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Smart grid standardization roadmap

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National foreword

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TECHNICAL REPORT

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Smart grid standardization roadmap

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SMART GRID STANDARDIZATION ROADMAP

FOREWORD

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IEC TR 63097, which is a Technical Report, has been prepared by IEC Systems Committee: Smart energy.

The text of this Technical Report is based on the following documents:

Enquiry draft	Report on voting
SyCSmartEnergy/50/DTR	SyCSmartEnergy/59/RVDTR

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

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INTRODUCTION

0.1 Context

Smart Grid is a term which embraces an enhancement of the power grid to accommodate the immediate challenges of today (such as the integration of distributed energy resources) and provides a vision for the future power. Its main focus is on an increased efficiency, reliability, observability and controllability of the power grid and connected users, for the benefit of all concerned actors.

“Smart Grid” is one of the major trends and markets which involve the whole energy conversion chain from generation to consumer. The power flow will change from a unidirectional power flow (from centralized generation via the transmission grids and distribution grids to the customers) to a bidirectional power flow. Traditional energy architectures consisting of bulk generation, transmission and distribution will be impacted by these new technologies and will need to adapt to support new configurations with more distributed energy generation and storage.

Furthermore, the way a power system is operated changes from the hierarchical top-down approach to a distributed control.

Consumers too are leveraging smart technologies along with new options for local energy generation and storage to access new energy options.

This will then demand a higher level of syntactic and semantic interoperability of the various products, solutions and systems that build up a power system. Furthermore, specific requirements like long term investment security and legacy systems need to be considered. These two rationales – interoperability and investment security – make it absolutely necessary to base all developments and investment on a sound framework of standards.

Thus standardization plays a key role to enable the development of new applications for today and a future power system.

As a reminder, within the IEC, SMB Strategic Group 3 “Smart Grid” published a first release 1.0 of the IEC Smart Grid roadmap.

This original document has been reworked, and updated thanks to IEC Systems Evaluation Group (SEG) 2, which was formed with the mission of assessing the need for an IEC system committee on Smart Grids.

This work is now undertaken by IEC SyC Smart Energy, and its first mission is to finalize this work.

As a reminder IEC SyC Smart Energy has the mission:

- to provide systems level standardization, coordination and guidance in the areas of Smart Grid and Smart Energy, including interaction in the areas of heat and gas;
- to widely consult within the IEC community and the broader stakeholder community to provide overall systems level value, support and guidance to the technical committees and other standards development groups, both inside and outside the IEC;
- to liaise and cooperate with the SEG Smart Cities and future SEGs, as well as the future Systems Resource Group.

Several updates to the IEC Smart Grid roadmap have been brought to this document, especially by including the latest publications and upcoming standards. This document also

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tries to take into account some of the relevant outcomes from other regions and countries, and among many sources, the work performed by the CEN-CENELEC-ETSI Smart Grid-Co-ordination Group [1][2][3][4][1] and the NIST SGIP roadmap [5][6].

At the current stage, the real scope considered in this approach remains the “Smart Grids”, meaning that the full Smart Energy scope has not been addressed yet (i.e. the consideration necessary to include the interactions with other energies such as gas, and heat).

Work is also underway within IEC SyC Smart Energy to progressively build a technical Smart Energy system framework. An alignment of this document with the IEC 62913[2] series will be performed as soon as these elements are available.

As a reminder, this document does not intend to present all standards which are applicable in the context of Smart Energy, but to highlight those which have been specifically designed and provide significant value to support a transition to a Smarter Energy, especially considering the need for an easier interoperability among devices and systems within the Smart Energy Domain.

This roadmap document is one element.

One other main element is the Smart Grid Standards Map (www.smartgridstandardsmap.com), a web tool presented in 5.4, and whose content will be aligned with this document.

Finally, IEC SyC Smart Energy also intends to create a specific relationship with user associations. The dissemination of the information included in this document will be one objective.

0.2 Overview

The aim of this document is to provide standards users with guidelines to select a most appropriate set of standards and specifications. These standards and specifications are either existing or planned, and are provided by IEC or other bodies also fulfilling use cases.

It also aims at creating a common set of guiding principles that can be referenced by end-users and integrators who are responsible for the specification, design, and implementation of Smart Energy Systems.

As a living document, this roadmap will be subject to future changes, modifications and additions, and will be incorporated into future editions.

At the current stage, the focus remains the “Smart Grids”. This means that the full Smart Energy scope has not been addressed yet (i.e. the consideration necessary to include the interactions with other energies such as gas, and heat) and will be considered in a future edition of this document.).

This roadmap presents an inventory of existing and future standards, and puts them into perspective regarding the different Smart Grid applications. The intention is to facilitate the choice of the relevant standards for all Smart Grid products, applications and systems, given the fact that such a scope is complex and moving.

The IEC, as the only international standardization organization in the field of electrotechnical standardization, is ideally positioned to provide such document. However, IEC is not the only

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[1] Numbers in square brackets refer to the Bibliography.

[2] Under preparation.

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body contributing to to Smart Energy standardization; this document shows that IEC covers only 50 % of the used standards or specifications.

Based on this assessment, this document tries to not restrict the set of standards, except the fact that preference is given to International Standards (IEC, ISO, ITU). Regional specificities are also taken into account, especially when they fill gaps not yet realized at an international level.

Other bodies are also considered as long as they fulfil the “open specification” criteria defined in 5.2.5.

Gaps between actual standards and future requirements are listed and will lead to recommendations for evolution within IEC (the recommendations are included in a separate IEC publication). This framework will be then at the core of new developments and benefits reached through the implementation of Smart Grid.

As a roadmap this document also shows possible developments and future trends in Smart Energy technologies: Evolutions in communication, centralization, micro-grids, etc. are outlined in 5.7.

0.3 Purpose of the document

The importance of these standards will vary in their relation to Smart Energy applications and solutions. A number of standards form a core set of standards, which are valid or necessary for nearly all Smart Energy applications. These standards will be considered as IEC priority standards. Their further promotion and development will be a key for the IEC to provide support for Smart Energy solutions. (See also http://www.iec.ch/smartgrid/standards/).

Besides these IEC priority standards, the goal will also be to provide an overview of the IEC standards specifically capable of serving as a base for Smart Energy. The objective is that the collection should be comprehensive and also provide an overview of all the standardization involved.

Furthermore, not only does the roadmap consider the available standards but also the coming ones (see in 5.2.5 the triggers attached to these definitions “available” and “coming”). With this the IEC will provide a necessary precondition for Smart Energy to become widely accepted by the market. Since Smart Energy investments are long-term investments, it is absolutely necessary to provide the stakeholders with a needed vision as a basis for a sustainable future investment.

A specific focus is put on interoperability standards, which will help to reach the goal of increased observability and controllability of the power system. In this respect the IEC offers the absolute precondition for a further promotion of Smart Grid. It offers as well the conditions for profiling the usage of these standards and then improves the interoperability as explained in 5.6. On the other hand, the IEC refrains from standardization of solutions or applications itself. This would actually block innovation and the further development of Smart Energy.

Even if standards from other Standards Development Organizations (SDOs) are not the main focus of this roadmap, they are part of the complete story, and so need to be included.

The IEC acknowledges the vast literature and documentation which is already available on the Smart Grid topic and, to a far lesser extent, also on the standardization of Smart Energy (some documents are identified in Annex C and in the Bibliography [5][6][7][8]).

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SMART GRID STANDARDIZATION ROADMAP

1 Scope

This document provides standards users with guidelines to select a most appropriate set of standards/specifications (either existing or coming, from IEC but possibly coming from other bodies) fulfilling the set of Smart Energy use cases, then relevant for Smart Energy project implementation.

It provides a summary of the core standards which form the pillars of the Smart Energy standards set.

Then the main areas of Smart Grid are investigated. The structure of this document has evolved in order to embrace the full scope of Smart Grids.

A new first area introduces the general IEC framework.

Then standards are presented, following these main guidelines:

– standards in relation with electrotechnics (planning the grid, integrating DER, coping with power electronics, coping with DC grids, and impact on the low voltage installations).
– standards related to communicating systems, divided into nineteen sections: generation management systems, FACTS, energy management systems, blackout prevention systems, advanced distribution management systems, distribution automation systems, smart substation automation systems, distributed energy resources operation systems, advanced meter infrastructure, meter-related back office systems, market place systems, demand response and load management systems, HBES/BACS systems, industrial automation systems, electrical storage management systems, electro-mobility systems, weather forecast systems, asset management and condition monitoring systems, micro-grid systems.
– standards which cover cross-cutting areas such as communication, data modelling, cyber-security, authentication, authorization, accounting, clock management, EMC, power quality, functional safety.

Annexes provide

– tables which indicate for each standard its main area of use;
– an overview of the core IEC standards;
– references to known Smart Grid/Smart Energy roadmaps provided by some regional bodies.

In total, this document identifies over 500 relevant standards/specifications and/or standard parts for the considered domain. Five electrotechnical domains, nineteen specific systems and nine cross-cutting topics have been analysed.

2 Normative references

There are no normative references in this document.

3 Terms, definitions and abbreviated terms

For the purposes of this document, the following terms and definitions apply.

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ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- IEC Electropedia: available at http://www.electropedia.org/
- ISO Online browsing platform: available at http://www.iso.org/obp

NOTE Definitions of Smart Grid components (shown in the Smart Grid system mappings) are given in 5.4.3.2.

3.1 Terms and definitions

3.1.1
ancillary services
services necessary for the operation of an electric power system provided by the system operator and/or by power system users

Note 1 to entry: System ancillary services may include the participation in frequency regulation, reactive power regulation, active power reservation, etc.

[SOURCE: IEC 60050-617:2009, 617-03-09]

3.1.2
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

[SOURCE: ISO/IEC/IEEE 42010:2011, 3.2]

3.1.3
available
<deliverable> which has reached its final stage (IS, TS, TR, …) by 2015-12-31.

Note 1 to entry: Refer to 5.2.5.3 for more details.

3.1.4
architecture framework
conventions, principles and practices for the description of architectures established within a specific domain of application and/or community of stakeholders

[SOURCE: ISO/IEC/IEEE 42010:2011, 3.4]

3.1.5
capability
function that a system is capable of running to support a certain business objective

Note 1 to entry: A capability may be described as a System Use Case (refer to IEC TS 62913-1[3)].

3.1.6
coming
<deliverable> having successfully passed the New Work Item Proposal (NWIP) process (or any formal equivalent work item adoption process) by 2015-12-31

Note 1 to entry: Refer to 5.2.5.3 for more details.

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3.1.7
DER
distributed energy resources
generators, including loads having a generating mode (such as electrical energy storage systems), connected to the low or medium voltage network, with their auxiliaries, protection and connection equipment, if any

[SOURCE: IEC 60050-617:2009/AMD2:–[4], 617-04-20, modified]

3.1.8
demand response
DR
incentivizing of customers by costs, ecological information or others in order to initiate a change in their consumption or feed-in pattern

Note 1 to entry: "Bottom-up approach" = customer decides.

Note 2 to entry: "Demand response" is defined in IEC 60050-617:2009/AMD1:2011, 617-04-16 as an action resulting from management of the electricity demand in response to supply conditions.

3.1.9
flexibility
elasticity of resource deployment (demand, storage, generation) providing ancillary services for the grid stability and/or market optimization (change of power consumption, reduction of power feed-in, reactive power supply, etc.)

3.1.10
interoperability
ability of two or more networks, systems, devices, applications, or components to interwork, to exchange and use information in order to perform required functions

3.1.11
SGAM domain
domain
one axis of the SGAM to cover the complete electrical energy conversion chain, currently partitioned into five: bulk generation, transmission, distribution, DER and customer premises

3.1.12
SGAM interoperability layer
layer
one axis of the SGAM to handle the interoperability abstract categories described in the GridWise Architecture model, currently partitioned into five: Business, Function, Information, Communication and Component

3.1.13
SGAM Smart Grid plane
plane formed by the domain and the zone axes for the management of the electrical process

3.1.14
SGAM zone
zone
one axis of the SGAM to represent the hierarchical levels of power system management, currently partitioned into six: Process, Field, Station, Operation, Enterprise and Market

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4 Under preparation. Stage at time of publication: IEC FDIS 60050-617:2009/AMD2.

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3.1.15
Smart Grid
electric power system that utilizes information exchange and control technologies, distributed computing and associated sensors and actuators, for purposes such as:

- to integrate the behaviour and actions of the network users and other stakeholders,
- to efficiently deliver sustainable, economic and secure electricity supplies

Note 1 to entry: Refer to 4.1.

[SOURCE: IEC 60050-617:2009/AMD1:2011, 617-04-13]

3.1.16
standard
document, established by consensus and approved by a recognized body, that provides, for common and repeated use, rules, guidelines or characteristics for activities or their results, aimed at the achievement of the optimum degree of order in a given context

Note 1 to entry: Refer to 5.2.5 for further details.

[SOURCE: IEC 60050-901:2013, 901-02-02]

3.1.17
system
set of interrelated elements considered in a defined context as a whole and separated from their environment

Note 1 to entry: System is defined in the Systems activities Administrative Circular AC/33/2013 as:

"a group of interacting, interrelated, or independent elements forming a purposeful whole of a complexity that requires specific structures and work methods in order to support applications and services relevant to IEC stakeholders".

However, in the context of this document, it has been considered in addition as a typical industry arrangement of components and systems, based on a single architecture, serving a specific set of use cases.

[SOURCE: IEC 62559-2:2015, 3.7]

3.1.18
use case
specification of a set of actions performed by a system, which yields an observable result that is, typically, of value for one or more actors or other stakeholders of the system

[SOURCE: ISO/IEC 19505-2:2012, 16.3.6]

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3.2 Abbreviated terms

Abbreviation	Meaning
3GPP	3rd Generation Partnership Project
6LoWPAN	IPv6 over Low power Wireless Personal Area Networks
ADSL	Asymmetric digital subscriber line
AMI	Advanced Metering Infrastructure
AMR	Advanced Meter Reading
AN	Access Network
ANSI	American National Standard Institute
AS	Application server
BACS	Building Automation and Control System
CC	Control Centre
CEM	Customer Energy Management (see 5.4.3.2 for details)
CEN	European Committee for Standardization (Comité Européen de Normalisation)
CENELEC	European Committee for Electrotechnical Standardization (Comité Européen de Normalisation Electrotechnique)
CHP	Combined Heat and Power
CIM	Common Information Model (IEC 61970 and IEC 61968 series)
CIS	Customer Information System
COMTRADE	Common Format for Transient Data Exchange (IEC 60255-24)
COSEM	Companion Specification for Energy Metering
CT	Current Transformer
cVPP	Commercial Virtual Power Plant
DA	Distribution Automation
DCS	Distributed Control System (usually associated with generation plant control systems)
DER	Distributed Energy Resources (see 5.4.3.2 for details)
DIN	Deutsches Institut für Normung
DLMS	Distribution Line Message Specification
DMS	Distribution Management System (see 5.4.3.2 for details)
DR	Demand Response
DSO	Distribution System Operator
ebIX®	(European forum for) energy Business Information Exchange
EC	European Commission
ECP	Electrical Connection Point
EDM	Energy Data Management
EFET	European Federation of Energy Traders
EGx	EU Smart Grid Task Force Expert Group x (1 to 3)
EMC	Electro Magnetic Compatibility
EMG	Energy Management Gateway (see 5.4.3.2 for details)
EMS	Energy Management System (see 5.4.3.2 for details)
ENTSO-E	European Network of Transmission System Operators for Electricity
ERP	Enterprise Resource Planning
ESO	European Standardization Organization
ETSI	European Telecommunications Standards Institute
EV	Electrical Vehicle

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Abbreviation	Meaning
FACTS	Flexible Alternating Current Transmission Systems (see 5.4.3.2 for details)
FEP	Front End Processor (see 5.4.3.2 for details)
FLISR	Fault Location Isolation and Service Restoration
GIS	Geographic Information System (see 5.4.3.2 for details)
GOOSE	Generic Object Oriented Substation Event (IEC 61850-7-2)
GPS	Global Positioning System
GSE	Generic Substation Event (IEC 61850-7-2)
GSM	Global System for Mobile
GSSE	Generic Substation State Event (IEC 61850-7-2)
GWAC	GridWise Architecture Council
HAN	Home Area Network
HBES	Home and Building Electronic System
HDSL	High-bit-rate Digital Subscriber Line
HES	Head-End System (see 5.4.3.2 for details)
HSPA	High Speed Packet Access
HV	High Voltage
HVDC	High Voltage Direct Current
ICT	Information and Communication Technology
IEC	International Electrotechnical Commission
IED	Intelligent Electronic Device
IEEE	Institute of Electrical and Electronics Engineers
IETF	Internet Engineering Task Force
IP	Internet Protocol
IPv6	Internet Protocol Version 6
IS	International Standard
ISO	International Organization for Standardization
IT	Information Technology
ITU	International Telecommunication Union
ITU-T	ITU's Telecommunication standardization sector (ITU-T)
JWG	Joint Working Group (of CEN, CENELEC and ETSI on standards for Smart Grids)
KNX	EN 50090 (also known as Konnex)
L2TP	Layer 2 Tunnelling Protocol
LAN	Local Area Network
LNAP	Local Network Access Point (see 5.4.3.2 for details)
LR	WPAN Low Rate Wireless Personal Area Network
LV	Low Voltage
M/490	Mandate issued by the European Commission to European Standardization Organizations (ESOs) to support European Smart Grid deployment [1]
MAC	Media Access Control
MADES	Market Data Exchange Standard
MDM	Meter data management (see 5.4.3.2 for details)
MMS	Manufacturing Message Specification (ISO 9506)
MPLS	Multiprotocol Label Switching
MPLS-TP	MPLS Transport Profile

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Abbreviation	Meaning
MV	Medium Voltage
NAN	Neighbourhood Area Network
NIC	Network Interface Controller (see 5.4.3.2 for details)
NNAP	Neighbourhood Network Access Point (see 5.4.3.2 for details)
NSM	Network and System Management (IEC TS 62351-7)
NWIP	New Work Item Proposal
OASIS	Organization for the Advancement of Structured Information Standards
OMS	Outage Management System (see 5.4.3.2 for details)
OPC	OLE for Process Control
OPC UA	OPC Unified Architecture
OSI	Open Systems Interconnection
OSGP	Open Smart Grid Protocol
PEV	Plug-in Electric Vehicles (see 5.4.3.2 for details)
PLC	Power Line Carrier communication
PLC	Programmable Logic Controller
PV	Photo-Voltaic – may also refer to plants using photo-voltaic electricity generation
QoS	Quality of Service
RBAC	Role-Based Access Control (IEC TS 62351-8)
RPL	Routing Protocol for Low power and lossy networks (LLN)
SAS	Substation Automation System
SCADA	Supervisory Control and Data Acquisition (see 5.4.3.2 for details)
SCL	System Configuration Language (IEC 61850-6)
SDO	Standards Development Organization
SG	Smart Grid
SGAM	Smart Grid Architecture Model – delivered by the SG-CG-RA team as part of the mandated deliveries of M/490, which proposes 3 different axes to map a Smart Grid feature (Domains, Zones and Layers) – details available in [2]
SG-CG	Smart Grid Co-ordination Group, reporting to CEN-CENELEC-ETSI and in charge of answering the M/490 mandate
SM-CG	Smart Metering Co-ordination Group, reporting to CEN-CENELEC-ETSI and in charge of answering the M/4441 mandate
SLA	Service Level Agreement
SNMP	Simple Network Management Protocol
SOA	Service Oriented Architecture (IEC TR 62357)
SIPS	System Integrity Protection System
TC	Technical Committee
TDM	Time Division Multiplexing
TF	Task Force
TMS	Transmission Management System
TR	Technical Report
TS	Technical Specification
TSO	Transmission System Operator
tVPP	technical Virtual Power Plant
UC	Use Case
UMTS	Universal Mobile Telecommunications System
VAR	Volt Ampere Reactive – unit attached to reactive power measurement

AVA Documents
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Abbreviation	Meaning
VLAN	Virtual Local Area Network
VoIP	Voice over IP
VPP	Virtual Power Plant
VT	Voltage Transformer
WAMS	Wide Area Measurement System (see 5.4.3.2 for details)
WAN	Wide Area Network
WG	Working Group
WPAN	Wireless Personal Area Network
xDSL	Digital Subscriber Line
XML	eXtensible Markup Language

4 Smart Grid context

4.1 Smart Grid definitions

“Smart Grid” is today used as a marketing term, rather than a technical definition. For this reason there is no well-defined and commonly accepted scope of what “smart” is and what it is not.

SG3 originally considered Smart Grids as the concept of modernizing the electric grid. The Smart Grid is integrating the electrical and information technologies in between any point of generation and any point of consumption.

This document relies on the definition of Smart Grid in IEC 60050-617:2009/AMD1:2011, 617-04-13). See 3.1.15.

Examples:

- Smart metering could significantly improve knowledge of what is happening in the distribution grid, which nowadays is operated rather blindly. For the transmission grid an improvement of the observability of system-wide dynamic phenomena is achieved by Wide Area Monitoring and System Integrity Protection Schemes.
- HVDC and FACTS improve the controllability of the transmission grid. Both are actuators, e.g. to control the power flow. The controllability of the distribution grid is improved by load control and automated distribution switches.
- Common to most of the Smart Grid technologies is an increased use of communication and IT technologies, including an increased interaction and integration of formerly separated systems.

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Other definitions may be mentioned such as the one[5] considered by the European Technology Platform Smart Grid [8].

4.2 Smart Grid drivers

On one hand, large parts of the power grid infrastructure (including large power plants) are reaching their designed end of life time, since a large portion of the equipment in the industrialized countries was installed in the 1960s.

On the other hand, there is a strong political and regulatory push for more competition and lower energy prices, more energy efficiency and an increased use of “greener” energy like solar, wind, biomass and water, potentially largely distributed.

In industrialized countries the load demand has decreased or remained constant in the previous decade, whereas developing countries have shown a rapidly increasing load demand.

In any case, efficient and reliable production, transmission and distribution of electricity remain a fundamental requirement for providing societies and markets with essential energy resources.

Thus the utilities as well as all energy-related stakeholders are today in a period of change and evolution. This has to be done in a context where, in many countries, regulators and liberalization are forcing utilities to reduce costs for the transmission and distribution of electrical energy.

In addition, consumers are being offered a growing range of energy options based on the expanding availability of local energy generation and storage technology. Utilities will need to adapt to this new competitive landscape for energy services and this will require greater emphasis on the need for standards developed in co-ordination with the sectors responsible for these new technologies.

Therefore new methods (mainly based on the efforts of modern information and communication techniques) to operate power systems, to produce and consume energy in a better way, to secure a sustainable and competitive energy supply, are required.

The key market drivers behind Smart Grid solutions are

- increased usage of renewable (intermittent and potentially largely distributed) energy resources, and associated new network codes implementation,
- deeper involvement of energy producers and consumers in optimising the energy and infrastructure usage,

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5 A Smart Grid is an electricity network that can intelligently integrate the actions of all users connected to it – generators, consumers and those that do both – in order to efficiently deliver sustainable, economic and secure electricity supplies.

A Smart Grid employs innovative products and services together with intelligent monitoring, control, communication, and self-healing technologies to:

- better facilitate the connection and operation of generators of all sizes and technologies;
- allow consumers to play a part in optimizing the operation of the system;
- provide consumers with greater information and choice of supply;
- significantly reduce the environmental impact of the whole electricity supply system;
- deliver enhanced levels of reliability and security of supply.

Smart Grid deployment needs to include not only technology, market and commercial considerations, environmental impact, regulatory framework, standardization usage, ICT (Information & Communication Technology) and migration strategy but also societal requirements and governmental edicts.

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- energy efficiency at all steps of energy handling (from producing down to consuming),
- sustainability,
- competitive energy prices,
- security of supply,
- ageing infrastructure and workforce, and
- growing availability of competitive energy options for consumers,
- availability of new technologies, such as DER, EVs, widespread (IoT) communications, and user applications to simplify decisions and decision management.

More specifically, the utilities have to master the following challenges:

- significant regulatory push;
- fluctuating intermittent renewables;
- increased use of distributed energy resources, including coordinating the grid management with large numbers of stakeholders whose equipment has different constraints and capabilities;
- new type of loads (hybrid/e-cars, energy storage);
- ageing infrastructure and workforce;
- high power system loading;
- increasing distance between generation and load;
- cost pressure;
- utility unbundling;
- increased energy trading;
- transparent consumption and pricing for active consumers;
- local energy generation with potential storage capabilities;
- mitigation of increased risks of cyber-attacks and/or related regulation requirements (thus new cyber-security requirements and their impacts on processes and systems);
- mastering the new technologies (including the one related to cyber-security).

It also happens in a very fast changing context such as:

- the very wide spreading of Internet technologies down to the level of any objects (Internet of Things – IoT);
- the increasing de-coupling between the IT layer and the OT layer (any OT has progressively its counterpart in the IT layer), also known as IT/OT convergence.

The priority of local drivers and challenges might differ from place to place. Some examples:

China is promoting the development of Smart Grid because of the high load increase and the need to integrate renewable energy sources.

The Indian power system is characterized by high inefficiency because of high losses (technical as well as very high non-technical losses). Smart Metering and flexible power system operation will make a change for the better.

The challenge in Europe is to implement Smart Grid technologies into an existing and running power grid. In addition the European Smart Grid has to bridge between different technologies and regulations used in different European countries

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In all countries with high portion of overhead lines in the distribution grid, the frequency of outages is high. The number of outages, outage duration and energy not delivered in time can be reduced by using Smart Grid technologies.

5 IEC Smart Grid Standardization Roadmap

5.1 High-level summary

5.1.1 IEC Core standards

The IEC can already look back at an impressive collection of standards in the field of Smart Grid. Some of these standards are considered to be core standards for any implementation of Smart Grid now and in the future.

Core standards are standards that have an enormous effect on any Smart Grid application and solution. They are seen as a backbone of a future Smart Grid.

These core standards form the “backbone” of the IEC standards portfolio. See Table 1. Refer to Annex B to get more insights on these standards.

Table 1 – Smart Grids – IEC core standards

Core standard or series	Title	Topic
IEC 61970	Energy management system application program interface (EMS-API)	Actually the core part of the CIM (Common Information Model)
IEC 61968	Application integration at electric utilities – System interfaces for distribution management	Applying mainly to: Generation management systems, EMS (Energy Management System); DMS (Distribution Management System); DA; SA; DER; AMI; DR; E-Storage
IEC 62325	Framework for energy market communications	CIM (Common Information Model) based, Energy market information exchange Applying mainly to: Generation management systems, EMS (Energy Management System); DMS (Distribution Management System); DER; AMI; DR; meter-related back office systems; E-Storage
IEC 61850	Communication networks and systems for power utility automation	Power Utility Automation, Hydro Energy Communication, Distributed Energy Resources Communication Applying mainly to: Generation management systems, EMS; DMS; DA; SA; DER E-Storage; E-mobility
IEC 62056	Electricity metering data exchange – The DLMS/COSEM suite	COSEM Applying mainly to: DMS; DER; AMI; DR; Smart Home; E-Storage; E-mobility Data exchange for meter reading, tariff and load control
IEC 62351	Power systems management and associated information exchange – Data and communications security	Applying mainly to: Security for all systems
IEC 61508	Functional safety of electrical/electronic/programmable electronic safety-related systems	Applying to all systems

As a coming one, the IEC 62913 series gathering generic Smart Grid requirements will progressively appear as a cornerstone of the standards of the domain.

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5.1.2 Other IEC highly important standards

Besides the core standards, IEC also offers a number of highly important standards for Smart Grid. See Table 2.

Table 2 – Smart Grids – Other IEC highly important standards

Standard or series	Topic
IEC TR 62357-1	Power utilities Reference Architecture – SOA Applying mainly to: Energy Management Systems; Distribution Management Systems; DER management systems, market and trading systems, DR systems, meter-related back office systems
IEC 60870-5	Telecontrol Applying mainly to: EMS; DMS; DA; SA
IEC 60870-6	TASE2 Inter Control Center Communication Applying mainly to: EMS; DMS
IEC TR 61334	"DLMS" Distribution Line Message Specification Applying mainly to: AMI
IEC 61400-25	Wind Power Communication Applying mainly to: DER management systems (Wind farms); EMS; DMS;
IEC 61851	EV-Communication Applying mainly to: E-mobility
IEC 62443	Industrial communication networks – Network and system security Applying mainly to: All
ISO/IEC 15118	Road vehicles – Vehicle to grid communication interface Applying mainly to: E-mobility
ISO/IEC TR 27019	Information technology – Security techniques – Information security management guidelines based on ISO/IEC 27002 for process control systems specific to the energy utility industry Applying mainly to: All

5.2 General framework

5.2.1 Overview

5.2.2 General method used for presenting existing Smart Grid standards

Considering the main expectation of readers of Clause 5, i.e. to get a standards selection guide, the entry points considered for presenting the existing Smart Grid standards are the Smart Grid systems as introduced in in 5.5.

The list of considered systems is provided in 5.5.

NOTE This list represents today's optimum, based on today's requirements, regulations and technologies. It may change for future reasons – technology evolution, new regulation, new market needs.

These systems are just to be considered as typical examples.

This list is considered as complete enough as soon as all major standards are exposed in a meaningful and appropriate context.

Then systems are mapped on the SGAM reference model (see 5.5.2.1). This mapping shows which standards are to be considered and where to use them.

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Standards are selected from standardization bodies, following the ranking method proposed in 5.2.5. For each of the listed standards “maturity information” according to 5.2.5.3 and 5.2.5.4 is provided.

This approach will be used as a template for any system-related section of this document.

Some cross-cutting domains (such as EMC, power quality, functional safety, security or communication) are treated separately in 5.10 to avoid too many repetitions and/or provide a global, higher level picture.

This means that cross-cutting standards may also apply to dedicated systems. Refer to each system details for more details. More specifically, 5.5.2.3 indicates how the upper OSI layers of communication, presented in each system, are bound to the lower OSI layers of communication (present in the general requirements subclause 5.10.1 dealing with communication).

In Annex A, tables provide lists of standards sorted by standardization bodies, their maturity levels and indicating the systems where the standards may be used.

5.2.3 Content of this document

This document results from the IEC SyC Smart Energy experts’ assessment (based on the former IEC SG3 and SEG2 group experts), and is intended to depict the portfolio of International Standards which may be used to support Smart Grids/Energy deployment worldwide.

The goal of this document is to facilitate interoperable solutions based on standards. This framework will assist Smart Grid system owners and others to specify their Smart Grid solutions corresponding to their own requirements and taking into account specific national legislation and local situations.

This document provides a selection guide, setting out, for the most common Smart Grid systems as introduced in 5.5,

- the set of possible “System Capabilities” (see 3.1.5) they can support, and
- which standards may be used, where, and for which purpose.

5.2.4 Limits of scope and usage

Here are some limits the reader of this document should be aware of.

- The list of Generic System Capabilities per sub-system cannot be exhaustive.
- The standards listed in this document represent a selection according to the rules set in 5.2.5.2 and 5.2.5.3. The list is not comprehensive.
- Detailed “application notes” for the standards are not in the scope of this document.
- The generic UCs are limited to “typical” applications. Special customized applications are not considered.
- Proprietary or non-standardized solutions covering the generic UCs are not considered in this document.
- This document represents the current status of the available and upcoming standards (considering their “maturity” level indicated in 5.2.5.3).
- Standardization projects which do not fulfil the maturity-time constraints defined in 5.2.5.3 are not part of this document.

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5.2.5 Selection of standards

5.2.5.1 General

All standards identified in this document have been selected by applying the following rules.

5.2.5.2 Standardization body ranking

In order to identify a standard fulfilling a defined set of requirements, the following procedure has been adopted.

1) This document has identified standards from the IEC, where available.
2) Where no standards were available from 1), then this document has considered ISO, or ITU standards.
3) If no standards from either 1) or 2) were available to support a particular set of requirements, then “open specification” (see criteria below) can be considered.

“Open specifications” that are considered applicable from this document's point of view, comply with the following criteria.

a) The specification is developed and/or approved, and maintained by a collaborative consensus-based process.
b) Such process is transparent.
c) Materially affected and interested parties are not excluded from such process.
d) The specification is subject to RAND/FRAND Intellectual Property Right (IPR) policies in accordance with the IEC Patent policy [11].
e) The specification is published and made available to the general public under reasonable terms (including for reasonable fee or for free).

NOTE Considering the purpose of this document, i.e. a selection guide, technical reports are also considered in the list of applicable Smart Grid standards, as long as they followed a neutral review and voting process, by the bodies listed above.

5.2.5.3 Maturity level

Two maturity levels of the standards are considered:

- A deliverable that has reached its final stage (IS, TS, TR, etc.) by 2015-12-31 is identified as “AVAILABLE”.
- A deliverable that has successfully passed the NWIP process (or any formal equivalent voting gates if NWIP is not within the standard process for issuing the considered deliverable) by 2015-12-31 is identified as “COMING”.

Further sets of deliverables (including newly developed ones) should be available in due course.

NOTE 1 "COMING" standards listed are presented with a brief summary of their scope.

NOTE 2 A specification may appear as “coming” while in reality it is already available. This is the consequence of the chosen trigger of 2015-12-31 and the time needed for the editorial team to compile the information. It is almost impossible to get a fully up-to-date list, because every day new standards are becoming available. However, coming back to the purpose of this document, the most important thing is for the reader to be aware that a document relates to the particular domain. In any case, the expected reader’s reflex is to check whether the said coming standards are available or not.

The same standard reference may appear in both AVAILABLE and COMING tables, when a release of this standard is available as such (fitting the rules defined above for AVAILABLE standards), but a new revision is in preparation (fitting the rules defined above for COMING standards).

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5.2.5.4 Release management

Should several releases of a standard exist, then – if not explicitly stated differently – the latest release is considered in this document.

If a standard reference appears both in available and coming tables, this means that an existing release is available, but a new version is coming.

5.2.6 Architecture framework: Reference architecture model (SGAM) introduction

5.2.6.1 General

NOTE The SGAM is a main outcome of the CEN-CENELEC-ETSI SG-CG/RA working group and is extensively described in [2].

The SGAM framework and its methodology are intended to present the design of Smart Grid use cases in an architectural but solution- and technology-neutral manner.

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 GWAC interoperability categories. Each layer covers the Smart Grid plane, which is spanned by electrical domains and information management zones. 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 of universality, localization, consistency, flexibility and interoperability.

5.2.6.2 SGAM Smart Grid plane

In general, power system management distinguishes between the 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 [9] and [10]). This Smart Grid plane (refer to Figure 1) enables the representation of the levels (hierarchical zones) of which power system management interactions between domains or inside a single domain take place.

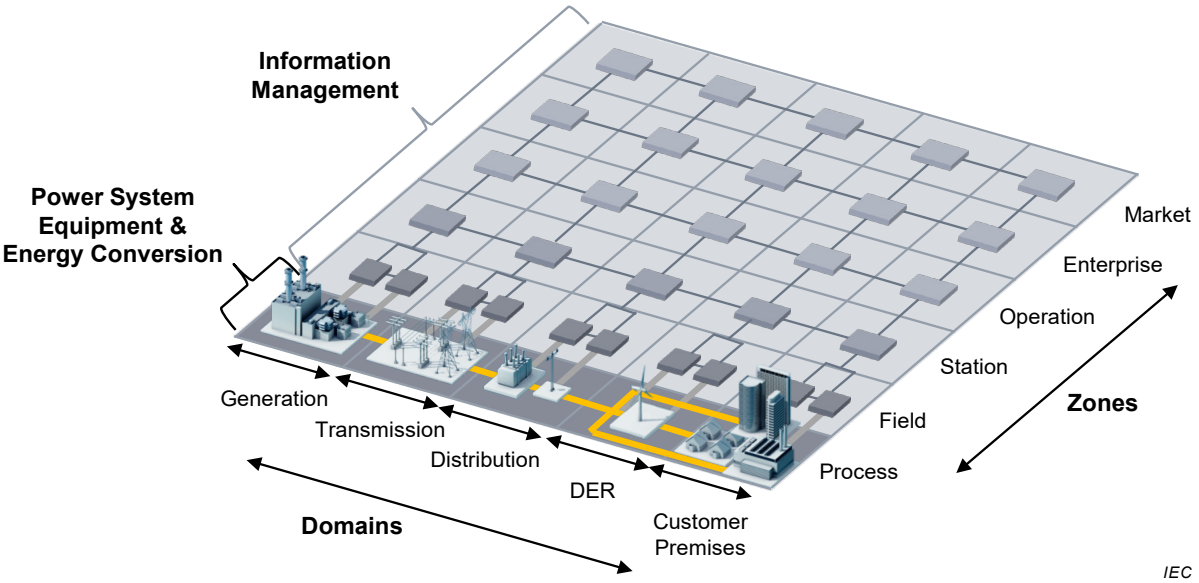

Figure 1 – Smart Grid plane – domains and hierarchical zones

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5.2.6.3 SGAM interoperability layers

As already introduced above in 5.2.6, the interoperability categories described in [10] are aggregated into five abstract interoperability layers (refer to Figure 2).

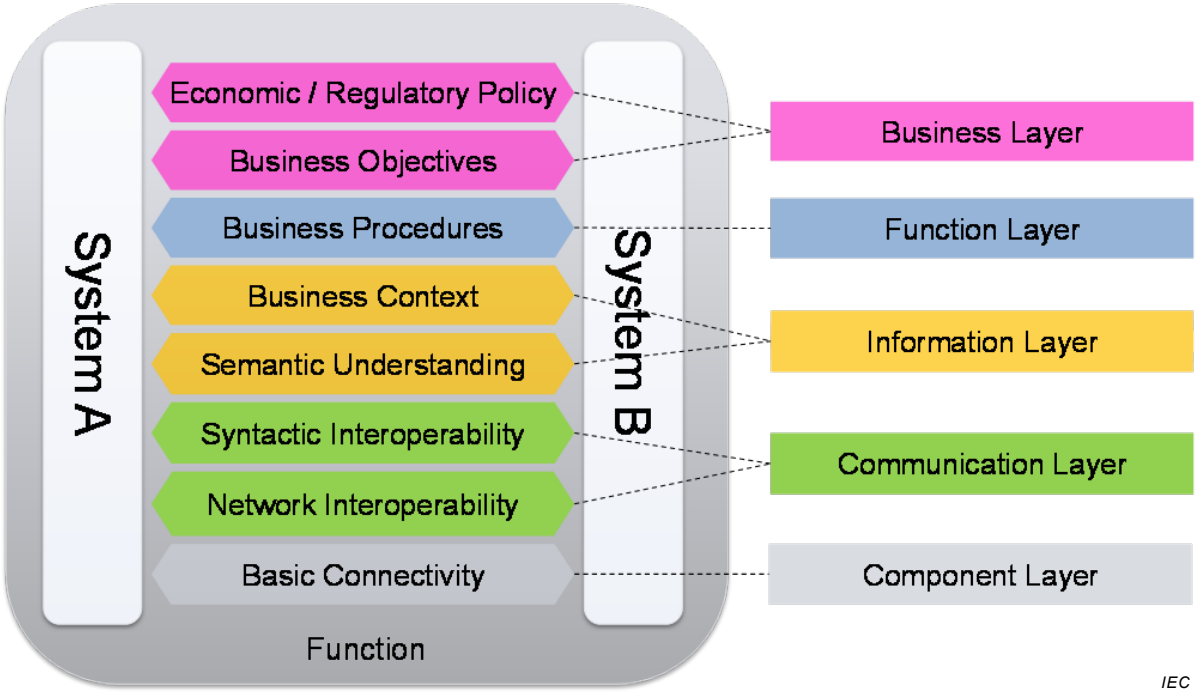

Figure 2 – Grouping into interoperability layers

5.2.6.4 SGAM framework

The SGAM framework is established by merging the concept of the interoperability layers defined in 5.2.6.3 with the previously introduced Smart Grid plane. This merge results in a model (see Figure 3) which spans three dimensions:

- X: Domain
- Y: Zone
- Z: Interoperability (Layer)

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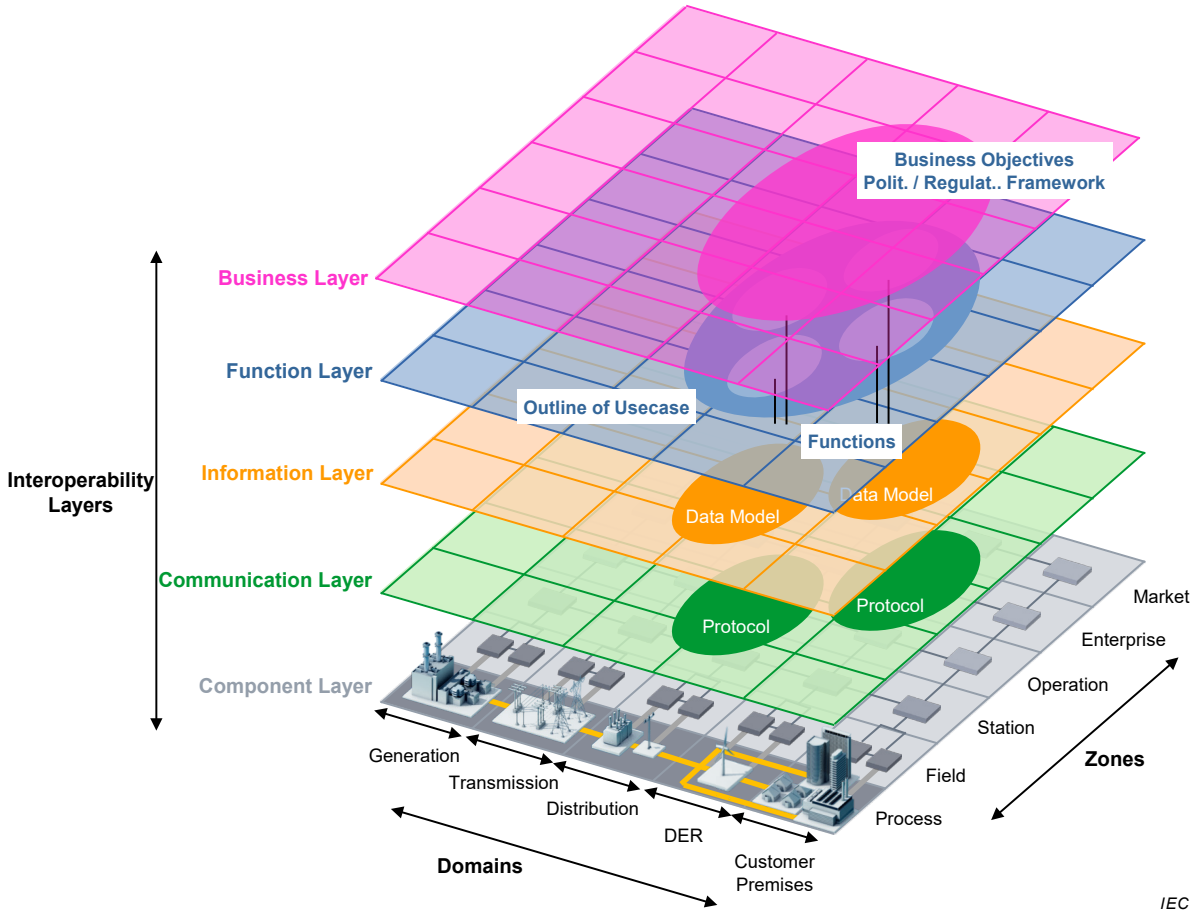

Figure 3 – SGAM framework

5.3 Use cases framework

5.3.1 Main principles and associated standards

Smart Grid is a means to support a set of applications, and standards are there to enable applications to be deployed. This means that the standardization process should offer a formal path between the application as "requested" by Smart Grid and the standards themselves, i.e. a "top-down" process.

For many reasons (including historical, organizational, technology maturity), in many cases, this path has not been the one implemented, leading to inconsistencies between standards, gaps and overlaps, or was partly implemented but with weak leak with other domains of expertise.

The challenge of IEC is to progressively promote this approach to all concerned TCs, but also provide guidance, technical framework, processes and tools to support it, and reach the expected consistency. This is one of the main challenges of the IEC System Committee.

This leads to the formalization of functional requirements, in a way which is independent from the body in charge of defining a standard, and which will ensure consistency within the Smart Grid system, i.e.:

- a single repository, where such definitions of functional requirements are hosted in a way that collaboration is supported, while different groups from different domains can work separately;
- a single glossary harmonized with IEC's terminology database(s);
- a single list of actors and roles for each domain;

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- a single method.

A use case-driven approach is necessary for a top-down development of standards. From a use case perspective actors and deliverables are identified and requirements are derived. This is the base for future system approach in standardization.

As a support and also as outcome of this approach, available and coming standards are listed in Table 3 and Table 4.

Table 3 – Use cases approach – Available standards

Layer/Type	Standard	Comments
General	IEC 60050 series	International Electrotechnical Vocabulary also available at www.electropedia.org
General	IEC 61360 series	Database standards – may be a good support for incremental approach of the Smart Grid (example: Actors list or use cases management)
Function	IEC PAS 62559	Template for specifying Energy systems – related use cases
General	IEC 62559-2	Use case methodology. Part 2: Definition of the templates for use cases, actor list and requirements list

Table 4 – Use cases approach – Coming standards

Layer/Type	Standard	Comments
General	IEC 62559-1	Use case methodology – Part 1: Concept and processes in standardization
General	IEC 62559-3	Use case methodology – Part 3: Definition of use case template artefacts into an XML serialized format
General	IEC TS 62913-1	Generic Smart Grid Requirements – Part 1: Specific application of Method and Tools for defining Generic Smart Grid Requirements
Business/Function	IEC TS 62913-2-1	Generic Smart Grid Requirements – Part 2-1: Grid related Domains
Business/Function	IEC TS 62913-2-2	Generic Smart Grid Requirements – Part 2-2: Market related Domain
Business/Function	IEC TS 62913-2-3	Generic Smart Grid Requirements – Part 2-3: Resources connected to the Grid Domains
Business/Function	IEC TS 62913-2-4	Generic Smart Grid Requirements – Part 2-4: Electric Transportation Domain

5.3.2 System Capabilities list

A summary list of the considered "System Capabilities" is provided in Table 5.

Then further in the document, for each system (refer to the list in Table 8), a specific section describes the detailed list of supported capabilities.

NOTE 1 Clusters are introduced here to provide an easy-to-read grouping of these elements.

NOTE 2 This list and associated wording still need to be harmonized under the umbrella of IEC System Committee.

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Table 5 – Summary list of System Capabilities

Cluster	System Capabilities
Access Control (Substation Remote Access Example)	Local access to devices residing in a substation, with higher level support (e.g. control centre) for authentication and authorization
	Local access to devices residing in a substation, with substation local authentication and authorization
	Remote access to devices residing in a substation, with higher level support (e.g. control centre) for authentication and authorization using a separate VPN
	Remote access to devices residing in a substation, with higher level support (e.g. control centre) for authentication and authorization using a communication protocol inherent security means
	Remote access to devices residing in a substation, with substation local authentication and authorization using a separate VPN
	Remote access to devices residing in a substation, with substation local authentication and authorization using a communication protocol inherent security means
(AMI) Billing	Obtain scheduled meter reading
	Set billing parameters
	Add credit
	Execute supply control
Billing	Obtain meter reading data
	Support prepayment functionality
	Manage tariff settings on the metering system
	Consumer move-in/move-out
	Supplier change
Blackout management	Blackout prevention through WAMS
	Provision of black start facilities for grid restoration
	Restore power after blackout
	Shedding loads based on emergency signals
	Under frequency shedding
(AMI) Collect events and status information	Manage supply quality
(AMI) Configure events, statuses and actions	Configure meter events and actions
	Manage events
	Retrieve AMI component information
	Check device availability
Connect an active actor to the grid	Managing generation connection to the grid
	Managing micro-grid transitions
Controlling the grid (locally/ remotely) manually or automatically	Enable multiple concurrent levels of control (local-remote)
	Feeder load balancing
	Switch/breaker control
Customer	Change of transport capacity responsible
	Change of balance responsible party
	Change of metered responsible
	Change of supplier
	End of metered data responsible
	End of supply
	Notify meter point characteristics
	Query metering point characteristics
	Request metering point characteristics
(AMI) Customer information provision	Provide information to consumer

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Cluster	System Capabilities
Demand and production (generation) flexibility	Generation forecast
	Load forecast
	Load forecast of a bunch of prosumers in a DR program (from remote)
	Managing energy consumption or generation of DERs via local DER energy management system bundled in a DR program
	Managing energy consumption or generation of DERs and EVSE via local DER energy management system to increase local self-consumption
	Participating in the electricity market
	Receiving metrological or price information for further action by consumer or CEM
	Registration/deregistration of customers in DR program
	Registration/deregistration of DER in DR program
(AMI) Energy market events	Manage consumer moving in
	Manage customer gained
	Manage customer lost
	Manage customer moving out
Exchange of metered data	Measure collected data
	Measure for imbalance settlement
	Measure for labelling
	Measure for reconciliation
	Measure, determine meter read
	Measure, determine meter read for switch
Flexibility markets	Operate flexibility markets
Generation Maintenance	Commissioning and Maintenance strategy (CMMS) definition
	Collection of additional maintenance counters for Boiler and Steam Turbine stress
	Collection of switching cycles and operating hours (maintenance counters)
	Condenser maintenance optimization
	Condition based operational advisories
	Field alarms collection for maintenance
	Field data collection for corrective and reactive maintenance
	Field data collection for predictive or condition based maintenance
	Field data collection for preventive maintenance
	Risk assessment
Generation Operation Scheduling	Ancillary services and reserve products control
	Day-ahead fleet scheduling
	Day-ahead hydro plant valley scheduling
	Fuel and other resources allocation, cogeneration and other by-products production
	Intra-day fleet scheduling
	Plant scheduling
Generation Transverse	Emissions compliance assessment
	Emissions reporting
	Equipment actual availability monitoring
	Performance monitoring
	Permit to work management
	Plant capability estimation
	Production reporting
Grid reliability using market-based mechanisms	Manage (auction/resale/curtailment) transmission capacity rights on interconnectors
	Consolidate and verify energy schedules
	Operate (register/bidding/clearing/publishing) Ancillary Services Markets
	Solve balancing issues through Balancing Market
	Solve grid congestion issues through Balancing Market
Grid stability	Monitoring and reduce harmonic mitigation
	Monitoring and reduce power oscillation damping
	Monitoring and reduce voltage flicker
	Stabilizing network by reducing sub-synchronous resonance (Sub synchronous damping)
	Stabilizing network after fault condition (Post-fault handling)

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Cluster	System Capabilities
(AMI) Installation and configuration	AMI component discovery and communication setup
	Clock synchronization
	Configure AMI device
	Security (Configuration) Management
Maintaining grid assets	Archive maintenance information
	Monitoring assets conditions
	Optimize field crew operation
	Supporting periodic maintenance (and planning)
Manage commercial relationship for electricity supply	Further from ESMIG
	Further suggestions to market
	Invoicing customers
	Registration/deregistration of customers
Managing power quality	Frequency support
	Voltage regulation
	VAR regulation
Market Settlements	Perform measurement and validation (M and V)
	Perform settlements
Monitor AMI event	Install, configure and maintain the metering system
	Manage power quality data
	Manage outage data
	Manage the network using metering system data
	Manage interference to metering system
	Enable and disable the metering system
	Display messages
	Facilitate DER for network operation
	Facilitate demand response actions
	Interact with devices at the premises
	Manage efficiency measures at the premises using metering system data
	Demand side management
Monitoring the grid flows	Archive operation information
	Capture, expose and analyse disturbance events
	Monitoring electrical flows
	Monitoring power quality for operation (locally)
	Producing, exposing and logging time-stamped events
	Supporting time-stamped alarms management at all levels
Operate DER(s)	Aggregate DER as commercial VPP
	Aggregate DER as technical VPP
	DER performance management
	DER process management
	DER process management with reduced power output
	DER remote control (dispatch)
	Registration/deregistration of DER in VPP
	Store energy from the grid
Operate wholesale electricity market	Receive energy offers and bids
	Clear day-ahead market
	Clear intraday market
	Clear real-time market
	Publish market results

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Cluster	System Capabilities
Protecting the grid assets	Perform networked protection logic (Intertripping, logic selectivity, etc.)
	Perform networked security logic (Interlocking, local/remote)
	Protect a single equipment (Incomer/feeder, Transformer, Generator)
	Protect a zone outside of the substation boundary
	Set/change protection parameters
Provide and collect contractual measurements	Collect metered data (for revenue purpose)
	Cross border transmission systems
	Measuring and exposing energy flows for revenue purpose (smart meter)
	Measuring and exposing power quality parameters for revenue purpose (smart meter)
	Transmission system/ distribution borders
Reconfiguring the network in case of fault	Supporting automatic FLISR
	Supporting reclosing sequence
	Supporting source switching
Secure adequacy of supply	Operate capacity markets
System and security management	User management
	Role management
	Rights/privileges management
	Key management
	Events management
	Configure newly discovered device automatically to act within the system
	Discover a new component in the system
	Distributing and synchronizing clocks
Trading front office operation	Bid into energy markets
	Compute optimized assets schedules to match commercial contracts
	Send assets schedules to operation systems
	Bid into ancillary services markets
	Purchase transmission capacity rights
	Nominate schedules to system operator
	Send market schedules to operation systems
	Publish market results
	Perform M and V
	Perform shadow settlements
Weather condition forecasting and observation	Wind forecasting
	Solar forecasting
	Temperature forecasting
	Providing weather observations
	Situational alerting
Connecting industry grid users	Facility and Smart Grid obtain current and past energy information
	Facility provides energy consumption and supply plan to Smart Grid
	Smart Grid provides stable (long term) price schedule to facility
	Smart Grid provides dynamic (short term) pricing to facility
	Facility informs Smart Grid about upcoming consumption and supply
	Smart Grid informs facility of blackout notice
	Smart Grid requests facility to alter consumption or supply
	Facility and Smart Grid negotiate price schedule

5.4 IEC Smart Grid Standards Map (use of)

5.4.1 Motivation

The increased dynamic in the field of standardization coupled with the increased complexity of the landscape (reaching more than 500 standards) creates the demand for an easier browsing of the set of standards, and as well a better transparency in the work of IEC. One of the aims of the IEC Smart Grid Standards Map is to give a better overview of which standards are already available and suitable for Smart Grid and how they can be applied. This will speed up the implementation of Smart Grid and avoid waste of resources due to double work.

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The other main goal of the IEC Smart Grid Standards Map is to support Smart Grid project managers to easily identify the standards they need in their Smart Grid. The solution will be constantly updated, new use cases and standards will be continuously fed into the open source database. It will allow users to search by pointing to areas or links between elements of the electric system.

5.4.2 Chart content

The IEC Smart Grid Standards Map has been designed to meet the objectives presented in 5.4.1, trying to make the best usage of web technologies.

As shown in Figure 4, it gives a visualization of the generic Smart Grid landscape covering all areas from generation to consumption (horizontal axis) and from the process equipment up to market applications (vertical axis). Its presentation structure is aligned with the SGAM coordinate plane.

The typical components (devices, applications, etc.) of the Smart Grid are visualized as boxes which are clustered according to their organizational or topological togetherness.

A filtering function should allow to limit shown components or standards according to defined groups or SDOs.

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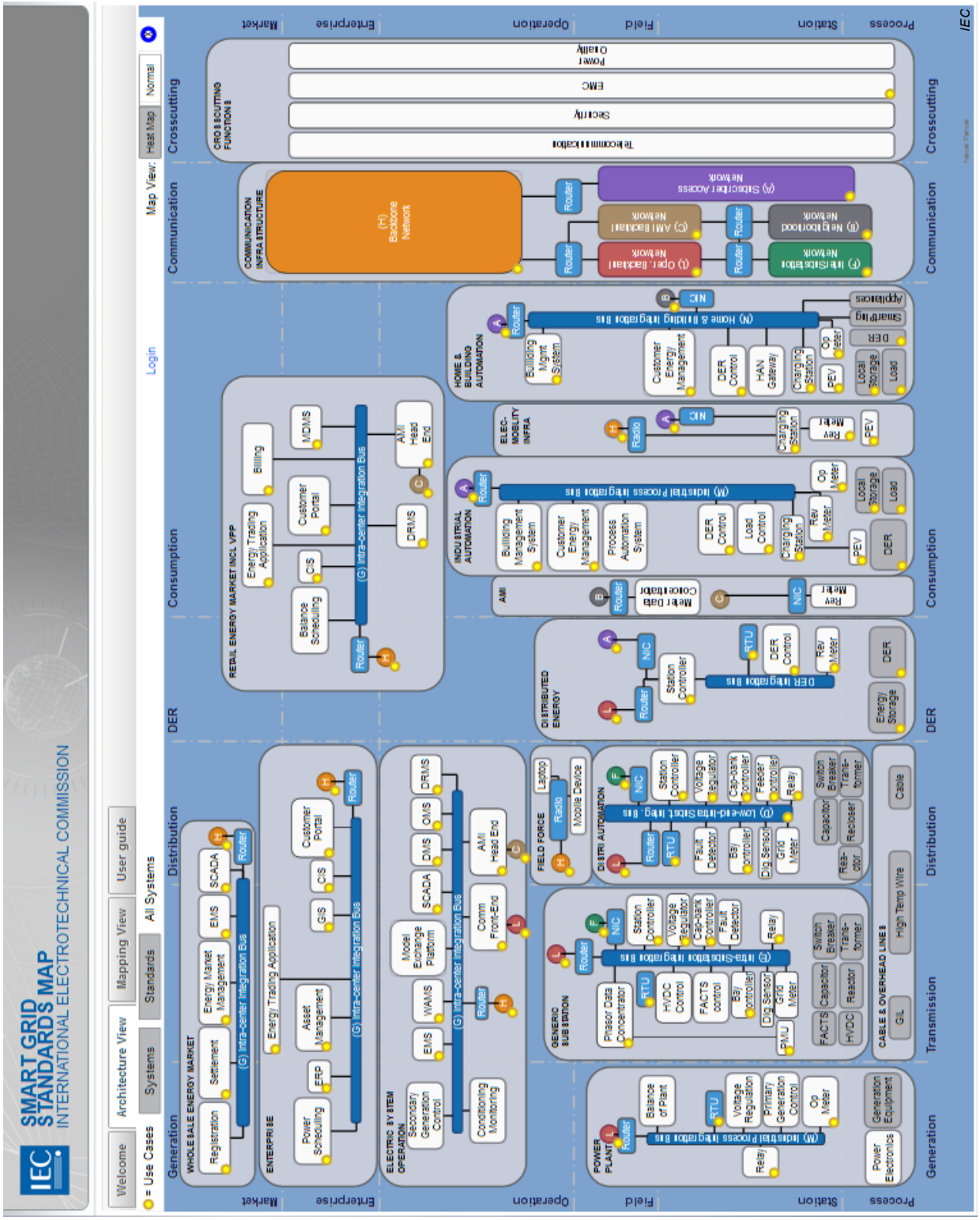

Figure 4 – Smart Grid Mapping Tool – www.smartgridstandardsmap.com

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5.4.3 Component cluster descriptions

5.4.3.1 General

See Table 6.

Table 6 – IEC Smart Grid Standards Map clusters description

Cluster name	Description
Wholesale Energy Market	contains major components which are typically implemented to establish market operation
Retail Energy Market	contains major components which are typically implemented to account as energy service provider and/or to market distributed energy resources
Enterprise	contains major components (applications) which are used in a utility to manage its assets, resources and customers
Electric System Operation	contains major components which are typically used in the control room environment of a grid operator
Power plant	contains major components which are typically used to operate a power plant
Generic substation	contains major components which can be implemented in a substation. Major high voltage substation might be equipped with all shown components while medium voltage substation uses using only a subset.
Field force	contains major components which are used by mobile field forces to achieve supporting information or to receive orders from the control centre
Distribution automation device	contains major components which are used in the more decentralized distribution automation, also known as feeder automation
Distributed Energy	contains major components which are used to integrate distributed generation, e.g. small wind turbines, solar production, combined heat and power, biomass, etc. into the grid
Industrial Automation	contains major components which are connected to the grid within larger industrial plants
E-mobility charging infrastructure	contains major components which are used to build up a charging infrastructure for e-cars.
Automated Metering infrastructure	(abbr. AMI) contains major components which are used to implement an automated metering infrastructure
Home and Building automation	contains major components which are used in the area of home or building automation. These components are typically implemented to achieve energy efficiency and comfort for the inhabitants/users.
Communication Infrastructure	contains the various communication network types used for information exchange between the clusters. Small bubbles with corresponding letters in the cluster show the interconnections.
Crosscutting	acts as placeholder for crosscutting topics

5.4.3.2 Component descriptions

Table 7 provides an early list of system roles. This proposal still needs to be harmonized with the coming outcome of the IEC System Committee WGs (typically the coming IEC 62913 series).

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Table 7 – IEC Smart Grid Standards Map – component description

Component	Description
AMI Head End	A system which acts as back-end for the metering communication and controls and monitors the communication to the meter devices. The collected meter information is provided for other system like meter data management.
Appliances	Appliances within buildings which are providing an interface to influence their consumption behaviour.
Asset Management	Application which optimizes the utilization of assets regarding loading, maintenance and lifetime.
Balance of Plant	Synonym for all automation which is required to maintain a safe, secure, efficient and economical operation of a power plant.
Balance Scheduling	Application which plants the energy procurement of a balance responsible energy retailer to satisfy the energy demand of its customer.
Bay Controller	A device or application which communicates with the substation to provide status information of the field equipment and to receive switching commands and control their execution.
Billing	Application which creates the energy bill information based on received metering information.
HBES/BACS system	devices intended to be used for control, monitoring, operation or management of building services and/or home electronic systems which can interact via a dedicated HBES network (Ref IEC 63044-1)
Bus	See “Network”.
Cap Bank Controller	Device or application which controls the reactive power generation of a controllable capacitor bank, typically to maintain the voltage at a certain node in the grid.
Capacitor	Two-terminal device characterized essentially by its capacitance
Charging Station	Single or multiple power outlets specially designed to charge the battery of cars. Typically including also facilities to meter the energy consumption and to authenticate the owner of the car to be charged for settlement reasons.
Communication Front End	Application or system providing communication with the substations to monitor and control the grid.
Conditioning Monitoring	Application or system which monitors the 'health' of grid equipment to detect upcoming failure in advance to extend the lifetime of the equipment.
Customer Energy Management System	Energy management system for energy customers to optimize the utilization of energy according to supply contracts or other economic targets.
Customer Information System	(CIS) System or application which maintains all needed information for energy customers. Typically associated with call centre software to provide customer services like hot-line, etc.
Customer Portal	Web-server application which allows utility customers to register and login to retrieve information about their tariffs, consumption and other information.
Demand Response Management System	(DRMS) A system or an application which maintains the control of many load devices to curtail their energy consumption in response to energy shortages or high energy prices.
DER Control	Control of a DER allows the adjustment of its active or reactive power output according a received set point.
Digital Sensors	Sensors for voltage, current, etc. with a digital interface that allows connecting the sensor directly to the substation integration bus.
Distributed Energy Resource	(DER) A small unit which generates energy and which is connected to the distribution grid. Loads which could modify their consumption according to external set points are often also considered as DER.
Distribution Management System (application server)	Application server of a Distribution Management System (DMS) which hosts applications to monitor and control a distribution grid from a centralized location, typically the control centre. A DMS typically has interfaces to other systems, like a GIS or an OMS. A DMS may have interfaces to other DMS.
Energy Management System (application server)	Application server of an Energy Management System (EMS) which hosts applications to monitor and control a transmission grid and the output of the connected power plants from a centralized location, typically the control centre. An EMS may have interfaces to other EMS.
Energy Market Management	Application of system which manages all transactions and workflows necessary to implement an energy market.
Energy Trading Application	Application(s) which are used to trade energy in corresponding markets, supports the dispatcher in the decision to buy, sell or to self-produce energy and also provides facilities to exchange the necessary information with the energy market IT systems.

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Component	Description
Enterprise Resource Planning	"Enterprise resource planning (ERP) systems integrate internal and external management information across an entire organization, embracing finance/accounting, manufacturing, sales and service, customer relationship management, etc." (source: Wikipedia at https://en.wikipedia.org/wiki/Enterprise_resource_planning)
FACTS	"Flexible Alternating Current Transmission System is a system composed of static equipment used for the AC transmission of electrical energy. It is meant to enhance controllability and increase power transfer capability of the network. It is generally a power electronics-based system." (source: Wikipedia at https://en.wikipedia.org/wiki/Flexible_AC_transmission_system). Despite their name, FACTS are also possibly used in Distribution.
FACTS controller	Control for FACTS in a way that the active or reactive power flow is adjusted according to received set points.
Fault Detector	Special devices typically mounted on distribution lines to detect whether a high current caused by a network failure has passed the supervised distribution line.
Feeder controller	Distributed Automation within a distribution feeder controlling typically voltage profile and providing fault restoration logic.
Front End Processor	(FEP) System component in charge of interfacing widely spread remote sub/systems or component usually communicating over WAN, to a central database.
Generator Equipment	Transforms mechanical power, e.g. from a turbine into electrical power.
Geographic Information System (application server)	(GIS) A server which hosts an application designed to capture, store, manipulate, analyse, manage, and present all types of geographical data. In the simplest terms, GIS is the merging of cartography, statistical analysis, and database technology.
Grid Meter	Device which meters the energy exchange between neighbouring grid operators or between grid operator and large energy producer/consumer.
HAN Gateway	A specialized gateway device or application which establishes the communication between external systems and the Home Automation Network (HAN) devices.
Head End System	(HES) Central data system exchanging data via the AMI of various meters in its service area. Equivalent to AMI Head End (see above).
HVDC	High Voltage/Direct Current, a technology to transport large amount of electrical energy over long distances with minimized losses, typically a point-to-point connection with converter station at both ends.
HVDC controller	Control for HVDC lines in a way that the active or reactive power flow is adjusted according to received set points.
Integration Bus	Middleware supporting the information exchange between the various applications within a control centre.
Laptop	Synonym for a mobile PC with keyboard, monitor and sufficient CPU power to run similar user interface clients as typically used in control rooms. Used by mobile workforces to work more independent from control room dispatcher.
Load	Energy consuming devices at customer site which might become subject for energy management.
Load controller	Control the energy consumption of a load according to a received set point without jeopardizing the desired process of the load.
Local Network Access Point	(LNAP) (Functional) Specialized Network Interface controller (NIC) between the Local Network (within the private area) and the AMI system.
Local Storage	An electrical energy storage which is installed behind the meter point and operated by the energy consumer/producer and not by the utility.
Meter Data Concentrator	Device or application typically in a substation which establishes the communication to smart meters to collect the metered information and send it in concentrated form to an AMI head end (or HES).
Meter Data Management System	Meter Data Management System (MDMS) is a system or an application which maintains all information to be able to calculate the energy bill for a customer based on the meter data retrieved from AMI head end(s). The energy bill information is typically forwarded to consumer relationship and billing systems.
Mobile Device	Synonym for a mobile hand held device with limited CPU power to run specialized user interface clients. Used by mobile workforces to work more independent from control room dispatcher.
Model Exchange Platform	Data warehouse system or application which enables the interchange of information described using the operation data model.
Neighbourhood Network Access Point	(NNAP) (Functional) Specialized Network Interface Controller between the Neighbourhood Network and Wide Area Network (WAN) connecting the Head End Systems. Equivalent to Meter Data Concentrator (see above).

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Component	Description
(Network) AMI Backhaul Network	Networks that can use public or private infrastructures, mostly to support meter data collection. They usually interconnect network devices and/or subsystems to the “AMI Head End” over a wide area (region or country).
(Network) Backbone Network	Inter-enterprise or campus networks, including backbone Internet network, as well as inter control centre networks.
(Network) DER Integration Bus	Networks that interconnect smart components or sub-systems in DER operation Systems.
(Network) Home and Building Integration Bus	Networks that interconnect home and or building communicating components and sub-systems to form a home or building management sub-system or system
(Network) Industrial Process Integration Bus	Networks that interconnect smart components or sub-systems in Industrial Automation Systems as well as in power plants.
(Network) Intra-Center Integration Bus	Networks inside two different types of facilities in the utility: utility data centres and utility control centres. They are at the same logical tier level, but they are not the same networks, as control centres have very different requirements for connection to real time systems and for security, as compared to enterprise data centres, 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.
(Network) (low-end) Intra Substation Integration Bus	Network inside a primary distribution substation or inside a transmission substation.
(Network) Inter Substation Network	Networks that interconnect substations with each other and with control centres. 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.
(Network) Neighbourhood Network	Networks 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 Neighbourhood Network level. These networks may service metering, distribution automation, and public infrastructure for electric vehicle charging, for example.
(Network) Operational Backhaul Network	Networks that can use public or private infrastructures, mostly to support remote operation. They usually interconnect network devices and/or subsystems to the “Operation level” over a wide area (region or country).
(Network) Subscriber Access Network	Networks that provide general broadband access (including but not limited to the internet) for the customer premises (homes, building, facilities). They are usually not part of the utility infrastructure and provided by communication service providers, but can be used to provide communication service for Smart Grid systems covering the customer premises like Smart Metering and Aggregated prosumers management.
Network Interface Controller	(NIC) “A network interface controller (also known as a network interface card, network adapter, LAN adapter and by similar terms) is a computer hardware component that connects a computer to a computer network.” (source: Wikipedia https://en.wikipedia.org/wiki/Network_interface_controller)
Operation Meter	Device which monitors the energy consumption for operational and control reasons. Their meter values are not used for commercial purposes.
Outage Management System	(OMS) System or application which intends to help a network operator to handle outage in optimizing the fix depending on many criteria (number of customer minutes lost, number of affected customer, capability of the network, etc.).
Phasor Data Concentrator	Specialized data concentrator collecting the information from Phasor measurement units (PMU) within a substation and forwarding this information in concentrated form to a system on higher level.
Phasor Measurement Units	(PMU) A device which measures the electrical waves on an electricity grid, using a common time source for synchronization. Time synchronization allows synchronized real-time measurements of multiple remote measurement points.
Plug-In Electric Vehicles	(PEV) A vehicle with an electric drive (as only drive or in combination with a fuel engine) and a battery which can be charged at a charging station.
Power Electronics	Generation which uses power electronics to inject electrical energy, typically resulting from renewable resources, into the grid.
Power Scheduling	Application deriving the optimal schedule to run the power plants to minimize costs.
Primary Generation Control	Device or application within a power plant monitoring actual frequency and adjusting generation if frequency deviates from desired value.

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Component	Description
Process Automation System	Automation system to monitor and control industrial production plants.
Protection Relay	Device or application which monitors voltage and current at the terminals of grid devices to detect failures of this equipment and then issues tripping commands to circuit breaker to avoid further damage.
Radio	Synonym for wireless communication.
Reactor	(also named inductor) Two-terminal device characterized essentially by its inductance).
Recloser	Special switch for distribution feeder typically combined with some automation logic to execute automated restoration after a failure in the corresponding feeder.
Registration	Application within an energy market system which handles the user registration for the market and monitors its transaction at the market.
Remote Terminal Unit	(RTU) A microprocessor-controlled electronic device that interfaces objects in the physical world to a distributed control system or SCADA by transmitting telemetry data to the system, and by using messages from the supervisory.
Revenue Meter	Device which measures the energy consumption within predefined cycles. The metered energy consumption is used to determine the energy bill (usually compliant with local metrology regulation).
Router	TCP/IP communication device which typically interconnects an internal network with the public network infrastructure.
Secondary Generation Control	Application which monitors the frequency and the energy exchange over tie-line and generates set points for controlled generating unit to maintain the desired values.
Settlement	Application within an energy market system which maintains the commercial information from the executed energy transactions.
Smart Plug	Synonym for a load switch which can be controlled by the customer energy management via the home automation network.
Station Controller	Automation system monitoring and controlling the devices in a substation. Provides interface to network control centre.
Supervisory Control And Data Acquisition	Supervisory Control And Data Acquisition (SCADA) system provides the basic functionality for implementing EMS or DMS, especially provides the communication with the substations to monitor and control the grid.
Switchgear	A general term covering switching devices and their combination with associated control, measuring, protective and regulating equipment, also assemblies of such devices and equipment with associated interconnections, accessories, enclosures and supporting structures, intended in principle for use in connection with generation, transmission, distribution and conversion of electric energy (ref. IEV 441-11-02). Switches and breaker may vary reading their switching automation and breaking capability.
Transformer	Electric energy converter without moving parts that changes voltages and currents associated with electric energy without change of frequency (ref. IEV 151-13-42).
Voltage Regulator	(VR) Device or application within the substation automation or a power plant to control the voltage at busbar(s) within the substation.
Wide Area Monitoring System (application server)	(WAMS) Application server which hosts the management of Wide Area Monitoring System, i.e. which evaluates incoming information from PMUs to derive information about the dynamic stability of the grid.

5.5 System breakdown over the SGAM

5.5.1 General

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

Here are, in Table 8, the systems which have been considered in this document, and which de facto form the set of the Smart Grid systems.

The guidelines mentioned indicate the purpose and limits associated with system definition and completeness of the considered list.

This list is actually made of three types of systems:

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- domain specific systems (Generation, Transmission, Distribution, DER, Customer Premises);
- function specific systems (usually crossing domain borders) (Marketplace systems, Demand flexibility systems, Smart metering systems, Weather observation and forecast systems);
- other systems usually focusing on administration features (asset management, clock reference, communication management, device management, etc.).

The two first types are mapped over the SGAM and depicted in Figure 5.

Table 8 – Smart Grids – list of the main systems

Domain or Function	Systems	Brief introduction/comments
Generation	Generation management system (Bulk)	Generation management system is the control centre for Bulk or Large renewable generation plant. Even if there may be some specificity for each of these, the rest of the document will mostly merge both into one system type.
	Generation management system (Large Renewable)	
Transmission	Substation automation system	Refer to Distribution
	Blackout prevention – WAMS Wide Area Monitoring Protection and control systems	Real-time blackout prevention systems, usually based on measure coming from phase measurement units
	EMS SCADA system	The Energy Management System (EMS) is the control centre for the Transmission Grid. Today customers require an open architecture to enable an easy IT integration and a better support to avoid blackouts (e.g. visualization of the grid status, dynamic network stability analysis).
	FACTS (Flexible AC Transmission Systems) and HVDC links and back-to-back systems	Power Electronics is among the “actuators” in the power grid. Systems like FACTS enable actual control of the power flow and can help to increase transport capacity without increasing short circuit power. HVDC links and back-to-back systems enable actual control of the power flow even in unsynchronized AC system and can help to increase and balance transport capacity.
Distribution	Advanced DMS SCADA system (including geographical information system – GIS and outage management system – OMS)	The Distribution Management System (DMS) is the counterpart to the EMS and is therefore the control centre for the distribution grid. In countries where outages are a frequent problem, the OMS is an important component of the DMS. Other important components are fault location and interfaces to GISs.
	Distribution automation systems – Feeder automation/smart reclosers system	Whereas automated operation and remote control is state of the art for the transmission grid, mass deployment of Distribution Automation has only recently become more frequent, leading to “Smart Gears”. Countries like the United States of America, where overhead lines are frequently used, benefit most. Advanced distribution automation concepts promote automatic self-configuration features, reducing outage times to a minimum (“self-healing grids”). Another step further is the use of distributed energy resources to create self-contained cells (“Micro-grids”). Micro-grids can help to assure energy supply in distribution grids even when the transmission grid has a blackout.
	Substation automation system	Substation Automation and Protection is the backbone for a secure grid operation. During recent years serial bus communication has been introduced (IEC 61850). Security is based on protection schemes.
	FACTS system	Refer to Transmission

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Domain or Function	Systems	Brief introduction/comments
DER	DER management system	A DER management system is responsible for operation and enterprise management level of the DER assets. It performs supervision and maintenance of the components and provides information to the operators and field crew personnel and includes DER EMS/VPP capabilities for the control of the generation. It can also act as a technical VPP (tVPP) interacting directly with the DSO or as a commercial VPP (cVPP) interacting with the energy market.
	Electrical energy storage management system	An electrical energy storage management system is used for operating and managing (at enterprise level) Electrical Energy Storage systems. It includes de facto such sub-systems. It performs supervision, control and maintenance of the components and provides information to the operators and field crew personnel.
Customer premises	AMI system	Advanced Metering Infrastructure (AMI) allows remote meter configuration, dynamic tariffs, power quality monitoring and load control. Advanced systems integrate the metering infrastructure with distribution automation. Smart Meter is a generic term for electronic meters with a communication link.
	Metering-related back office system	Metering-related Back Office systems refer to a range of back-office systems employed to use and manage data deriving from smart metering, mostly referring to the Meter data management (MDM) related application.
	Demand-Response / Load management system	Demand response (DR) system is a system used to manage on demand, grid user's electric behaviour, in requesting them to adapt their electricity consumption or production in response to a specific request.
	Smart homes and buildings systems	Smart homes are houses which are equipped with a home automation system that automates and enhances living. A home automation system interconnects a variety of control products for lighting, shutters and blinds, HVAC, appliances and other devices with a common network infrastructure to enable energy-efficient, economical and reliable operation of homes with increased comfort. Building Automation and Control System (BACS) is the brain of the building. BACS includes the instrumentation, control and management technology for all building structures, plant, outdoor facilities and other equipment capable of automation. BACS consists of all the products and services required for automatic control including logic functions, controls, monitoring, optimization, operation, manual intervention and management, for the energy-efficient, economical and reliable operation of buildings.
	Industrial Automation systems	Brain of the industrial plant in charge of monitoring and controlling the industrial process, and associated facilities.
	E-mobility systems	The E-mobility system comprises all elements and interfaces which are needed to efficiently operate Electric Vehicles including the capability to consider them as a flexibility resource in a Smart Grid system.
Transverse	Micro-grid systems	A Micro-grid system comprises all elements and interfaces which are needed to efficiently operate a micro-grid, i.e. a group of interconnected loads and distributed energy resources (DER) with clearly defined electrical boundaries that acts as a single controllable entity with respect to the grid and can connect and disconnect from the grid.
	Market places (including trading systems)	A marketplace refers to a system where buyers and sellers of a commodity (here related to electricity) meet to purchase or sell a product in a transparent and open manner according to guidelines called market rules.
	Weather observation and forecast system	A weather forecast and observation system refers to the system and all elements needed to perform weather forecast and observation calculation and to distribute the calculated geospatially referenced information to connected other systems enabling them in many cases optimized decision processes or automation

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Domain or Function	Systems	Brief introduction/comments
	Asset management and condition monitoring system	Asset Management Systems and Condition Monitoring devices are promising tools to optimize the OpEx and CapEx spending of utilities. Condition-based maintenance, for example, allows the reduction of maintenance costs without sacrificing reliability. Furthermore they may also be used to utilize additional transport capacity due to better cooling of primary equipment, e.g. transmission lines on winter days.
Administration[a]	Communication network management system	A communication network management system executes applications that monitor and control managed communicating devices. The communication network management systems provide the bulk of the processing and memory resources required for communication network management.
	Clock reference system	The clock reference system refers to the system and all elements needed to support clock master definition, time distribution and clock synchronization services to ensure a unified time management within the system.
	Authentication authorization accounting system	Authentication, Authorization, Accounting (AAA) refers to information systems used to grant granular access to a device or a service by controlling what a given user or system can access and how.

[a] "Administration" systems can/may be implemented in superposition of previous "operational systems". In most cases, they re-use communication capabilities already present in the "operational system.

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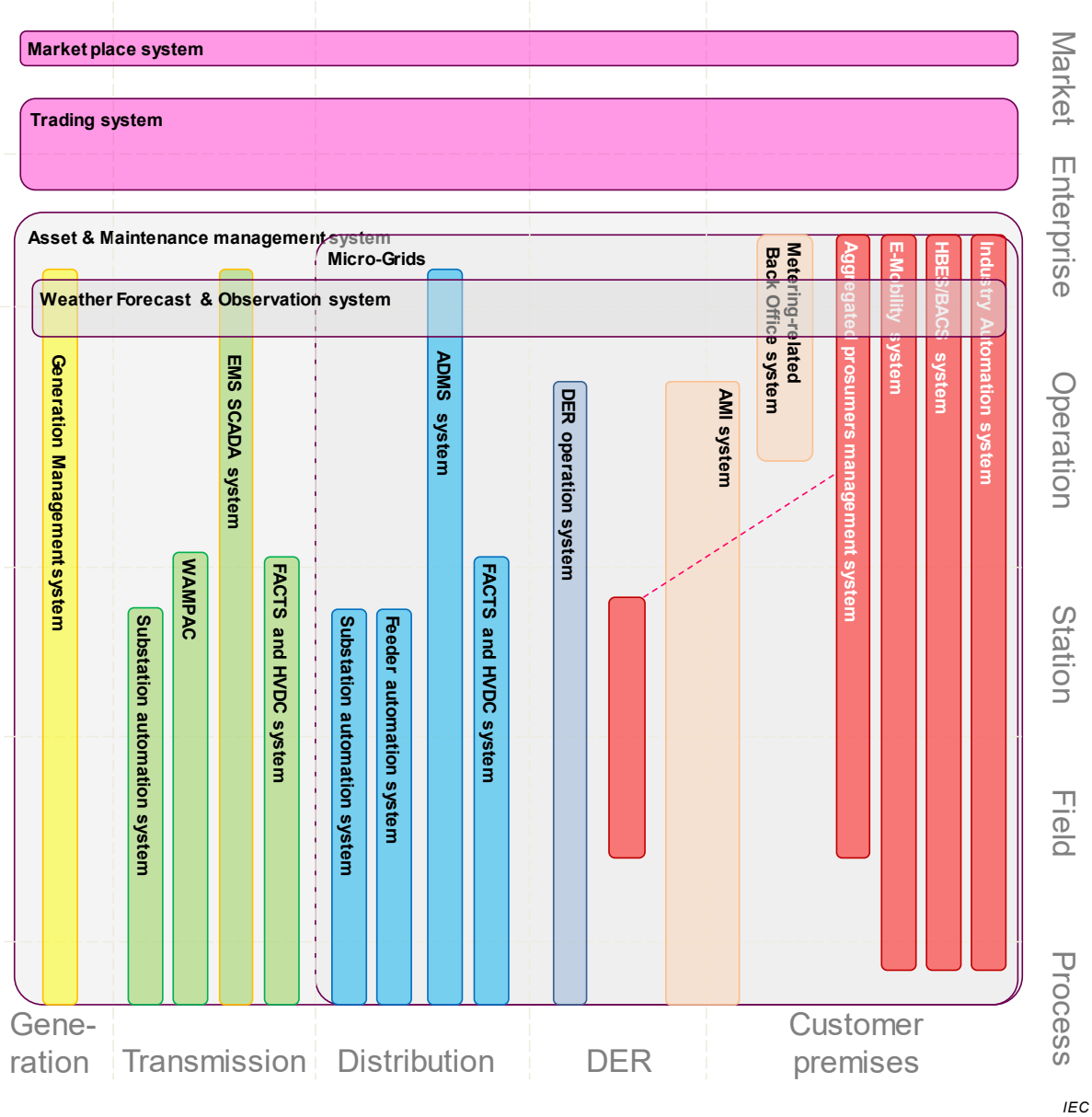

Figure 5 – Systems mapping over the SGAM plane

5.5.2 Mapping systems on SGAM – Rules

5.5.2.1 Specific usage of the SGAM in this document

For a structured system description, each system will be mapped to the SGAM model described in 5.2.6.4. Each system mapping follows the same path, as depicted in Figure 6:

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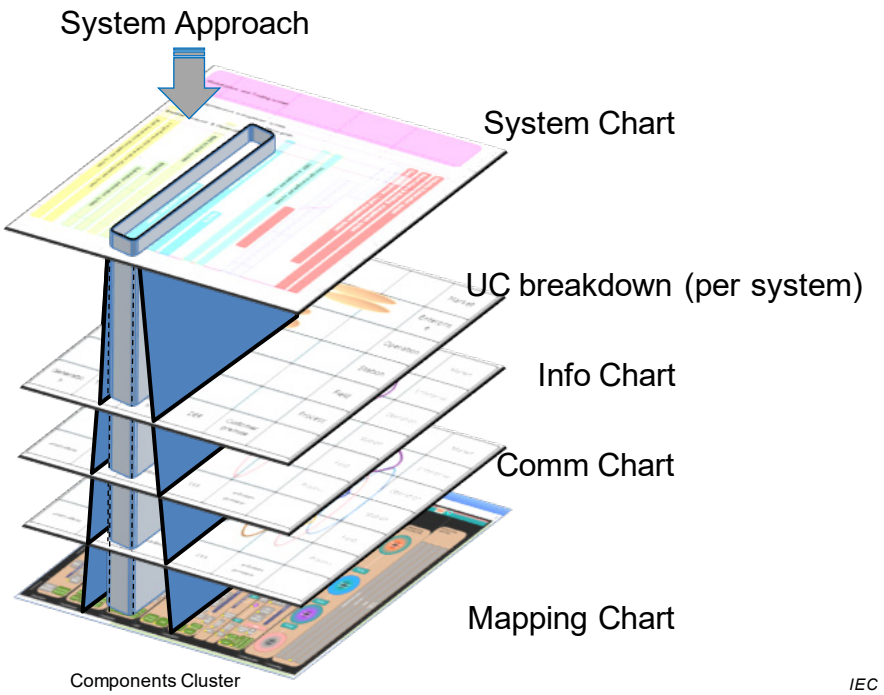

Figure 6 – Mapping principles of systems over the SGAM planes

- Definition of the set of "System Capabilities" (see 3.1.5) the considered system can/may support:
  - This "function layer" is described as a flat list.
- Drawing of the typical architecture and components used by this system (component layer).
- List of standards to be considered for interfacing each component within this system:
  - at "component" layer – the IEC Smart Grid Standards Map – see 5.45.4;
  - at "communication" layer – an overview is provided in 5.10.1;
  - at "information" layer – an overview is provided in 5.10.3.

The drawing indicates through the blue planes that, even if theoretically all layers should be aligned, we may observe some drawing constraints forcing us to extend the real effective mapping of systems outside the original scope of systems (specifically when looking at the IEC Smart Grid Standards Map).

5.5.2.2 Conventions used to draw the component layer of a system mapping

There are multiple ways to implement a system.

The challenge for mapping such a system on the SGAM to represent associated standards is then

- to be accurate enough to show the typical usage of standards, and
- to be generic enough not to "dictate" any preferences regarding such system arrangement.

So the main rules which have been considered in the system-related section below to draw the component layers of a system on the SGAM tool are:

- The drawing represents a functional view of the system.
- The components and arrangement are represented in very generic ways as shown in Table 9.

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