).

A second objective is to support flexibility to adapt to local regulatory frameworks

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The objective for the Reference Architecture is to partition systems to identify the interfaces for communication standards such as CIM, IEC 61850, Tase-2, IEC 60870 to minimize the dependencies. Then changing one function will minimize the effect on the others.

- Need to cope with increasing complexity

The interaction of systems and markets interactions are increasing and becoming more complex. Regulatory requirements increase the number and variety of market players and require much more sophisticated, forecasting and faster reacting systems.

The objective is to provide sustained foundations to existing and future systems

The expectation of standard users is to get longer lasting assets; it is an expected top priority of the Reference Architecture to guarantee the most stable technical principles and resilience to future changes.

The principle is for standardization to provide all needed means to define and manage in a sustained way the data models, which are considered as the most stable part of the Reference Architecture.

The objective is to reduce integration efforts while anticipating an increased complexity of the systems

The cost of integration is really one of the main challenges in making system smarter. It is the role of the IEC Reference Architecture to offer to the market the most efficient way to integrate such a system, and then consider the processes and services needed to support the full system cycle from its specification down to its deconstruction.

One way to reach this objective is relying on the ability of systems, sub-systems and components to support pre-defined meaningful data models (meaningful, means with a defined standard semantic).

The objective is to make as easy as possible the use of the proposed set of standards

For most of the stakeholders, moving to smarter systems raises the need for this market player to get the needed knowledge as quickly as possible and at the lowest costs and to adapt its processes and tools to manage the new set of technologies.

It is the role of the Reference Architecture to provide the easiest access to the standard technologies and to foresee better ways to support the needed process and tools to make the life of the user the easiest.

Among one of the main challenges of the expected properties is to focus on the most limited number of semantic domains.

5 Overview

5.1 Standardisation context

Power Systems are mainly based on the standards shown in Figure 1:

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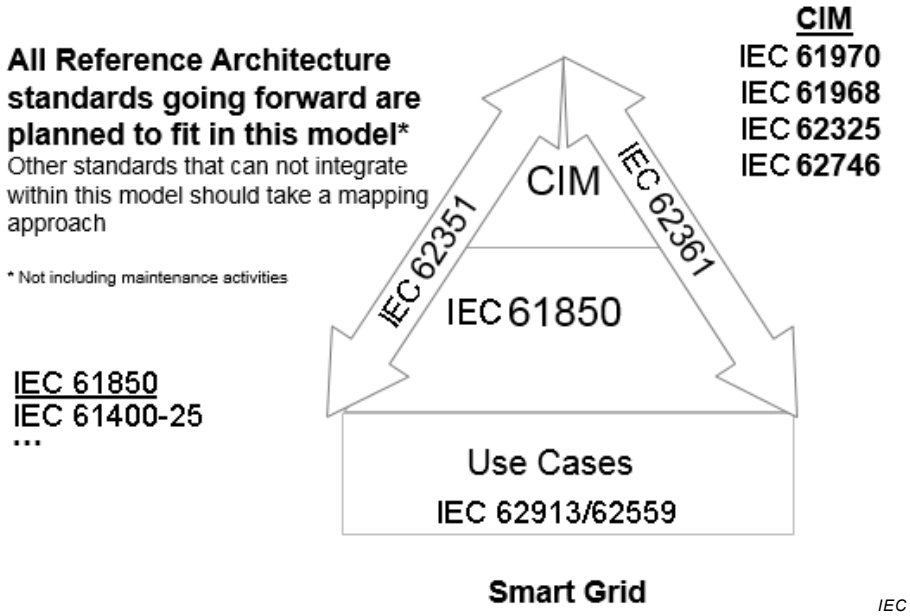

Figure 1 – Core domain of Reference Architecture

These key standards, with other related standards will be spread over the Reference Architecture. The core domain of Reference Architecture revolves mostly around IEC standards and has connection to other semantic domains such as Electric Vehicle (EV) or metering[1].

5.2 Relevant business domains

During the coming years the structure, operation and management of the power system will undergo fundamental changes. In order to define standards that support this transition in a consistent way, a generic conceptual model is required. This conceptual model is to be regarded as the starting point for all modelling activities, and for all other models, frameworks, and architectures, which are used to arrive at standards required for Smart Grids and Markets.

The IEC System Committee Smart Energy is the coordinator for the development of these Generic Smart Grid requirements in collaboration with the various IEC Technical Committees. SyC Smart Energy promotes a system perspective.

The IEC TS 62913 series[2], proposed by SyC Smart Energy WG6 (Generic Smart Grid Requirements), has broken down the scope of Smart Grids applications into domains[3]. This is an arbitrary yet necessary split, and it has been inspired by existing conceptual models which have been drafted previously, such as the National Institute of Standards and Technology (NIST) Smart Grids conceptual Model or the conceptual model developed as part of the European mandate M/490 Smart Grids Coordination Group.

A conceptual model can be defined as the grouping of roles and actors (systems, components, operators etc.) within coherent domains related to a general system. It provides

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1 Some Technical Committees have chosen to extend IEC 61850: TC 38 (IEC 61869), TC 88 (IEC 61400-25), SC 17C (IEC 62271), etc.

2 Under preparation.

3 Excerpt from IEC 62913-1:–, Clause 2, Conceptual Models.

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a high-level Reference Architecture model and proposes a decomposition of a system in domains and sub-domains.

This facilitates the description of Smart Grids systems and interoperability analysis. The roles and systems of each domain interact with each other, as well as with the roles and systems of other domains.

Based on the commonly accepted breakdown and other existing Conceptual models (NIST conceptual model, European Union (EU) M/490 Smart Grids conceptual model), IEC TS 62913 has organised the Smart Grids domains in five clusters:

– Grid-related domains – these include the Transmission Grid domain, the Distribution Grid domain, and the Micro-Grids domain,
– Market-related domain – this consists of the Market domain,
– Resources-connected-to-the-Grid domains – these domains are the Bulk Generation domain, the Distributed Energy Resources domain, the Smart Home / Commercial / Industrial / Demand Response (DR)-Customer Energy Management domain, and the Energy Storage domain,
– Electric Transportation domain – this consists of the Electric Transportation domain (DCT8),
– Support functions domains – these include the Smart Substation Automation domain, Advanced (Smart Grids and) Smart Metering Infrastructure domain and the Asset Management domain.

Figure 2 provides an overview of the Smart Grids domains and their high-level interactions. It represents a conceptual model for IEC TS 62913:

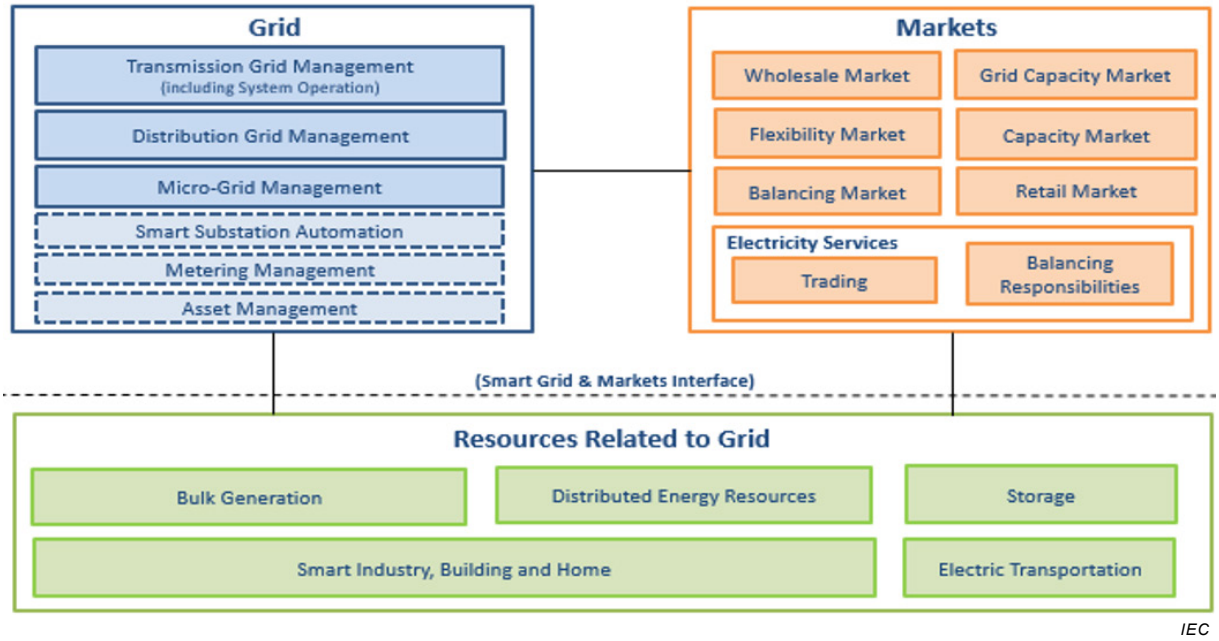

Figure 2 – IEC TS 62913 conceptual model

Its main underpinning is the analysis of roles and responsibilities. While this model is based on an electricity market structure, the roles and responsibilities are clearly defined and provide a solid basis; new parties may enter certain markets, responsibilities may be redistributed, but the fundamental roles and their respective responsibilities are expected to remain constant.

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Reference Architecture facilitates the conceptual model of Smart Grids Use Case (UC and requirements enabling the different UC to be implemented and describing links between, Grid, Markets and Grid Users domain.

Both the conceptual model and the Reference Architecture plan to use the same methodology and the same definition of actors and roles.

The term IT (Information Technology) is typically connected with devices used to perform business operations, for example product life cycle management, enterprise resource planning, business planning, billing, asset tracking, and/or maintaining customer information. The devices used are mainly located in offices and data centres. In contrast OT (Operation Technology) is associated with field level devices, used to perform actual operations like discrete or continuous control, metering, etc. These OT systems are based on vendor-specific and often proprietary technologies operating in a real time or near to real time environment. The meaningful convergence or the bridging of both (IT and OT) relates to the integration of operational technologies like Supervisory Control And Data Acquisition (SCADA), Meters/Sensors working in real time with IT systems allowing an end-to-end management of both. This allows for cost and risk reductions (burden sharing) on the economic side and on reuse of existing technologies on the other. The Reference Architecture aims to support this IT/OT interoperability shown in Figure 3.

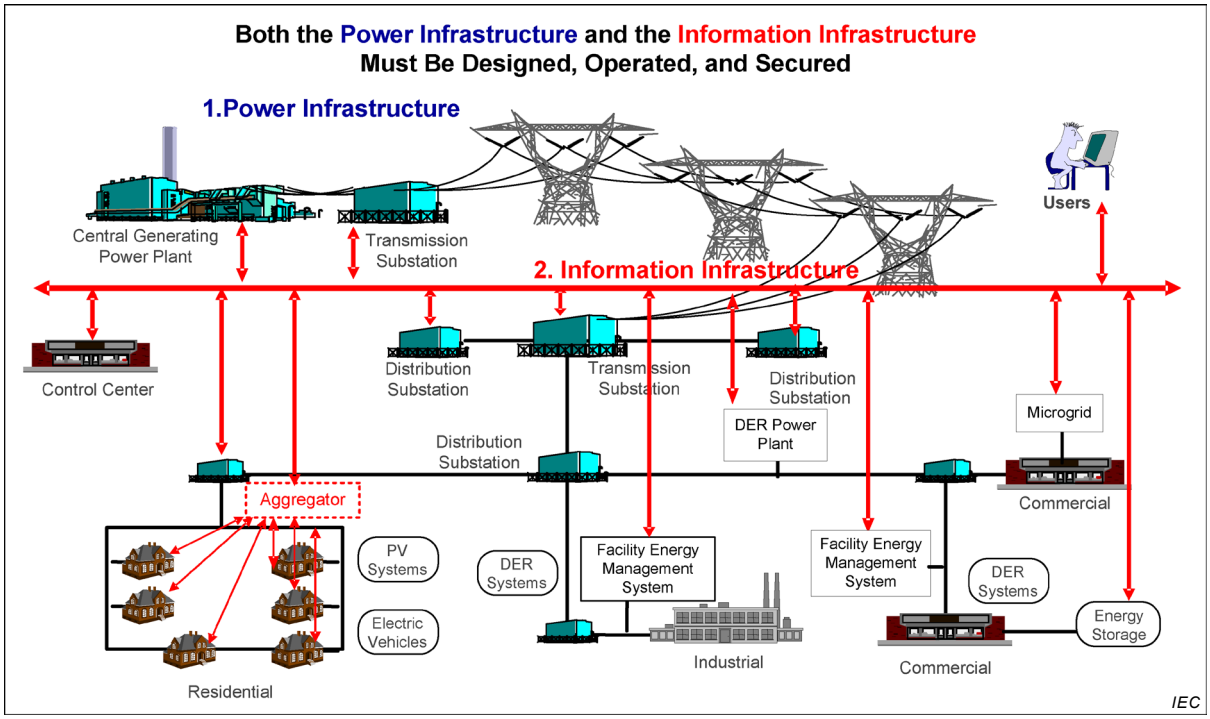

Figure 3 – Two infrastructures (OT/IT) must be designed, operated, and secured

For instance high performance automation on distribution will provide more and more data at higher levels (IT level) in order to conduct data analytics. Therefore the OT/IT paradigm is still a stake for many utilities.

The problem of aligning and integrating business processes and OT/IT is hampering many companies in their strategic and tactical development. Constructing integrated architecture models contributes to tackling this problem. In current business practice, an integrated approach to business processes and OT/IT is indispensable.

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5.3 Intended audience

5.3.1 General

The Reference Architecture provides the high level assumptions about how systems should interoperate.

The main purposes of the Reference Architecture are:

– To guide designers of standards for data exchange, by clarifying the purpose of data exchanges between systems, applications, components.
– To guide application designers by clarifying what the overall vision expects from their systems.
– To guide utilities in establishing implementation architecture that will accomplish their tasks effectively.

The role of the Reference Architecture is to support and assist standardization groups and to provide them with easily applicable methods and architectures and ensure an easy understanding of the approach. Though the main intended audience is standardization technical committees, it can also be used by other actors like research projects testing new concepts or engineers developing Smart Grids products, or even the legislator in order to check the legislative framework.

The intended audience is based on key roles described in Reference Role Model. It is not intended to go through all Roles. For a detailed Role Model description please refer to IEC TS 62913-1[4].

5.3.2 Implementing actors

5.3.2.1 Transmission System Operators and Grid Operators

The increased penetration of generation capacities, mostly connected to the distribution network, as well as the development of new usages of electricity will tend to intensify the need for cooperation between system operators at distribution and transmission level. If Transmission System Operators (TSO) were traditionally responsible for the overall system stability and Distribution System Operators (DSO) for operating their respective network, they will need to strengthen their coordination at different timeframes in order to ensure the security of the system.

TSO business processes are impacted by new regulations that are coming into force and developed by regulatory authorities.

5.3.2.2 Distribution System Operators and Grid Operators

The Distribution Grid Management (DGM) domain today faces several challenges, which tend to significantly change the way its actors operate. These changes and their combination contribute to transform in depth Distribution Grid Operators. They already started and will continue to impact their roles, business models and business processes.

The distribution domain will also see more and more self-healing grids, micro-grids and interconnected micro-grids.

It includes business processes and functions related to:

- The long-term planning and development of the electricity distribution system, including connection and access;

[4] Under preparation. Stage at the time of publication: IEC/CDM 62913-1:2016.

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- The operational planning and scheduling of the electricity distribution system;
- The operation and maintenance of the electricity distribution system;
- The facilitation of electricity markets;
- The possibility to provide regulated services based on data management and provision to external roles such as TSOs, Energy Regulators, or local authorities, in order to facilitate national and local public policies and enable customer empowerment.

5.3.2.3 Resources related stakeholders

Different resources are connected to the Grid (Distributed Energy Resources, Smart Home / Commercial / Industrial / DR-Customer Energy Management, Energy Storage, and Bulk Generation, These resources are managed by different stakeholders. This document must help concerned stakeholders in order to identify which standards will be used to connect these resources to the Grids, which standards can be used to define these resources in order to have them interoperable.

5.3.2.4 Market players

Market players are numerous: Balance Responsible Party, Billing Agent, Consumer, Electricity trader / Broker, Flexibility Aggregator/Operator, Imbalance settlement responsible, Service Provider, (Electricity) Supplier / Retailer. The business processes of the Market domain, especially those related to the contribution to system security, need to comply with the applicable Grid/Network Codes. This document will help market players understand the big picture, identify potential new developments and identify which main standards they have to comply with.

5.3.2.5 Vendors

This document supports vendors as a guide to workable standards useful for developing best state of the art products and solutions fitting business requirements. It shall help vendors to understand that their respective product will have to interoperate with other vendor product using a recognized international standard.

5.3.3 Standardization actors

5.3.3.1 Regulators

This document should help regulators as a guide to workable standards useful to delivering the best value for consumers by ensuring that technical investments by energy providers utilize standards wisely, and introduction to standards related to Smart Grids privacy and security.

Regulators are defining Grid Codes which have an impact on different stakeholders' business processes, and as a consequence on their supporting architecture.

5.3.3.2 Standard Development Organisations

The IEC has several liaisons within its own Technical Committees (TC) and with external Standards Development Organizations (SDOs) (International Standardization Organization (ISO), International Telecommunications Union (ITU), UN-CEFACT, etc.). This document shall help SDOs to identify their boundaries and needs for harmonisation.

5.4 Reference to relevant sources

Figure 4 describes the main relevant sources of input to this document. Refer to these documents as complementary documents:

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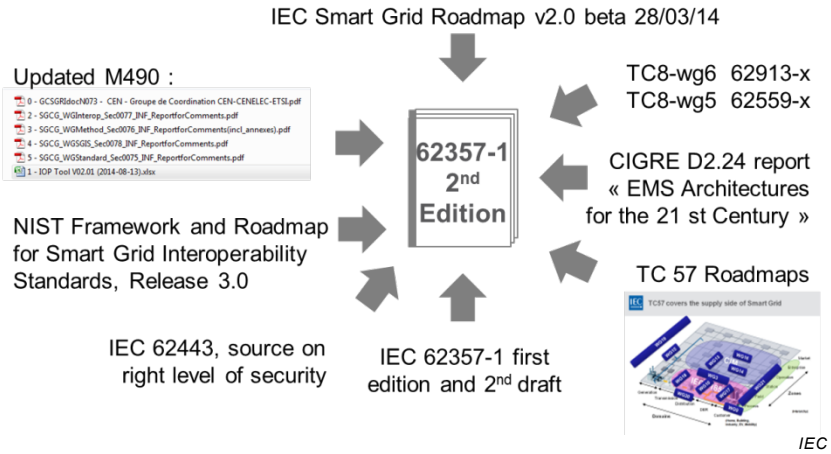

Figure 4 – Relevant sources for IEC TR 62357-1:2016

Refer also to the bibliography.

6 Reference Architecture

6.1 Underlying methodology

6.1.1 General

The development of system requirements is a key ingredient for the development of information exchange standards for the Smart Grids and their Markets. Identifying the actors of and their interactions within Smart Grids and Markets is an important step therein from the market level to the technology level.

Power system management distinguishes between electrical process and information management. These viewpoints can be partitioned into the physical domains of the electrical energy conversion chain and the hierarchical zones for the management of the electrical process (refer to IEC TR 62357-1:2016, IEC TR 62357-200:2015 and IEC 62264-1:2013).

“Zones” illustrate the physical and management aspects of the grid. The notion of zones is derived from IEC 62264-1 manufacturing process interfaces. Zones describe the process hierarchy from the power system through the various entities that participate in the production, transmission, and consumption of electricity.

Applying this concept to the Smart Grids conceptual model allows the foundation of the *Smart Grids Plane* that spans in one dimension the complete electrical energy conversion chain, partitioned into five domains: Generation, Transmission, Distribution, Distributed Energy Resources (DER) and Customers Premises. And in the other dimension the hierarchical levels of power system management, partitioned into six zones: Process, Field, Station, Operation, Enterprise and Market. Figure 5 shows the domains and zones.

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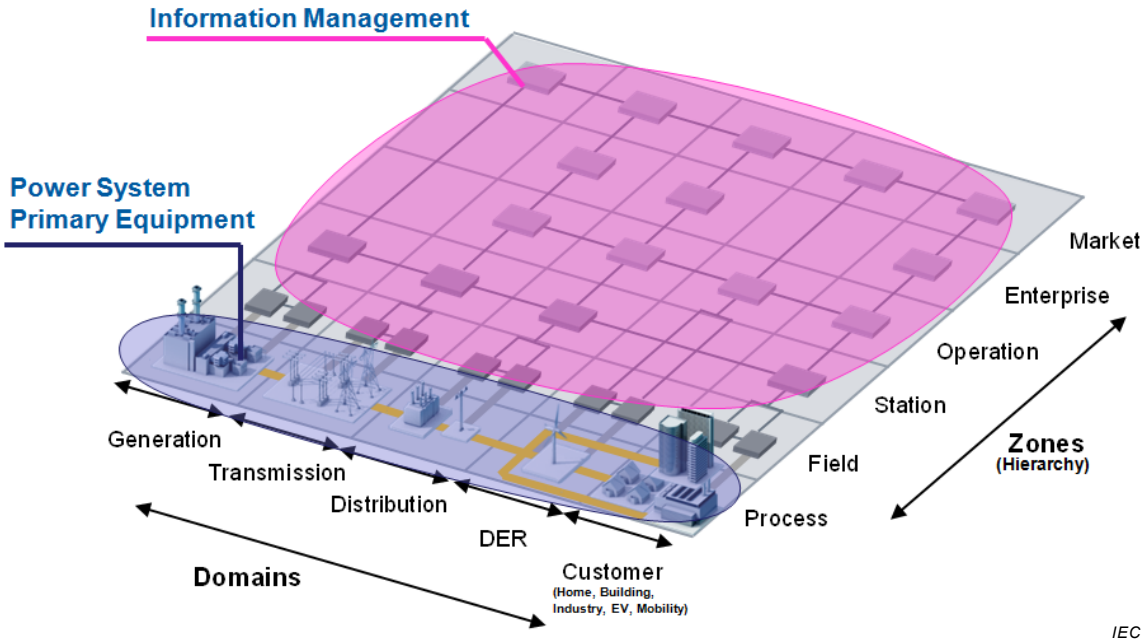

Figure 5 – SGAM plane

6.1.2 The Smart Grids architectural methodology

The Smart Grids is a complex system of systems, serving the diverse needs of many stakeholders. It must support:

- Devices and systems developed independently by many different solution providers
- Many different utilities
- Millions of industrial, business, and residential customers
- Different regulatory environments

Moreover, these systems must work together not just across Smart Grids' technical domains but across stakeholder communities in enterprises which are not part of the existing utility industry. Achieving interoperability in such a massively scaled, distributed system requires architectural guidance, which is provided by SGAM-described in this clause/subclause?.

Interoperability as a key enabler for Smart Grids is inherently addressed in SGAM by the five superimposed layers Component, Communication, Information, Function and Business. It aims at decomposing the Electric Power System by interoperability layers, Domains, and Zones as depicted in Figure 6:

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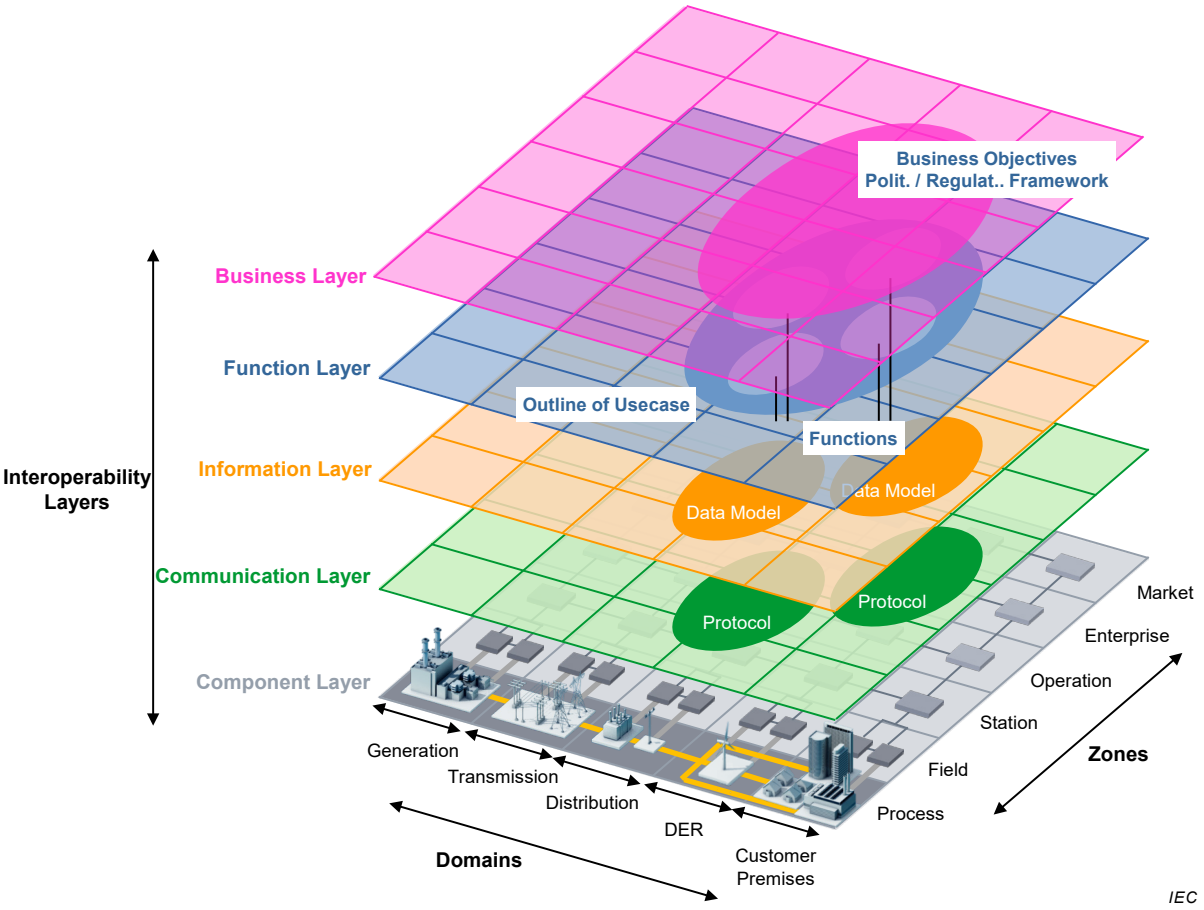

Figure 6 – SGAM Model

The SGAM is a template for architects to follow while building aspects of a Smart Grids architecture, regardless of an architect's speciality (such as in areas of transmission, distribution, IT, back office, communications, asset management, and grid planning).

The SGAM Interoperability Layers allow the modelling of different views from business as well as technical viewpoints. On the business layer SGAM can be used to map regulatory and economic (market) structures and policies, business models, business portfolios (products and services) of market parties involved. Also business services and 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 perspective is modelled in SGAM on the first upper layer:

- The Business layer represents business models and regulatory requirements.

The technical perspectives are modelled in SGAM on the four lower layers:

- The Service/Function layer (OSI 6/7) describes functions and services including their relationships following business needs. Functions are represented independent from their physical implementation in systems or devices (implementations are represented in the component layer).
- The Information layer describes the information that is being used and exchanged between functions. It contains information objects and the underlying canonical data models.

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- The emphasis of the Communication layer is to describe mechanisms and protocols for the interoperable exchange of information between functions.
- Finally, the Component layer shows the physical distribution of all participating components. This includes power system equipment (typically located at process and field level), protection and tele-control devices, network infrastructure (wired / wireless communication connections, routers, switches) and any kind of computers. For a specific implementation of a use case the identified functions can be mapped onto components complementing the relationships between all layers.

6.1.3 SGAM levels of abstraction

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

An overview of exemplary abstraction levels is given in Figure 7. Each layer therein depicts some concepts (examples) used in steps of successive model refinements that can be carried out on the respective interoperability layer. The identification may then finally support a definition of interoperability requirements. The abstraction levels on different layers depicted in Figure 7 do not necessarily relate to abstraction levels on the same level of abstraction on other layers.

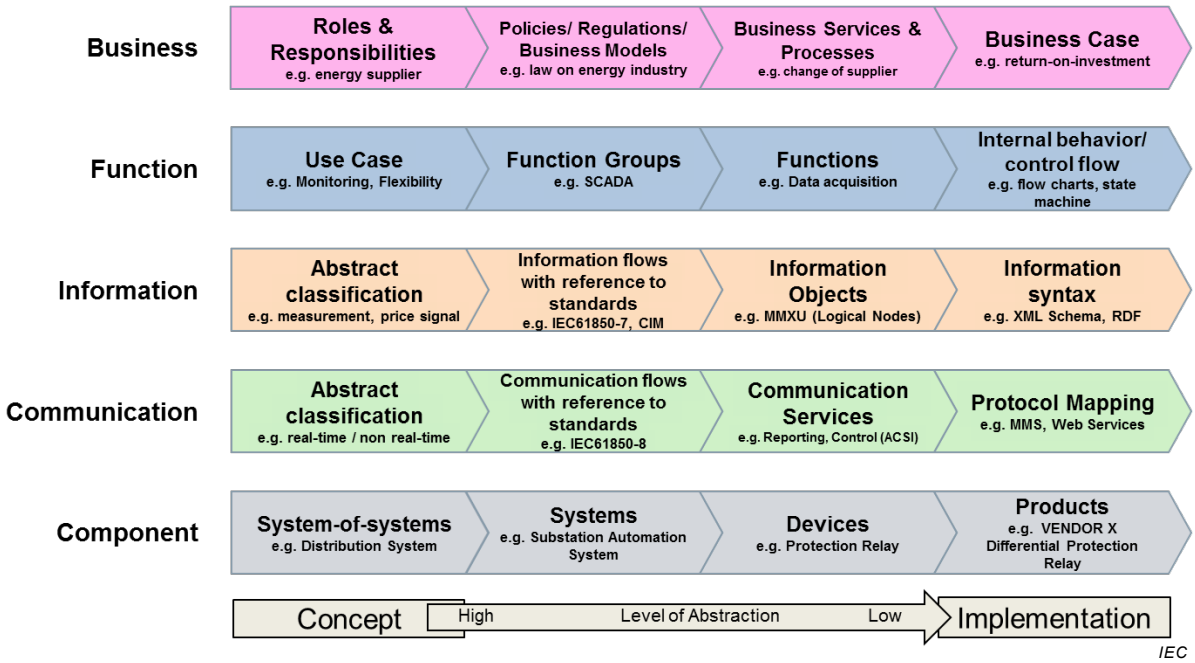

Figure 7 – SGAM levels of abstraction

Complete description of SGAM and SGAM usage can be found in SG-CG/F] SG-CG/M490/C_ Smart Grids Reference Architecture, [SG-CG/F] SG-CG/M490/F_ Overview of SG-CG Methodologies.

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6.1.4 The use case methodology

According to IEC TR 62390:2005, a use case is a "class specification of a sequence of actions, including variants that a system (or other entity) can perform, interacting with actors of the system". The concept has been further defined by IEC 62559-2 as "a specification of a set of actions performed by a system which yields an observable result that is of value for one or more actors or other stakeholders of the system". In other words, it describes, in text format, how one or several actors interact within a given system to achieve goals. In order to clearly explain the definition, it seems important to further detail the different concepts used.

The notion of 'Role' is fundamental in the use case methodology. A role may be defined as "an intended behaviour of a business party"[5]. It is associated with responsibilities. A business party, when carrying out a business transaction, takes on a certain role. According to European Network of Transmission System Operators for Electricity (ENTSO-E) Role Model (ENTSO-E, European Federation of Energy Traders EFET, and European forum for energy Business Information eXchange ebIX, 2011), "the objective of decomposing the electricity system 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 (service). Business processes should be designed to satisfy the requirements of the roles and not of the parties."

Roles should be differentiated from Actors, which are more general and include Roles, information systems, or devices.

- An actor can be defined as anyone or anything with behaviour. It can include:
  - Roles, which are the external intended behaviour of a business party which cannot be shared – examples: Distribution System Operator, Grid User, DSO Network development unit;
  - Persons – examples: SCADA operator;
  - Information Systems – examples: SCADA, Active Demand Management System;
  - Physical components – examples: Energy Storage, network captor.
- The system defines the scope of a use case or a set of use cases, i.e. its boundaries. It can be an organisation, a project, or an information system for instance.

Use cases are above all a textual description. Existing literature on the methodology has provided several use case templates. The use case template proposed by IEC 62559-2:2015 is the most widely accepted within the Smart Grids community. Any Smart Grids project can use this template to describe its Business Use Case as well as its System Use Case.

Use cases literature (Cockburn, 2001) highly recommends distinguishing different levels of goals. Indeed, goals the actors are pursuing are not necessarily on the same level, some being very high-level and others really specific, related to the task the user of a system may perform. In order to structure these goals in a consistent way and avoid producing use cases which do not have the same granularity and/or overlap, the literature has identified two types of use cases, corresponding to two levels of details:

- Business Use Cases describe business processes and their associated requirements, which are included in the present document,
- System Use Cases detail functions or sub-functions supporting the business processes, and their associated requirements.

Table 1 highlights the differences between these two types of use case.

5 SG-CG/M490/C:2012-12.

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Table 1 – Business and System Use Case

	Description	Involved actors
Business Use Cases	A business process implementing a service	Roles (organisations or organisational entities)
System Use Cases	A function or sub-function supporting one or several business processes	Systems and Persons (operators of an information system)

In Business Use Cases, aspects related to technology are treated using a 'black-box' approach, i.e. by focusing on the functions required to enable / execute the business process and their associated requirements – the 'what' –, but not on their implementation from a technical perspective – not the 'how'. By describing business needs and business rules related to the activities of a business process,

Business Use Cases writers contribute to define requirements which might impact the tools or systems needed to implement the identified functionalities. However, they "must never pre-empt designers and try to use the use-case model to design the system" (Bittner and Spence, 2003). In other words, Business Use Cases should not describe solutions, but only express requirements.

Based on the SGAM method and according to the literature on use case methodology:

- Business Use Cases describe Business Processes and their activities/steps (Business Layer), their execution within different Domains and Zones, as well as their interactions with Functions (Function Layer);
- System Use Cases describe Functions (Function Layer) supporting the Business Processes described on the Business Layer and their interactions with data models (Information Layer), protocols (Communication Layer), and components (Component Layer).

A business-driven and top-down approach to describe new and relevant business processes of the electric power system impacted by Smart Grids technologies from which details on the needed Smart Grids functions supporting these processes are given. These requirements will serve as input for the development of Smart Grids standards (data models, protocols etc.), like the ones developed by the IEC.

Figure 8 shows the interactions between the Business and Function layers and their associated concepts – roles, services, business processes, activities, functions and systems.

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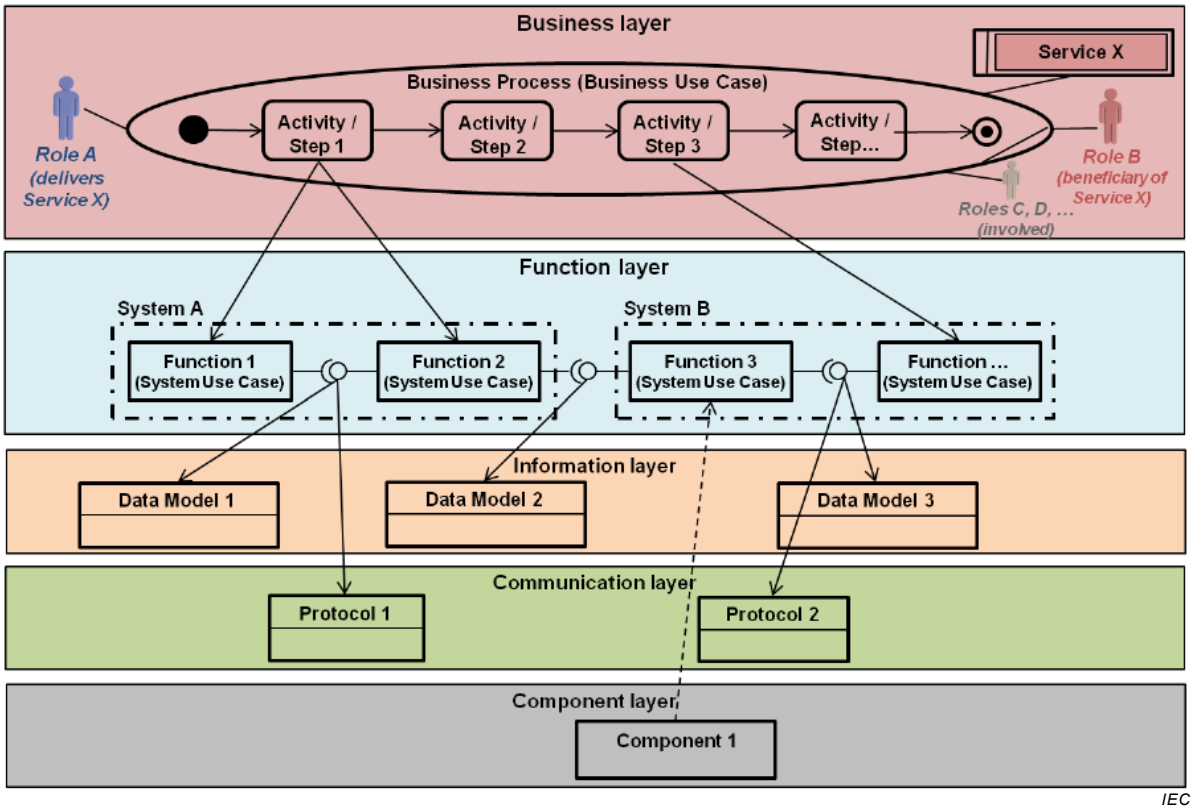

Figure 8 – Interactions between the Business and Function layers

A generic actor list, derived from generic use cases, includes the role-actor relationships. This supports the analysis of the business context when defining requirements of Smart Grids systems from use cases, as the first step towards standards. Moreover, it ensures the required applicability of standards based on these requirements in all market models.

In 2012, SG-CG/F] SG-CG/M490/E_ Sustainable Process Annex A proposed a list of Actors. NIST SGIP consolidated an actor list. IEC Smart Energy System Committee WG6 will provide a consistent list of actors, in coordination with other IEC technical committees.

The system use cases which are developed at the functional layer will have to be developed according to the Interface Reference Model concept defined by IEC 61968-1, and which is going to be extended to new Smart Grids business domains.

Complete description of Use Case methodology can be found in IEC 62913-1, and "SGCG/M490/K_SGAM User Manual", 6.2.

6.1.5 Data modelling

Because of the increasing need of Smart Grids stakeholders, to deploy solutions offering a semantic level of interoperability, data modelling appears as the corner stone and foundation of the Smart Grids framework.

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

Currently the IEC framework relies on three main pillars, as far as data modelling is concerned, represented in Figure 9.

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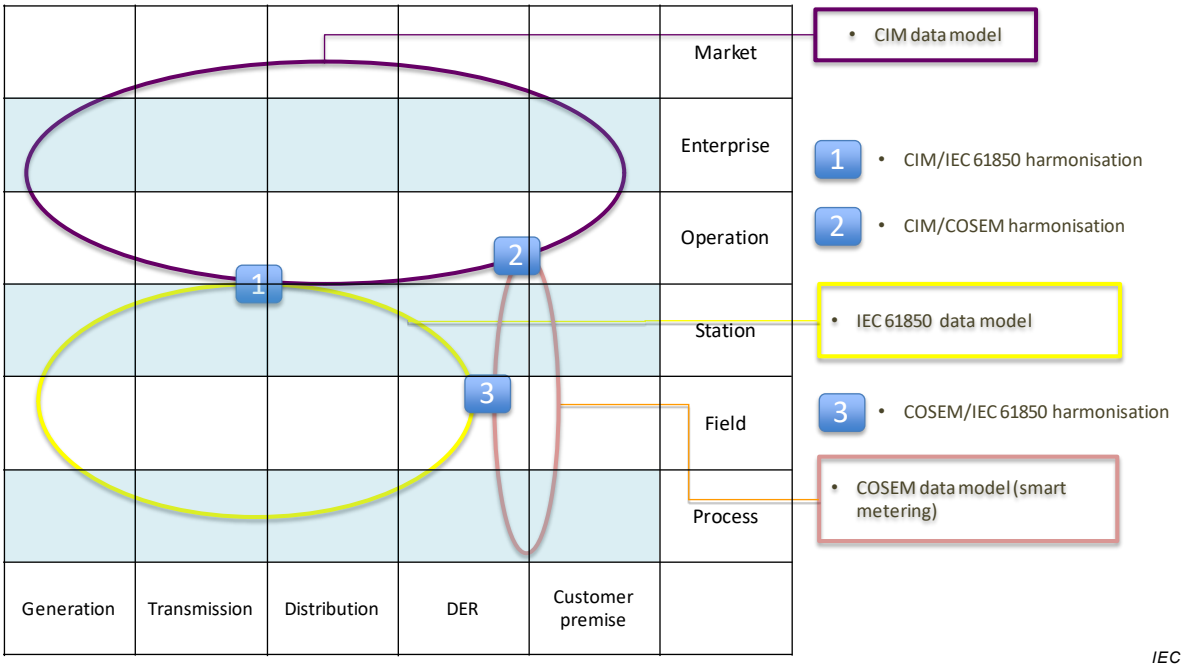

Figure 9 – Data modelling and harmonization work mapping

CIM (IEC 61970, IEC 61968, IEC 62325) provides the information model containing equipment and functions and their properties for power system management, analysis and related use cases (Generation, market and grid).

The Companion Specification for Energy Metering (COSEM) provides the information model containing equipment and functions and their properties for metering and related use cases.

Figure 9 also represents the three harmonisation works (i.e. the definition of unified shared semantic sub-areas, or formal transformation rules) which need to be performed in order to allow an easy bridging of these semantic domains:

- Harmonization between CIM and IEC 61850, mostly to seamlessly connect the field to operation and enterprise level[6]
- Harmonisation between CIM and COSEM, mostly to seamlessly interconnect electricity supply and grid operation[7]
- Harmonisation between COSEM and IEC 61850, where smart metering may co-habit with Power Utility Automation systems[8]

6.1.6 Profiling methodology

A profile is a specification that governs information exchanged within a specific business exchange context. Profiles can be developed to serve the information needs of specific user groups. These user groups can be diverse and can be characterized either by geographic context or by application domain. Examples of such user groups could be for instance regional or country specific. Individual companies i.e. utilities or manufacturers can also develop their own profiles, as subsets of the more generic profiles of a user group.

6 See IEC 62361-102.

7 See IEC 62056-6-9.

8 See IEC TS 61850-80-4.

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One of the most important purposes of a profile is to help improve interoperability between systems. By adopting and implementing an accepted profile, one is, in a sense, entering into an informal agreement with entities that have adopted the same profile. Adopting a profile means increasing the possibilities for seamless information exchange and interoperability between systems. Open standards sometimes can be vague or have ambiguous specifications; the use of profiles can enforce one possible interpretation.

As an example, related to the CIM environment, each noun used in a 61968 message identifies a payload type. Payload types are typically derived from the IEC CIM or other semantic models. Payload types used by the parts of IEC 61968 are always derived from the IEC CIM and have design artefacts (e.g. XML Schema Definition XSDs) that describe their structure. Cases where XSDs are not required include:

- Messages using Resource Description Framework (RDF) payloads as defined by IEC 61968-13 and the IEC 61970-45x series.
- Response messages from services that dynamically generate XML (as in the case of SQL XML result sets).
- Non-XML compressed and encoded payloads.
- Encoded binary data (where XML formatting is not efficient as in the case of 'high speed data')

If an XSD is not available to describe the payload, it is the responsibility of the sender and receiver(s) to agree upon the specific formatting.

The CIM logical information model is described as a set of UML packages. The diagram in Figure 10 shows the use of the CIM from the perspectives of UML modelling and generation of design artefacts needed by integration tools. It illustrates the relationships between information models and contextual profiles that are used in conjunction with assembly rules in order to derive design artefacts.

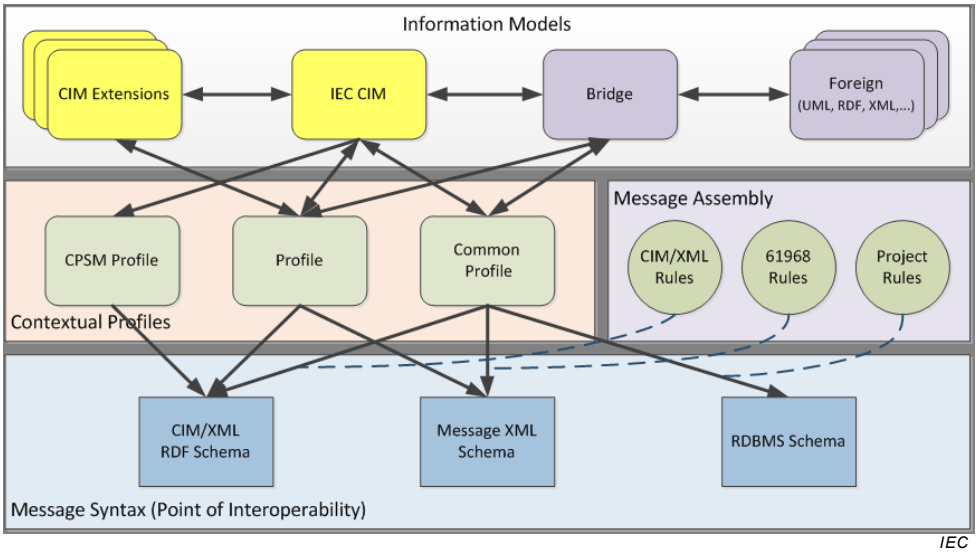

Figure 10 – Information Models, Profiles and Messages

Profiling is also envisaged with IEC 61850, COSEM, etc.

6.2 Reference Architecture overview

Using SGAM Domain & Zones, Figure 11 describes TC 57 standards, with some other TC related standards (TC 13 for Smart Metering Systems, TC 69 for electro-mobility).

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The Reference Architecture is based on the “Elements” (blue and red bordered boxes) and the “relationships / interactions” between the “Elements” mirrored on use cases. Elements and relationships have been mapped to SGAM domains and zones in Figure 11.

The Reference Architecture covers e the information and communication layer in a high level abstraction view.

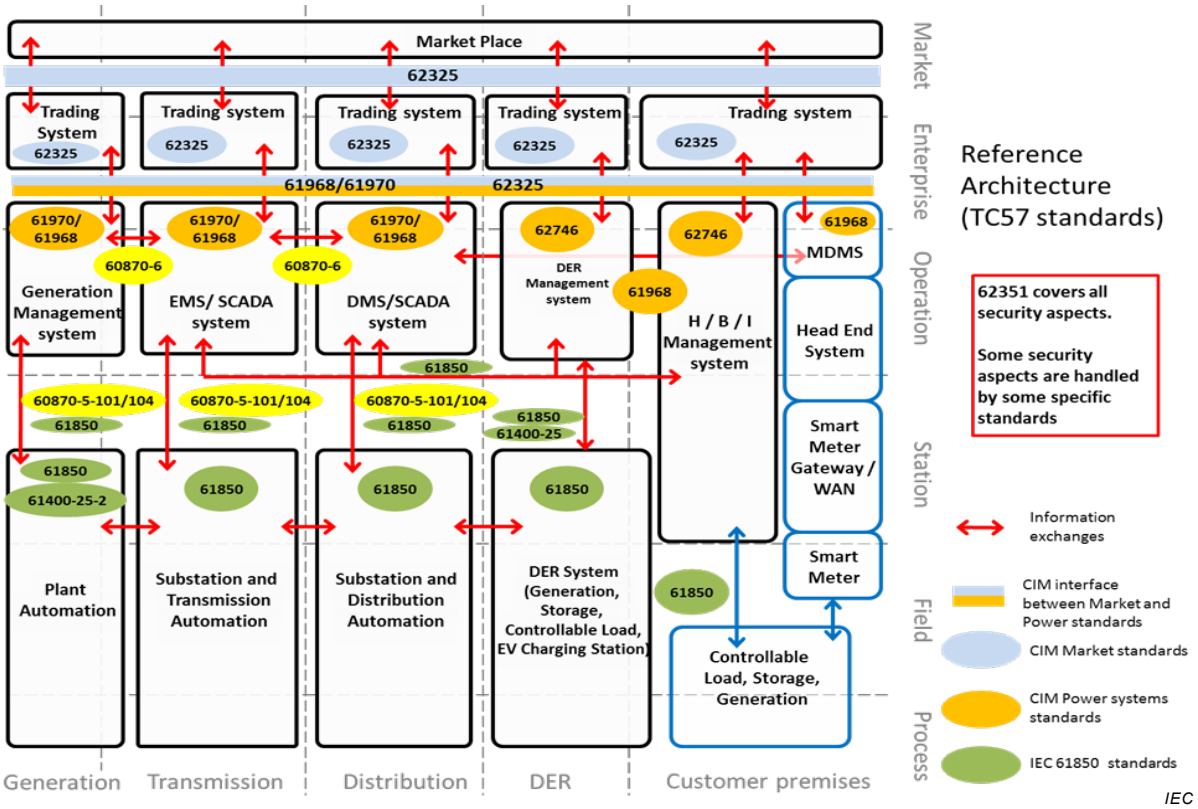

Figure 11 – Reference Architecture

Complementary standards are proposed by the IEC or other organisations. See D12 for a list of some of these complementary standards.

6.3 Elements of Reference Architecture

6.3.1 General

Figure 12 describes the power systems related standards that will be used by some of the following elements:

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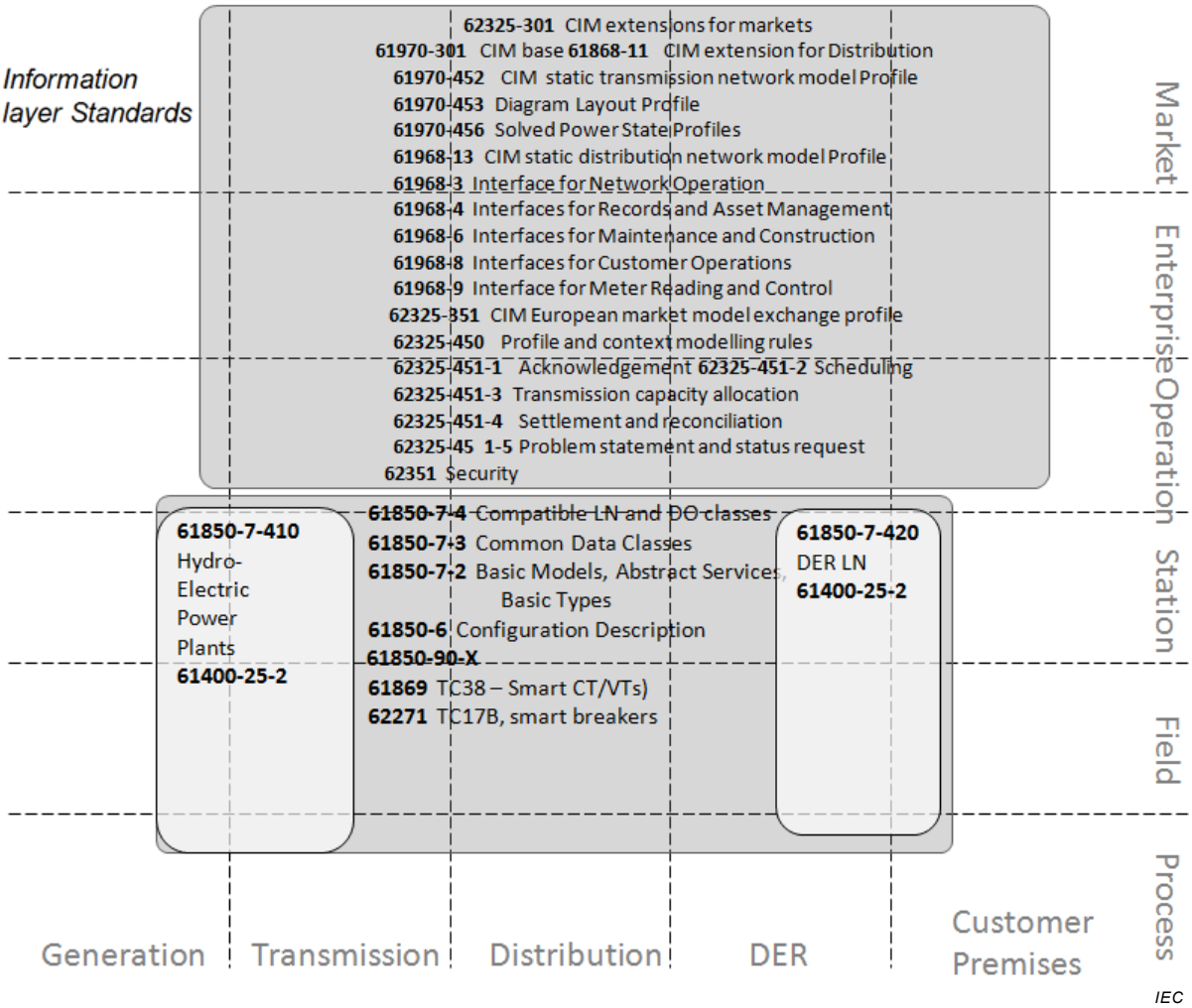

Figure 12 – Power systems information related standards

The following parts of IEC 62351 define security information elements like a MIB or a credential:

- IEC TS 62351-7: definition of information elements for network management in terms of (system or security) events (Management Information Base MIB-elements) Transport of these elements based on mapped protocols, IEC TS 62351-7 focusses on Simple Network Management Protocol (SNMP)
- IEC TS 62351-8: Information element for carrying role information to be used for role-based access control (basically an extension to X.509 certificates) Transport of this information is also targeted in IEC TS 62351-8
- IEC 62351-9: Information elements in terms of certificates needed for authentication described also the handling of certificates

Other parts of IEC 62351 (3, 4, 5, 6, 11) simply use them to achieve a dedicated protection goal.

6.3.2 Elements as Interface Reference Model abstract components

Various organizations cooperate to perform the planning, design, construction, operation, management and use of the Smart Grids. This segmentation by business function is provided

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in the Interface Reference Model (IRM) standard (IEC 61968-1). The IRM for Distribution[9] is presented in Figure 13:

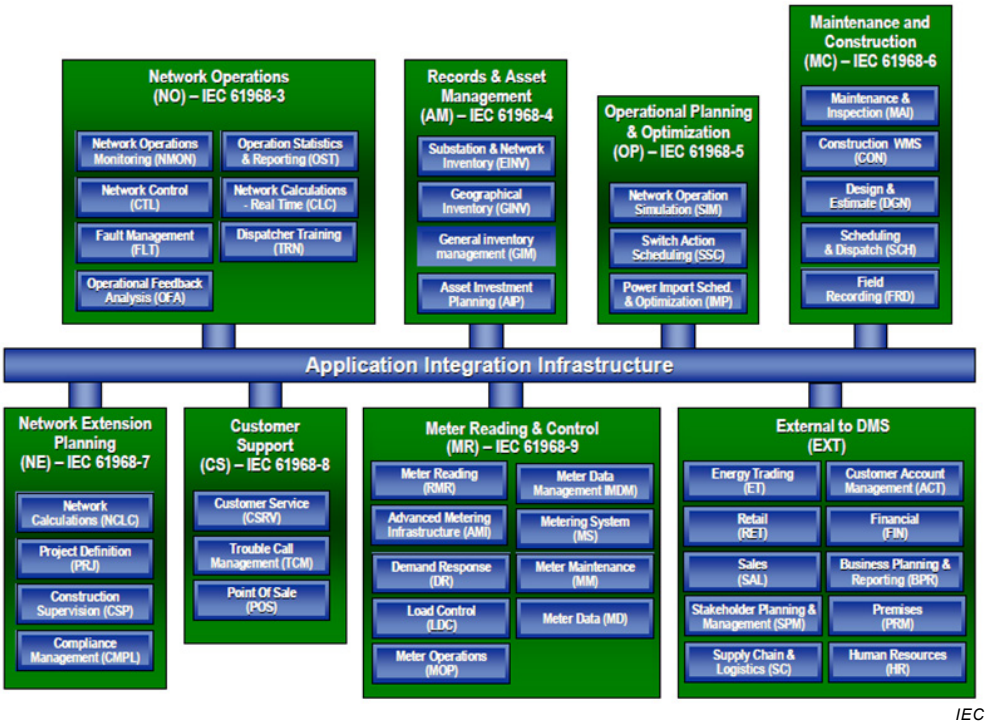

Figure 13 – Distribution IRM Model

In addition to providing an organizational framework for defining industry information exchange standards, use of a business-related model helps ensure independence from vendor-produced system solutions.

It is expected that a concrete (physical) application will provide the functionality of one or more abstract (logical) components as listed in IEC 61968-1. These abstract components are grouped by the business functions and sub-functions of the IRM. In the IEC 61968 series, the term abstract component is used to refer to that portion of a software system that supports one or more of the interfaces defined in the CIM-based standards. It does not necessarily mean that compliant software is delivered as separate modules.

Some abstract components may be used by several different business functions. For example, a component like power flow can be used for network operation, short term operational planning and optimization, and long term network extension planning. Much of the information exchanged for power flow purposes in each of these areas will therefore use many of the same Information Exchange Message Types.

Applications from different vendors package the functionality of these abstract components in different ways. To use the IEC 61968 services, each application must support one or more of the interfaces for the abstract components.

When the functions are implemented this lead to Application, when the applications are distributed on components this lead to Systems. The “IEC Mapping Tool” is a concrete example as described in http://smartgridstandardsmap.com/.

9 IRM is extended for Transmission and Markets.

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As another example, as described in M490 C-Reference Architecture, Figure 14 illustrates the flexible assignment of element, as functions, to SGAM segments.

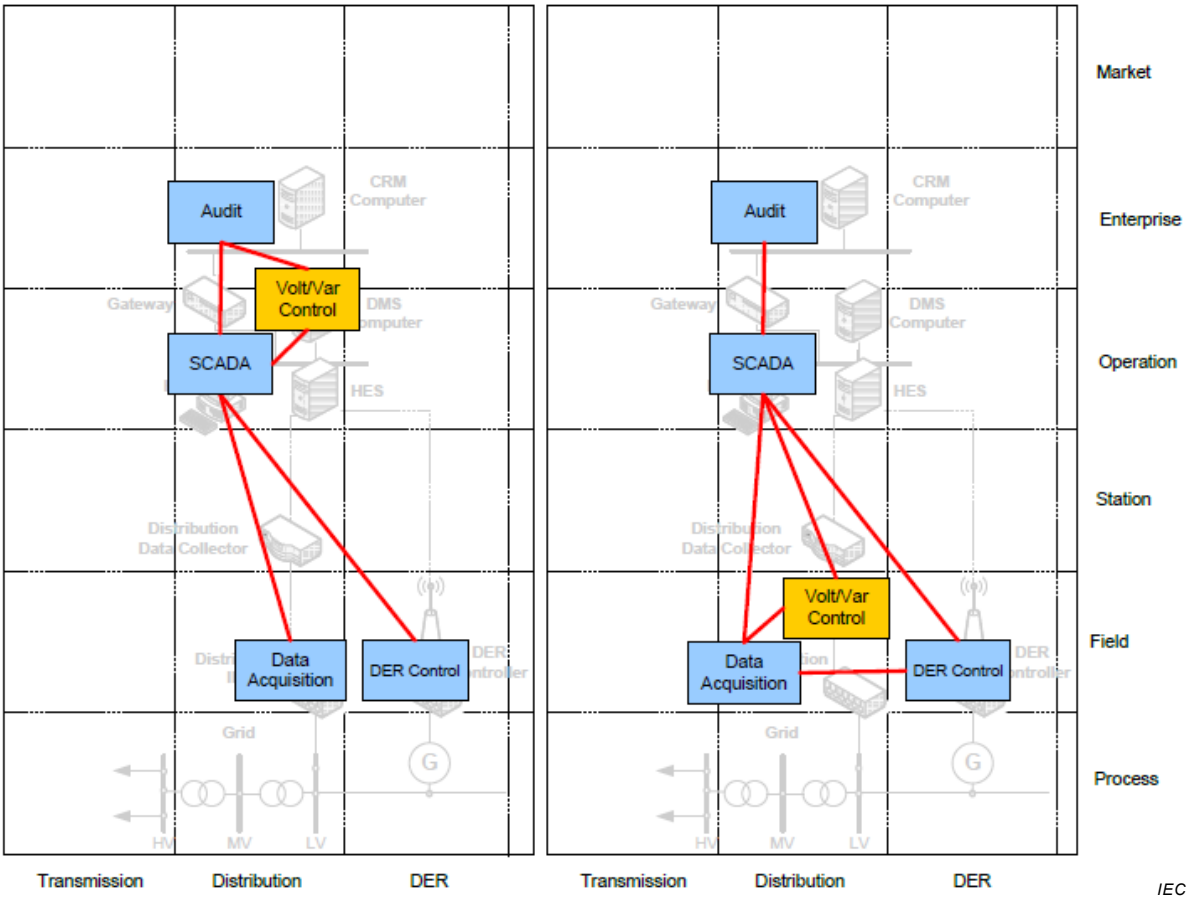

Figure 14 – Flexibility for assignment of element "Volt/Var Control" to SGAM segments (M490 C-Reference Architecture)

6.3.3 Elements as some typical Smart Grids Systems

Some typical Smart Grids systems are described in SGCG/M490/G as follow, and a list of Smart Grids components (SGCG/M490, Table 12) is provided in Figure 15.

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