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TECHNICAL REPORT

colour inside

Smart grid standardization roadmap

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INTERNATIONAL
ELECTROTECHNICAL
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INTERNATIONAL ELECTROTECHNICAL COMMISSION

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SMART GRID STANDARDIZATION ROADMAP

FOREWORD

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

IEC 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.

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

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- withdrawn,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

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

IMPORTANT – The 'colour inside' logo on the cover page of this publication indicates that it contains colours which are considered to be useful for the correct understanding of its contents. Users should therefore print this document using a colour printer.

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 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

1 Numbers in square brackets refer to the Bibliography.

2 Under preparation.

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]).

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.

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.

3 Under consideration.

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

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

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]

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

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

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

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.

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.

- 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

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.

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.

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.

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).

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.

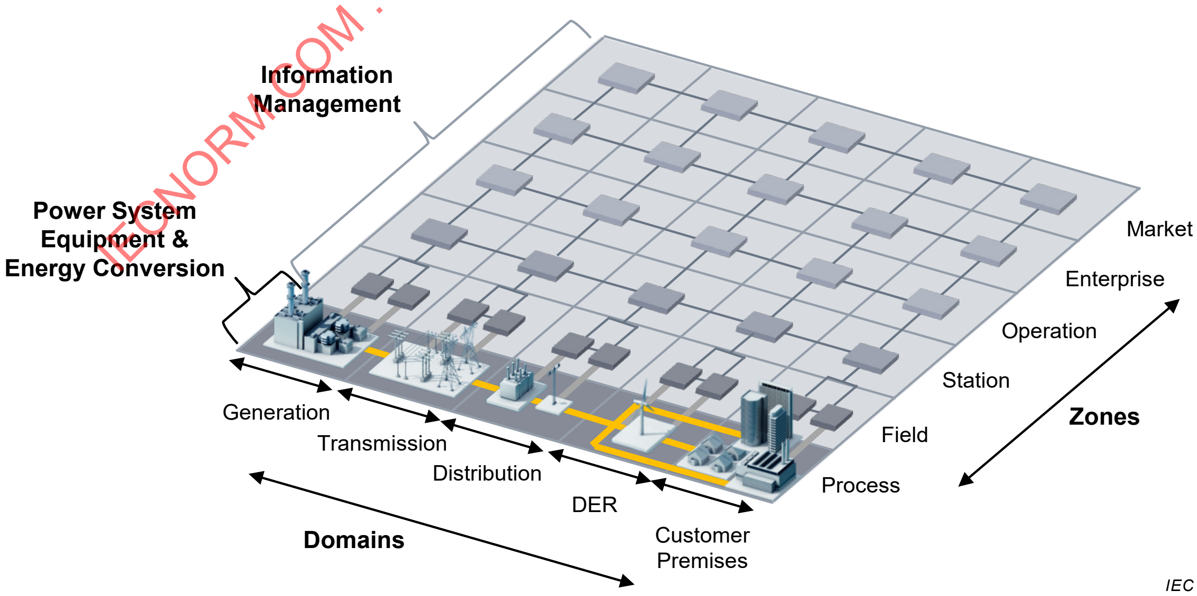


Figure 1 – Smart Grid plane – domains and hierarchical zones

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).

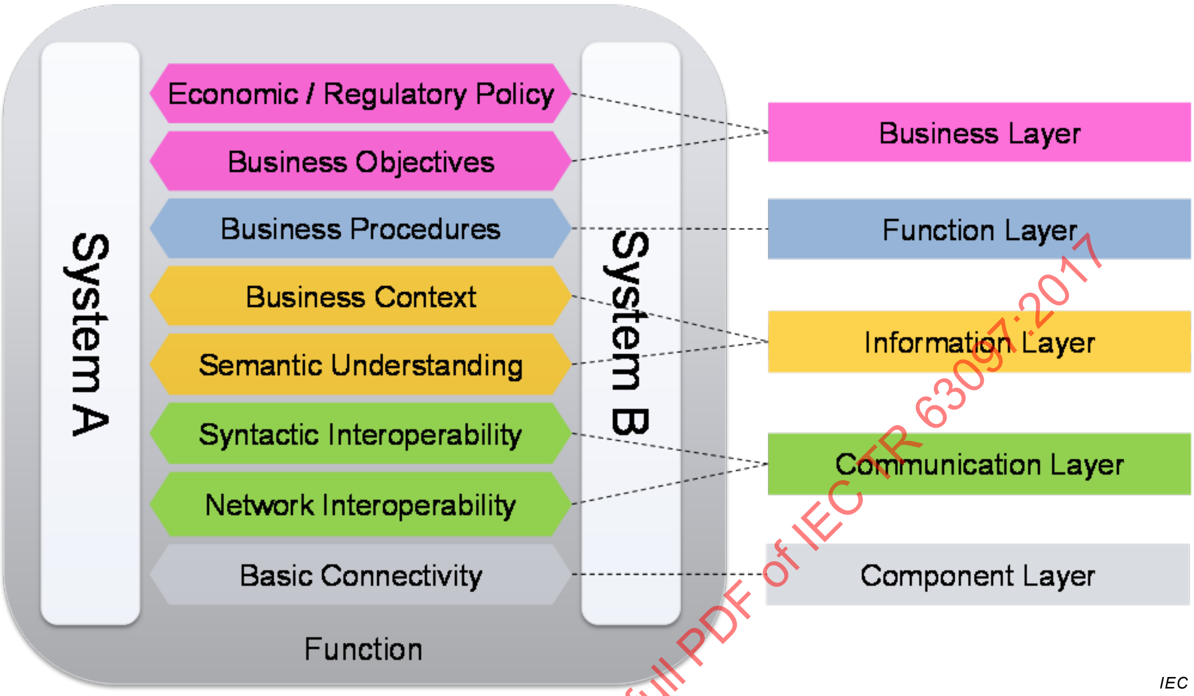


Figure 2 – Grouping into interoperability layers

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)

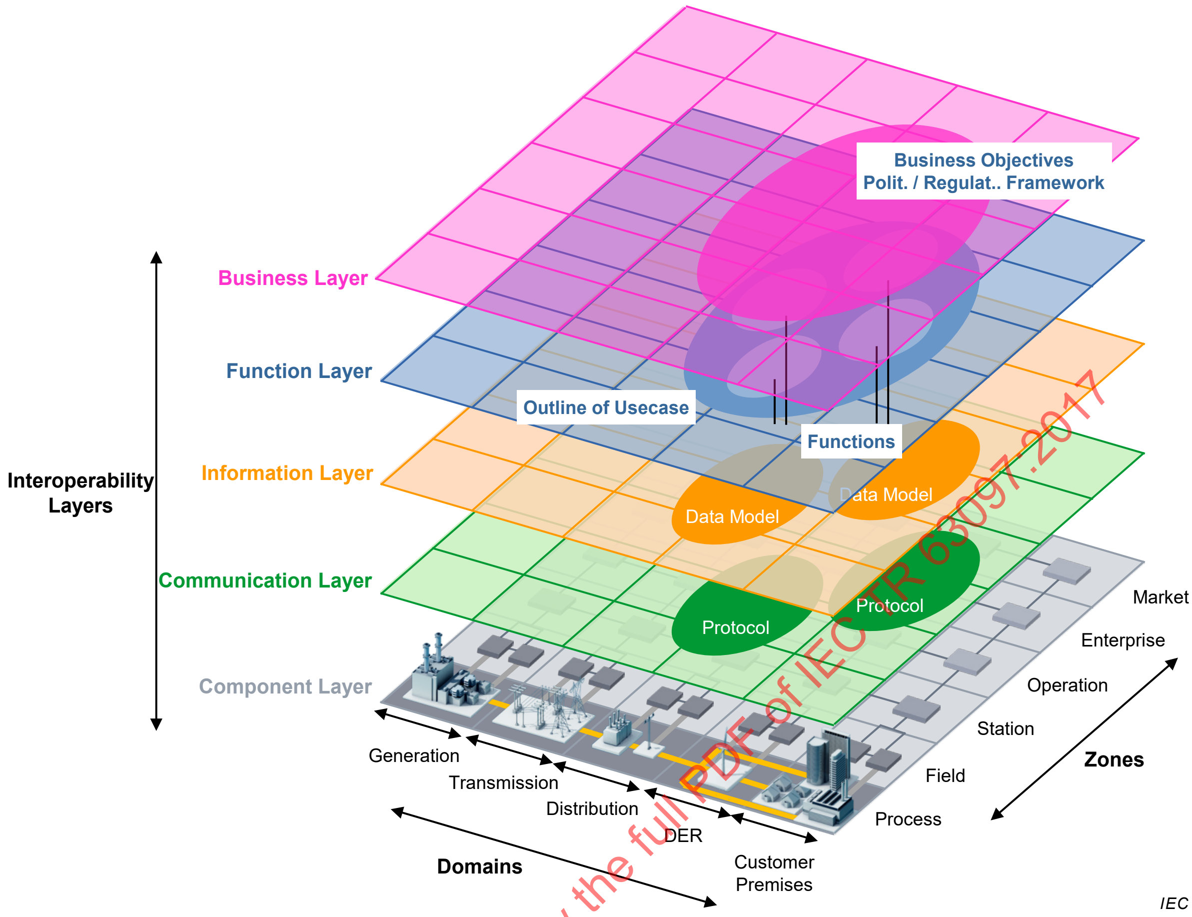


Figure 3 – SGAM framework

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;

- 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.

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

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)

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

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.

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.

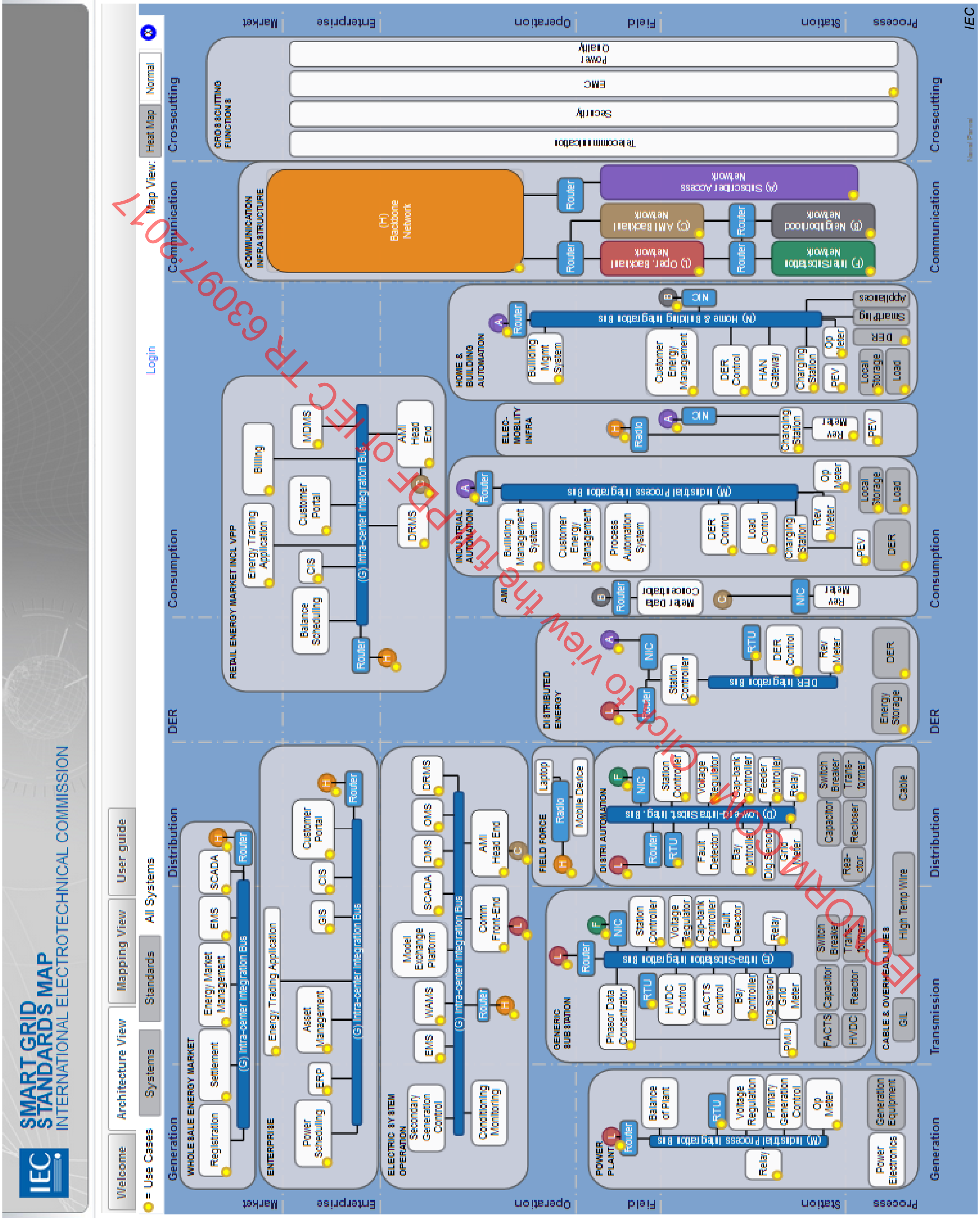


Figure 4 – Smart Grid Mapping Tool – www.smartgridstandardsmap.com

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).

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.

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).

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.

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:

- 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

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

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.

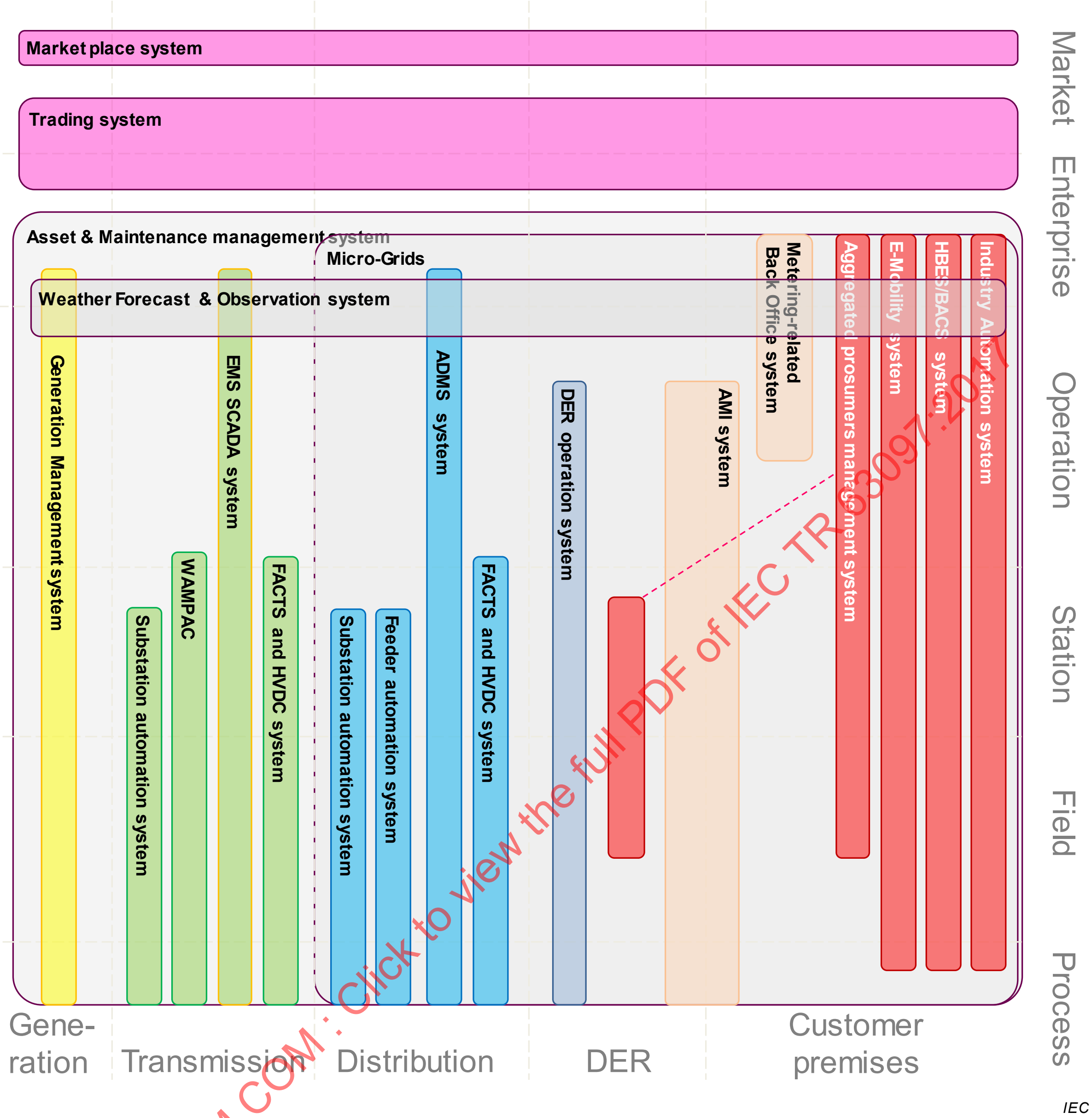


Figure 5 – Systems mapping over the SGAM plane

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:

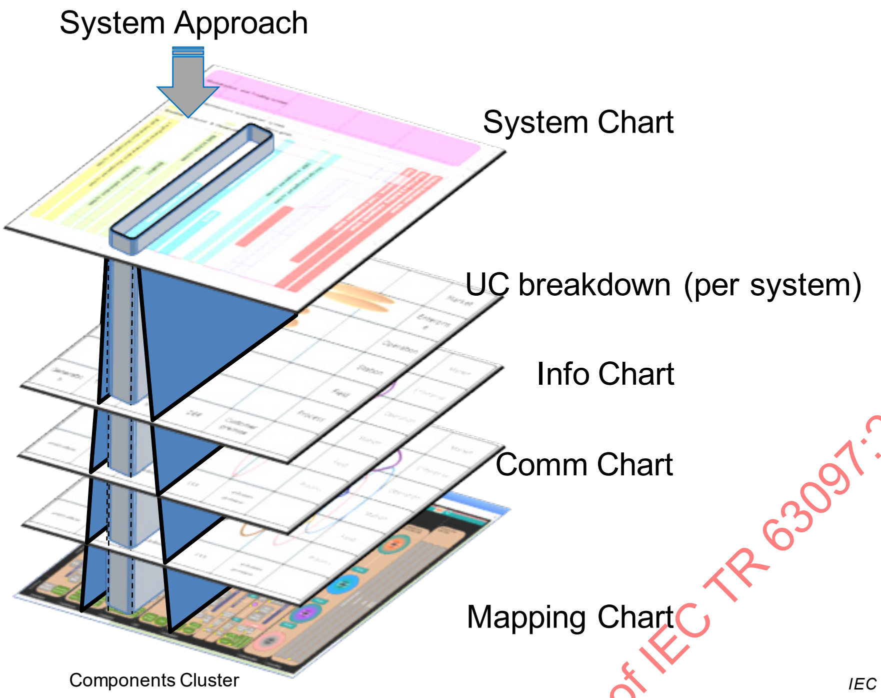


Figure 6 – Mapping principles of systems over the SGAM planes

- 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.

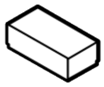
The challenge for mapping such a system on the SGAM to represent associated standards is then

- 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.

Table 9 – Typical components used for system mapping on SGAM

Graphical representation	Description	Comment
	A software base application	Usually met at higher level of the architecture May be grouped with other components
	An operator interface	May be grouped with other components
	A generic “field” component	Usually hosting field level interface/treatment function. May be grouped with other components

- The links represent a requirement of information (data) exchange between the selected components. See Table 10.

Table 10 – Typical links used for system mapping on SGAM

Graphical representation	Description	Comment
	Electrical connection between process level component	Showing the presence of an electrical network
	Communication path between two (or more) components	Showing the presence of a communication network
	Communication between a component and another system	Expressing the potentiality for one system to contribute to UCs hosted by another one. Showing the presence of a communication network, when noted in a level different than the “process” zone level

5.5.2.3 Conventions used to draw the communication layer of a system mapping

When a communication path appears between two (or more) components, then it has to be represented on the communication layer.

The rules for drawing the communication layer of a system are as follows.

- System-related sections (listed in 5.9) and associated standards mostly focus on application layers (layers 5 to 7 of the OSI model).
- Upper layers of communication are represented on the mapping using a large green arrow.

  Typically this will appear in the following way:

where NN indicates the standard body and XXXX indicates the standard reference.

- Communication technologies corresponding more to OSI layers 1 to 4 are described in 5.10.1.

  13 types of network have been identified, which are noted by letters from “A” to “M”.

  More specifically the communication standards categories able to fulfil the requirement of the considered type(s) of network are listed in 5.10.1.2 (on a per type of network basis).

- The two parts mentioned above are bound graphically by adding to the communication network representation (a green arrow which appears on each SGAM mapping of the communication layer of the corresponding system) a blue disk showing the type of network to consider.

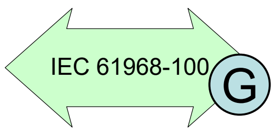
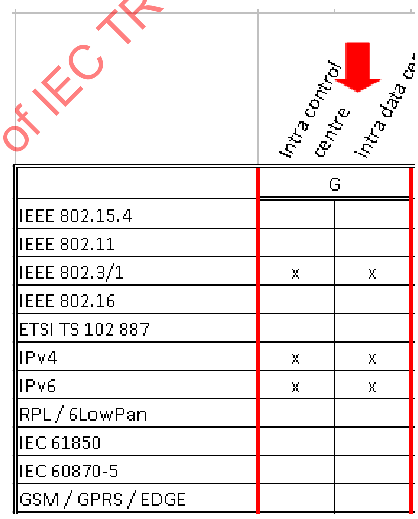
  The tag used to express this bind is 

.

Then, when a communication dataflow is mapped on the SGAM, for a selected system, it will be shown with a large green arrow, but close to this arrow a blue disk is placed, including a letter (from A to M) indicating which type(s) of network this dataflow relies on.

An example is provided in Table 11.

Table 11 – Example in binding system standards and low OSI layer communication standards

<table>
<tr><th>Representation of a communication flow</th><th>Meaning</th><th>Relationship with lower OSI layers of communication</th></tr>
<tr><td>
</td><td>Such a drawing means that for this communication dataflow:
• “IEC 61968-100” may be considered for the OSI layers 5 to 7,
• and that the network said to be of type “G” may be considered as the lower OSI layers 1 to 4, i.e. “Intra-control centre / intra-data centre network” as explained in 5.10.1.2.
Then Table 73 indicates which standard(s) category may support the lower OSI layers of a communication network of type “G”.
In that example, Table 73 indicates that the categories IEEE 802.3/1, IPv4 … standards may fit
(the screenshot on the right shows how to understand the usage of Table 73).
In that example, Table 73 indicates that the categories IEEE 802.3/1, IPv4, etc. may fit.
(The screenshot on the right shows how to understand the usage of Table 73.)</td><td>

The figure above shows how Table 73 may contribute to select the appropriate lower OSI layer communication standards category for a given type of network.</td></tr>
</table>

5.5.2.4 Conventions used to draw the information layer of a system mapping

When a communication path appears between two (or more) components, then it has to be represented on the information layer, in order to express which standard data model is considered for this data exchange.

The rules for drawing the information layer of a system are as follows.

- Data modelling standards mostly focus on OSI layers greater than 7.
- Data modelling primitives (like, “Binary”, “Analog”, “String”, etc.) are not considered as such. Only semantic level modelling is considered.
- Data modelling standards are shown on the drawing using a yellow ellipse such as

NN ZZZZ where NN indicates the standard body, and ZZZZ indicates the standard reference.

5.5.2.5 Convention of notation for the coverage of System Capabilities by standards (C, I, CI, X)

While attaching Capabilities (see 3.1.5) to each system, this document aims also to provide additional information to better evaluate the real coverage of standards in their ability to fulfil these Capabilities.

Within each system-specific section, describing the detailed list of supported Capabilities, three columns were added as shown below in Table 12.

Four possibilities of support are considered:

1) “C”, as in “communication”, means that at least one of the communication standards (standards represented in the communication layer, and mostly covering the OSI layers from 3 to 7) which fits the AVAILABLE or COMING triggers can/will host the data exchange flow.
2) “I”, as in “information”, means that at least one of the information model standards (standards represented in the information layer, and mostly above the OSI layer 7) which fit the AVAILABLE or COMING triggers can/will host the specific data exchange flow.
3) “CI” means that both above conditions are/will be met.
4) “X” in the “AVAILABLE” or “COMING” column means that at least one of the available/coming communication standards supports/will support this use case but the exact level of support (could be C or I or CI) needs further investigation.

   “X” in the “Not yet” column means that no standard supports the use case yet.

An empty cell means that further information/knowledge is needed to answer it.

Table 12 – Capabilities coverage example

Possible combination of “use-case support” tags			
AVAILABLE	**COMING**	**Not yet**	**Explanation**
CI			Example 1: CI in “AVAILABLE” means that available standards for Communication and Information layers cover market requirement for the considered Capability.
C	I		Example 2: C in “AVAILABLE” with I in “COMING” means that available standards for communication cover market requirement for the considered Capability but standards covering the information layer for the same Capability are still in the pipeline of standardization.
CI	C		Example 3: CI in “AVAILABLE” with C in “COMING” means that available standards for communication and information layers cover market requirement for the considered Capability but standard improvements covering the communication layer for the same Capability are in the pipeline of standardization.
C		I	Example 4: C in “AVAILABLE” with I in “Not yet” means that available standards for communication cover market requirement for the considered Capability but no specific standardization activity covering the information layer is fitting the triggers yet (see 5.2.5), i.e. too early stage or not started at all.
		X	Example 5: X in “Not yet” means that neither Communication nor Information layer standards are in “AVAILABLE” or “COMING” state, i.e. too early standardization stage or not started at all.
			Example 6: Blank/empty line means that further information/knowledge is needed to answer the coverage of the considered Capability.

5.6 Interoperability

A Smart Grid consists of numerous components provided by different actors, working together to provide a smart power system. For such a system to operate and the desired services and functionalities to be provided in a sustainable way, interoperability of components and attached processes to set up and demonstrate such interoperability become of major importance.

Interoperability means (derived from GWAC[6] work as presented in [12]):

- exchange of meaningful information between two or more components of the system,
- a shared understanding of the exchanged information,
- a consistent behaviour of components within the system, complying with system rules, and
- a requisite quality of service: reliability, time performance, privacy, and security.

Many levels of difficulty to reach the interoperability can be considered, from plug-and-play (i.e. no need for extra human interventions) down to a 100 % manual process with additional gateways ensuring the needed transformations. In order to be deployed at a reasonable cost and quality and considering the number of interconnected devices (possibly hundreds of thousands), Smart Grids require interoperability at one of the highest levels (compared to other industry domains), i.e. at information semantic level. This will remove the need of gateways, and will ensure a same semantic convention on both ends of the communication, reducing by far the need for semantic transformations, then the need for human work for making machines work together.

The current roadmap, identifying standards to be used per selected areas, is a path towards seamless interoperability.

However, further standardization steps have to be considered to reach the ultimate goal, such as:

- ensure an accurate definition of the semantic of any exchanged information, with no risk of ambiguity;
- define the behaviour of the object which implements the standard (state machine), consistently with the system behaviour;
- define profiles which would restrict the options offered by the standards, in order to ensure a minimum set of functionalities, to support a predefined set of use cases;
- include a conformance statement, to check the implementation of the standard against the standard specification;
- offer profile testing means and procedures.

The absence of answers to the above expectations does not mean that a system won't interoperate, but mostly means additional complexity for setting up and maintaining Smart Grid systems.

5.7 Main expected evolutions (in five years' time)

5.7.1 General

The smartness of many Energy infrastructures will further increase certainly at the regional and distribution level of the networks. Smartening of a grid in general is realized by adding communication and by adding of advanced monitoring and control to the conventional energy infrastructures. In many cases the interfaces of customers connected to the grid are involved. Experiences with communication, advanced control, management and protection systems are

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6 GWAC = GridWise Architecture Council

already known from the application in the transmission grids for many decades. Transmission networks are already equipped with advanced communication and control systems.

There is an increasing need to provide much better observability of the grid and grid user's behaviour, to equip local and regional networks with advanced control, data analytics and communication systems. Further increase of communication bandwidth over this time period and the application and new developments in telecommunication media make this possible. This allows for the connection of an extensive number of smart devices and sensors that use regional control and protection facilities. In order to support the simplification of interoperability amongst all devices of the grid, existing standards, and new standards where gaps exist, will be required to cover the following aspects:

- new telecommunications media developed and applied;
- advanced protocols that support this greater bandwidth and the plethora of connected objects that need to be connected, and potentially interact;
- advanced system management to support connection, disconnection, re-connection of connected objects, firmware update, parameters update, easy fix and repair, etc.;
- IT–OT convergence, including among many the virtualization of the OT level into the IT level;
- Extensive Data storage;
- End to End cyber security to ensure protection and privacy of this data;
- Energy Storage technologies;
- Energy Convertor technologies;
- safety as it applies to smart devices and other modes of operation that differ from the past Active devices connected to the grid and isolated operation of premises/grid subsets.

New and modified/extended standards have to support the development and the use of Smart Energy applications. Involvement of all stakeholders is key to reach consensus about those new and modified standards.

Different communication media are available, i.e. by using the power lines in the different PLC techniques or GPRS, Wireless techniques (3G, 4G, etc.) and will be applied to gain experience regarding large volumes and numbers of data.

In many cases the ISO "OSI model" is and will be applied to analyse the different applications, data models, data-links, communication protocols and physical media that are available and most of them are already used in other parts of the network and installations connected to the grid. Furthermore, architectures and concepts from ICT and Telecommunication infrastructures will be used in the smartening of existing energy infrastructures. In smartening the grids it is seen that the different worlds from ICT, Telecommunication and electrical and other forms of Energy meet. Integration of other applications, i.e. transportation, health, safety and environment will lever Smart Grids to the smart city initiatives and developments.

5.7.2 Exchange of information: communication and advanced control

Privacy issues and security of information appear to be of major concern because data exchange between different stakeholders in the market and connected to the distribution grids will be more intensive than ever before. This will not only involve the exchange of information but, based on the information exchange, advanced control and protection systems will be applied for the interaction with premises like houses, commercial businesses and buildings, also indicated as demand response. The transformation to Smart Grids not only appears to be a technical challenge; because of the behaviour of the different parties in the market, commercial and regulatory issues are involved too.

5.7.3 Decentralized developments: dispersed generation and storage, transition from network operator to system operator at a regional level

Decentralized generation is increasing in number and size, PV panels are becoming less expensive, converter technology is becoming mature and commercially available. In the majority of cases decentralized generation and storage, the latter still in a relatively small amount and mostly applied at device level, are switched off from the distribution grids during emergency situations in the grid. Network restoration is approached starting at transmission level down to the distribution networks.

As already mentioned, storage is used on a very small scale in premises and mostly as backup at device level. Due to the technical development in manufacturing batteries, this technique will be emerging and will be applied in larger volumes in the future. This development of batteries is accelerated by the development of electrical vehicles where the size of battery power remains an issue of major concern regarding the distance that can be covered by these cars. Additionally, as more and more renewable energy resources such as wind and solar are integrated into the infrastructure, the issue of renewables variability will become a major challenge. The mitigation of this variability in generation will consequently drive the need for new storage technologies on a larger scale. This amount of storage will also be applied to manage peak demand.

Managing reactive power in relation with power system voltage control will become more important in situations and regions where distributed generation and power storage is or will become a substantial part of the total power demand of that region. The total power demand in the region will be generated partly by the central power stations that are connected to the transmission system and the power generated locally by generators and storage facilities connected to the distribution networks in that region. It will not be sufficient to switch distributed generators and/or storage facilities of premises off during emergency situations in the power system. In the future it will be thinkable, and it already happens, that in certain regions distributed generation and storage will support power system restoration in emergency situations in the network. Voltage and frequency will not only be controlled by central power stations and dispatch centres: a more advanced control will be needed, supported by appropriate energy market arrangements (contracts and transparent arrangements between different parties involved).

5.7.4 Isolated operation: "to be or not to be" connected to the distribution network

In the future it can be expected that premises go in isolated (island) operation from the distribution system. Such premises will be isolated or "switched off" by the network operator or by the premises' own control facilities based on appropriate monitoring arrangements. The ability of island operation comes from the fact that they are able to cover their own power demand by the premises' own "distributed" generator and/or storage facilities, i.e. batteries. In such situations the distribution network can be in operation or out of service due to emergency situations and/or planned maintenance and/or repair activities. Premises with their own generation and storage facilities can cover their total demand or at least part of their total demand controlled by a Customer Energy Management system whether or not they are connected to the distribution network. In normal situations, surplus of energy generated by the premises can be delivered back to the distribution system. Reconnecting the premises to the distribution system after a period of island operation has to be arranged in a safe and coordinated manner. That can be arranged by a synchronizing facility/unit with built-in monitoring and control arrangements; the latter can be part of the aforementioned CEM.

5.7.5 Smart Metering

Smart Metering is applied in some countries and will emerge from the pilot project phase to bigger nationwide deployments. Energy Markets are transforming towards the use of dynamic pricing of energy use and energy generation. Use of private information is an issue of concern and discussion in many countries and needs to be resolved before nationwide deployments take place. Legislation and Regulation focus on privacy arrangements and measures to secure information that is involved in the information exchange between different stakeholders.

5.7.6 Micro-grids: where a distribution grid is not available or its reliability is not enough

Micro-grids are grids that cover all functions and controls needed to support a small community and/or industry without being connected to a distribution grid in normal situations. There are different business cases which may justify applying micro-grids, as listed below:

a) Guarantee a continuity in load service by islanding.
b) Electrify remote areas using renewable energy resources.
c) Optimize local resources to provide customer service inside the micro-grids.
d) Optimize local resources to provide services to the grid / disaster preparedness.
e) Develop larger energy system by interconnection of islanded micro-grids.
f) Optimize energy supply cost and exploitation of local asset inside community-run distribution by managing local resources. In case different loads and generators are available and connected to the micro-grid, a kind of central control system usually manages generation and demand (balancing).

5.7.7 Electrical Vehicles: the act of charging and storage and the impact on the distribution grids

Nowadays connecting electrical vehicles to the grid for charging is possible for limited numbers and the use of conventional charging methods. If in future the number of EVs connected increases and new fast charging methods are applied, the impact on the grid needs to be investigated and known. Consequently appropriate measures need to be taken to control the charging of EVs connected to the grid. Future use of EV batteries connected to the grid and the installations in premises need to be investigated not only regarding charging but also regarding the use of batteries for energy storage for use in the distribution grid and for use on individual premises. The charging of the batteries has to be coordinated in relation with other demand and distributed generation and the local capacity of all assets in the distribution networks and the individual premises involved.

5.7.8 Managing the network and interfaces: supporting the Energy market with flexibility in normal and abnormal situations

Distribution Automation and Energy Management functions will integrate further in the distribution networks with a high amount of distributed generation and storage connected compared to the amount of energy supplied by the central power generators connected to the transmission networks. The Distribution Network Operators of today will be transformed to Distribution System Operators managing the energy production and energy demand at a regional level like the Transmission System Operators do at a national level. System Operators will support the functioning of the Energy market in a more or less regulated way. Markets have to comply with regulatory frameworks; flexibility of networks will be assessed and controlled by System Operators during normal and abnormal, emergency situations. Network restoration will be based not only on the top down approach from transmission to distribution level but will consider regional possibilities. Self-healing concepts will be applied at a regional level considering distributed generation and storage facilities connected to the grid and a more regional based Energy Management scenario to support network restoration at a regional level.

5.7.9 Transmission networks: even smarter than they already are

At transmission level the use of HVDC and FACTS will further increase if energy exchange between continents and countries or just the energy transmission over large distances seems to be advantageous regarding the primary resources used and available for generation and the energy demand in areas where no primary resources are available for generation. Transmission System Operators will extend the control, protection and communication facilities where more advanced interaction is needed, regarding the energy exchange between continents, countries and with the underlying distribution networks. In the future, the latter can have substantially different behaviour than in the past, because energy flow is not determined by impedance and load any more but also depends on distributed generation and storage. In the future more advanced control of frequency and reactive power is needed in order to secure the availability of supply during normal and abnormal situations. The control will cross all kinds of interfaces and interact with all the different stakeholders.

5.7.10 Blockchains: decentralized consensus

Blockchain is a new trend enabling the decentralized consensus between two parties without the need of a third party to verify the transaction. Blockchains are by design inherently resistant to modification of the data. The Transaction is secure by the use of a distributed computing system with high fault tolerance. A blockchain is a decentralized digital record that registers transactions on thousands of computers globally, which increases dramatically the difficulty to alter or falsify data.

Due to the fact that two parties can exchange data, negotiate and transact, blockchain could revolutionize trading not only in the energy sector. Standards which are implemented today should take this trend into account.

5.8 Standards related to the electrotechnical aspects of Smart Grids

5.8.1 Planning for Smart Grid

Planning for the Smart Grid includes transmission system planning and distribution network planning. In general the planning standards are enacted by a country or an organization individually. However, some standards related to power system planning, such as large-scale wind farm and PV system connection into transmission systems and interconnection of distributed generation into power networks should be released by international standard organizations.

Currently, the electrical energy system faces a major change regarding the type and location of its energy sources. While the power plants in the past were erected not far from the energy consumption, today the location of bulk generation is often driven by the availability of renewable sources. Additionally, energy consumers are installing small generation units on their premises to become so-called "Prosumers". This fact creates new challenges to the energy grid: the transportation distances become longer, a major share of generation will be connected to the distribution grid, the grid has to cope with the fluctuating behaviour of renewable generation and the dynamic behaviour of generation connected via power electronics to the grid differs from the behaviour of rotating machines.

To maintain a stable grid operation, the grid frequency has to be controlled within defined limits. Also, the voltage needs to be maintained to avoid voltage collapses and the combination of all generating units needs to have enough inertia to withstand large steps of load or generation. Additionally the grid equipment needs to fulfil certain requirements to ensure the functional safety of the energy supply process.

While the latter device-specific requirements are typically defined in device-oriented standards, some operational requirements appear for operating the grid, on how to connect generation or load to the grid (often defined in so-called grid connecting guidelines issued by regulatory bodies, e.g. ACER/ENTSO-E, FERC or similar). IEC TC 8 is starting to set up some working groups for technical topics, like the customer interface or the design of interconnected power systems or micro-grids. However, these activities are still at an early stage.

5.8.2 Connecting and managing DER (Distributed Energy Resources)

5.8.2.1 Description

In parallel with the liberalization of the energy markets, the decentralized generation of electrical power as well as energy storage becomes more and more important. The management of these energy resources near to the consumers offers economic and ecological benefits. They can sometimes provide heating and/or cooling services as well as electricity.

In this context, interest is also directed to non-conventional operation modes such as so-called virtual power plants (VPP) and micro-grids.

A virtual power plant is a collection of decentralized generation and storage units that are monitored, aggregated and controlled by a central entity in view of providing higher efficiency and more flexibility.

5.8.2.2 Associated requirements

So that the Smart Grid can provide its benefits, such massive introduction of DER requires appropriate grid connections and operational rules as well as product specifications.

The purpose of the standards is to provide favourable conditions for renewable energy and connection of distributed energy resources while contributing, as a complement to the regulatory framework, to:

- system security, especially control of frequency and voltage in steady and disturbed states. This also includes the capability to provide ancillary service, especially for regulation, spinning and non-spinning reserve;
- quality of the supply, especially preventing excessive voltage variations;
- safety of persons, especially preventing undesired islanding and un-eliminated faults;
- reasonable network development/reinforcement costs;
- addressing new safety and protection issues raised by DER and micro-grids at the demand side level. The multi-sources and bi-directional aspects have to be covered by installation rules.

5.8.2.3 Available standards

See Table 13. Refer to 5.2.5.3 for the definition of the criteria considered in this document for stating that a standard is "available".

Table 13 – Connecting and managing DER – Available standards

Layer	Standard	Title and comments
Component	IEC 62446 series	*Photovoltaic (PV) systems – Requirements for testing, documentation and maintenance*
Component	IEC 61000-4-30	*Electromagnetic compatibility (EMC) – Part 4-30: Testing and measurement techniques – Power quality measurement methods*
Component	IEC 61727	*Photovoltaic (PV) systems – Characteristics of the utility interface*
Component	IEC TS 62257 series	*Recommendations for renewable energy and hybrid systems for rural electrification*
Component	IEC 60364 series	*Low-voltage electrical installations*
Component	IEC 61400 series	*Wind turbines*
Component	IEC 60364-5-55	*Electrical installations of buildings – Part 5-55: Selection and erection of electrical equipment – Other equipment* NOTE Especially the two following subclauses: – 551.6 Additional requirements for installations where the generating set provides a supply as a switched alternative to the normal supply to the installation – 551.7 Additional requirements for installations where the generating set may operate in parallel with other sources including systems for distribution of electricity to the public

Layer	Standard	Title and comments
Component	IEC TS 62749	*Assessment of power quality – Characteristics of electricity supplied by public networks*
Component	IEC 61400-21	*Wind turbines – Part 21: Measurement and assessment of power quality characteristics of grid connected wind turbines*
Component	IEC 61400-27-1	*Wind turbines – Part 27-1: Electrical simulation models – Wind turbines*
Component	IEC 61000-4-30	*Electromagnetic compatibility (EMC) – Part 4-30: Testing and measurement techniques – Power quality measurement methods*
Other specifications		
Component	EN 50438	*Requirements for micro-generating plants to be connected in parallel with public low-voltage distribution networks* NOTE In Europe EN 50438 provides requirements for connection of micro-generators (currently under revision). Draft TS for larger units currently are being prepared by WG3 of Cenelec TC8X, which specifies the generic requirements for connecting DG to the public distribution network.
Component	CLC TS 50549-1	*Requirements for generating plants to be connected in parallel with distribution networks – Part 1: Connection to a LV distribution network above 16 A*
Component	CLC TS 50549-2	*Requirements for generating plants to be connected in parallel with distribution networks – Part 2: Connection to a MV distribution network*
Component	IEEE Std. 1547.1 [a]	*Standard for Conformance Test Procedures for Equipment Interconnecting Distributed Resources with Electric Power Systems* Published in 2005, this standard further describes the testing of the interconnection in order to determine whether or not it conforms to standards.
Component	IEEE Std. 1547.2 [a]	*Application Guide for IEEE 1547 Standard for Interconnecting Distributed Resources with Electric Power Systems* This provides a technical background on the standard.
Component	IEEE Std. 1547.3 [a]	*Guide for Monitoring, Information Exchange and Control of Distributed Resources Interconnected with Electric Power Systems* Published in 2007, this standard details techniques for monitoring of distributed systems.
Component	IEEE Std 1547.4 [a]	*Guide for Design, Operation, and Integration of Distributed Resource Island Systems with Electric Power Systems*
Component	IEEE Std 1547.6 [a]	*Recommended Practice For Interconnecting Distributed Resources With Electric Power Systems Distribution Secondary Networks*
Component	IEEE Std 1547.7 [a]	*Guide to Conducting Distribution Impact Studies for Distributed Resource Interconnection*
[a] In the US, the IEEE 1547 series is a set of standards concerning Interconnecting Distributed Resources with Electric Power Systems. Since 2003, three standards in the IEEE 1547 Series have been released by the IEEE and another three are still in the draft phase. The Energy Policy Act of 2005 established IEEE 1547 as the national standard for the interconnection of distributed generation resources. An amendment IEEE 1547a was published in 2014.		

5.8.2.4 Coming standards

See Table 14. Refer to 5.2.5.3 for the definition of the criteria considered in this document for stating that a standard is “coming”.

Table 14 – Connecting and managing DER – Coming standards

Layer	Standard	Title and comments
Component	IEC 62786	*Distributed energy resourcesconnection with the grid*
Component	IEC 62898 series[a]	*Microgrids*
Other specifications		
Component	IEEE P1547	*Draft Standard for Interconnection and Interoperability of Distributed Energy Resources with Associated Electric Power Systems Interfaces* *(full revision of IEEE Std 1547)*
Component	IEEE P1547.8	*(draft) Recommended Practice for Establishing Methods and Procedures that Provide Supplemental Support for Implementation Strategies for Expanded Use of IEEE Standard 1547*

[a] Under preparation.

5.8.3 Integrating power electronics in the electrical grid

5.8.3.1 General

Power electronics will play a major role in Smart Grids as the connecting element for renewable generation, especially wind and solar, as well as control actor for the active and reactive power flow within the grid, e.g. FACTS and HVDC lines.

Both application areas will have their specific aspects regarding electrotechnical characteristics of the Smart Grid.

5.8.3.2 Power electronics for connecting generation sources

In the past the electric power grid was mainly driven by synchronous generators and the electrotechnical behaviour of these rotating machines took a major contribution to the dynamic stability of the grid as well as for the fault identification within the grid.

- The kinetic energy stored in the rotating part of turbine and generator took care of the frequency stability against big fluctuation of generation or load.
- Additionally some synchronous generators are equipped with a damping winding, which improves the stabilizing impact to the grid.
- In case of a short circuit at a short electrical distance from a synchronous generator, a large short circuit current (above its rated current) will be injected into the grid. This results from the fact that the mechanical power fed into the generator from the turbine stays constant in the first seconds of the short circuit, while the voltage at the generator's grid connection point is decreased due to the short circuit in the grid. Since the generator cannot store energy, the generated current needs to be increased to keep the power value which is injected into the grid constant. Of course the protection system of the generator has to reduce this overcurrent within a short time to avoid damages.

Most of the inverters used today to connect renewable generation to the grid do not provide comparable services to the grid, as they are designed to follow the grid frequency and to inject the power produced by the renewable generating unit. Technically at least the behaviour described in the first two bullets above could be implemented into an inverter, but this would require some kind of energy storage connected to the inverter to decouple the power fed into the grid to some extent from the power received from the renewable generating unit. The short circuit behaviour of synchronous generators could also be implemented, but this isn't technically feasible as it would require a huge overdimensioning of the power electronics inside the inverter.

So if more and more generation will be connected to the grid by means of power electronics and the number of big rotating machines decreases as a consequence, then the dynamic stability of the grid may become endangered. To secure a reliable grid operation also with a large share of renewable generation, it is necessary to investigate the impact of losing grid inertia when replacing rotating generation with power electronics.

5.8.3.3 Power electronics for controlling active and reactive power flow

See also 5.9.2.

FACTS utilizes power electronics to implement a flexible control element into the grid which can control the active and power flow through a single grid branch and indirectly via the reactive power the voltage at both ends of this branch. These capabilities can be used to influence the static energy flow as well as the voltage profile in the surrounding of the FACTS location. If integrated into a wide area control system, FACTS may also be utilized to damp power swing within a large interconnected power grid.

HVDC lines may be used to exchange energy between decoupled AC grids. From the grid point of view the connected end of the HVDC line could be seen as an inverter connected generation or load and for the generating operation the aspects are discussed in 5.8.3.2.

The other application for HVDC lines is the improvement of the transfer capability of an AC grid as a dedicated point to point HVDC connection or by creating a so-called HVDC overlay network.

Point to point connections can be seen as similar to FACTS, except the distance between the two end points of the controlled DC branch is bigger.

HVDC based overlay grids with nodes and meshes require some means to isolate faulty DC branches to avoid a complete outage if one part of the grid has a failure. To identify the faulty part of the DC grid, protection systems are also required which are able to locate the fault in the DC grid.

The long distance between the ends of a DC connection or grid will result often in the ends being connected to different AGC[7] control areas of the grid. Therefore, it will become necessary to define methods for integrating HVDC lines into the generation and power interchange control mechanisms.

5.8.4 Low voltage DC grids

As more and more solar generation and battery storage are connected to the low voltage and on the other hand many consumer devices require internal DC power (e.g. TV set, computers, LED lighting, etc.), there are thoughts to implement a DC grid at the consumer site to avoid multiple conversion from AC to DC and vice versa. These DC grids will have only small size, e.g. within a single building.

To secure vendor independent connectivity for a LV DC grid, it will be necessary to standardize the physical details of the plugs and sockets as well as the voltage level.

5.8.5 LV installation

5.8.5.1 General

The LV installation shall be according to the requirements of the IEC 60364 series.

7 AGC = Automatic Generation Control, a function of an energy management system responsible for controlling the grid frequency and power interchange with other grid.

In particular, the standards listed in Table 15 and Table 16 are seen to be very important for Smart Grid LV-installations.

Table 15 – LV installations available standards

Layer	Standard	Title and comments
Component	IEC 60364-4-41	*Low-voltage electrical installations – Part 4-41: Protection for safety – Protection against electric shock*
Component	IEC 60364-5-53	*Electrical installations of buildings – Part 5-53: Selection and erection of electrical equipment – Isolation, switching and control*
Component	IEC 60364-5-55	*Electrical installations of buildings – Part 5-55: Selection and erection of electrical equipment – Other equipment*
Component	IEC 60364-7-712	*Electrical installations of buildings – Part 7-712: Requirements for special installations or locations – Solar photovoltaic (PV) power supply systems*
Component	IEC 60364-7-722	*Electrical installations of buildings – Part 7-722: Requirements for special installations or locations – Supplies for electric vehicles*

Table 16 – LV installations coming standards

Layer	Standard	Title and comments
Component	IEC 60364-8-2	*Low voltage electrical installations – Part 8-2: Smart Low-Voltage Electrical Installations*

5.8.5.2 Verification

The LV installation shall be tested according to IEC 60364-6, which lays down requirements for the verification, by inspection and testing, of the compliance of the installation with the relevant requirements of other parts of IEC 60364. Criteria for testing are given and tests described. This IEC 60364-6 part is concerned only with new installations; it is not concerned with the inspection and testing of existing installations. However, the criteria for inspection and the tests described may be applied, if thought appropriate, to existing installations.

5.9 Per system standard breakdown

5.9.1 Generation management system

5.9.1.1 Description

In considering the energy crisis and sustainable development, renewable energy generation is becoming more and more important, beside conventional bulk generation. Compared to conventional generation (thermal power, hydropower, nuclear generation, etc.), renewable energy generation (wind power, solar power, etc.) is much more uncertain. It is a great challenge to interconnect renewable energy generation to power systems. Therefore, one important task of Smart Grid is to provide a dynamic platform for free and safe interconnection of renewable energy generation to power systems, including the impact of these large renewable energy generation plants on the monitoring and control of the conventional one. Smart Grid will play an important role in ensuring power supply security and sustainable development.

According to different kinds of energy, generation can be classified into the following categories:

- wind power (testing and certification of wind turbines, design requirements of wind turbines, assessment and measurement of wind power, etc.);

- solar power (test and certification of photovoltaic devices, utility interface of photovoltaic systems, over-voltage protection of photovoltaic systems, assessment and measurement of solar power);
- marine power (design requirements for marine energy systems, assessment of performance of wave energy converters, etc.);
- fuel cell (safety of fuel cell power systems, performance test method for fuel, etc.)
- pumped storage (acceptance tests of hydraulic turbines, storage pumps and pump-turbines, etc.);
- distributed generation (distributed resources interconnected with power systems, design, test interconnecting and protection of small renewable energy and hybrid systems for rural electrification, etc.);
- nuclear generation (interconnecting of nuclear generation, etc.);
- conventional generation (test and certification for hydraulic turbines, communication networks for power utility automation, interconnecting of conventional power plants to power systems, active power and frequency control, reliability standards, protection and control, etc.)

Nowadays large-scale solar photovoltaic generation plants the size of 10 GW are under construction, and also large-scale wind power fields. These plants in such a large size will bring great challenges to power system security. Interconnecting standards for large-scale renewable energy generation plants are urgently needed.

Marine power generation will typically have different load profiles that are highly variable as far as resources are concerned. For tidal power, these load profiles are predictable; however, for wave power, the nature of the resource results in an intermittent loading profiling, similar to some extent to wind energy. Where a Smart Grid is to be designed to incorporate a wave or tidal generation unit, the designer shall take into account the intermittency and possible profiles of this generation. The designer shall consider the requirements and information provided in the IEC 62600 series. Designers of Smart Grids that are to incorporate a wave or tidal generation unit shall consider the work programme of TC 114 in order to identify any forthcoming documents that could be relevant

A growing share of renewable energy sources connected to the power grid is foreseen and will lead to a steady transition towards a complex combination of a few large centralized power plants and a great number of small and decentralized power generating facilities. Integrating these facilities into a reliable and affordable power system will require an unprecedented level of co-operative action within the electric industry and between the industry and states.

The power grid has existing flexibility in the system to cost-effectively integrate wind and solar resources but, as operated today, that flexibility is largely unused. The Generation management system will address such challenges as:

- expand sub-hourly dispatch and intra-hour scheduling;
- improve reserves management;
- access greater flexibility in the dispatch of existing generating plants;
- focus on flexibility for new generating plants.

5.9.1.2 System summary

Generation management system refers to the real-time information system and all the elements needed to support all the relevant operational activities and functions used in day to day operation of the generation system, including the control of generation assets under normal and abnormal operating conditions. It enables implementing generating programs that are prepared for a certain period, improves the information made available to operators at the control room, field and crew personnel, customer service representatives and management. It may thus support or help in making operational decisions.

Such a system is usually made of one or many interconnected IT systems, connected to field generation operation systems, through the use of LAN/WAN communication systems. It may also include the components needed to enable field crew to operate the generation system from the field.

A generation management system usually provides the following major functions:

- EMS/SCADA, real time monitoring and control of the (geographically localized) generation system at the Transmission Operator level;
- DCS, real time monitoring and control of the generation assets at the station/field level;
- scheduling, monitoring and control of the (scattered) generation fleet at the generation company level for the production of energy, ancillary services and by-products in close relation to the Asset Management System;
- advanced generation management applications;
- work management;
- support of trading functions;
- black start facilities.

Addressing these challenges requires process-level and asset management system constraints to be more closely integrated within the higher levels of the generation management system.

5.9.1.3 Set of System Capabilities

Table 17 provides a set of System Capabilities which may be supported by a generation management system.

The meanings of the three last columns (AVAILABLE, COMING, Not yet) and of the “C”, “I”, “CI”, “X” conventions are given in 5.5.2.5.

Table 17 – Generation management systems – Capabilities

Cluster	System Capabilities	Supported by standards		
		AVAILABLE	COMING	Not yet
Maintaining grid assets	Monitoring assets conditions	CI		
	Supporting periodic maintenance (and planning)			X
	Optimize field crew operation			X
	Archive maintenance information	CI		
Managing power quality	VAR regulation	CI		
	Frequency support	CI		
Provide and collect contractual measurements	Collect metered data (for revenue purposes)			
Connect an active actor to the grid	Managing generation connection to the grid	CI		
Blackout management	Restore power after blackout	CI		
	Under frequency shedding			

Cluster	System Capabilities	Supported by standards		
		AVAILABLE	COMING	Not yet
Demand and production (generation) flexibility	Receiving metrological or price information for further action by consumer or CEM			
	Load forecast (from local)	CI		
	Generation forecast (from remote)	CI		
	Generation forecast (from local)	CI		
	Participating in the electricity market			
	Registration/deregistration of customers in DR program			X
Grid stability	Stabilizing the network after fault condition (Post-fault handling)			
	Monitoring and reduce power oscillation damping			
	Stabilizing network by reducing sub-synchronous resonance (Sub-synchronous damping)			
	Monitoring and reduce harmonic mitigation	I		
	Monitoring and reduce voltage flicker	I		
Generation Operation Scheduling	Day-ahead fleet scheduling			X
	Intra-day fleet scheduling			X
	Plant scheduling			X
	Ancillary services and reserve products control			X
	Fuel and other resources allocation, cogeneration and other by-products production			X
	Day-ahead hydro plant valley scheduling			X
Generation Maintenance	Commissioning and maintenance strategy definition			X
	Field data collection for corrective and reactive maintenance			X
	Field data collection for preventive maintenance			X
	Field alarms collection for maintenance	CI		
	Collection of switching cycles and operating hours (maintenance counters)			X
	Field data collection for predictive or condition based maintenance	CI		
	Collection of additional maintenance counters for boiler and steam turbine stress			X
	Risk assessment	I		
	Condition based operational advisories			X
	Condenser maintenance optimization			X
Generation Transverse	Permit To Work management			X
	Plant capability estimation			X
	Equipment actual availability monitoring	CI		
	Performance monitoring	CI		
	Production reporting			X
	Emissions reporting			X
	Emissions compliance assessment			X

5.9.1.4 Requirements

Technical standards for interconnecting to power systems of different kinds of renewable energy generation should be paid special attention and fully studied, to meet the requirements of the present and future development of renewable energy and power grids. Technical standards for renewable energy generation in different sizes and at different voltage levels should be studied. In particular, technical standards for large-scale renewable energy generation plants should be studied as soon as possible.

5.9.1.5 List of standards

5.9.1.5.1 Available standards

Table 18 provides a summary of the standards which appear relevant to support the generation management system.

According to 5.2.2, standards for cross-cutting domains such as EMC or security are treated separately (IEC 62351 series, ISO/IEC 27001, EN 61000, etc.).

Refer to 5.2.5.3 for the definition of the criteria considered in this document for stating that a standard is "available".

Table 18 – Generation management system – Available standards

Layer	Standard	Title and comments
Information	IEC 61131 series	*Programmable controllers*
Information	IEC 61499 series	*Function blocks*
Information	IEC 61804 series	*Function blocks (FB) for process control*
Information	IEC 62264 series	*Enterprise-control system integration (ISA 95)*
Information	IEC 61512 series	*Batch control* (ISA 88)
Information	IEC 61987 series	*Industrial-process measurement and control – Data structures and elements in process equipment catalogues*
Information	IEC 61360	*CDD – Common Data Dictionary*, available from <http://std.iec.ch/iec61360>
Information	IEC 61968-1 IEC 61968-2 IEC 61968-3 IEC 61968-4 IEC 61968-9 IEC 61968-11	*Application integration at electric utilities – System interfaces for distribution management*
Information	IEC 61968-6	*Application integration at electric utilities – System interfaces for distribution management – Part 6: Interfaces for maintenance and construction*
Information	IEC 61970-1 IEC 61970-2 IEC 61970-301 IEC 61970-401 IEC 61970-452 IEC 61970-453 IEC 61970-456 IEC 61970-501 IEC 61970-552	*Energy management system application program interface (EMS-API)*

Layer	Standard	Title and comments
Information	IEC 62325-301 IEC 62325-451-1 IEC 62325-451-2 IEC 62325-451-3 IEC 62325-451-4 IEC 62325-451-5	*Framework for energy market communications* CIM information model (Market profiles)
Information	IEC 61850-7-4 IEC 61850-7-3 IEC 61850-7-2 IEC 61850-6	*Communication networks and systems for power utility automation* Core Information model for the IEC 61850 series
Information	IEC 61850-7-410	*Communication networks and systems for power utility automation – Part 7-410: Basic communication structure – Hydroelectric power plants – Communication for monitoring and control*
Information	IEC 61400-25-2	*Wind turbines – Part 25-2: Communications for monitoring and control of wind power plants – Information models*
Information	IEC 62541-1 IEC 62541-2 IEC 62541-3 IEC 62541-5 IEC 62541-8 IEC 62541-9 IEC 62541-10 OPC UA part 11 OPC UA part PLCopen	*OPC unified architecture* OPC foundation open specifications for OPC UA parts 11 and PLCopen are not yet announced in the IEC TC 65/SC 65E work program
Information	IEC 62325-450	*Framework for energy market communications – Part 450: Profile and context modelling rules* CIM information model (Market profiles)
Communication	IEC TR 61850-90-4	*Communication networks and systems for power utility automation – Part 90-4: Network engineering guidelines* Guidelines for communication within substation
Communication	IEC 61158 series IEC 61784-1	*Industrial communication networks – Fieldbus specifications* *Industrial communication networks – Profiles – Part 1: Fieldbus profiles*
Communication	IEC 62439 series	*Industrial communication networks – High availability automation networks* Based on the ISO/IEC 8802-3 (Ethernet) technology
Communication	IEC 62541-4 IEC 62541-6 IEC 62541-7	*OPC unified architecture* IEC standards for OPC UA
Communication	IEC 61850-8-1	*Communication networks and systems for power utility automation – Part 8-1: Specific communication service mapping (SCSM) – Mappings to MMS (ISO 9506-1 and ISO 9506-2) and to ISO/IEC 8802-3* IEC 61850 communication except Sample values
Communication	IEC TR 61850-90-1	*Communication networks and systems for power utility automation – Part 90-1: Use of IEC 61850 for the communication between substations*

Layer	Standard	Title and comments
Communication, Information	IEC TR 61850-90-2	*Communication networks and systems for power utility automation* *Part 90-2: Using IEC 61850 for the communication between substations and control centres*
Communication	IEC 60870-5-104	*Telecontrol equipment and systems – Part 5-104: Transmission protocols – Network access for IEC 60870-5-101 using standard transport profiles* to connect to the Plant (standard transport protocol)
Communication	IEC 60870-5-101	*Telecontrol equipment and systems – Part 5-101: Transmission protocols – Companion standard for basic telecontrol tasks* to connect to the Plant (serial link)
Communication	IEC 60870-5-103	*Telecontrol equipment and systems – Part 5-103: Transmission protocols – Companion standard for the informative interface of protection equipment* to connect to protection Relays
Communication	IEC 61850-9-2	*Communication networks and systems for power utility automation – Part 9-2: Specific communication service mapping (SCSM) – Sampled values over ISO/IEC 8802-3* IEC 61850 Sample values communication
Communication	IEC PAS 61850-9-3	*Communication networks and systems for power utility automation – Part 9-3: Precision time protocol profile for power utility automation*
Communication	IEC 61968-100	*Application integration at electric utilities – System interfaces for distribution management – Part 100: Implementation profiles*
Communication	IEC 62351 series	*Power systems management and associated information exchange – Data and communications security* Cyber-security aspects (see 5.10.4)
Component	IEC 60255 series	*Measuring relays and protection equipment*
Component	IEC 61400 series	*Wind turbines*
Component	IEC 60904 series	*Photovoltaic devices*
Component	IEC 61727	*Photovoltaic (PV) systems – Characteristics of the utility interface*
Component	IEC 62446 series	*Photovoltaic (PV) systems – Requirements for testing, documentation and maintenance*
Component	IEC 62282 series	*Fuel cell technologies*
Component	IEC 60193	*Hydraulic turbines, storage pumps and pump-turbines – Model acceptance tests*
Component	IEEE Std 1547	*Standard for Interconnecting Distributed Resources with Electric Power Systems*

Refer also to 5.7.10 for standards related to the connection to the Grid, and more specifically to 5.8.3 dealing with the use of power electronics.

5.9.1.5.2 Coming standards

See Table 19. Refer to 5.2.5.3 for the definition of the criteria considered in this document for stating that a standard is “coming”.

Table 19 – Generation management system – Coming standards

Layer	Standard	Title and comments
Information	IEC 61970-458 IEC 61970-502-8	*Energy management system application program interface (EMS-API)*
Information	IEC 62325-351	*Framework for energy market communications – Part 351: CIM European market model exchange profile*
Information	IEC 62361-100 IEC 62361-101	*Power systems management and associated information exchange – Interoperability in the long term* CIM information model (profiling rules)
Communication	IEC 61850-8-2 [a]	*Communication networks and systems for power utility automation – Part 8-2: Specific communication service mapping (SCSM) – Mappings to Extensible Messaging Presence Protocol (XMPP)*
Communication	IEC/IEEE 61850-9-3	*Communication networks and systems for power utility automation – Part 9-3: Precision time protocol profile for power utility automation*
Communication	IEC 62351 series	*Power systems management and associated information exchange – Data and communications security* Cyber-security aspects (refer to 5.10.4)

[a] Under preparation.

Refer also to 5.7.10 for standards related to the connection to the Grid, and more specifically to 5.8.3 dealing with the use of power electronics.

5.9.1.6 Gaps

IEC standards need to add new standards for wind power and solar power. There are two missing standards for wind power: wind turbine/wind farm low voltage ride through capability testing standard; and wind power generation prediction standard. There are three missing standards for solar power:

- testing methodology and regulation for PV system connecting to power grid[8];
- PV system low voltage ride through capability testing standard; and
- PV power generation prediction standard.

5.9.1.7 Generation management systems mapping

5.9.1.7.1 Component layer

As shown in Figure 7, the Generation operation component architecture involves all Zones from Process to Enterprise levels, which may be interconnected through wires or communication.

The lower level components are easily identified as Generation related or not. The higher level components are more tightly integrated with Market, Asset Management and Transmission related components.

The Process level is populated with:

- electrical equipment, sensors and actuators (such as current and voltage transformers, breakers or switches);
- electro-mechanical machines with associated sensors and actuators (turbines and generators);

8 IEEE 1547.1 and UL 1741 SA provide testing standards for both PV system connection to the power grid and for voltage (and frequency) ride-throughs.

- industrial equipment with general purpose sensors and actuators (typically hydro or thermal plant).

The Field level is in charge of protection, monitoring and control. It is mostly based on PLCs, which can be replaced by IEDs for electrical equipment.

Above the DCS HMI, higher level components are to be integrated with Market, Asset Management and Transmission related components.

The Transmission EMS/SCADA system communicates with the Generation Management System RTU to implement the Secondary Generation Control.

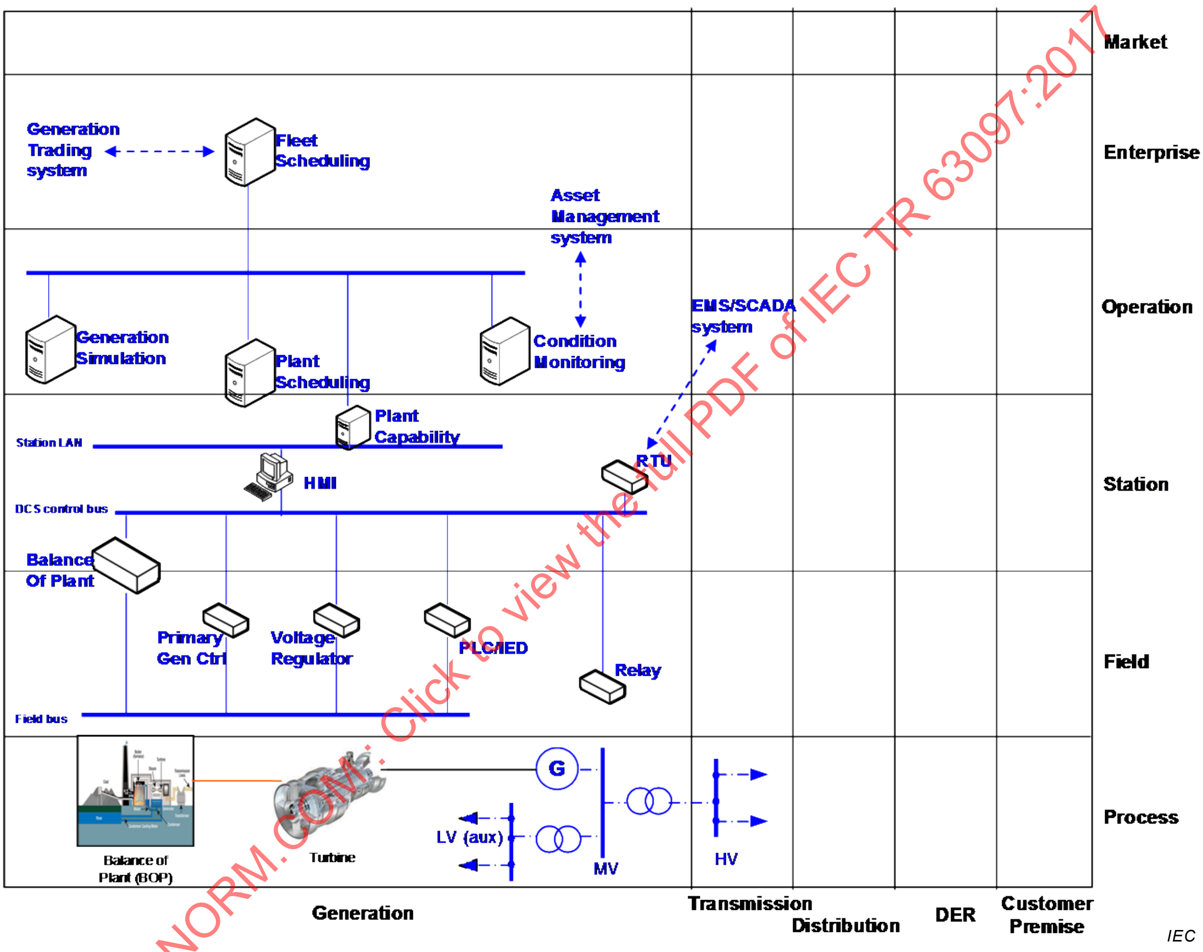


Figure 7 – Generation management system – Component layer

5.9.1.7.2 Communication layer

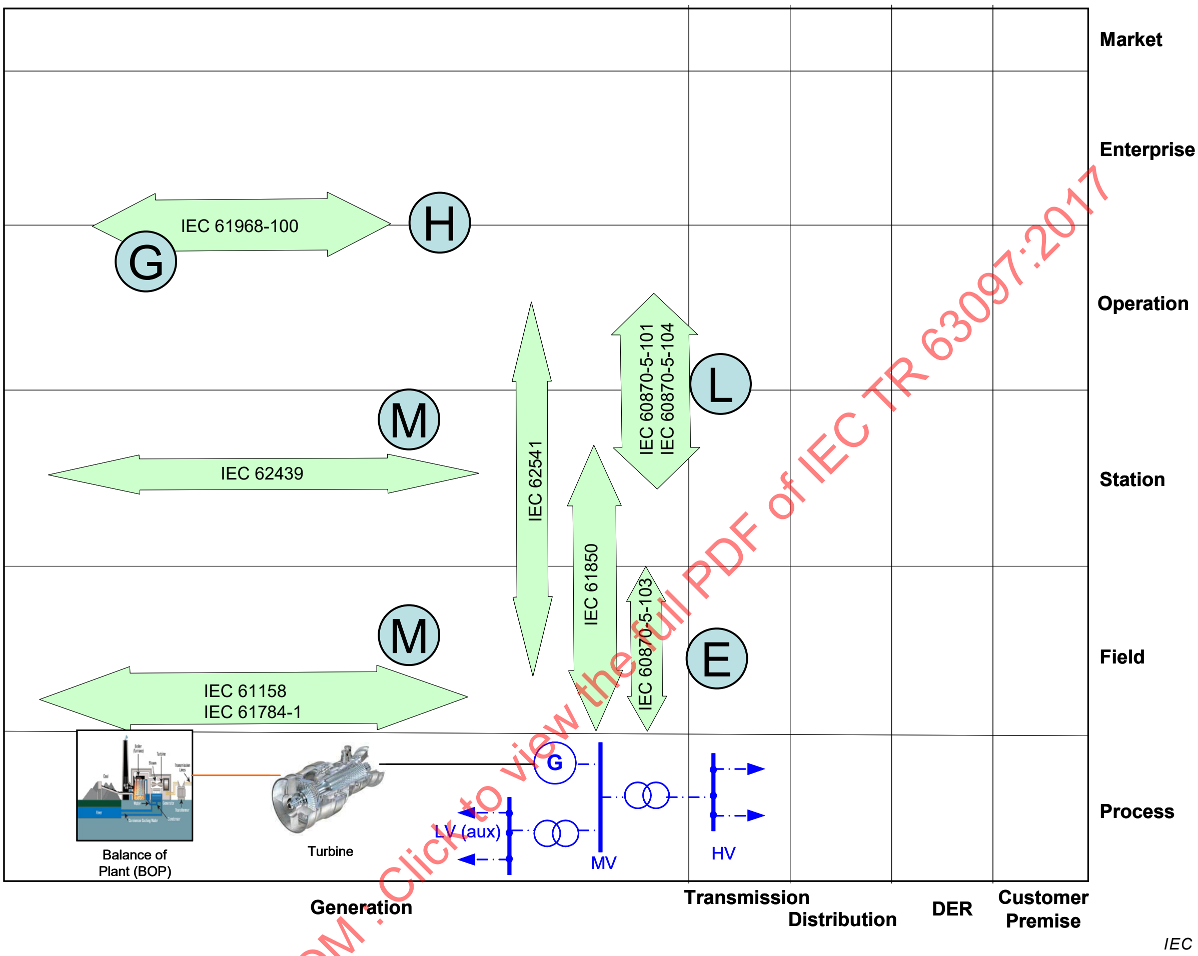
Within the Generation management system, the significant communication protocols, as shown in Figure 8, are the following:

- field bus protocols are standardized within the IEC 61158 series and IEC 61784-1.
- mission-critical networks hosted in Station level rely on IEC 62439 series high availability automation networks;
- the communication standards of the IEC 60870-5 family (profiles 101 and 104 to connect to the Plant, profile 103 to connect to protection Relays);
- the messaging standard IEC 61968-100 for Enterprise and Operation level messages;
- the communication standards of the IEC 61850 family for IED components;

- the communication standards of the IEC 62541 family for OPC UA servers and clients.

This set of standards can be positioned in this way on the communication layer of SGAM.

Refer to 5.10.4 for getting details on cyber-security standards and more specifically on where and how to apply the IEC 62351 series and/or other cyber-security mechanisms.



NOTE The letters in the blue disks refer to the network types defined in 5.10.1.2.

Figure 8 – Generation management system – Communication layer

5.9.1.7.3 Information (Data) layer

The information layer of Generation management, presented in Figure 9, is based on the following families of information models.

- Field device functions and interfaces are standardized within the IEC 61131 series, with associated work in progress: IEC 61499 and IEC 61804 series.
- Plant electrical devices are standardized within the IEC 61850 series, with work in progress for other field devices: IEC 61400-25-2 for wind turbines, IEC 61850-7-410 for hydro power plants.
- Industrial plant information models are standardized in the following family: IEC 62264 series (ISA 95), IEC 61512 (ISA 88), IEC 61987 series and IEC 61360. Their relevance to the Generation management system is at the Station level.

Operation and Enterprise level information models are standardized in the CIM family: IEC 61968, IEC 61970, IEC 62325 series and IEC 62361. The relevance of IEC 61968 parts to Generation has not been formally assessed yet. Few parts are fully appropriate for

Generation domain, but most parts can be extended to become relevant to Generation domain.

Mappings between most of these information models and the IEC 62541 address space are defined or in progress.

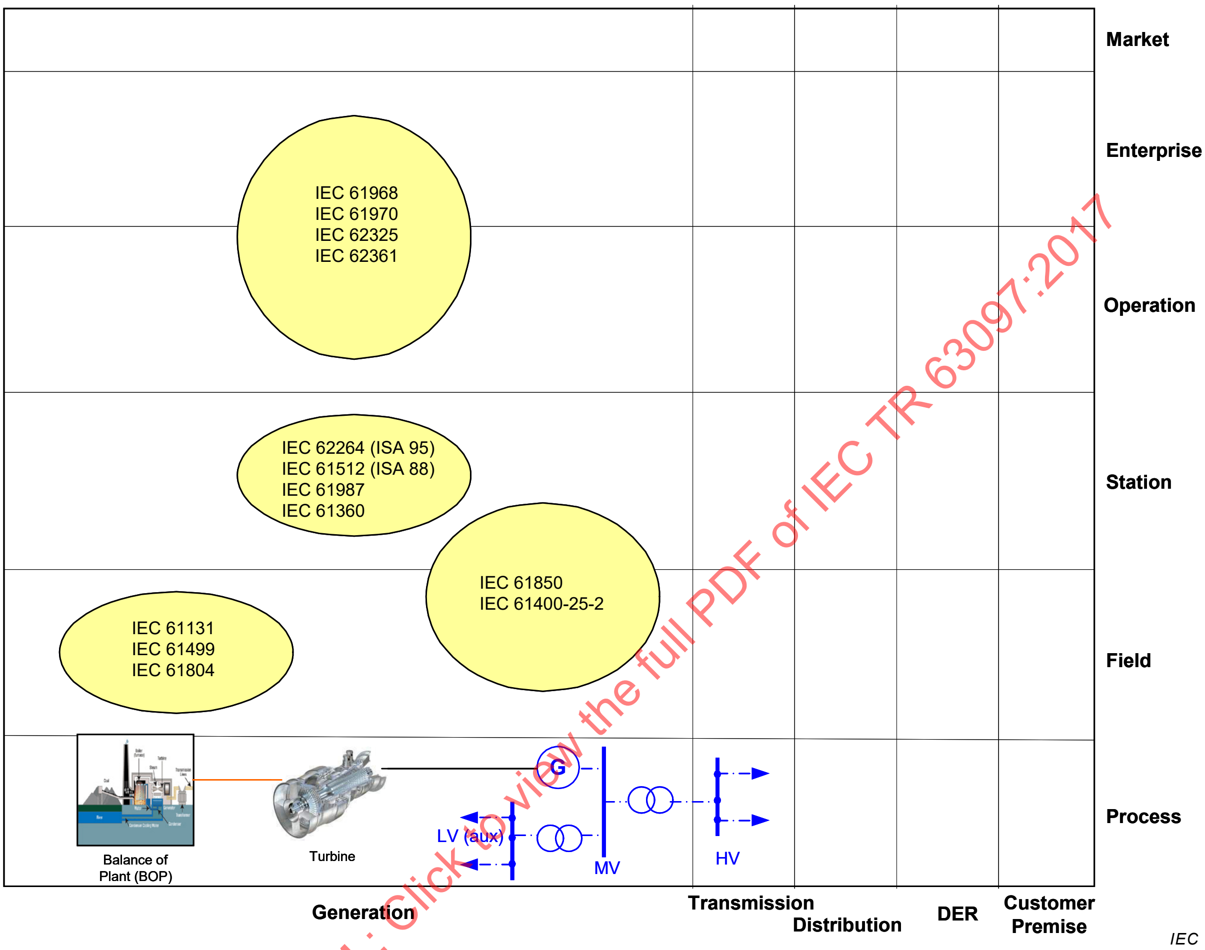


Figure 9 – Generation management system – Information layer

5.9.2 FACTS and HVDC systems for grids

5.9.2.1 Description

Today's power transmission systems have the task of transmitting power from point A to point B reliably, safely and efficiently. It is also necessary to transmit power in a manner that is not harmful to the environment.

Typical transmission applications are FACTS (Flexible AC Transmission Systems) and HVDC (High Voltage Direct Current) links and Back-to-back systems.

The System Capabilities for FACTS include fast voltage control, increased transmission capacity over long lines, power flow control in meshed systems and power oscillation damping. With FACTS, more power can be transmitted within the power system. When the technical or economic feasibility of the conventional three-phase technology reaches its limit, HVDC will be a solution. Its main application areas are economical transmission of bulk power over long distances and interconnection of asynchronous power grids.

HVDC (High Voltage Direct Current) 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.

The new system of voltage-sourced converters (VSC) includes a compact layout of the converter stations and advanced control features such as independent active and reactive power control and black start capability.

The main types of HVDC converters are distinguished by their DC circuit arrangements, as follows:

- Back-to-back:

  Indicates that the rectifier and inverter are located in the same station. These converters are mainly used:

  – to connect asynchronous high-voltage power systems or systems with different frequencies;

  – to stabilize weak AC links or to supply even more active power where the AC system reaches the limit of short circuit capability;

  – grid power flow control within synchronous AC systems.

- Cable transmission:

  The most feasible solution for transmitting power across the sea with cables to supply islands/offshore platforms from the mainland and vice versa.

- Long-distance transmission:

  For transmission of bulk power over long distances (beyond approximately 600 km, considered as the break-even distance). This includes voltage levels of 800 kV and higher.

Flexible AC Transmission Systems (FACTS) have been evolving into a mature technology with high power ratings. This technology, proven in various applications requiring rapid dynamic response, ability for frequent variations in output, and/or smoothly adjustable output, has become a first-rate, highly reliable one. FACTS, based on power electronics, have been developed to improve the performance of weak AC systems and to make long distance AC transmission feasible. FACTS can also help solve technical problems in the interconnected power systems.

FACTS are available in parallel connection:

- Static Var Compensator (SVC),
- Static Synchronous Compensator (STATCOM),

or in series connection:

- Fixed Series Compensation (FSC),
- Thyristor Controlled/Protected Series Compensation (TCSC/TPSC).

With FACTS, a number of benefits can be attained in power systems, such as dynamic voltage control, increased power transmission capability and stability, facilitating grid integration of renewable power, and maintaining power quality in grids dominated by heavy and complex industrial loads.

- Damping of power oscillations (POD).
- Load-flow control.
- Mitigation of SSRs (sub-synchronous resonances).
- Increase in system capability and stability of power corridors, without any need to build new lines. This is a highly attractive option, costing less than new lines, with less time expenditure as well as impact on the environment.

- Dynamic voltage control, to limit over-voltages over lightly loaded lines and cable systems, as well as, on the other side, prevent voltage depressions or even collapses in heavily loaded or faulty systems. In the latter case, systems with dominant air conditioner loads are becoming increasingly important as examples of what can be achieved with FACTS when it comes to dynamic voltage support in power grids in countries or regions with a hot climate.
- Facilitating connection of renewable generation by maintaining grid stability while fulfilling grid codes.
- Facilitating the building of high speed rail by supporting the feeding grid and maintaining power quality in the point of connection.
- Maintaining power quality in grids dominated by heavy and complex industrial loads such as steel plants and large mining complexes.
- Support of fast restoration by stabilizing the network after fault conditions.

5.9.2.2 System summary

FACTS and HVDC systems cover several power electronics based systems utilized in AC power transmission and distribution. They are particularly justifiable in applications requiring rapid dynamic response, ability for frequent variations in output, and/or smoothly adjustable output. Under such conditions, they are a highly useful option for enabling or increasing the utilization of transmission and distribution grids.

5.9.2.3 Set of System Capabilities

Table 20 provides a set of System Capabilities which may be supported by FACTS and HVDC systems.

The meanings of the three last columns (AVAILABLE, COMING, Not yet) and of the “C”, “I”, “CI”, “X” conventions are given in 5.5.2.5.

Table 20 – FACTS and HVDC systems – System Capabilities

Cluster	System Capabilities	Supported by standards		
		AVAILABLE	COMING	Not yet
Controlling the grid (locally/ remotely) manually or automatically	Feeder load balancing	CI		
Managing power quality	(dynamic) Voltage optimization at source level as grid support (VAR control)			
	Local voltage regulation by use of FACTS			
System and security management	Discover a new component in the system	C		I
	Configure newly discovered device automatically to act within the system	C		I
	Distributing and synchronizing clocks	I	C	
Grid stability	Stabilizing network after fault condition (Post-fault handling)			
	Monitoring and reduce power oscillation damping			
	Stabilizing network by reducing sub-synchronous resonance (Sub-synchronous damping)			
	Monitoring and reduce harmonic mitigation	I		
	Monitoring and reduce voltage flicker	I		
Connect an active actor to the grid	Managing generation connection to the grid	CI		

5.9.2.4 Requirements

From a Smart Grid viewpoint, the main requirement is the seamless integration of the described advanced equipment into the overall system architecture of an energy management system. This means that HVDC back-to-back, long distance transmission and FACTS have to be integrated in the overall concept of Wide Area Monitoring and Control for optimized load flow and network stability.

Long distance transmission via HVDC is equivalent to other transmission systems with lower voltage and power transmission. The technological challenges are of course high but regarded from a Smart Grid perspective, HVDC itself does not pose new requirements. The technological developments and the respective standardization are treated elsewhere (e.g. SG 2, SC 22F and TC 115).

5.9.2.5 List of Standards

5.9.2.5.1 Available standards

See Table 21. Refer to 5.2.5.3 for the definition of the criteria considered in this document for stating that a standard is “available”.

Table 21 – FACTS – Available standards

Layer	Standard	Title and comments
Information	IEC TS 61850-80-1	*Communication networks and systems for power utility automation – Part 80-1: Guideline to exchanging information from a CDC-based data model using IEC 60870-5-101 or IEC 60870-5-104*
Information	IEC 61850-7-4 IEC 61850-7-3 IEC 61850-7-2 IEC 61850-6	*Communication networks and systems for power utility automation* Core Information model and language for the IEC 61850 series
Information	IEC TR 61850-90-3	*Communication networks and systems for power utility automation – Part 90-3: Using IEC 61850 for condition monitoring diagnosis and analysis*
Communication, information	IEC TR 61850-90-2	*Communication networks and systems for power utility automation – Part 90-2: Using IEC 61850 for communication between substations and control centres*
Communication	IEC 60870-5-101	*Telecontrol equipment and systems – Part 5-101: Transmission protocols – Companion standard for basic telecontrol tasks*
Communication	IEC 60870-5-104	*Telecontrol equipment and systems – Part 5-104: Transmission protocols – Network access for IEC 60870-5-101 using standard transport profiles*
Communication	IEC 62351 series	*Power systems management and associated information exchange – Data and communications security* Cyber-security aspects (refer to section 5.10.4)
Component	IEC 60633	*Terminology for high-voltage direct current (HVDC) transmission*
Component	IEC 60919 series	*Performance of high-voltage direct current (HVDC) systems with line-commutated converters*
Component	IEC 60700-1	*Thyristor valves for high voltage direct current (HVDC) power transmission – Part 1: Electrical testing*
Component	IEC 61954	*Static var compensators (SVC) – Testing of thyristor valves*
Component	IEC 61803	*Determination of power losses in high-voltage direct current (HVDC) converter stations*
Other specifications		
Communication	IEEE 1815	*Also known as DNP3*
Information	IEEE 1815-1	*Mapping of IEC 61850 data model over DNP3*

NOTE IEEE 1815 (DNP 3.0) and proprietary standards are mostly in use for telecontrol purposes. However these standards are usually not suitable to meet the higher requirements regarding data exchange, bandwidth, etc. to be integrated in a distributed protection-related automation system.

5.9.2.5.2 Coming standards

See Table 22. Refer to 5.2.5.3 for the definition of the criteria considered in this document for stating that a standard is "coming".

Table 22 – FACTS and HVDC systems – Coming standards

Layer	Standard	Title and comments
Information	IEC TR 61850-90-14[a]	*Communication networks and systems for power utility automation – Part 90-14: Using IEC 61850 for FACTS modelling*
Communication	IEC 62351 series	*Power systems management and associated information exchange – Data and communications security* Cyber-security aspects (see 5.10.4)

[a] Under preparation.

5.9.2.6 Gaps

5.9.2.6.1 Product standards

These standards describe the general requirements, safety and testing of the equipment itself. As always, this is necessary to document the state of the technology and allow a safe and efficient use of the equipment. However this is not a Smart Grid requirement in itself and therefore the available standards are simply listed. These product standards themselves have no effect on Smart Grid.

A further development of system standards in the area of FACTS and HVDC can be expected from the newly founded IEC TC 115 (DC Systems). SG2 coordinates and supports the work of IEC TC 115 and IEC TC 22/SC 22F.

5.9.2.6.2 Interoperability standards

Large substations, especially at transmission level, can have serial links as defined in IEC 60870-5-101 (serial), although IEEE 1815 (DNP 3.0) is also found in some places (serial), but with higher transmission rates. In any case there is a trend towards wide area networks using Ethernet. For IEC 60870-5-104 or similar protocols (IEEE 1815 – DNP 3.0) a minimum of 64 kbit/s should be taken into account. If large data volumes are to be exchanged and additional services (e.g. Voice over IP, Video over IP) provided, the connection should have more bandwidth (64 kbit/s < Bandwidth ≤ 2 048 kbit/s).

IEC 60870-5 has been in use in some installations for switchgear automation. However when confronted with the full scope of IP network requirements, IEC 60870-5 cannot fully support the capability of IEC 61850 and therefore IEC 60870-5-104 is not an ideal candidate to meet future Smart Grid requirements. IEC 61850 seems to be better suited for this approach.

There are existing standards available from IEC to connect this type of equipment to the overall system. However, these need to be amended in order to fulfil the requirements. Generally communication between switchgear and control centre is already possible with IEC 61850, since data exchange is based on TCP/IP. A fixed TCP/IP connection with the respective bandwidth is required.

However, apart from the necessary minor amendments above, IEC 61850 can be implemented without change. The definition contained therein applies to all power levels and therefore also for HVDC and FACTS.

5.9.2.7 FACTS and HVDC systems – mapping

5.9.2.7.1 Preamble

Considering that this system is not interacting with the “Enterprise”, “Market”, “Operation” and “Station” zones of the SGAM, only the “Process” and “Field” zones are shown in Figures 10. 11 and 12.

5.9.2.7.2 Component layer

The FACTS and HVDC systems component architecture, shown in Figure 10, is mostly made of two layers of components, which may be interconnected through wires or communication.

- The Process zone is mostly made of sensors for measurements for the FACTS equipment (SVC/STATCOM, Series Capacitor) with applications and communication to SCADA system through RTU.
- The Station/Operation zone is mostly supporting SCADA application for remote monitoring and control of FACTS and HVDC systems components.

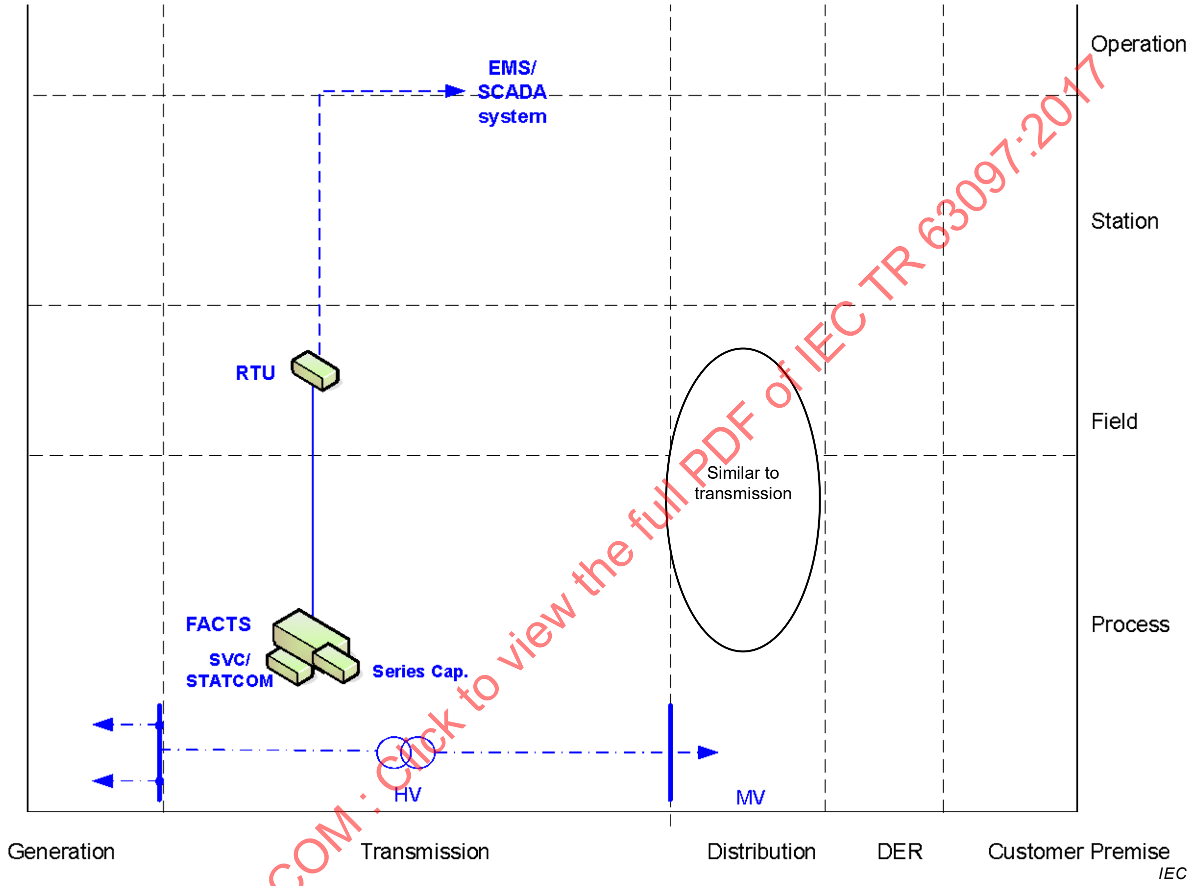
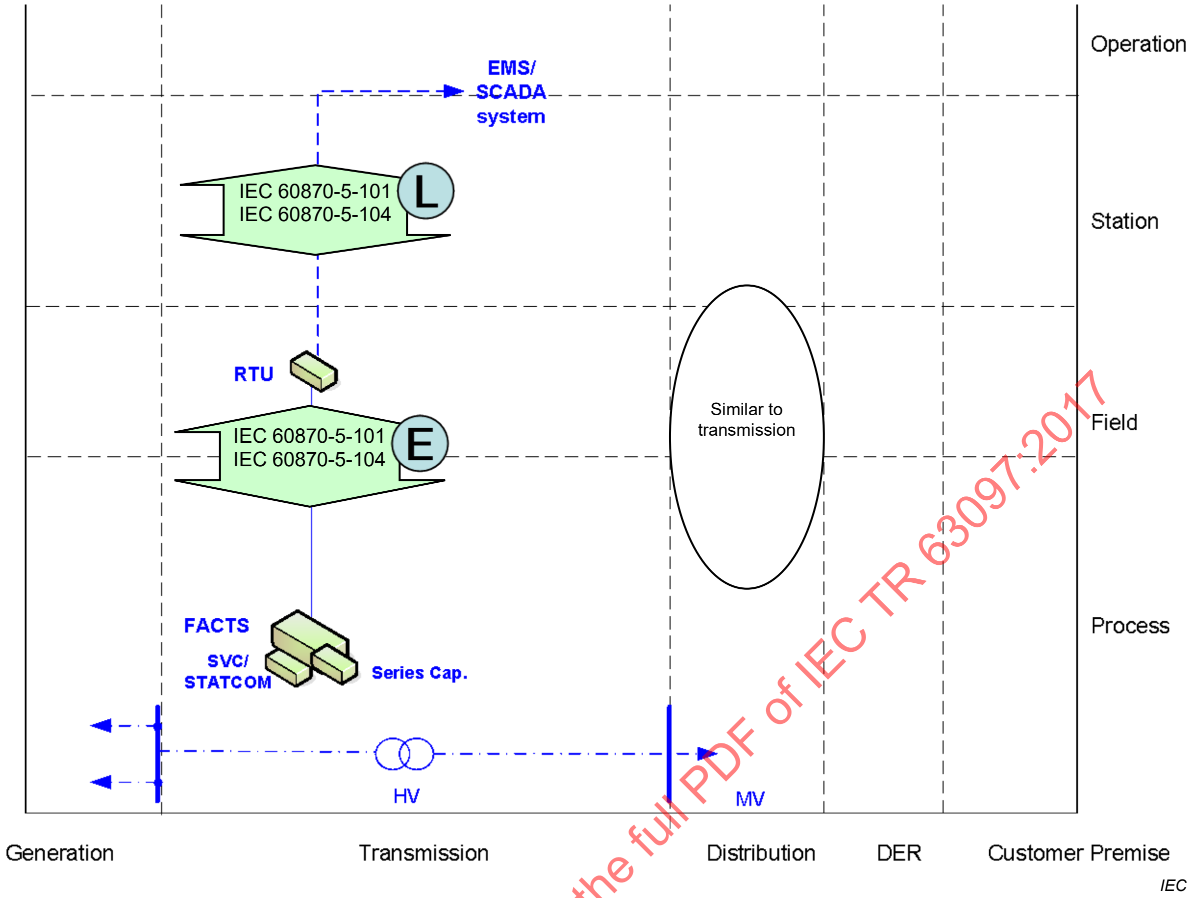


Figure 10 – FACTS and HVDC systems – Component layer

5.9.2.7.3 Communication layer

Vertical communication protocols can be IEC 60870-5-101 or IEC 60870-5-104 from FACTS and HVDC equipment (FACTS controller) via RTU to SCADA, as shown in Figure 11.

Refer to 5.10.4 for details on cyber-security standards and more specifically on where and how to apply the IEC 62351 series and/or other cyber-security mechanisms.



NOTE The letters in the blue disks refer to the network types defined in 5.10.1.2.

Figure 11 – FACTS and HVDC systems – Communication layer

5.9.2.7.4 Information (Data) layer

See Figure 12.

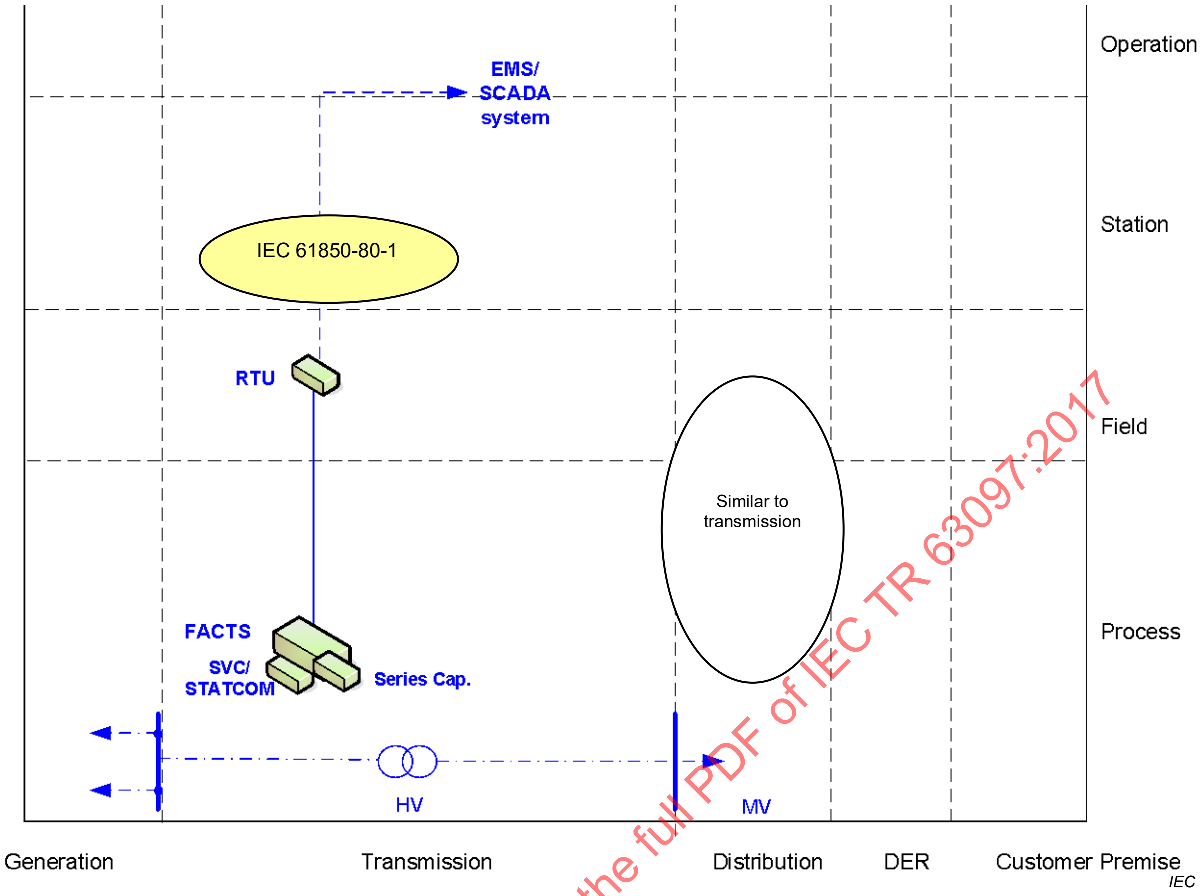


Figure 12 – FACTS and HVDC systems – Information layer

5.9.3 Energy management system

5.9.3.1 Description

The nature of transmission networks will change and grow in importance due to Smart Grid. The increased distance of bulk power generation and load centres will result in a tendency to interconnect systems that used to be independent. Furthermore the exchange and trade of power over long distances will grow in the future.

Information exchange may be necessary across large geographical areas and across traditional systems operation boundaries.

Transmission networks are equipped for obtaining a large number of measurement values; they are able to determine the current load flow situation by means of estimation algorithms. In an estimate, the algorithm uses a numerical network model to try to find a load flow solution in which the root mean square value of the difference between the load flow solution and measurement values is minimal. The estimation of the network state supplies the operator with a complete load flow solution for supervising the network, including those sections of the network for which no measurement values are transmitted to the control system.

The network state estimation is generally followed by a limit value monitoring process that compares the result of the estimation with the operating limits of the individual operational equipment, in order to inform the operator about overloads or other limit value infringements in a timely fashion.

The load flow solution of the network state estimation is then used for ongoing functions such as outage analysis, short-circuit analysis or optimizing load flow as a basic solution for further calculations.

The outage analysis carries out "What if?" studies in which the failure of one or more items of operational equipment is simulated. The results of these load flow calculations are then compared with the operational equipment limits in order to be able to detect secondary faults resulting from an operational equipment failure. If such violations of the so-called (n − 1) security are detected, an attempt can be made by, for example, using a bottleneck management application to define measures with which (n − 1) security can be re-established.

The short-circuit analysis simulates short-circuit situations for all kinds of different network nodes on the basis of numerical model calculations. It checks whether the ensuing short-circuit currents are within the operational equipment limits. The quantities to be checked are the breaking power of the circuit breakers and the peak short-circuit current strength of the systems. Here again, the operator is informed about any limit violations so that suitable remedial action can be taken in a timely fashion.

The optimizing load flow attempts to determine an optimum network state by varying the controlled variables in the power supply system. The following target functions for "optimum" are possible:

The voltage/reactive power optimization attempts to minimize the reactive power flow in the network in order to reduce transmission losses. In particular, the reactive power generation of the generators or compensation equipment and the setting levels of the in-phase regulator act as controlled variables.

The active power optimization system tries to minimize the transmission losses by re-dispatching the incoming supplies from the generator. Any available quadrature or phase-angle regulators can also be used for optimization.

If system reliability has been selected as the target function of the optimization, the optimizing load flow tries to find a system state in which the capacity of all operational equipment is utilized as evenly as possible. The purpose of this is to avoid further secondary failures in the event of failure of heavily utilized resources.

The challenge posed by Smart Grid implementation and the increased use of bulk power transmission will be a change from the quasi-static state of the transmission grid to a more complex and dynamic behaviour. Therefore the current available supervision, management and control functions will need to be adapted.

State estimation, for example, will have to include the transient behaviour of the net. In addition, the traditional power, voltage and current measurements need to be extended to phasor measurement provided by PMUs (Phasor Measurement Units).

An optimal representation and visualization as well as decision-supporting tools have to be developed in order to support the operator of such complex systems. The massive amount of data need to be transmitted, synchronized and represented in a way to safeguard the system integrity of the overall transmission net.

5.9.3.2 System summary

EMS SCADA System refers to the real-time information system and all the elements needed to support all the relevant operational activities and functions used in transmission automation at dispatch centres and control rooms. It improves the information made available to operators at control room, field and crew personnel, management and in certain cases to parties connected to the transmission system, i.e. distribution network operators, power producers, etc.

Such a system is usually made of one or many interconnected IT systems, connected to field communicating devices or sub-systems, through the use of WAN communication systems. It may also include the components needed to enable field crew to operate the network from the field.

EMS SCADA provides following major functions:

- SCADA, real time monitoring and control of the generation system;
- advanced network applications including network modelling;
- outage management including crew and resource management;
- work management.

5.9.3.3 Set of System Capabilities

Table 23 provides the set of System Capabilities which may be supported by an EMS SCADA System.

The meanings of the three last columns (AVAILABLE, COMING, Not yet) and of the “C”, “I”, “CI”, “X” conventions are given in section 5.5.2.5.

Table 23 – EMS SCADA system – Capabilities

		Supported by standards		
Cluster	**System Capabilities**	**AVAILABLE**	**COMING**	**Not yet**
Monitoring the grid flows	Monitoring electrical flows	CI		
	Monitoring power quality for operation (locally)	CI		
	Producing, exposing and logging time-stamped events			
	Supporting time-stamped alarms management at all levels			
	Capture, expose and analyse disturbance events			
	Archive operation information	CI		
Maintaining grid assets	Monitoring assets conditions	CI		X
	Supporting periodic maintenance (and planning)			X
	Optimize field crew operation			X
	Archive maintenance information	CI		
Controlling the grid (locally/ remotely) manually or automatically	Switch/breaker control	CI		
	Enable multiple concurrent levels of control (local-remote)			
Managing power quality	VAR regulation	CI		
Operate DER(s)	DER remote control (dispatch)			X
Connect an active actor to the grid	Managing micro-grid transitions			X
	Managing generation connection to the grid	CI		
Blackout management	Blackout prevention through WAMS			
	Shedding loads based on emergency signals			
Demand and production (generation) flexibility	Receiving metrological or price information for further action by consumer or CEM			
	Load forecast (from remote based on revenue metering)	CI		
	Generation forecast (from remote)	CI		
System and security management	Distributing and synchronizing clocks			

5.9.3.4 Requirements

Requirements to fulfil the described tasks include new sensor devices (e.g. PMU), the definition of standardized data models and protocols to exchange the required information as well as the semantic representation of these devices in the overall system architecture.

A specific requirement for this kind of information is voltage measurement with phase angle information and time synchronization of the data acquisition, which is necessary to correctly assess the system status. Applications need to meet latency and real-time application requirements. Processing needs to be able to integrate data from field level up to EMS systems.

Cyber security will be a major requirement, because of the negative effects on a critical infrastructure, which can occur due to corrupted information and control signals. The main requirements are integrity and reliability of the data exchange and controls (refer to 5.10.4).

The decrease in easily adjustable power generation due to the integration of renewable energy sources poses new challenges to future energy management systems. Therefore new forecast techniques for non-dispatchable renewables plants are required for EMS/DMS systems to reduce the uncertainty associated with these resources.

5.9.3.5 List of standards

5.9.3.5.1 General

Here is the summary of the standards which appear relevant to support EMS SCADA System. According to 5.5, standards for cross-cutting issues such as EMC and security are treated separately (IEC 62351 series, ISO/IEC 27001, EN 61000, etc.)

5.9.3.5.2 Available standards

See Table 24. Refer to 5.2.5.3 for the definition of the criteria considered in this document for stating that a standard is "available".

Table 24 – EMS SCADA system – Available standards

Layer	Standard	Title and comments
Information	IEC 61970-1 IEC 61970-2 IEC 61970-301 IEC 61970-401 IEC 61970-453 IEC 61970-501	*Energy management system application program interface (EMS-API)*
Information	IEC 61970-452	*Energy management system application program interface (EMS-API) – Part 452: CIM static transmission network model profiles*
Information	IEC 61970-456	*Energy management system application program interface (EMS-API) – Part 456: Solved power system state profiles*
Communication	IEC 62325 series	*Framework for energy market communications*
Communication	IEC 60870-5-101 IEC 60870-5-104 IEC 60870-6	*Telecontrol equipment and systems*
Information, communication	IEC 61850 series	*Communication networks and systems for power utility automation* See substation automation system in 5.9.7.
Information	IEC 62361 series	*Power systems management and associated information exchange – Interoperability in the long term* Harmonization of quality codes
General	IEC TR 62357-1	*Power systems management and associated information exchange – Part 1: Reference architecture* Reference architecture power system information exchange
Communication	IEC 62351 series	*Power systems management and associated information exchange – Data and communications security* Cyber-security aspects (see 5.10.4).
Other specifications		
Communication	IEEE 1815	*Also known as DNP3*
Information	IEEE 1815-1	*Mapping of IEC 61850 data model over DNP3*

5.9.3.5.3 Coming standards

Refer to 5.2.5.3 for the definition of the criteria considered in this document for stating that a standard is “coming”.

The list in Table 25 is closely related with the substation automation system paragraph (see 5.9.7) for the communication and information exchange within substations and from substation to the dispatch centres.

Table 25 – EMS SCADA system – Coming standards

Layer	Standard	Title and comments
Information, Communication	IEC 61850 series	*Communication networks and systems for power utility automation* See substation automation system in 5.9.7.
Information	IEC 61970-458 [a]	*Energy management system application program interface (EMS-API) – Part 458: Common Information Model (CIM) extension to generation*
Communication	IEC 61970-502-8 [a]	*Energy management system application program interface (EMS-API) – Part 502-8: Web Services Profile for 61970-4 Abstract Services*
Information	IEC 61970-552	*Energy management system Application Program Interface (EMS-API) – Part 552: CIMXML Model exchange format*
Communication	IEC 62351 series	*Power systems management and associated information exchange – Data and communications security* Cyber-security aspects (see 5.10.4).
Communication	IEC 62325 series	*Framework for energy market communications*

[a] Under preparation.

5.9.3.6 Gaps

IEC 61850 needs to still be harmonized with IEEE C37.118, *Synchrophasors for Power Systems* (Dual Logo IEC/IEEE planned, NWIP already active).

Data models, classes and functionalities may be required for advanced state estimation, which includes phasor information. This has to be specified as a data model in the IEC 61850 and IEC 61970 series.

Data exchange via XML file using the IEC 61970 data model is not suitable for real time processing. Interface standards like OPC-UA have to be defined to also use the IEC 61970 data model for real time processing.

In the existing standard architecture, no uniform platform specifications are described that might limit the extent and depth of a complex dispatching system in bulk electricity power systems.

5.9.3.7 Energy Management system mapping

5.9.3.7.1 Preamble

The EMS SCADA interacts with the GIS, the field force management system as well as the asset management system. The EMS SCADA manages the on-line operation of the transmission assets and the transmission system as a whole. Regarding the network stability and balancing between production and demand, there is the necessary interaction with distribution and power plants connected to the transmission system.

5.9.3.7.2 Component layer

The EMS SCADA component architecture is given in Figure 13 below. Data and information of the actual status of the transmission system is on-line available through the RTUs of all substations and transformer stations in the network. The transmission network is operated and controlled from the dispatch centres by remote controlled circuit breakers in all relevant fields of the network. These circuit breakers are controlled by the operators in the network dispatch centres. The operators are supported (coached and controlled) by the EMS SCADA system regarding energy flows in the network, during normal, maintenance and emergency operation of (parts) of the network.

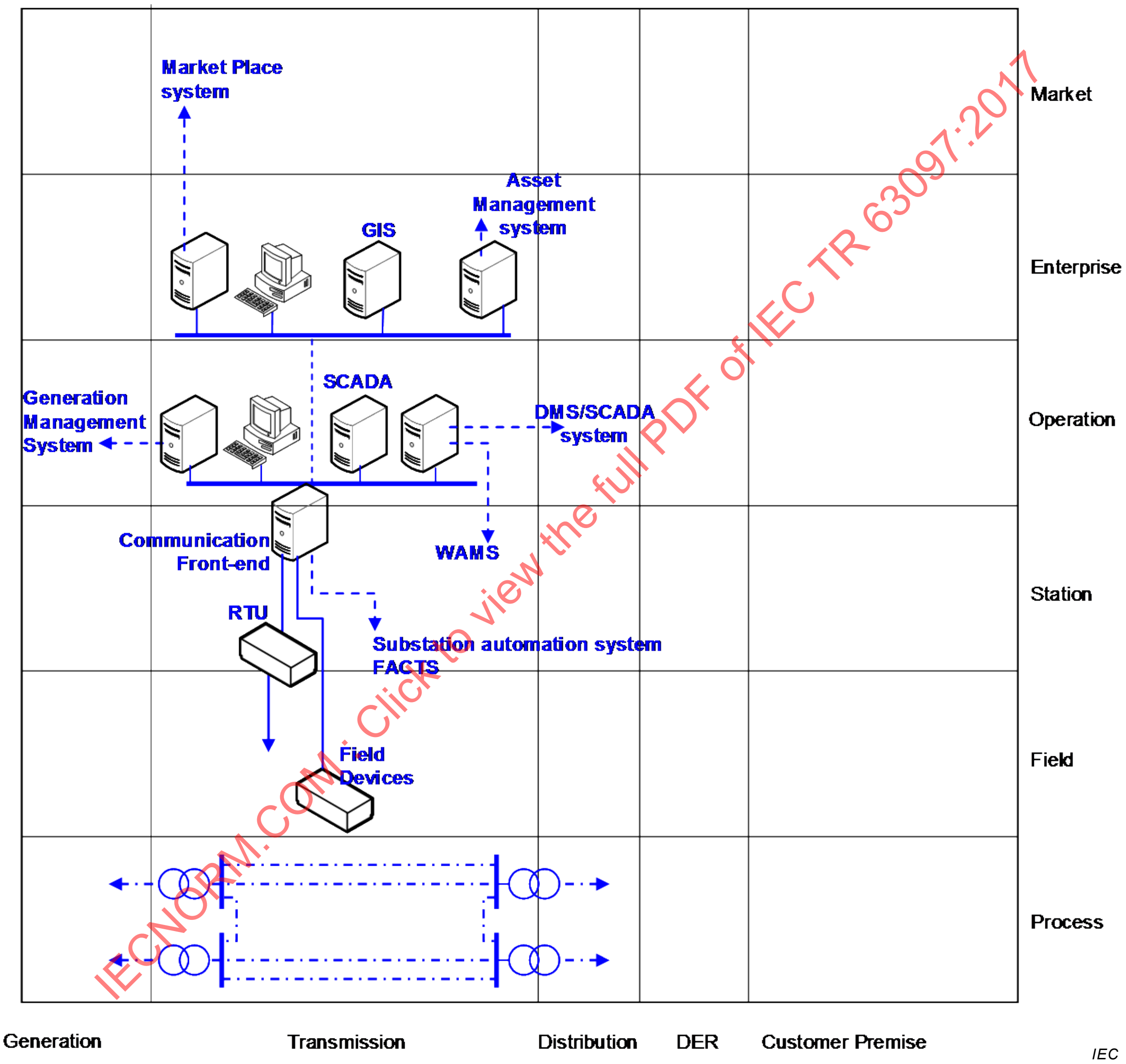


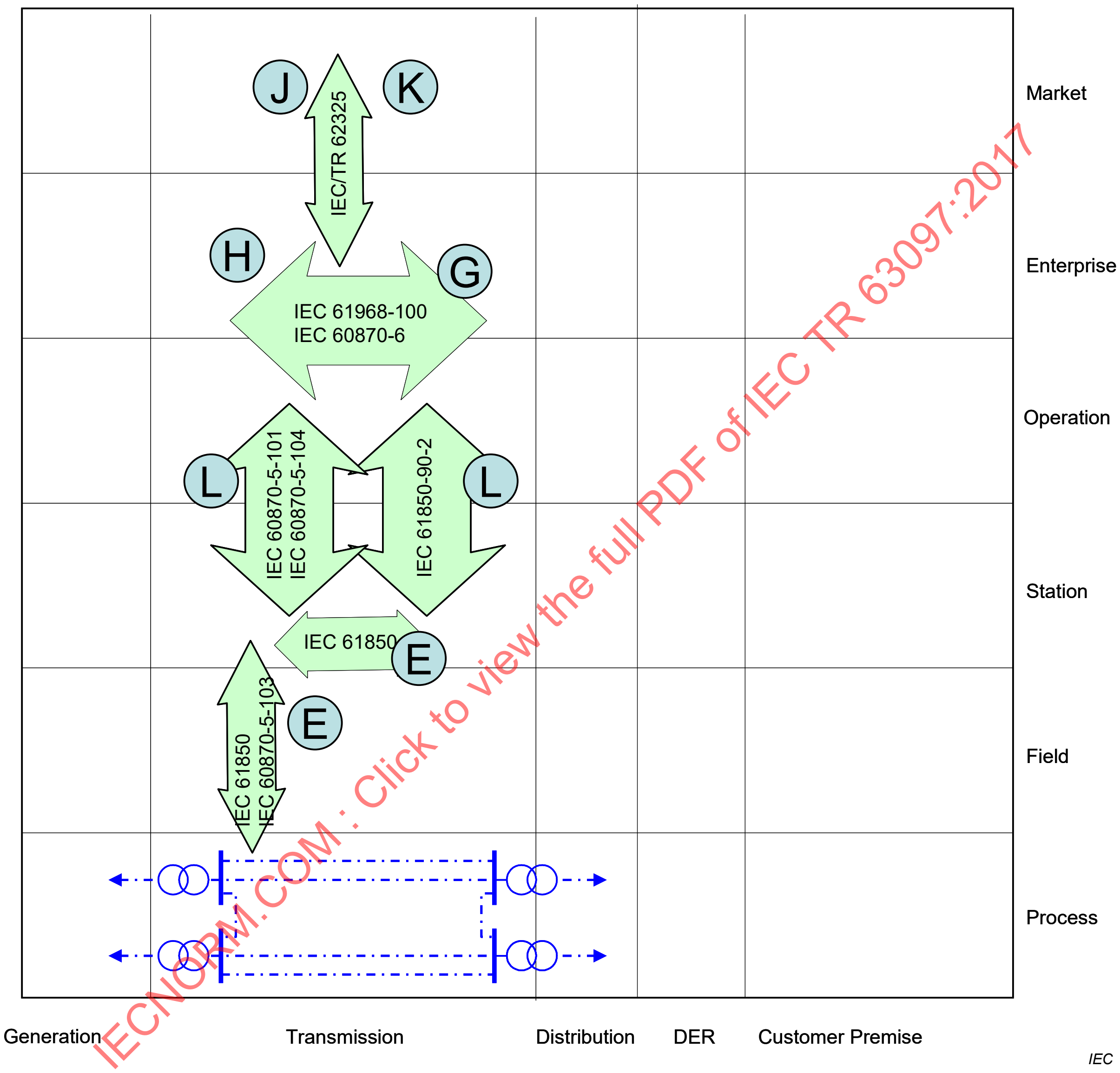
Figure 13 – EMS SCADA system – Component layer

5.9.3.7.3 Communication layer

Communication protocols can be used according to the ones mentioned in the Substation automation subclause of this document (5.9.7), because the EMS SCADA system interacts with the protection, monitoring and control systems in the substations. Furthermore, the EMS SCADA will have direct interaction with power plants connected to the transmission system and Transmission System Operators (TSO) are responsible for balancing power generation and demand. Finally TSOs have a responsibility in supporting the energy market interactions to bulk generation connected to the substations in their EHV and HV transmission networks.

The set of standards representing the related protocols regarding EMS SCADA can be positioned as shown in Figure 14 below. This diagram shows the communication layer of Smart Grid Architecture Model. The significant standards regarding communication are IEC 60870-5-101 and IEC 60870-5-104 to connect power plants to the grid.

Refer to 5.10.4 for details on cyber-security standards and more specifically on where and how to apply the IEC 62351 series and/or other cyber-security mechanisms.



NOTE The letters in the blue disks refer to the network types defined in 5.10.1.2.

Figure 14 – EMS SCADA system – Communication layer

5.9.3.7.4 Information (Data) layer

The information layer of EMS SCADA, as shown in Figure 15, is based on standards and guidelines that cover the Information Models relevant for EMS SCADA Systems used for operating the EHV and HV networks of TSOs.

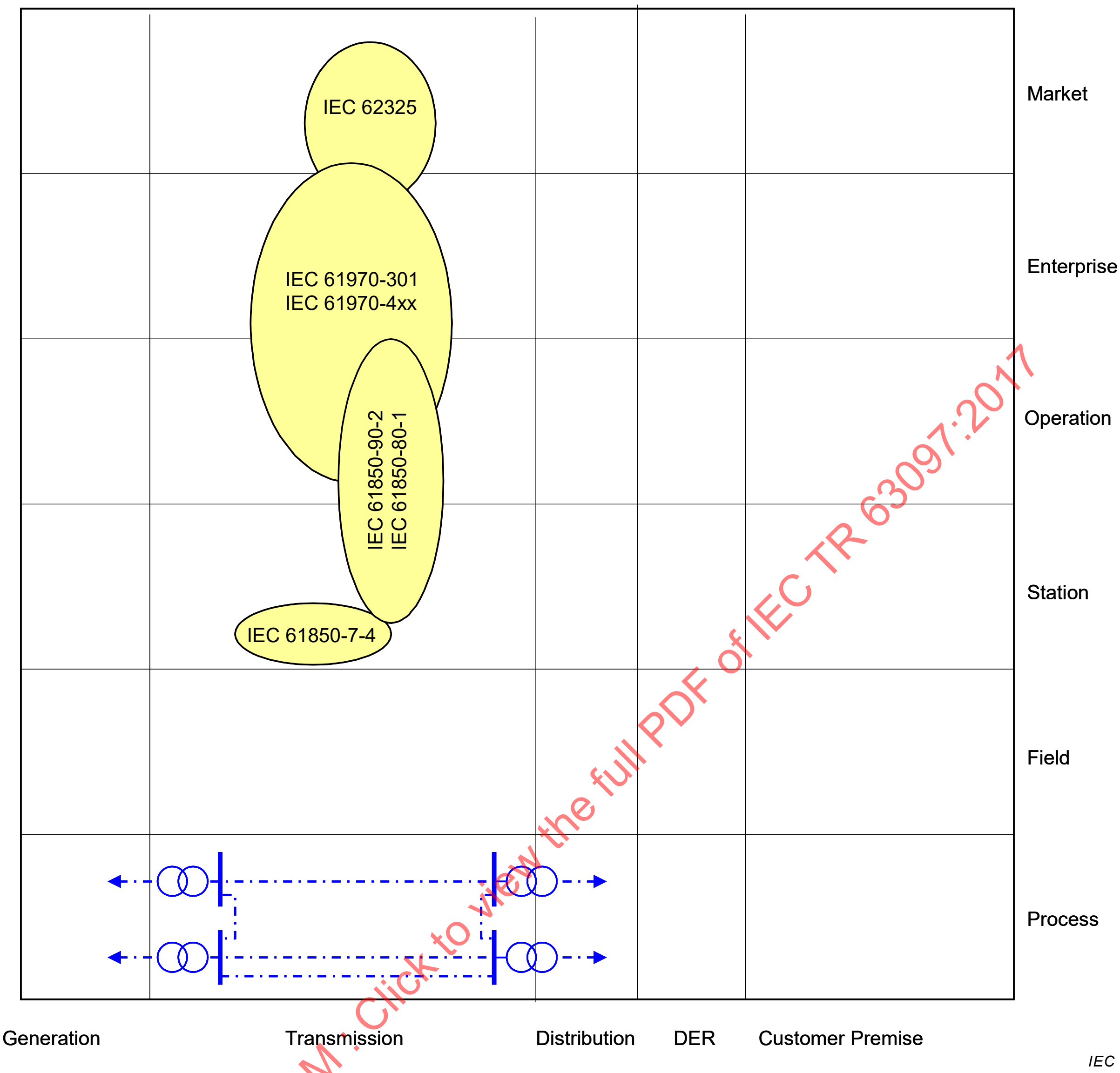


Figure 15 – EMS SCADA system – Information layer

NOTE 1 CIM is covered in the IEC 61970 series and IEC 61968 series.

NOTE 2 IEC TS 61850-80-1 presents a way to map IEC 61850 over IEC 60870-5-101 and IEC 60870-5-104.

5.9.4 Blackout prevention system

5.9.4.1 Description

The challenge posed by Smart Grid implementation and the increased unpredictable intermittency of generation, the more sophisticated and automated adaptation of consumption based on market and/or local conditions, the use of grids closer to their limits, leads to a change from the quasi-static state of the grid to a more complex and highly dynamic behaviour. Therefore, the current available supervision, management and control functions will need to be adapted with, in addition, some specific systems put in place to prevent blackout or at least to reduce the size of impacts of blackouts.

State estimation, for example, will have to include the transient behaviour of the net. In addition, the traditional power, voltage and current measurements need to be extended to phasor measurement provided by PMUs (Phasor Measurement Units).

An optimal representation and visualization as well as decision-supporting tools have to be developed in order to support the operator of such complex systems. The massive amount of data need to be transmitted, synchronized and represented in a way to safeguard the system integrity of the overall transmission net.

Although it is not possible to avoid multiple contingency blackouts, the probability, size, and impact of widespread outages could be reduced. Investment strategies in strengthening the electrical grid infrastructure, such as rebuilding the T and D grid, installing new generation and control systems (e.g. reactive power devices, FACTS, HVDC systems) should be emphasized. The use of Wide-Area Monitoring, Protection And Control (WAMPAC) schemes should be viewed as a cost-effective solution to further improve grid reliability and should be considered as a complement to other vital grid enhancement investment strategies.

5.9.4.2 System summary

The objectives of a WAMPAC system are to protect power systems from instabilities and collapses with continued load growth and with reduced operational margins within stability limits. In contrast to conventional protection devices which provide local protection of individual equipment (transformer, generator, line, etc.), the WAMPAC provide comprehensive protection covering the whole power system. The system utilizes phasors, which are measured with high time accuracy with PMU units installed in the power system. WAMPAC can be seen as a complement to SCADA, FACTS and Substation Automation systems for a region/country power network.

5.9.4.3 Set of System Capabilities

Table 26 provides a set of System Capabilities which may be supported by a WAMPAC.

The meanings of the three last columns (AVAILABLE, COMING, Not yet) and of the “C”, “I”, “CI”, “X” conventions are given in 5.5.2.5.

Table 26 – WAMPAC – System Capabilities

Cluster	System Capabilities	Supported by standards		
		AVAILABLE	COMING	Not yet
Blackout management	Blackout prevention through WAMS	C		
System and security management	Distributing and synchronizing clocks	C		

5.9.4.4 Requirements

Requirements to fulfil the described tasks include new sensor devices (e.g. PMU), the definition of standardized data models and protocols to exchange the required information as well as the semantic representation of these devices in the overall system architecture.

A specific requirement for this kind of information is voltage measurement with phase angle information and time synchronization of the data acquisition, which is necessary to correctly assess the system status. Applications need to meet latency and real-time application requirements. Processing needs to be able to integrate data from field level up to EMS systems.

Cyber security will be a major requirement, because of the negative effects on a critical infrastructure, which can occur due to corrupted information and control signals. The main requirements are integrity and reliability of the data exchange and controls.

The decrease in easily adjustable power generation due to the integration of renewable energy sources poses new challenges to future energy management systems. Therefore new forecast techniques for non-dispatchable renewables are required for EMS/DMS systems to reduce the uncertainty associated with these resources.

5.9.4.5 List of standards

5.9.4.5.1 General

Here is the summary of the standards which appear relevant to WAMS:

5.9.4.5.2 Available standards

See Table 27. Refer to 5.2.5.3 for the definition of the criteria considered in this document for stating that a standard is "available".

Table 27 – WAMPAC – Available standards

Layer	Standard	Title and comments
Information	IEC 61850-7-4 IEC 61850-7-3 IEC 61850-7-2 IEC 61850-6	*Communication networks and systems for power utility automation* Core Information model and language for the IEC 61850 series
Information	IEC TS 61850-80-1	*Communication networks and systems for power utility automation – Part 80-1: Guideline to exchanging information from a CDC-based data model using IEC 60870-5-101 or IEC 60870-5-104* Mapping of IEC 61850 data model over IEC 60870-5-101 and IEC 60870-5-104
Communication, Information	IEC TR 61850-90-2	*Communication networks and systems for power utility automation – Part 90-2: Using IEC 61850 for communication between substations and control centres*
Information	IEC TR 61850-90-3	*Communication networks and systems for power utility automation – Part 90-3: Using IEC 61850 for condition monitoring diagnosis and analysis*
Communication	IEC 61850-8-1	*Communication networks and systems for power utility automation – Part 8-1: Specific communication service mapping (SCSM) – Mappings to MMS (ISO 9506-1 and ISO 9506-2) and to ISO/IEC 8802-3* IEC 61850 communication except Sample values
Communication	IEC TR 61850-90-1	*Communication networks and systems for power utility automation – Part 90-1: Use of IEC 61850 for the communication between substations*
Communication	IEC 60870-5-101	*Telecontrol equipment and systems – Part 5-101: Transmission protocols – Companion standard for basic telecontrol tasks*
Communication	IEC 60870-5-103	*Telecontrol equipment and systems – Part 5-103: Transmission protocols – Companion standard for the informative interface of protection equipment*
Communication	IEC 60870-5-104	*Telecontrol equipment and systems – Part 5-104: Transmission protocols – Network access for IEC 60870-5-101 using standard transport profiles*
Communication	IEC 61850-9-2	*Communication networks and systems for power utility automation – Part 9-2: Specific communication service mapping (SCSM) – Sampled values over ISO/IEC 8802-3* IEC 61850 Sample values communication

Layer	Standard	Title and comments
Information	IEC TR 61850-90-4	*Communication networks and systems for power utility automation – Part 90-4: Network engineering guidelines* Network Engineering Guidelines for IEC 61850 based system (including clock synchronization guidelines)
Communication	IEC TR 61850-90-5	*Communication networks and systems for power utility automation – Part 90-5: Use of IEC 61850 to transmit synchrophasor information according to IEEE C37.118*
Communication	IEEE C37.118	*Synchrophasors for power systems*
Communication	IEEE Std. 1344	*IRIG-B extension*
Communication	IEC 61588 (IEEE 1588)	*Precision clock synchronization protocol for networked measurement and control systems* PTP (Precision Time protocol)
Information	ISO 8601	*Data elements and interchange format – Representation of dates and times Coordinated Universal Time (UTC)*
Component	IEC 61869 series	*Instrument transformers*
Communication	IEC 62351 series	*Power systems management and associated information exchange – Data and communications security* Cyber-security aspects (refer to 5.10.4).

5.9.4.5.3 Coming standards

See Table 28. Refer to 5.2.5.3 for the definition of the criteria considered in this document for stating that a standard is “coming”.

Table 28 – WAMPAC – Coming standards

Layer	Standard	Comments
Communication	IEC 61850-8-2 [a]	*Communication networks and systems for power utility automation – Part 8-2: Specific communication service mapping (SCSM) – Mappings to Extensible Messaging Presence Protocol (XMPP)*
Component	IEC 61869-6 and IEC 61869-9	*Instrument transformers –* *Part 6: Additional general requirements for low-power instrument transformers* *Part 9: Digital interface for instrument transformers*
Communication	IEC 62351 series	*Power systems management and associated information exchange – Data and communications security* *Cyber-security aspects (see 5.10.4)*

[a] Under preparation.

5.9.4.6 Gaps

Data models, classes and functionalities may be required for advanced state estimation, which includes phasor information. This has to be specified as a data model in the IEC 61850 and IEC 61970 series.

Data exchange via XML file using the IEC 61970 data model is not suitable for real time processing. Interface standards like OPC-UA have to be defined to also use the IEC 61970 data model for real time processing.

In the existing standard architecture, no uniform platform specifications are described that might limit the extent and depth of a complex dispatching system in bulk electricity power systems.

5.9.4.7 Blackout Prevention System mapping

5.9.4.7.1 Preamble

Considering that this system is not interacting with the “Enterprise” and “Market” zones of the SGAM, only the “Process”, “Field”, “Station” and “Operation” zones are shown in Figures 16, 17 and 18.

5.9.4.7.2 Component layer

The WAMS component architecture as shown in Figure 16 is mostly present in three zones, which may be interconnected through wired connection and digital communication link.

- The Process zone is mostly (but not only) made of sensors (such as current and voltage transformers) and of actuators (such as breakers or switches).
- The Field zone is made of PMUs/IEDs, which mostly handle equipment protection, monitoring and control features, and data streaming of the measurements from the power system.
- The Station/Operation zone mostly supports three main technical functions, which can be grouped or separated in different components: WAMS application (e.g. SIPS) based on phasor measurements collected from the PMUs/IEDs in the power system, SCADA application based on phasor measurements and substation automation systems for monitoring and control.

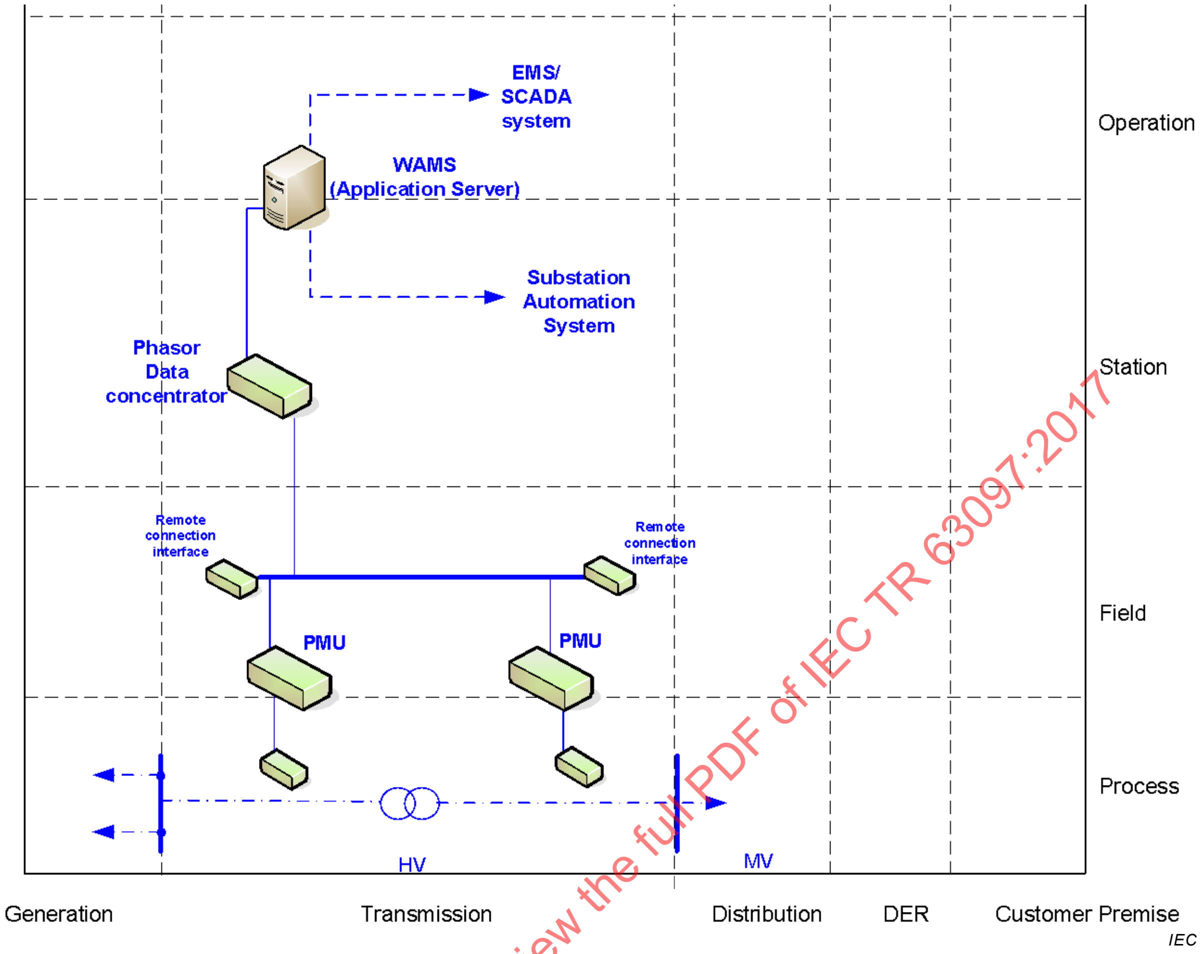


Figure 16 – WAMPAC – Component layer

5.9.4.7.3 Communication layer

Communication protocols can be used either as in a) or b).

a) Within the WAMPAC, IEC 61850-8-1 (for any kind of data flows except sample values) is used to support the selected set of generic System Capabilities.

   IEC TR 61850-90-4 provides detailed guidelines for communication inside a substation.

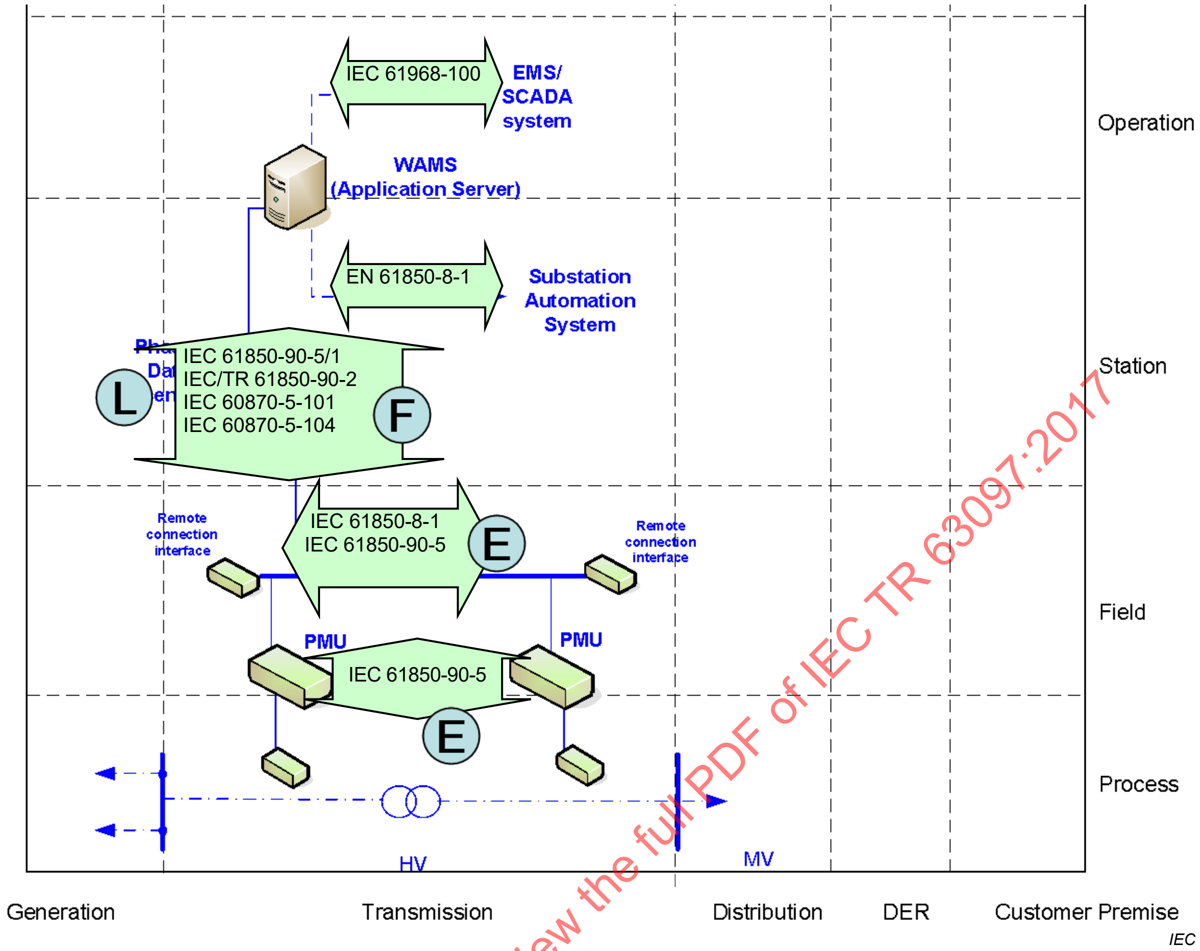
   IEC 61850 mostly replaces the former IEC 60870-5-103, used for connecting PMUs/IEDs.

b) Vertical communications can rely on IEC 60870-5-101 or IEC 60870-5-104, while horizontal communications can rely on IEC TR 61850-90-5 (full mapping over UDP) or IEC TR 61850-90-1 (tunnelling).

   Future vertical communication may rely on IEC TR 61850-90-2 (guideline for using IEC 61850 to control centres) to provide a seamless architecture, based on IEC 61850.

Refer to 5.10.4 for details on cyber-security standards and more specifically on where and how to apply the IEC 62351 series and/or other cyber-security mechanisms.

This set of standards can be positioned this way (refer to Figure 17) on the communication layer of SGAM.



NOTE The letters in the blue disks refer to the network types defined in 5.10.1.2.

Figure 17 – WAMPAC – Communication layer

5.9.4.7.4 Information (Data) layer

The information layer, as presented in Figure 18, is mostly based on the IEC 61850 information model:

- IEC TR 61850-90-2: Communication to control centres
- IEC TR 61850-90-3: Condition monitoring
- IEC TR 61850-90-4: Network management
- IEC TR 61850-90-5: Synchrophasors

For protocols which are not IEC 61850 native such as the IEC 60870-5-101 or IEC 60870-5-104, a mapping of the IEC 61850 series information model is possible using IEC TS 61850-80-1, enabling users of these technologies to use the power of data modelling (and then more seamless integration) without changing communication technologies.

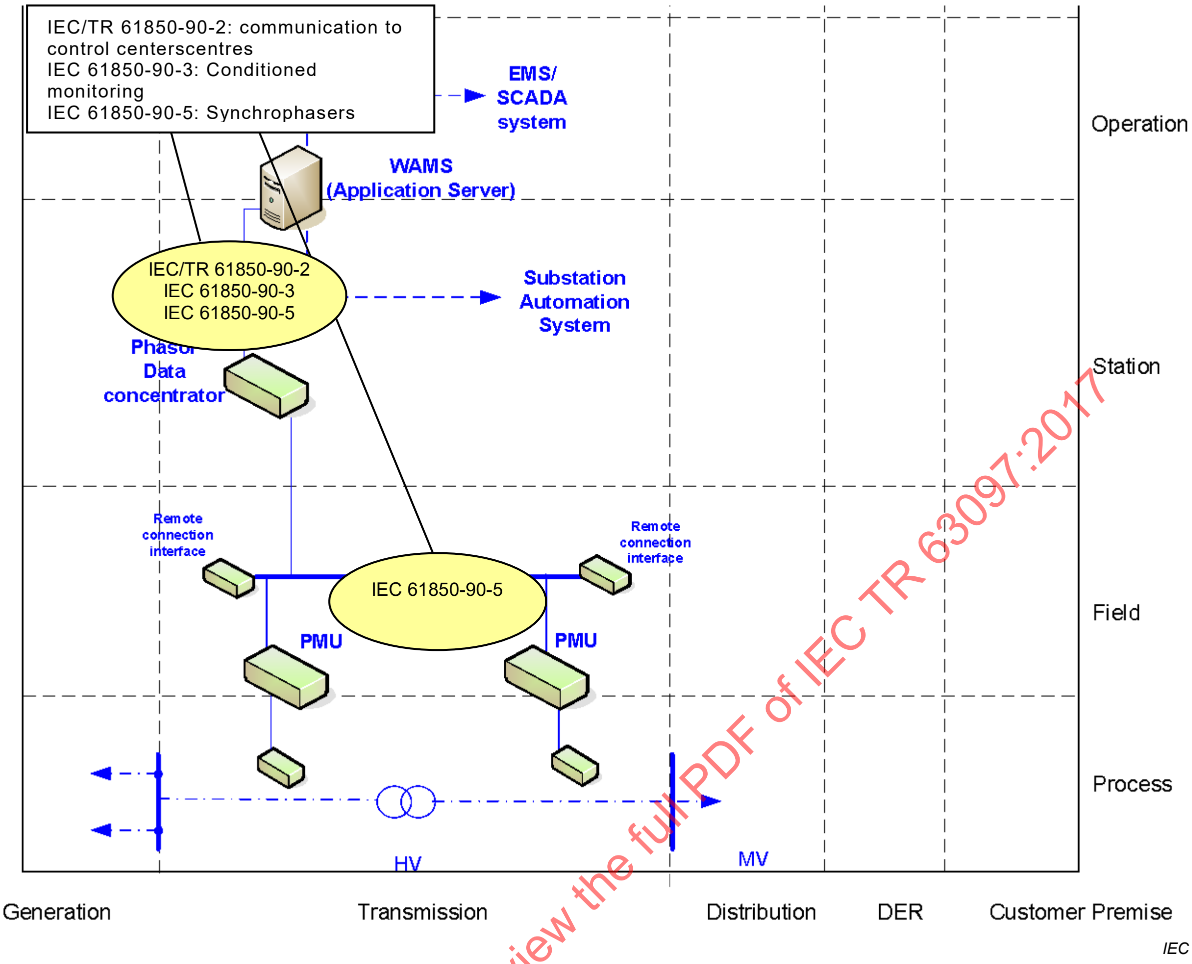


Figure 18 – WAMPAC – Information layer

5.9.5 Advanced distribution management system (ADMS)

5.9.5.1 Description

Over the past few decades, management of the Electrical Distribution Network has been progressively supported by Advanced Distribution Management Systems to improve work-flow and optimize network operations and overall security. This has mainly resulted in the implementation of individual advanced network applications specific to each function and functional group of the utility.

An ADMS is made up of a number of components:

- SCADA, real time monitoring and control;
- advanced network applications including network modelling;
- outage management including crew and resource management;
- work management.

To maintain a network model, ADMSs often interface directly or through SOA interfaces to a Geographical Information System. Geographical Information System (GIS) refers to the information system and all the elements needed to capture, store, manipulate, analyse, manage and present all types of geographical data and information to support the network operator or asset manager regarding decision making in the operation of the energy infrastructure. The system supports all kinds of processes, from planning and design to the day-to-day operation and maintenance activities. It provides the operator and planner with the Asset location and other relevant Asset specifications and dimensions.

The need for ADMSs has been driven by liberalization and deregulation, together with a globally stagnating economy, forcing utilities to find new ways to improve supply quality and customer services and at the same time company profitability by saving costs in their business processes, while maintaining energy prices at a competitive level.

It can be assumed that their current work organization is mature and that the skills of their personnel and available IT systems' functionalities are well utilized. Thus a major solution to reach the additional company objectives will be through a better integration of their IT systems.

ADMS is a key component for Distribution Management.

An ADMS covers all the functions needed to efficiently operate an electric distribution network from a control centre. Distribution networks are medium-voltage and low-voltage networks which distribute electrical power from a high-voltage network (via substations and transformer stations) to the consumers.

Given the enormous areas covered by distribution networks as well as the extremely large amount of electrical equipment employed, operational requirements in such networks are multi-faceted and complex. This is why control technology calls for functions that precisely address these requirements and provide operational support. Key control technology functions in distribution networks include:

- SCADA (supervision control and data acquisition);
- load and generation forecasting;
- outage and work order management (OMS);
- fault management;
- troubleshooting;
- planned outages;
- corrective action;
- demand response and load management;
- switching procedures;
- trouble call management;
- crew management;
- geographic information systems (GIS);
- customer information;
- asset management;
- model management.

In the past, it was not usual to apply network calculation functions for distribution systems, because such systems were equipped for only a small number of measurements. This ruled out the use of estimation algorithms. The size of medium-voltage supply systems also posed resource problems as far as computing power and time were concerned.

Today distribution system analysis software packages are available which have been developed specifically for large electric distribution systems. These software applications comprise functions for monitoring and optimizing system operation and apply so-called load calibration techniques instead of estimation algorithms. The missing dynamic measurement value information is replaced by corresponding statistical information that, for example, enables load profiles to be defined for the loads. However, the high proportion of radial sections in a distribution network makes applications such as outage analysis rather pointless, because failure in a radial section of the system leads to an immediate interruption of the power supply.

On the other hand, fault management plays a greater role in the operation of distribution systems than it plays in transmission systems. The lower selectivity of the protection in the distribution network means that larger sections of the network are disconnected in the event of a fault than is the case in a transmission network, where usually only the operational equipment affected by the fault is isolated from the grid.

For this reason, it is imperative to localize faults in the distribution network as precisely as possible in order to be able to restore power as quickly as possible to those sections of the network which have been de-energized although they are not faulty. For this purpose, there are applications designed for distribution system operation which narrow down the fault location as far as possible by analysing the fault messages received in the control system. On this basis, they then propose ways of isolating the operational equipment which is suspected of being faulty. After that equipment has been isolated, switching proposals are then formulated whereby voltage can be restored to the fault-free but de-energized sections of the system without causing overload situations.

There are special programs which allow the automatic or semi-automatic implementation of these corrective switching operations and which also support the preparation and implementation of all other switching measures in the network. Fault and outage management, combined with applications for call centres and deployment management for field service personnel, enable planned and unscheduled interruptions of the supply to be implemented quickly and efficiently in order to maximize the supply quality.

Distribution companies frequently have multi-utility network management in one control centre, i.e. management of electricity, gas and water networks is centrally located. The main function of demand management is the supervision and control of the exchange of energy in the electricity/gas distribution system using a dual optimization strategy:

- maximum utilization of existing contracts for energy purchasing and exchange;
- avoiding violations of contractually agreed-upon limits for energy purchasing and exchange.

This dual optimization strategy is implemented in part by online functions such as load shedding, increasing power generation or voltage reduction, and by pressure management and use of storage.

Distribution network model management tools, for example Geographic Information System (GIS) and design tools, will also become important for utilities to model and manage the complexity of intelligent grids.

A good description of the situation is given in IEC TR 62357.

5.9.5.2 System summary

DMS SCADA System refers to the real-time information system and all the elements needed to support all the relevant operational activities and functions used in distribution automation at dispatch centres and control rooms. It improves the information made available to operators, field and crew personnel, customer service representatives, management and, ultimately, to the end customers.

Such a system is usually made of one or many interconnected IT systems, connected to field communicating devices or sub-systems, through the use of WAN communication systems. It may also include the needed components to enable field crew to operate the network from the field.

DMS SCADA provides following major functions:

- SCADA, real time monitoring and control;
- advanced network applications including network modelling;

- outage management including crew and resource management;
- work management.

Geographical information system refers to the information system and all the elements needed to capture, store, manipulate, analyse, manage and present all types of geographical data and information to support the network operator or asset manager regarding decision making in the operation of the energy infrastructure. The system supports all kind of processes, from planning and design to the day-to-day operation and maintenance activities. It provides the operator and planner with the Asset location and other relevant Asset specifications and dimensions.

5.9.5.3 Set of System Capabilities

The set of System Capabilities which may be supported by a DMS SCADA System are given in Table 29. The GIS system does not host a specific capability, but contributes to several of them as a supplier for the network model as listed below.

The meanings of the three last columns (AVAILABLE, COMING, Not yet) and of the “C”, “I”, “CI”, “X” conventions are given in 5.5.2.5.

Table 29 – DMS SCADA and GIS system – Capabilities

Cluster	System Capabilities	Supported by standards		
		AVAILABLE	COMING	Not yet
Monitoring the grid flows	Monitoring electrical flows	CI		
	Monitoring power quality for operation (locally)	CI		
	Producing, exposing and logging time-stamped events	X		
	Supporting time-stamped alarms management at all levels	X		
	Capture, expose and analyse disturbance events	X		
	Archive operation information	CI		
Maintaining grid assets	Monitoring assets conditions	C		I
	Supporting periodic maintenance and planning	C	I	
	Optimize field crew operation		C	I
Manage Commercial relationship for electricity supply	Registration/deregistration of customers		C	I
Operate DER(s)	Registration/deregistration of DER in VPP		C	I
	Aggregate DER as technical VPP		C	I
	Aggregate DER as commercial VPP		C	I
Controlling the grid (locally/remotely) manually or automatically	Switch/breaker control	CI		
	Feeder load balancing	X		
	Enable multiple concurrent levels of control (local-remote)	X		
Managing power quality	Voltage regulation	CI		
	VAR regulation	CI		
Reconfiguring the network in case of fault	Supporting reclosing sequence	X		
	Supporting source switching	X		
	Supporting automatic FLISR			
Connect an active actor to the grid	Managing micro-grid transitions			X
	Managing generation connection to the grid	X		
Demand and production (generation) flexibility	Receiving metrological or price information for further action by consumer or CEM			X
	Load forecast (from remote based on revenue metering)	X		
	Generation forecast (from remote)	X		
	Participating in electricity market	X		
System and security management	Distributing and synchronizing clocks	X		

5.9.5.4 Requirements

All functions described above require an increase in information exchange; therefore, a syntactic and semantic understanding of a variety of different domains including AMI, Transmission, Market and Prosumer will be required.

Because the effective sharing and exchange of information between the systems of various departments is usually a tortuous process for utilities, the standard interfaces will address major needs in terms of:

- data exchange between the various business processes,
- limitation of data entry effort and mistakes,
- more accurate updating process of the various data,
- more efficient sharing of data between processes.

In addition, the standards can facilitate the harnessing of legacy applications and the re-use of information and application functionality across the business.

Increasing numbers of utilities are recognizing the strategic importance of A2A (Application to Application) and B2B (Business to Business) integration. This is seen as a key enabler for improving operational and business performance.

Increasingly we will see connections to Home Area Networks (HAN) as a means for utility companies to extend their reach beyond meters and incorporate smart thermostat, direct load control appliances, smart appliances and in-home energy displays into ADMS systems, as well as enabling demand-response (DR) and energy efficiency programs. Advanced Metering Infrastructure (AMI) uses a smart electric meter or other energy gateway to enable continuous two-way communications between utilities and HAN based devices.

Also, cyber security is a requirement as well as the incorporation of pricing information.

5.9.5.5 Standards context

5.9.5.5.1 General – Interoperability standards

IEC 61968 and IEC 61970, which form the CIM foundations, are core standards for the operation and enterprise levels of DMS SCADA systems.

The IEC 61968 series is intended to facilitate inter-application integration of the various distributed software application systems supporting the management of utility electrical distribution networks within a utility’s enterprise systems environment. Refer to B.2.9 for more details on the IEC 61968 series.

5.9.5.5.2 and 5.9.5.5.3 provide a summary of the standards which appear relevant to support the DMS SCADA and GIS system.

5.9.5.5.2 Available standards

See Table 30. Refer to 5.2.5.3 for the definition of the criteria considered in this document for stating that a standard is “available”.

Table 30 – DMS SCADA and GIS system – Available standards

Layer	Standard	Title and comments
Communication, Information	IEC 61850 series	*Communication networks and systems for power utility automation – Part 1: Introduction and overview* See substation automation system in 5.9.7.
General	IEC TR 62357-1	*Power systems management and associated information exchange – Part 1: Reference architecture* Reference architecture power system information exchange
Information	IEC 62361 series	*Power systems management and associated information exchange – Interoperability in the long term* Harmonization of quality codes
Information	IEC 62361-100	*Naming and design rules for CIM profiles to XML schema mapping*
Communication and Information	IEC 61970 series	*Energy management system application program interface (EMS-API)* Some issues will be relevant of this family of standards but focus in this family of standards is on transmission
General	IEC 61968-1	*Application integration at electric utilities – System interfaces for distribution management – Part 1: Interface architecture and general requirements*
Information	IEC TS 61968-2	*Application integration at electric utilities – System interfaces for distribution management – Part 2: Glossary*
Information	IEC 61968-3	*Application integration at electric utilities – System interfaces for distribution management – Part 3: Interface for network operations*
Information	IEC 61968-4	*Application integration at electric utilities – System interfaces for distribution management – Part 4: Interfaces for records and asset management*
Information	IEC 61968-6	*Application integration at electric utilities – System interfaces for distribution management – Part 6: Interfaces for maintenance and construction*
Information	IEC 61968-8	*Application integration at electric utilities – System interfaces for distribution management – Part 8: Interfaces for customer operations*
Information	IEC 61968-9	*Application integration at electric utilities – System interfaces for distribution management – Part 9: Interfaces for meter reading and control*
Information	IEC 61968-11	*Application integration at electric utilities – System interfaces for distribution management – Part 11: Common information model (CIM) extensions for distribution*
Information	IEC 61968-13	*Application integration at electric utilities – System interfaces for distribution management – Part 13: CIM RDF Model exchange format for distribution*
Communication	IEC 61968-100	*Application integration at electric utilities – System interfaces for distribution management – Part 100: Implementation profiles*
Communication	IEC TS 62351-1	*Power systems management and associated information exchange – Data and communications security – Part 1: Communication network and system security – Introduction to security issues*
Communication	IEC 62351 series	*Power systems management and associated information exchange – Data and communications security* Cyber-security aspects (see 5.10.4).

Layer	Standard	Title and comments
Other specifications		
Communication	IEEE 1815	*Also known as DNP3*
Information	IEEE 1815-1	*Mapping of IEC 61850 data model over DNP3*
Information, communication	Multispeak® 4.0	The MultiSpeak®[a] Initiative is a collaboration of the National Rural Electric Cooperative Association (NRECA) of United States, and some leading software vendors supplying the utility market and utilities. The initiative has developed and continues to expand a specification that defines standardized interfaces among software applications commonly used by electric utilities. This initiative has been quite successful in North America and is working collaboratively with IEC TC 57 to effectively address the needs of smaller utilities on an international basis. As most utility and vendor involvement in IEC TC 57 has been more oriented to large utilities with significant information technology needs and capabilities, this collaboration is invaluable.
[a] MultiSpeak® is a registered trademark of Cooperative Energy Services, a subsidiary of the US Rural Electric Cooperative Association. This information is given for the convenience of users of this document and does not constitute an endorsement by IEC.		

5.9.5.5.3 Coming standards

See Table 31. Refer to 5.2.5.3 for the definition of the criteria considered in this document for stating that a standard is “coming”.

Table 31 – DMS SCADA and GIS system – Coming standards

Layer	Standard	Comments
Information	IEC 61968 series	*Application integration at electric utilities – System interfaces for distribution management*
Communication, Information	IEC 61850 series	*Communication networks and systems for power utility automation* See substation automation system in 5.9.7.
Communication	IEC 62351 series	*Power systems management and associated information exchange – Data and communications security* Cyber-security aspects (see 5.10.4).

5.9.5.6 Gaps

The following gaps regarding functions described in the IEC 61968 series are present:

- Operational Planning and Optimization (OP) – Part 5
- Maintenance and Construction (MC) – Part 6
- Network Extension Planning (NE) – Part 7
- Mapping between Multispeak® 4.0 – Part 14-1
- CIM profile for Multispeak® 4.0 – Part 14-2
- Distributed Energy Resources – possible Part 10

IEC 61968 series needs also to be extended regarding modelling of DR command signals. Different signals, for example for interruptible load, emergency DR and DR bidding are not in the standard yet.

Further gaps are described in IEC TR 62357.

5.9.5.7 Advanced distribution management system mapping

5.9.5.7.1 Preamble

The ADMS SCADA System is supported by substation automation, protection and control. It is equivalent to the EMS SCADA used in Transmission. The amount of automation is growing in distribution systems, certainly with the increasing role of distributed generation and distributed storage. Furthermore focus is on further decrease of outage minutes by support of remote sensing and switching in the network. Remote control and operation of distribution networks will have a positive influence on network management during normal and emergency situations, dependency of fieldworkers will be less. With the growing amount of distributed generation, distribution networks have to support balancing generation and demand at regional level. Hierarchically this system is covering the station and operational zones within the Distribution System Operator's influence.

The GIS system interacts with the ADMS SCADA, Asset and Maintenance management system (GMAO), the CIS and EMS/VPP system.

5.9.5.7.2 Component layer

The ADMS SCADA System as described in Figure 19 covers the online operation of the distribution network and part of the interaction with distributed generation and storage in medium- and low-voltage networks (DER). Focus is on remote sensing and switching of main feeders and distributed generators. Interconnection points to the feeding HV transmission networks are the upper boundary points of the ADMS SCADA System. In near future the interaction and information from AMI will be an issue, because load and generation profiles will be available through measuring load and distributed generation with a certain time interval. Management of self-healing functionalities in the network will be done by ADMS SCADA System.

The GIS component architecture focuses also on the Enterprise and Operation zone.

- At the Enterprise zone, the GIS system itself is usually located.
- Various systems at the Operation zone (ADMS SCADA, OMS) use the GIS data (e.g. network models and diagrams including coordinates of the assets at the process zone) for their purpose.

Figure 19 is an example of architecture of an ADMS SCADA system, and associated components.

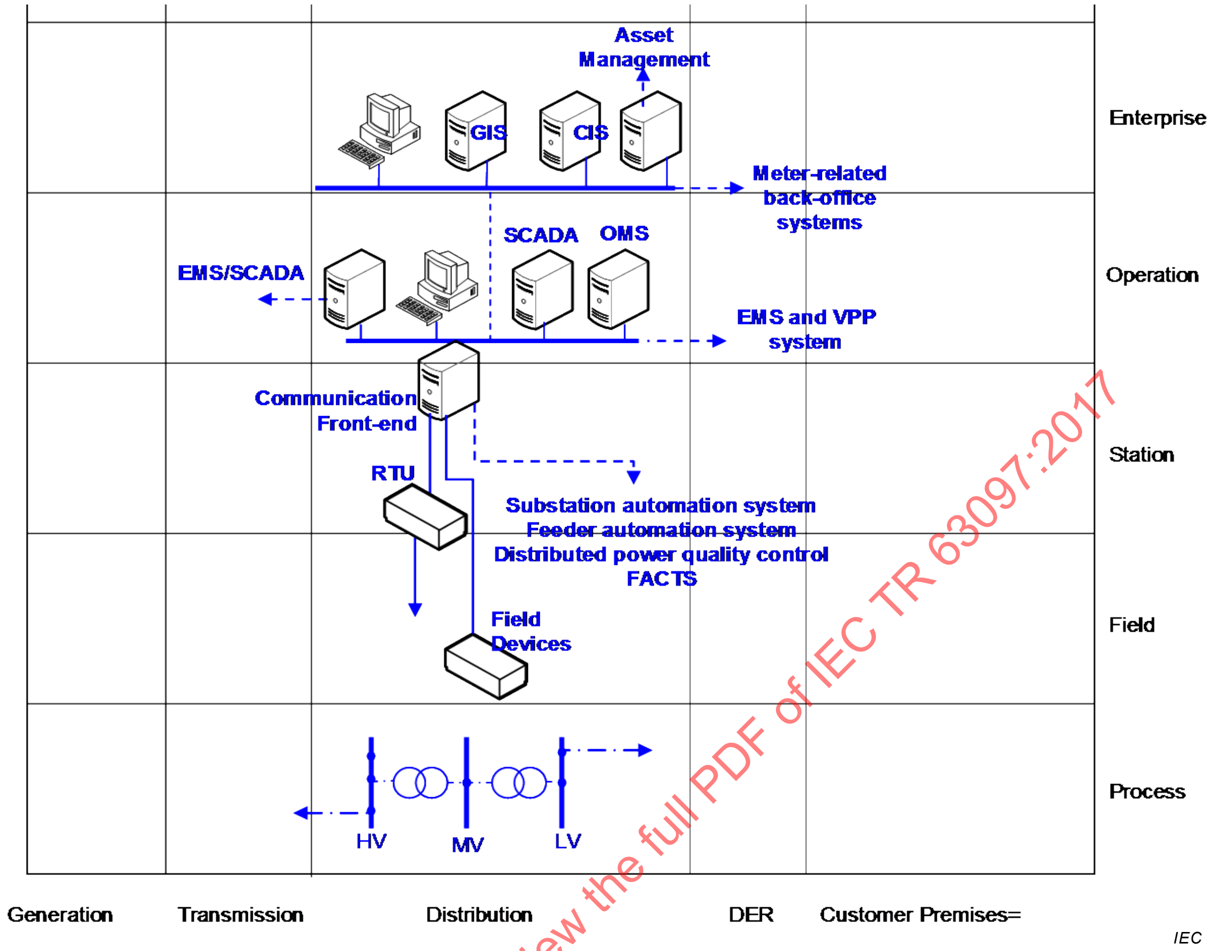


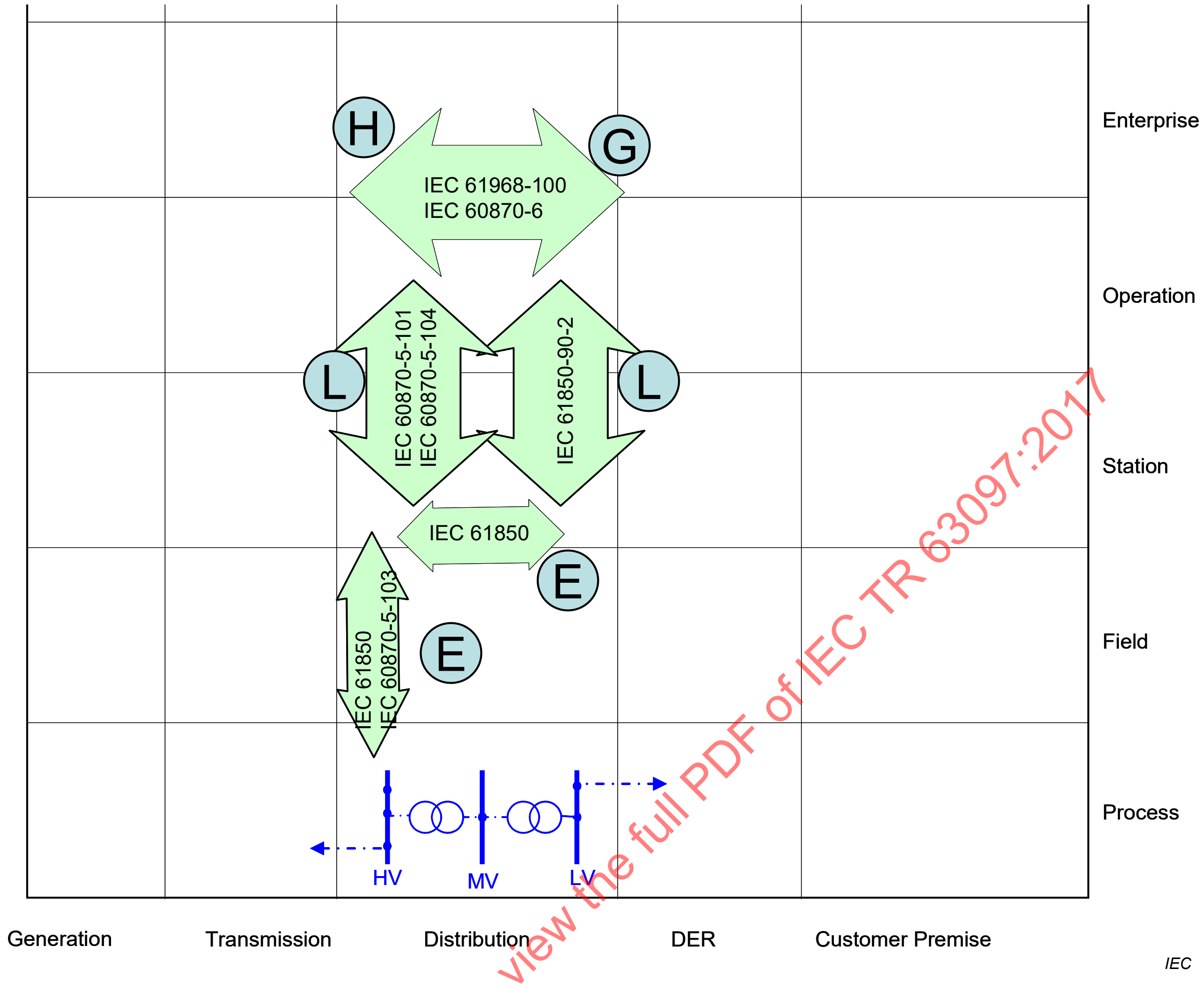
Figure 19 – DMS SCADA and GIS system – Component layer

5.9.5.7.3 Communication layer

Communication protocols mentioned under Substation Automation will be applied for retrieving necessary information and control of the network.

This set of standards regarding DMS SCADA can be positioned as is shown in Figure 20 representing the communication layer of SGAM.

Refer to 5.10.4 for details on cyber-security standards and more specifically on where and how to apply the IEC 62351 series and/or other cyber-security mechanisms.



NOTE The letters in the blue disks refer to the network types defined in 5.10.1.2.

Figure 20 – DMS SCADA and GIS system – Communication layer

5.9.5.7.4 Information (Data) layer

DMS SCADA makes use of the information models at station and operation level of course. For DMS SCADA System most of the parts of IEC 61968 series (and IEC 61970 series) are applicable. It describes the Common Information Model (CIM) for distribution management and it covers most of the interfaces between the different applications and the head-end level of the utility. GIS related information is defined in IEC 61698-4 and IEC 61968-13.

This leads to the mapping shown in Figure 21.

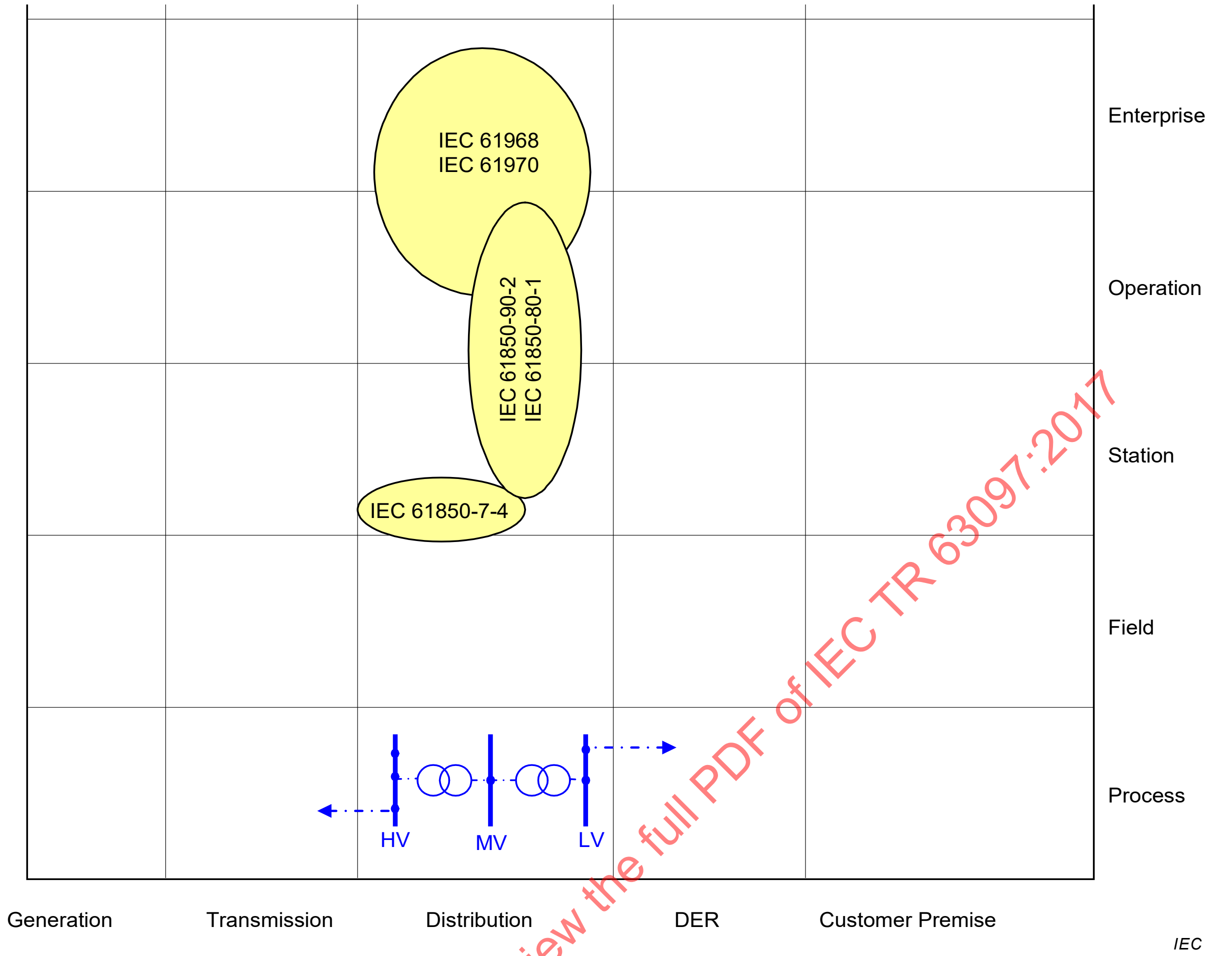


Figure 21 – DMS SCADA and GIS system – Information layer

Standards Identified for Substation Automation are also relevant for the application of the DMS SCADA system, because the DMS SCADA system will retrieve online information from the substations in the Distribution Networks.

5.9.6 Distribution automation system

5.9.6.1 Description

The electric distribution system in the USA, Canada and many other countries of the world (Brazil, Mexico, Australia, South Africa, Korea, etc.) is significantly different to the distribution system in Europe. However, there are some European countries with a partly US-style power distribution system, for example Estonia and Latvia.

Both distribution systems include overhead line distribution and underground distribution with cables.

US-style overhead line distribution consists of distribution substations with outdoor equipment and long to very long distribution lines. In some cases, the length of these overhead lines can exceed 150 miles (240 km). Consequently, line losses and voltage drop due to line resistance and reactance are serious problems. The average number of supplied customers with these overhead lines is quite high (several thousand). As a consequence, the number of affected customers is high in case of an outage. This causes significant revenue losses for utilities and leads to decreasing customer satisfaction. To overcome the addressed problems, overhead distribution lines are segmented by reclosers and sectionalizers, which may be used for feeder reconfiguration in case of disturbances. Other equipment like voltage regulators (regulating transformer and controller), reactive power regulators (capacitor banks and controller), fault indicators and other equipment are used for optimal operation and fault identification and localization.

For a very long time, the above-mentioned distribution equipment has been operated locally. However, with the introduction of microprocessor based Intelligent Electronic Devices (IEDs) and the availability of affordable communication technology, Distribution Automation for fast fault detection, isolation and system reconfiguration is currently one of the major Smart Grid components.

With successful distribution automation, utilities have the opportunity to set up new business models for increased customer satisfaction, for example, the availability of highly reliable power supply for critical industry sites.

On the other hand, the power distribution structure with long distribution lines may also create significant problems, even if power is available. In summer, when all customers switch on their air conditioner, the load on distribution lines may reach dangerous dimensions, leading to thermal overload of the line and other components, and causing significant voltage stability and quality problems. In such situations, intelligent load shedding is a much-desired item. The integration of electronic meters with integrated load disconnection capability is a significant move in the right direction. However more customer-friendly solutions will be intelligent home and building focused energy management systems.

The distribution system in (middle) Europe is based on a different concept, compared to the US-style distribution system. The backbone of this structure is the highly meshed 110 kV subtransmission system, covering nearly all load areas, and the very high number of distribution substations. As a consequence, distribution lines are quite short (typically 5 km to 20 km), and the average number of customers supplied by one single distribution feeder is typically below 1 000. In addition, the connection of loads is done with precise planning and measurement, leading to highly balanced loads of distribution transformers. In contrast, the US-style distribution system is partly highly unbalanced, leading to additional power quality problems and thermal problems for transformers.

In Europe, Distribution Substations are being integrated and automated using microprocessor-based protection relays, bay controllers, remote terminal units, etc. to enable remote control and to reduce outage times. However, the (quite short) distribution feeder is not segmented, and the low voltage transformer stations are operated manually. Because of the highly advanced structure of the European distribution system, there is no incentive for utilities to deploy the automation of distribution feeders. In case of a disturbance on a distribution feeder, the number of affected customers is low, and the amount of revenue loss is also low.

However the increasing integration of Distributed Energy Resources (DERs), for example photovoltaic systems at low-voltage level and wind generators at medium-voltage level, causes voltage quality problems. In some of these areas, voltage magnitude is much higher than the acceptable maximum level of nominal voltage plus 10 %. With the integration of these “Generators”, the distribution system is no longer a radial system, which can be easily protected by simple non-directional overcurrent protection relays. In the future, the application of differential protection systems will be required to meet the requirements of DERs.

In summary, the automation of the European distribution system, including low-voltage transformer houses as well as so-called micro-grids, will be strongly influenced by the acceptance and application of DER solutions.

For the automation of distribution systems, tele-control and supervision of secondary substation and transformer houses is crucial. Therefore, information exchange between those components and DMS systems shall be based on common protocols and shall be cyber-secure. The communication concepts shall be flexible for the use of different communication media and technologies due to different geographic and infrastructural conditions.

5.9.6.2 System summary

A distribution automation system refers to the system and all the elements needed to perform Power Quality regulation and/or automated operation of components placed along the MV network itself (feeders), and/or on the LV side, including (but not limited to) fault detectors, pole or ground mounted MV-switches, MV-disconnectors and MV-circuit-breakers – without or with reclosing functionality (also called reclosers) between the HV/MV substation (MV side included) and the MV/LV substations.

The typical considered operations are protection functionalities (from upwards and/or distributed), service restoration (after fault conditions) or feeder reconfiguration, or monitoring of quality control parameters (i.e. *V, I, f, THD*, dips, surges, etc.) as well as Volt/VAR and frequency/W distributed regulation through active control.

5.9.6.3 Set of System Capabilities

Table 32 provides a set of System Capabilities which may be supported by Feeder automation system and smart reclosers system.

The meanings of the three last columns (AVAILABLE, COMING, Not yet) and of the “C”, “I”, “CI”, “X” conventions are given in 5.5.2.5.

Table 32 – Distribution automation system – System Capabilities

Cluster	System Capabilities	Supported by standards		
		AVAILABLE	COMING (CI[a])	Not yet
Protecting the grid assets	Protect a zone outside of the substation boundary	CI		
	Perform networked protection logic (Intertripping, logic selectivity, etc.)	CI		
	Perform networked security logic (Interlocking, local/remote)	CI		
	Set/change protection parameters	CI		
Monitoring the grid flows	Monitoring electrical flows	CI		
	Producing, exposing and logging time-stamped events	CI		
	Supporting time-stamped alarms management at all levels	CI		
	Archive operation information	CI		
Maintaining grid assets	Archive maintenance information	CI		
Controlling the grid (locally/remotely) manually or automatically	Switch/breaker control	CI		
	Enable multiple concurrent levels of control (local-remote)	CI		
Reconfiguring the network in case of fault	Supporting reclosing sequence	CI		
	Supporting source switching	CI		
	Supporting automatic FLISR	CI		
Managing power quality	Voltage regulation	X		
	VAR regulation	X		

[a] IEC 61850-90-6, IEC 61850-8-2 as well as IEC 61869 may provide some enhancement of the current set of standards to better fit Feeder automation scope, both at communication and information levels.

5.9.6.4 Standards context

5.9.6.4.1 Available standards

See Table 33. Refer to 5.2.5.3 for the definition of the criteria considered in this document for stating that a standard is “available”.

Table 33 – Distribution automation system – Available standards

Layer	Standard	Title and comments
Information	IEC 61850-7-4 IEC 61850-7-3 IEC 61850-7-2 IEC 61850-6	*Communication networks and systems for power utility automation* Core Information model and language for the IEC 61850 series
Information	IEC 61850-7-410	*Communication networks and systems for power utility automation – Part 7-410: Basic communication structure – Hydroelectric power plants – Communication for monitoring and control*
Information	IEC 61850-7-420	*Communication networks and systems for power utility automation – Part 7-420: Basic communication structure – Distributed energy resources logical nodes*
Information	IEC TR 61850-90-7	*Communication networks and systems for power utility automation – Part 90-7: Object models for power converters in distributed energy resources (DER) systems*
Information	IEC TR 61850-90-3	*Communication networks and systems for power utility automation – Part 90-3: Using IEC 61850 for condition monitoring diagnosis and analysis*
Information	IEC TS 61850-80-1	*Communication networks and systems for power utility automation – Part 80-1: Guideline to exchanging information from a CDC-based data model using IEC 60870-5-101 or IEC 60870-5-104* IEC 61850 communication except Sample values
Information	IEC TS 61850-80-4	*Communication networks and systems for power utility automation – Part 80-4: Translation from the COSEM object model (IEC 62056) to the IEC 61850 data model*
Information	IEC 61400-25 series	*Wind turbines – Communications for monitoring and control of wind power plants – Information models*
Information	IEC 61968 series	*Application integration at electric utilities – System interfaces for distribution management* Common Information Model (System Interfaces For Distribution Management)
Information	IEC 61970 series	*Energy management system application program interface (EMS-API)* Common Information Model (System Interfaces For Energy Management)
Communication	IEC 61850-8-1	*Communication networks and systems for power utility automation – Part 8-1: Specific communication service mapping (SCSM) – Mappings to MMS (ISO 9506-1 and ISO 9506-2) and to ISO/IEC 8802-3* IEC 61850 communication except Sample values
Communication	IEC 61850-9-2	*Communication networks and systems for power utility automation – Part 9-2: Specific communication service mapping (SCSM) – Sampled values over ISO/IEC 8802-3* IEC 61850 Sample values communication
Communication	IEC PAS 61850-9-3	*Communication networks and systems for power utility automation – Part 9-3: Precision time protocol profile for power utility automation*

Layer	Standard	Title and comments
Communication	IEC TR 61850-90-1	*Communication networks and systems for power utility automation – Part 90-1: Use of IEC 61850 for the communication between substations*
Information, Communication	IEC TR 61850-90-2	*Communication networks and systems for power utility automation – Part 90-2: Using IEC 61850 for the communication between substations and control centres*
Communication	IEC 60870-5-101	*Telecontrol equipment and systems – Part 5-101: Transmission protocols – Companion standard for basic telecontrol tasks*
Communication	IEC 60870-5-103	*Telecontrol equipment and systems – Part 5-103: Transmission protocols – Companion standard for the informative interface of protection equipment*
Communication	IEC 60870-5-104	*Telecontrol equipment and systems – Part 5-104: Transmission protocols – Network access for IEC 60870-5-101 using standard transport profiles*
Information, Communication	IEC TR 61850-90-4	*Communication networks and systems for power utility automation – Part 90-4: Network engineering guidelines for communication within substation – Network management*
Communication	IEC TR 61850-90-5	*Communication networks and systems for power utility automation – Part 90-5: Use of IEC 61850 to transmit synchrophasor information according to IEEE C37.118* May also be relevant for use between substations
Communication	IEC 60255-24	*Measuring relays and protection equipment – Part 24: Common format for transient data exchange (COMTRADE) for power systems*
Communication	IEC TR 61850-90-12	*Communication networks and systems for power utility automation – Part 90-12: Wide area network engineering guidelines*
Component	IEC 62271-3	*High-voltage switchgear and controlgear – Part 3: Digital interfaces based on IEC 61850*
Communication	IEC 62439 series	*Industrial communication networks – High availability automation networks* (including PRP and HSR)
Component	IEC 61869 series	*Instrument transformers*
Communication	IEC 62351 series	*Power systems management and associated information exchange – Data and communications security* Cyber-security aspects (see 5.10.4)
Other specifications		
Communication	IEEE 1815	Also known as DNP3
Information	IEEE 1815-1	Mapping of IEC 61850 data model over DNP3

5.9.6.4.2 Coming standards

See Table 34. Refer to 5.2.5.3 for the definition of the criteria considered in this document for stating that a standard is "coming".

Table 34 – Distribution automation system – Coming standards

Layer	Standard	Title and comments
Information	IEC 61850-7-420	*Communication networks and systems for power utility automation – Part 7-420: Basic communication structure – Distributed energy resources logical nodes*
Information, Communication	IEC TR 61850-90-6 [a]	*Communication networks and systems for power utility automation – Part 90-6: – Use of IEC 61850 for distribution automation systems*
Information	IEC TR 61850-90-11 [a]	*Communication networks and systems for power utility automation – Part 90-11: – Methodologies for modelling of logics for IEC 61850 based applications*
Communication	IEC/IEEE 61850-9-3	*Communication networks and systems for power utility automation – Part 9-3: Precision time protocol profile for power utility automation*
Communication	IEC 61850-8-2 [a]	*Communication networks and systems for power utility automation – Part 8-2: Specific communication service mapping (SCSM) – Mappings to Extensible Messaging Presence Protocol (XMPP)*
Component	IEC 62689 series [a]	*Current and voltage sensors or detectors, to be used for fault passage indication purposes*
Component	IEC 61869-6 and IEC 61869-9	*Instrument transformers –* *Part 6: Additional general requirements for low-power instrument transformers* *Part 9: Digital interface for instrument transformers*
Communication	IEC 62351 series	*Power systems management and associated information exchange – Data and communications security* Cyber-security aspects (see 5.10.4).
[a] Under preparation.		

5.9.6.5 Gaps

The existing standards (especially IEC 61850) provide quite a good coverage of distribution automation of high- and medium-voltage power systems in their semantic data models. Power Electronic fault detectors as well as some specific LV features may need extensions to be fully covered.

5.9.6.6 Distribution automation system mapping

5.9.6.6.1 Preamble

Most parts of the functions (System Capabilities) represented are covered by the same standards as for other systems being part of distribution networks; the differences being mainly in the customization of the applications and the specific functionalities used.

Considering that this system is not interacting with the “Enterprise” and “Market” zones of the SGAM, only the “Process”, “Field”, “Station” and “Operation” zones are shown in Figures 22, 23 and 24.

5.9.6.6.2 Component layer

On the SGAM representation of the component layer (see Figure 22) the current transformer, the switching element and the voltage transformer are supposed to be placed along the feeder but not in the derivation to the MV/LV transformer.

The feeder automation and smart reclosers component architecture is mostly made of three zones of components, which may be interconnected through wires or communication.

- The Process zone includes the primary equipment of the electrical network mainly switching (i.e. circuit-breakers, switches and disconnectors) and measuring elements (i.e. current and voltage sensors/transformers). The representation on the SGAM is generic and does not necessarily correspond to any specific example.
- The Field zone includes equipment to protect, control and monitor the process of the electrical network, mainly IEDs (which mostly handle protection, monitoring and control features like reclosing sequences), NIC (the controller of the LAN or HAN) and router (the remote connection interface).
- The Station zone includes the aggregation level which interfaces with other elements and systems of the distribution network. It mostly supports three main technical functions, which can be grouped or separated in different components: the RTU which serves as terminal for remote activities, the local controller which is in charge of performing automatic functions, and possibly an HMI/archiving component which offers the local operators capabilities of visualizing and archiving local data.

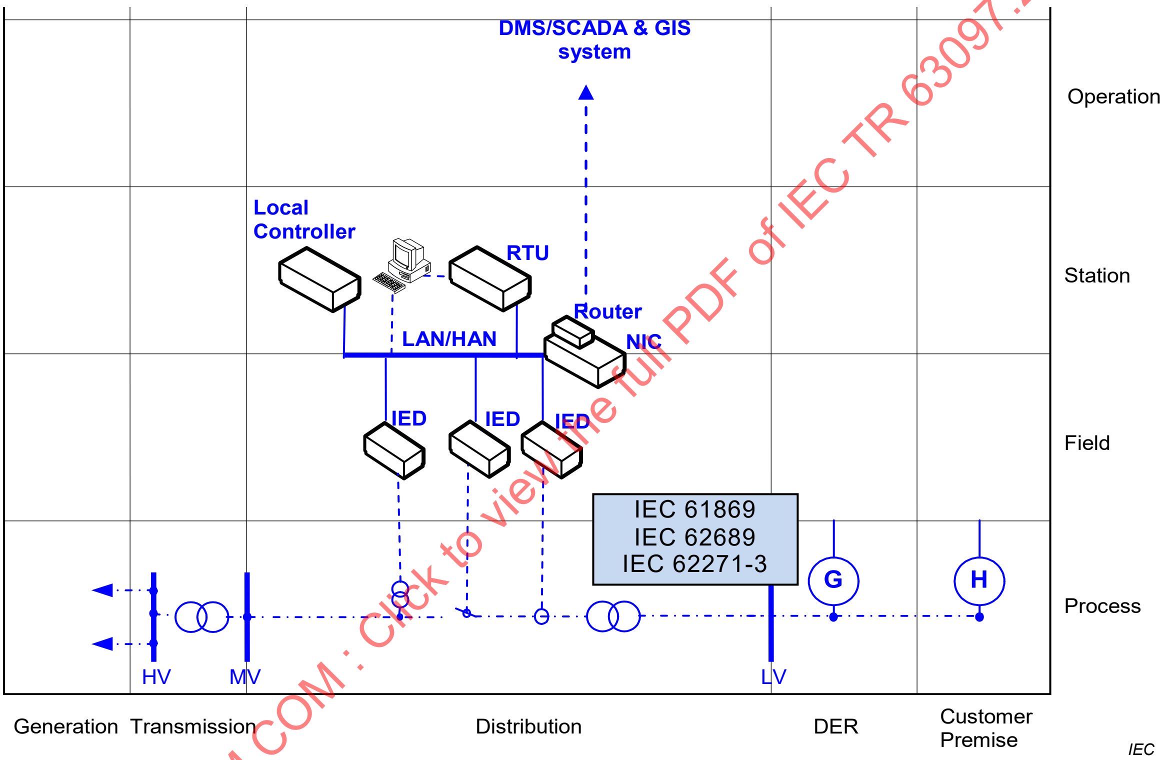


Figure 22 – Distribution automation system – Component layer

5.9.6.6.3 Communication layer

Communication protocols can be used either as in a) or b).

a) Within each switching location along the feeder or within the feeders inside the substation, IEC 61850-8-1 (for any kind of data flows except sample values) and IEC 61850-9-2 (for sample values) are used to support the selected set of System Capabilities.

   Considering that such a feeder may be seen as a distributed substation, many detailed guidelines provided by IEC TR 61850-90-4 can be applied.

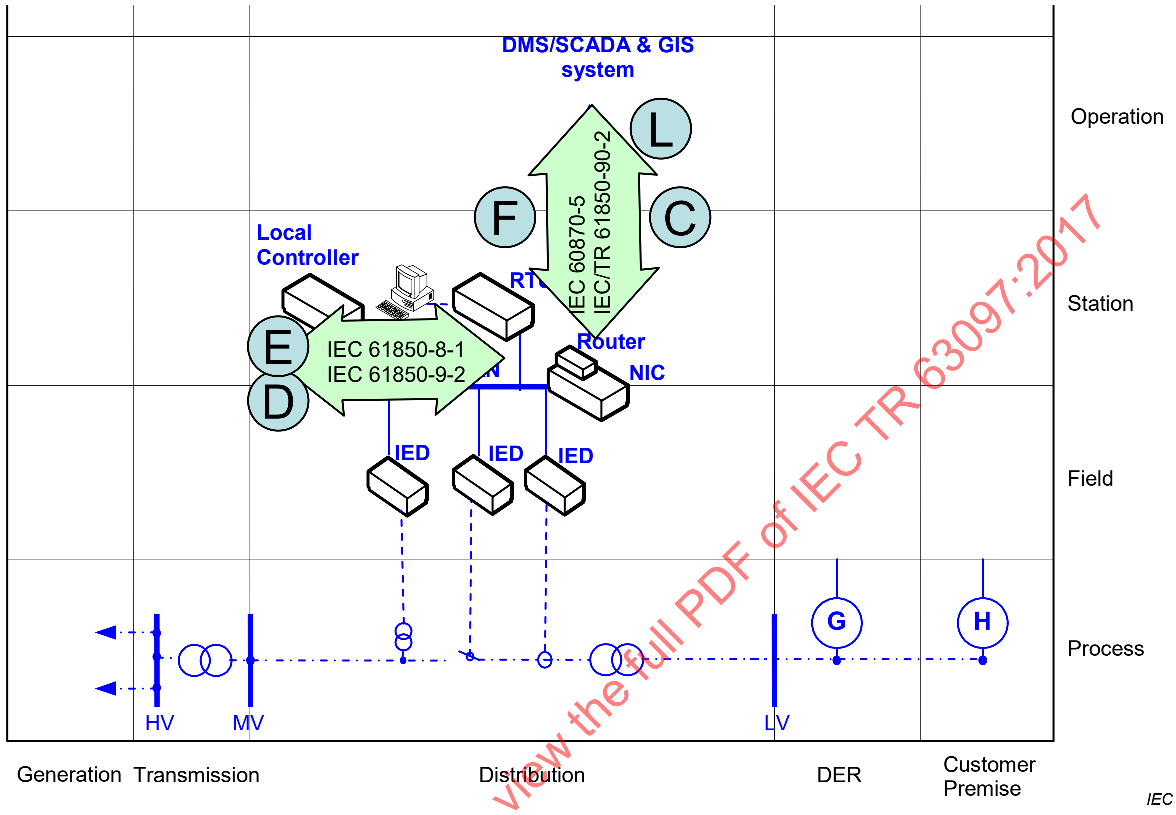
   IEC 61850 mostly replaces the former IEC 60870-5-103, used for connecting protection relays.

b) Outside each switching location, “vertical communications” can rely on IEC 60870-5-101, or IEC 60870-5-104.

   A new mapping of IEC 61850 over the web services technology (IEC 61850-8-2) is under preparation, in order to enlarge (in security) the scope of application of IEC 61850 outside the substation, and more specifically address feeder automation needs.

Refer to 5.10.4 for details on cyber-security standards and more specifically on where and how to apply the IEC 62351 series and/or other cyber-security mechanisms.

This set of standards can be positioned this way on the communication layer of SGAM (see Figure 23).



NOTE The letters in the blue disks refer to the network types defined in 5.10.1.2.

Figure 23 – Distribution automation system – Communication layer

5.9.6.6.4 Information (Data) layer

The information layer (see Figure 24) of feeder automation or smart reclosers is mostly based on the IEC 61850 information model.

It is indicated that the IEC 61850-7-4 is the core part depicting this model for each switching location along each feeder, and IEC TR 61850-90-2 for the communication to the control centre. However, other parts of the IEC 61850 series can also be used.

IEC TR 61850-90-6 is also indicated on the SGAM, which is expected to be a guide for the implementation of IEC 61850 on feeder automation.

For protocols which are not IEC 61850 native such as IEC 60870-5-101 or IEC 60870-5-104, a mapping of the IEC 61850 information model is possible using IEC TS 61850-80-1, enabling users of these technologies to use the power of data modelling (and then more seamless integration) without changing communication technologies.

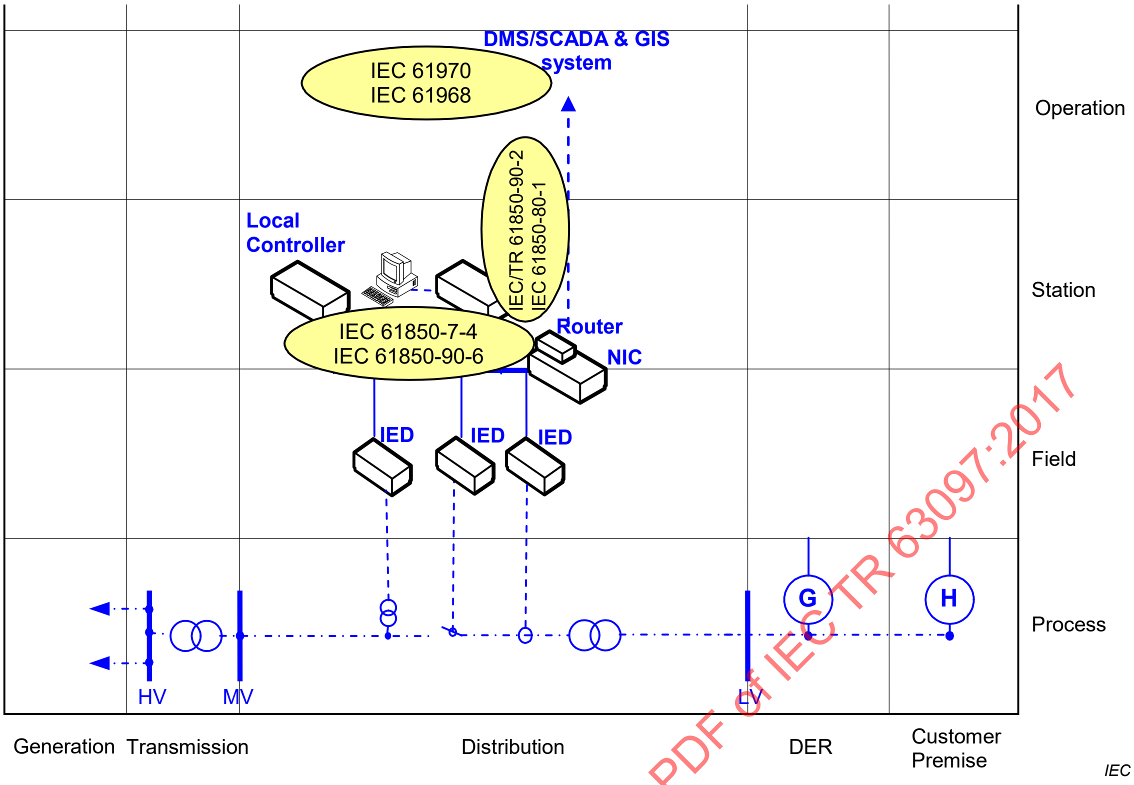


Figure 24 – Distribution automation system – Information layer

5.9.7 Substation automation system

5.9.7.1 Description

The task of building substation automation systems rests on the strong technological development of large-scale integrated circuits, leading to the present availability of advanced, fast, and powerful microprocessors. The result has been an evolution of substation secondary equipment, from electro-mechanical devices to digital devices. This in turn has provided the possibility of implementing Substation Automation using several intelligent electronic devices (IEDs) to perform the required functions (protection, local and remote monitoring and control, asset management, metering, etc.).

Substation Automation is quite a mature application, which has been performed for many years. Its core functions are:

- protection;
- local control and supervision;
- remote control and supervision;
- equipment supervision;
- metering;
- measuring;
- online diagnosis.

The functionality of microprocessor-based IEDs includes multiple functions for protection, control and monitoring. This is the basis of Substation Automation systems which have been widely introduced in substations but with proprietary communication solutions. The driving force for a communication standard is interoperability between devices of different suppliers to be independent from one supplier and one generation of IEDs. IED communication is also referred to as "IEC 61850 station-bus application", which lets IEDs communicate with each other and with a substation controller. An extension to this communication is the so called

"IEC 61850 process bus". This technology (see Figure 25) allows signals of a conventional or non-conventional instrument transformer to be sampled and digitally transmitted to one or several protection and measuring devices.

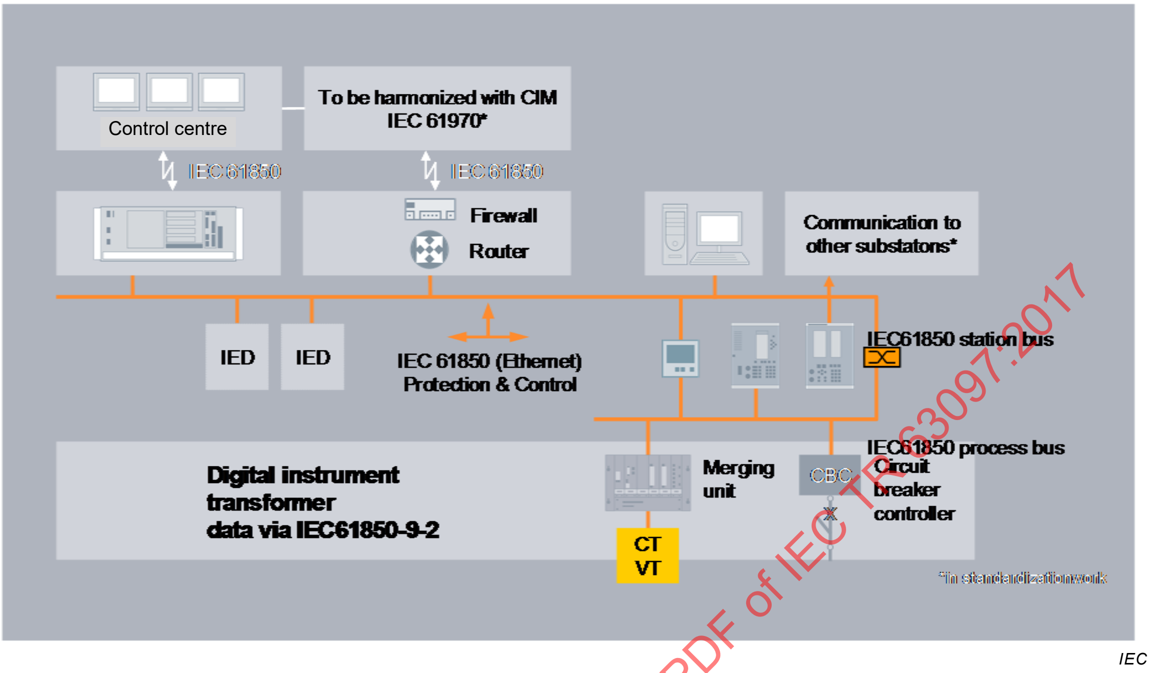


Figure 25 – Smart Substation Automation with a process bus

5.9.7.2 System summary

The substation automation system refers to the system and all the elements needed to perform automated operation of a substation, and of connected assets (grid lines, loads, etc.).

The typical considered operations are protection functionalities, automatic equipment control for network reconfiguration, including possibly feeder reconfiguration, automatic power quality regulation.

Substation automation system may also act as a remote terminal for upper levels of grid monitoring and control for operation (monitoring and control) and/or maintenance.

Some of the capabilities are fully automatic, i.e. are providing a spontaneous response of the system triggered by external events. Some others are in support of remote and/or manual operation.

Substation automation system is often implemented in the Distribution, Transmission, Generation domains. It can also be implemented on large industrial or infrastructure.

As a particular simplified case, substation automation system may be used for Automated MV/LV transformer Substation System, where the automated operations may include also LV feeders placed on the MV/LV transformer substation and typically (but not limited to) MV-switching elements connected to the MV/LV transformer, (controllable) MV/LV transformers and automated low-voltage boards.

5.9.7.3 Set of System Capabilities

Table 35 provides a set of System Capabilities which may be supported by a substation automation system.

The meanings of the three last columns (AVAILABLE, COMING, Not yet) and of the “C”, “I”, “CI”, “X” conventions are given in section 5.5.2.5.

Table 35 – Substation automation system – Capabilities

Cluster	System Capabilities	Supported by standards		
		AVAILABLE	COMING	Not yet
Protecting the grid assets	Protect a single equipment (incomer/feeder, transformer, generator)	CI		
	Protect a zone outside of the substation boundary	CI		
	Perform networked protection logic (intertripping, logic selectivity, etc.)	CI		
	Perform networked security logic (interlocking, local/remote)	CI		
	Set/change protection parameters	CI		
Monitoring the grid flows	Monitoring electrical flows	CI		
	Monitoring power quality for operation (locally)	CI		
	Producing, exposing and logging time-stamped events	CI		
	Supporting time-stamped alarms management at all levels	CI		
	Capture, expose and analyse disturbance events	CI		
	Archive operation information	CI		
Maintaining grid assets	Monitoring assets conditions	C	I	
	Supporting periodic maintenance (and planning)	C	I	
	Archive maintenance information	CI		
Controlling the grid (locally/ remotely) manually or automatically	Switch/breaker control	CI		
	Feeder load balancing	CI		
	Enable multiple concurrent levels of control (local-remote)	CI		
Managing power quality	Voltage regulation	CI		
	VAR regulation	CI		
Reconfiguring the network in case of fault	Supporting reclosing sequence	CI		
	Supporting source switching	CI		
	Supporting automatic FLISR	CI		
Provide and collect contractual measurements	Measuring and exposing energy flows for revenue purpose (smart meter)	C	I	
	Measuring and exposing power quality parameters for revenue purpose (smart meter)	C	I	
Connect an active actor to the grid	Managing generation connection to the grid	CI		
Blackout management	Blackout prevention through WAMS	CI		
	Shedding loads based on emergency signals	CI		
	Restore power after blackout	CI		
System and security management	Discover a new component in the system	C		I
	Configure newly discovered device automatically to act within the system	C		I
	Distributing and synchronizing clocks	CI		

5.9.7.4 Specific requirements

Devices of different vendors need to be able to communicate. Interoperability is a major requirement as well as backward compatibility and sustainability. Interoperation of devices from different vendors would be an advantage to users of substation automation devices.

A standard needs to support different operation methods and needs to allow an open configuration of functions.

Specific communication requirements:

- high data amount for sample values and configuration data sets;
- short transmission times for single signals like breaker position, etc.;
- time synchronization for sequence of events (accuracy 1 ms) and for sample values (accuracy ≤ 1 μs);
- use of open communication standards like Ethernet, TCP/IP, XML, etc.

All data that is used for calculation (impedance) or comparison (differential) by the protection need to be time coherent. This generates a requirement to synchronize the different sources (IEDs) of related data with each other. The ultimate requirement for the data used by the applications in the bay devices is that it shall be time-coherent. The often-used term "synchronization" can be misleading in the sense that it suggests a central clock that distributes time information to all bay devices. Although this may be required for some applications like time tagging of events (1 ms), it is not a requirement for the sampled analogue samples.

Since the data exchange is crucial for the substation automation system, a system for redundancy is required.

For future process bus applications, vitally important functions of the substations now depend on communication. This communication system has to meet extraordinarily high requirements for availability and reliability.

5.9.7.5 Standards context

5.9.7.5.1 General

Multiple protocols were existing and still exist for substation automation, which include many proprietary protocols with custom communication links, requiring complicated and costly protocol converters when using IEDs from different vendors.

IEC provides nowadays a modern and futureproof solution based on IEC 61850 series. All details related to this series can be found in 5.9.7.

Different control centre connection protocols are also available, including IEC 60870-5-101, IEC 60870-5-104, DNP V3.00 (serial and “over IP”; non-IEC standard).

The IEC 61850 series also targets this application between substation and control centre (through the IEC TR 61850-90-2 and the IEC TR 61850-90-12 coming standards), with the aim to avoid painful and expensive gateways for protocol translations.

Refer to 5.9.7.7 for a deeper understanding of the mapping of these standards on the SGAM.

5.9.7.5.2 Available standards

See Table 36. Refer to 5.2.5.3 for the definition of the criteria considered in this document for stating that a standard is “available”.

Table 36 – Substation automation system – Available standards

Layer	Standard	Comments
Information	IEC 61850-7-4 IEC 61850-7-3 IEC 61850-7-2 IEC 61850-6	*Communication networks and systems for power utility automation* Core Information model and language for the IEC 61850 series
Information	IEC 61850-7-410	*Communication networks and systems for power utility automation – Part 7-410: Basic communication structure – Hydroelectric power plants – Communication for monitoring and control*
Information	IEC 61850-7-420	*Communication networks and systems for power utility automation – Part 7-420: Basic communication structure – Distributed energy resources logical nodes*
Information	IEC TR 61850-90-7	*Communication networks and systems for power utility automation – Part 90-7: Object models for power converters in distributed energy resources (DER) systems*
Information	IEC TS 61850-80-1	*Communication networks and systems for power utility automation – Part 80-1: Guideline to exchanging information from a CDC-based data model using IEC 60870-5-101 or IEC 60870-5-104* Mapping of IEC 61850 data model over IEC 60870-5-101 and IEC 60870-5-104
Information	IEC TS 61850-80-4	*Communication networks and systems for power utility automation – Part 80-4: Translation from the COSEM object model (IEC 62056) to the IEC 61850 data model*
Information	IEC 61400-25 series	*Wind turbines – Communications for monitoring and control of wind power plants*
Information	IEC 61968 series	*Application integration at electric utilities – System interfaces for distribution management* Common Information Model (System Interfaces For Distribution Management)
Information	IEC 61970 series	*Energy management system application program interface (EMS-API)* Common Information Model (System Interfaces For Energy Management)
Communication	IEC 61850-8-1	*Communication networks and systems for power utility automation – Part 8-1: Specific communication service mapping (SCSM) – Mappings to MMS (ISO 9506-1 and ISO 9506-2) and to ISO/IEC 8802-3* IEC 61850 communication except sample values
Communication	IEC TR 61850-90-1	*Communication networks and systems for power utility automation – Part 90-1: Use of IEC 61850 for the communication between substations*
Communication, information	IEC TR 61850-90-2	*Communication networks and systems for power utility automation – Part 90-2: Using IEC 61850 for the communication between substations and control centres*
Information	IEC TR 61850-90-3	*Communication networks and systems for power utility automation – Part 90-3: Using IEC 61850 for condition monitoring diagnosis and analysis*
Communication, Information	IEC TR 61850-90-4	*Communication networks and systems for power utility automation – Part 90-4: Network engineering guidelines* Guidelines for communication within substation

Layer	Standard	Comments
Communication	IEC 60870-5-101	*Telecontrol equipment and systems – Part 5-101: Transmission protocols – Companion standard for basic telecontrol tasks*
Communication	IEC TR 61850-90-12	*Communication networks and systems for power utility automation – Part 90-12: Wide area network engineering guidelines*
Communication	IEC 60870-5-103	*Telecontrol equipment and systems – Part 5-103: Transmission protocols – Companion standard for the informative interface of protection equipment*
Communication	IEC 60870-5-104	*Telecontrol equipment and systems – Part 5-104: Transmission protocols – Network access for IEC 60870-5-101 using standard transport profiles*
Communication	IEC 61850-9-2	*Communication networks and systems for power utility automation – Part 9-2: Specific communication service mapping (SCSM) – Sampled values over ISO/IEC 8802-3* IEC 61850 Sample values communication
Communication	IEC PAS 61850-9-3	*Communication networks and systems for power utility automation – Part 9-3: Precision time protocol profile for power utility automation*
Communication	IEC TR 61850-90-5	*Communication networks and systems for power utility automation – Part 90-5: Use of IEC 61850 to transmit synchrophasor information according to IEEE C37.118* May also be relevant for use between substations
Communication	IEC 60255-24	*Electrical relays – Part 24: Common format for transient data exchange (COMTRADE) for power systems*
Communication	IEC 62439 series	*Industrial communication networks – High availability automation networks* Based on the ISO/IEC 8802-3 (Ethernet) technology (including PRP and HSR)
Component	IEC 62271-3	*High-voltage switchgear and controlgear; Part 3: Digital interfaces based on IEC 61850*
Component	IEC 61869	*Instrument transformers*
Communication	IEC 62351 series	*Power systems management and associated information exchange – Data and communications security* Cyber-security aspects (see 5.10.4)
Communication	IEC 61158 series	This standards series includes many industrial communication protocols which may partly answer substation automation systems requirements
Other specifications		
Communication	IEEE 1815	Also known as DNP3
Information	IEEE 1815-1	Mapping of IEC 61850 data model over DNP3
Communication	IEEE 1686	Standard for Intelligent Electronic Devices Cyber Security Capabilities

5.9.7.5.3 Coming standards

See Table 37. Refer to 5.2.5.3 for the definition of the criteria considered in this document for stating that a standard is “coming”.

Table 37 – Substation automation system – Coming standards

Layer	Standard	Comments
Information, Communication	IEC TR 61850-90-6 [a]	*Communication networks and systems for power utility automation – Part 90-6: Use of IEC 61850 for distribution automation systems*
Information	IEC TR 61850-90-11 [a]	*Communication networks and systems for power utility automation – Part 90-11: Modelling of logics with IEC 61850*
Communication	IEC 61850-8-2 [a]	*Communication networks and systems for power utility automation – Part 8-2: Specific communication service mapping (SCSM) – Mapping to Extensible Messaging Presence Protocol (XMPP)*
Communication	IEC/IEEE 61850-9-3	*Communication networks and systems for power utility automation – Part 9-3: Precision time protocol profile for power utility automation*
Component	IEC 61869-6 and IEC 61869-9	*Instrument transformers – Part 6: Additional general requirements for low-power instrument transformers Part 9: Digital interface for instrument transformers*
Component	IEC 62689 series [a]	*Current and voltage sensors or detectors, to be used for fault passage indication purposes*
Communication	IEC 62351 series	*Power systems management and associated information exchange – Data and communications security* Cyber-security aspects (see 5.10.4)
Communication, information	IEC 61400-25 series	Edition 2 – Set of standards more specific to wind turbines and wind farms
[a] Under preparation.		

5.9.7.6 Gaps

The IEC 61850 series is becoming the cornerstone of the Smart Grids standards, and its scope is extending year after year.

An electronic machine readable data model is becoming more and more needed to ensure the standard is used error free. Web access to this data model could also be of high value, crossing all the data model namespaces, for the user's ease of use.

Some features are also of interest to be complemented:

- use of IEC 61850 over WAN;
- data modelling for logics;
- system management;
- Power Quality data modelling in order to support IEC 61000-4-30.

Reaching full interoperability still needs further work, especially by defining the testing context, associated features and interoperability test running.

5.9.7.7 Substation automation system mapping

5.9.7.7.1 Preamble

It is important to consider that, from a standard point of view, there are a lot of similarities between distribution substation automation system, and transmission and generation one. For an easy reading of the document only the distribution substation automation is mapped, but this schema can be transposed on transmission and generation domains.

This is expressed by adding a circle indicating that the same principles can apply on these domains.

Considering that this system is not interacting with the “Enterprise” and “Market” zones of the SGAM, only the “Process”, “Field”, “Station” and “Operation” zones are shown in Figures 26, 27 and 28.

NOTE In the particular simplified case of Automated MV/LV transformer Substation System, we may observe a smaller number of IEDs, a lower level of complexity of operations to perform and possibly a simpler local area network (LAN) relying on standard technologies like the one used for home area networks (HAN) or industrial networks.

5.9.7.7.2 Component layer

The substation automation component architecture represented in Figure 26 is mostly made of three zones of components, which may be interconnected through wires or communication.

- The Process zone includes the primary equipment of the substation mainly switching (i.e. circuit-breakers, switches and disconnectors), power transformer regulator and measuring elements (i.e. current and voltage sensors/transformers) including digital sensors.
- The Field zone includes equipment to protect, control and monitor the process of the substation, mainly through IEDs, and controllers.

  IED is a generic representation covering components such as (but not limited to):
  – protection relays or reclosers;
  – operation, revenue and grid meters;
  – fault detectors;
  – bay or switch controller;
  – generic I/O interface.
- Field Controller is a generic representation covering components such as (but not limited to):
  – feeder controller (connecting/disconnecting/reclosing sequences);
  – voltage regulator controller;
  – network interface controller (NIC) or router (remote connection interface sometimes integrated in NIC).
- The Station zone supports the aggregation level which interfaces with other elements and systems of the electrical network. It mostly supports four main technical functions, which can be grouped or separated in different components:
  – RTU which serves as terminal for remote activities, the Station controller, which is in charge of performing automatic functions;
  – possibly HMI/archiving which offers the local operators capabilities of visualizing and archiving local data;
  – controller such as (but not limited to) a station or feeder controller, or also a capacitor bank controller or a load tap changer controller;
  – communication which can be an NIC and/or just a router function.

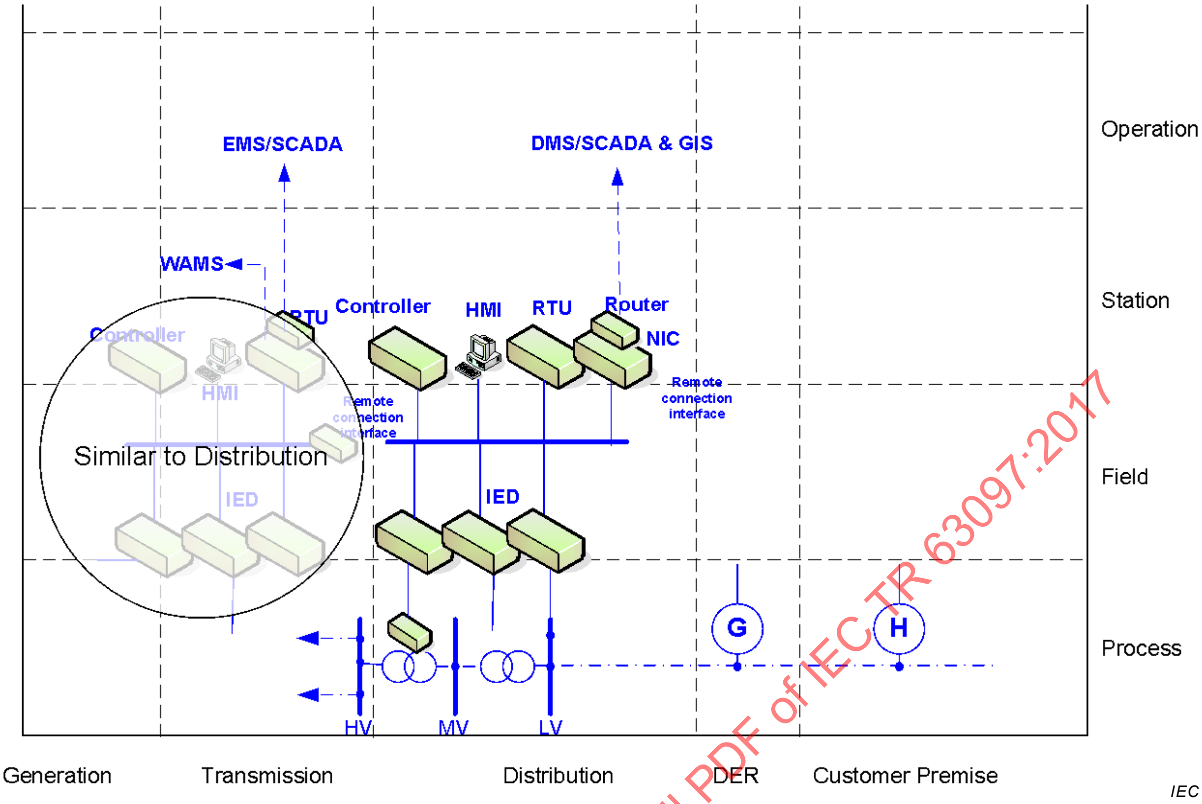


Figure 26 – Substation automation system – Component layer

5.9.7.7.3 Communication layer

Communication protocols, as presented in Figure 27, can be used either as in a) or b).

a) Within the substation, IEC 61850-8-1 (for any kind of data flows except sample values) and IEC 61850-9-2 (for sample values) are used to support the selected set of System Capabilities.

   IEC TR 61850-90-4 provides network engineering guidelines for communication inside a substation (automated MV/LV substations are not really covered yet).

   IEC 61850 mostly replaces the former IEC 60870-5-103, used for connecting protection relays.

   In the specific case of automated MV/LV substations, communications are more commonly based on industrial networks.

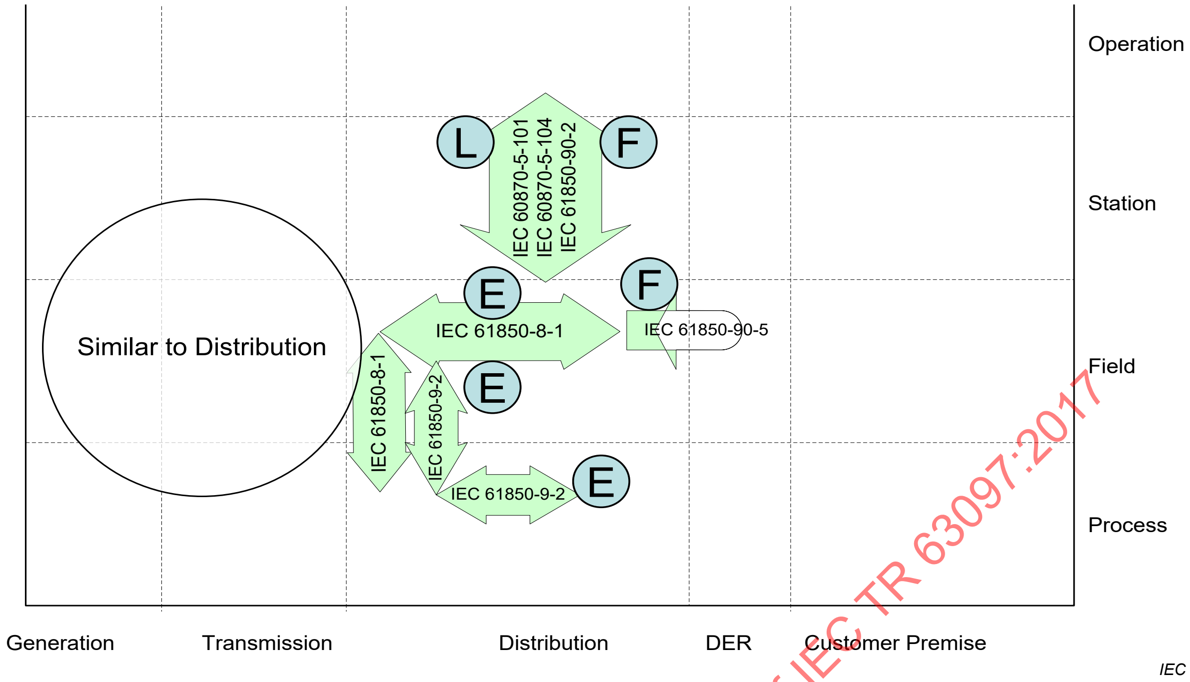
b) Outside the substation, “vertical communications” can rely IEC 60870-5-101 or IEC 60870-5-104, while horizontal communications can rely on IEC TR 61850-90-5 (full mapping over UDP) or IEC TR 61850-90-1 (tunnelling).

Future vertical communication may rely on IEC TR 61850-90-2 (guideline for using IEC 61850 to control centres) and on IEC TR 61850-90-12 (guidelines for using IEC 61850 over WAN) to provide a seamless architecture, based on IEC 61850.

A new mapping of IEC 61850 over the web services technology (IEC 61850-8-2) is under preparation, in order to enlarge (in security) the scope of application of IEC 61850 outside the substation, while facilitating its deployment.

Refer to 5.10.4 for getting details on cyber-security standards and more specifically on where and how to apply the IEC 62351 series and/or other cyber-security mechanisms.

This set of standards can be positioned in this way on the communication layer of SGAM.



NOTE The letters in the blue disks refer to the network types defined in 5.10.1.2.

Figure 27 – Substation automation system – Communication layer

5.9.7.7.4 Information (Data) layer

The information layer of substation automation, represented in Figure 28, is mostly based on the IEC 61850 information model.

It is indicated that the IEC 61850-7-4 is the core part depicting this model, however other "namespaces" of the IEC 61850 series can be used such as:

- IEC 61850-7-410: Hydroelectric power plants
- IEC 61850-7-420: Distributed energy resources (DER) logical nodes
- IEC 61400-25 series: Wind turbine power plants
- IEC TR 61850-90-2: Communication to control centres
- IEC TR 61850-90-3: Condition monitoring
- IEC TR 61850-90-4: Network engineering guidelines
- IEC TR 61850-90-5: Synchrophasors
- IEC TR 61850-90-7: PV inverters

For automated MV/LV substation IEC TR 61850-90-6 should also be considered, which is expected to be a guide for the implementation of IEC 61850 on distribution automation.

For protocols which are not IEC 61850 native such as the IEC 60870-5-101 or IEC 60870-5-104, a mapping of IEC 61850 information model is possible using the IEC TS 61850-80-1, enabling users of these technologies to use the power of data model driven engineering (and then more seamless integration) without changing of communication technologies.

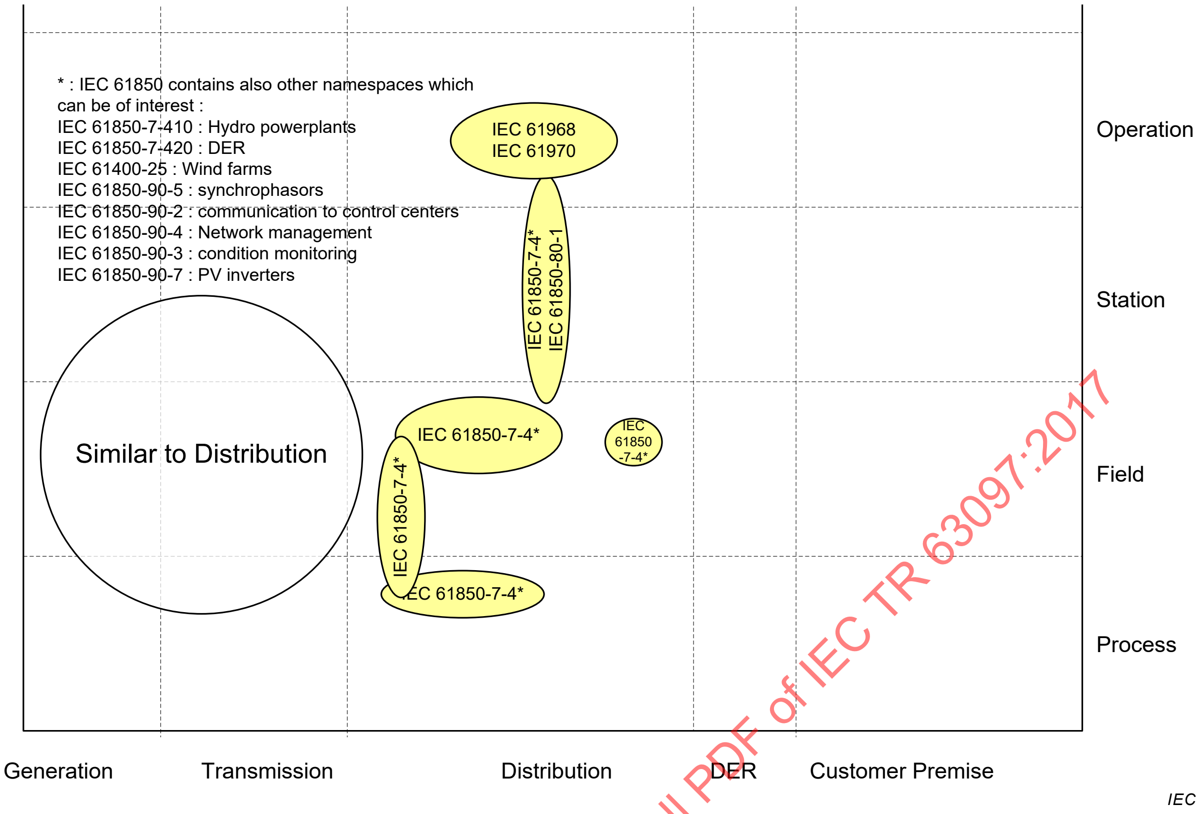


Figure 28 – Substation automation system – Information layer

5.9.8 DER management system

5.9.8.1 Description

In parallel with the liberalization of the energy markets, the decentralized generation of electrical power and heating and air conditioning energy becomes more and more important. The generation of these types of energy near to the consumers offers economic and ecological benefits. In this context, interest is directed to so-called virtual power plants. A virtual power plant is a collection of small and very small decentralized generation units that is monitored and controlled by a super-ordinated energy management system. In general, these generation units produce heating and air conditioning energy as well as electricity. A successful operation of a virtual power plant requires the following technical equipment:

a) an energy management system that monitors, plans and optimizes the operation of the decentralized power units;
b) a forecasting system for loads that is able to calculate very short-term forecasts (one hour) and long-term forecasts (up to seven days);
c) a forecasting system for the generation of renewable energy units. This forecast uses weather forecasts in order to predict the generation of wind power plants and photovoltaics;
d) an energy data management system which collects and keeps the data that is required for optimization and forecasts, for example, profiles of generation and loads as well as contractual data for customer supply;
e) a powerful front end for the communication of the energy management system with the decentralized power units.

First, a virtual power plant needs a bidirectional communication between the decentralized power units and the control centre of the energy management system. For larger units, control systems based on protocols such as IEC 61850 or IEC 61400 can be used. In the future, with an increasing number of small decentralized power units, communication channels and protocols will play a more important role. It is likely that the costly conventional telemetry technique will be substituted by other techniques based on simple TCP/IP adapters or based on power line carrier techniques.

All operation planning and scheduling applications require forecasts with sufficient accuracy.

The special structure of a virtual power plant places high demands on the mathematical models for the optimization. The models need to be very precise because rough models could yield optimization results that cannot be realized by the power system. Because the virtual power plant has to provide an automatic mode for online control of the decentralized power units, e.g. for compensating imbalances, no operator can check and correct the results.

The components/units of a virtual power plant and their energy flow topology are modelled in DER by some classes of model elements, e.g. converter units, contracts, storage units, renewable units and flexible loads.

The DER control applications provide control and supervision capability of all generation units, storage units and flexible demands, as well as control capability to maintain an agreed-upon electrical interchange energy profile.

The functions of VPP/DER can be subdivided into planning functions and control functions. The respective planning functions are:

- weather forecast;
- load forecast;
- generation forecast;
- unit commitment;
- generation and load management.

Generation management functions allow for the control and supervision of all generation and storage units of the virtual power plant. Dependent on the control mode of the respective unit (independent, manual, schedule or control mode) and the unit parameters (minimum/maximum power, power gradients, energy content), the actual state (start-up, online, remote controllable, disturbed) and the actual power output of the unit, the start/stop commands and power set points for the units are calculated and transmitted. In the event of a unit disturbance, the generation management can start a spontaneous unit commitment calculation to force a rescheduling of the remaining units under the changed circumstances while also considering all integral constraints.

Load management functions allow the control and supervision of all flexible loads in the virtual power plant.

5.9.8.2 System summary

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. The system may control one or more DERs which can be geographically distributed. These DERs could be single generation plants or could be combined to VPPs.

It controls the actual generation and storage including VAR regulation and frequency support based on requests and schedules received from the market or DSO.

5.9.8.3 Set of System Capabilities

The System Capabilities given in Table 38 might be supported by a DER management system.

The meanings of the three last columns (AVAILABLE, COMING, Not yet) and of the “C”, “I”, “CI”, “X” conventions are given in 5.5.2.5.

Table 38 – DER management system – Capabilities

Use case cluster	System Capabilities	Supported by standards		
		AVAILABLE	COMING	Not yet
Protecting the grid assets	Protect a single equipment (Incomer/feeder, Transformer, Generator)	CI		
	Protect a zone outside of the substation boundary	CI		
	Perform networked protection logic (Intertripping, logic selectivity, etc.)	C	I	
	Perform networked security logic (Interlocking, local/remote)	C	I	
	Set/change protection parameters	CI		
Monitoring the grid flows	Monitoring electrical flows	CI		
	Monitoring power quality for operation (locally)	C	I	
	Producing, exposing and logging time-stamped events	CI		
	Supporting time-stamped alarms management at all levels	CI		
	Capture, expose and analyse disturbance events	CI		
	Archive operation information	I	C	
Maintaining grid assets	Monitoring assets conditions	CI	C	
	Supporting periodic maintenance (and planning)		CI	
	Optimize field crew operation	C	C	I
	Archive maintenance information		CI	
Managing power quality	VAR regulation		CI	
	Frequency support		CI	
Operate DER(s)	DER process management	CI		
	DER process management with reduced power output	CI		
	DER performance management		CI	
	DER remote control (dispatch)		CI	
	Registration/deregistration of DER in VPP		CI	
	Aggregate DER as technical VPP		CI	
	Aggregate DER as commercial VPP		CI	
Connect an active actor to the grid	Managing micro-grid transitions		CI	
	Managing generation connection to the grid		CI	
Blackout management	Restore power after blackout			?

Use case cluster	System Capabilities	Supported by standards		
		AVAILABLE	COMING	Not yet
Demand and production (generation) flexibility	Receiving metrological or price information for further action by consumer or CEM		CI	
	Generation forecast (from remote)		C	I
	Generation forecast (from local)		C	I
	Participating in electricity market	I	CI	
	Managing energy consumption or generation of DERs via local DER energy management system bundled in a DR program		CI	
	Managing energy consumption or generation of DERs and EVSE via local DER energy management system to increase local self-consumption			
	Registration/deregistration of DER in DR program		CI	
System and security management	Discover a new component in the system		CI	
	Configure newly discovered device automatically to act within the system		CI	
	Distributing and synchronizing clocks	CI		

It still has to be evaluated in detail which parts of the Capabilities are supported by existing or new IEC 61850 standards and what is missing.

5.9.8.4 Requirements

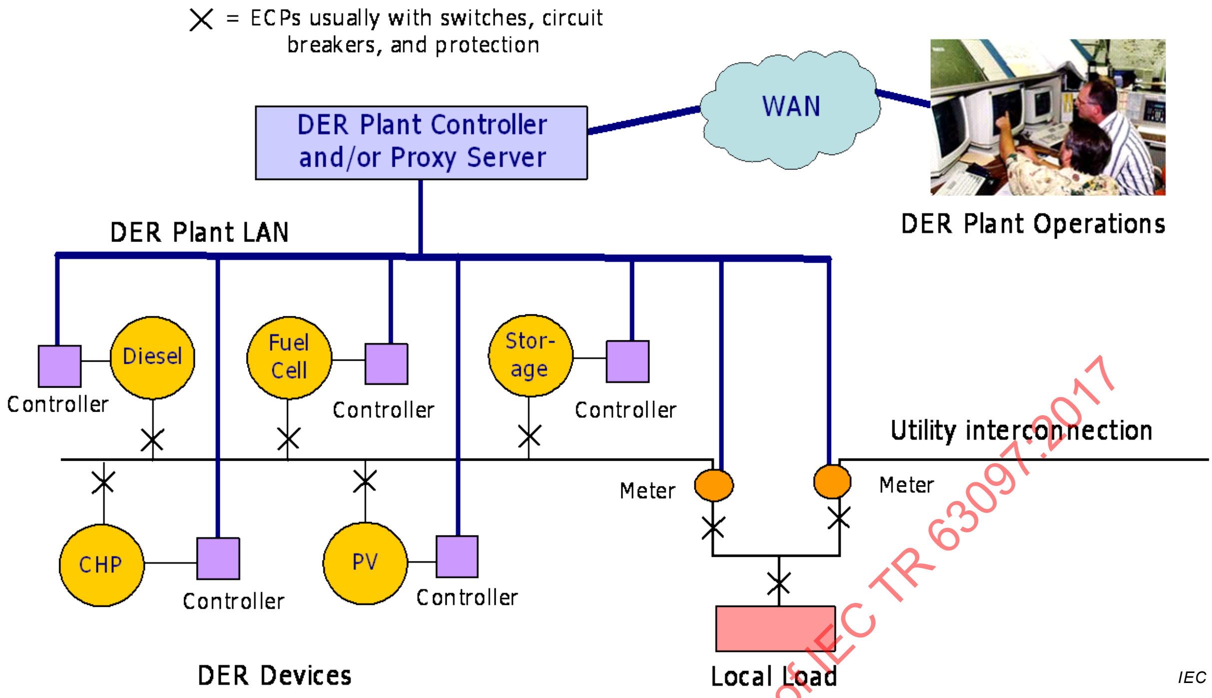
An essential requirement for DER is the interface, data models and protocols for the communication of the individual components with the management unit. An interface to other Web applications will be necessary.

Pricing information will be required.

Technical connection criteria for renewable resources are required. These include solar photovoltaic, small wind turbines, combined heat and power generation, etc.

5.9.8.5 Existing standards

Figure 29 shows an example of the communication and control of a DER plant.



Key

CHP	combined heat and power
WAN	wide area network
DER	distributed energy resources
PV	photovoltaics
LAN	local area network

Figure 29 – Example of a communications configuration for a DER plant

Decentralized energy generation systems can be described according to their information exchange through the definitions of IEC 61850-7-420 as well as through other logical nodes of IEC 61850-7-4, IEC 61850-7-410 (hydro power) and IEC 61400-25-2 (wind power).

An important recent enhancement is IEC TR 61850-90-7, which provides data modelling for Inverter-based DER and associated ancillary services.

The DER plant electrical connection point (ECP) logical device defines the characteristics of the DER plant at the point of electrical connection between one or more DER units and any electric power system (EPS), including isolated loads, micro-grids, and the utility power system. Usually there is a switch or circuit breaker at this point of connection.

ECPs can be hierarchical. Each DER (generation or storage) unit has an ECP connecting it to its local power system; groups of DER units have an ECP where they interconnect to the power system at a specific site or plant; a group of DER units plus local loads have an ECP where they are interconnected to the utility power system.

In a simple DER configuration, there is one ECP between a single DER unit and the utility power system. However, as shown in Figure 30, there may be more ECPs in a more complex DER plant installation. In this figure, ECPs exist between:

- each single DER unit and the local bus;
- each group of DER units and a local power system (with load);
- multiple groups of DER units and the utility power system.

The ECP between a local DER power system and a utility power system is defined as the point of common coupling (PCC) in IEEE Std 1547, *Standard for Interconnecting Distributed Resources with Electric Power Systems* (see Figure 30).

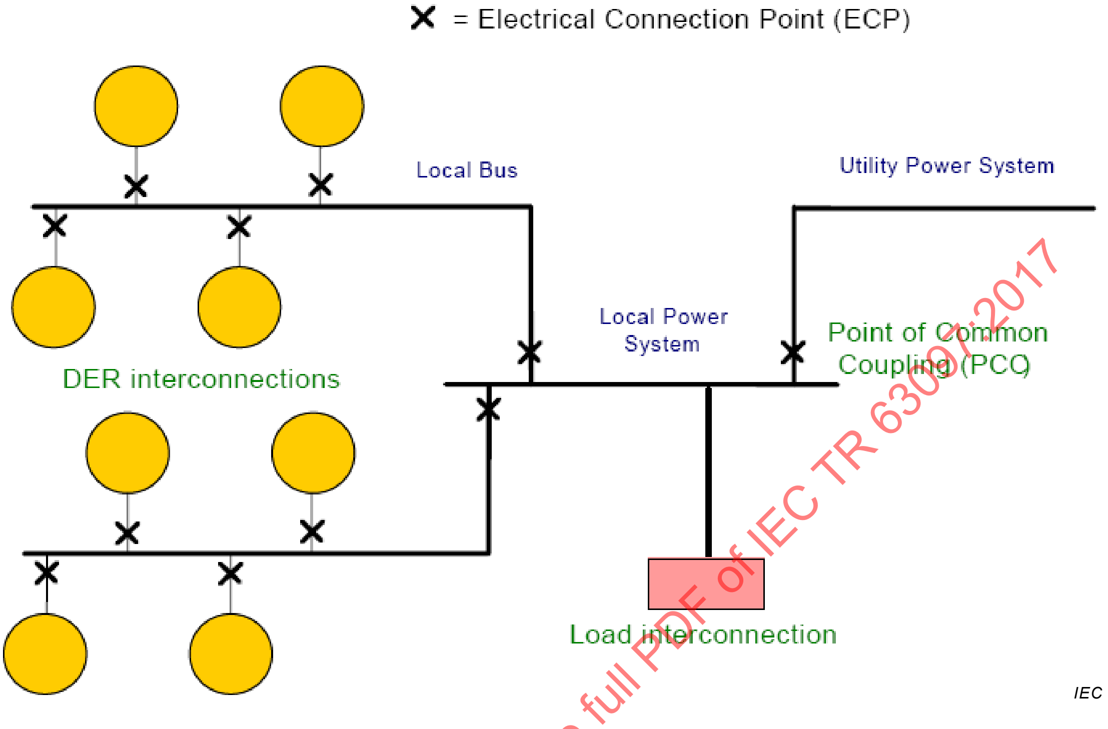


Figure 30 – Illustration of electrical connection points (ECP) in a DER plant

IEC 61850-7-420 is a relatively new standard, which still needs to gain maturity. However, it is perfectly suited to the overall IEC system architecture (refer to IEC TR 62357).

Alternatively DER equipment can be directly connected and controlled via HEBS/BACS and/or to industrial control systems. The relevant standards and description are given in 5.9.14 and 5.9.15.

IEC 61850-7-410 is the equivalent standard to IEC 61850-7-420 for hydro power plants. The circle of users is much smaller and the content more specialized, however the same summary and assessment applies as for IEC 61850-7-420.

IEC 61850-7-420 will be complemented by the coming IEC TR 61850-90-15 in order to support aggregated/hierarchical ways of managing DERs, but also by IEC TR 61850-90-9 dealing with batteries' storage.

Standards related to “Connecting DER to the grid” are treated in 5.8.1.

5.9.8.6 List of standards

5.9.8.6.1 General

Here is the summary of the standards which appear relevant to DER management systems.

5.9.8.6.2 Available standards

See Table 39. Refer to 5.2.5.3 for the definition of the criteria considered in this document for stating that a standard is “available”.

Table 39 – DER management system – Available standards

Layer	Standard	Title and comments
Information	IEC 61850-7-4 IEC 61850-7-3 IEC 61850-7-2 IEC 61850-6	*Communication networks and systems for power utility automation* Core Information model and language for the IEC 61850 series
Information	IEC 61400-25-2	*Wind turbines – Part 25-2: Communications for monitoring and control of wind power plants – Information models*
Information	IEC 61400-25-3	*Wind turbines – Part 25-3: Communications for monitoring and control of wind power plants – Information exchange models*
Information	IEC 61850-7-410	*Communication networks and systems for power utility automation – Part 7-410: Hydroelectric power plants – Communication for monitoring and control*
Information	IEC 61850-7-420	*Communication networks and systems for power utility automation – Part 7-420: Basic communication structure – Distributed energy resources logical nodes*
Information	IEC TR 61850-90-7	*Communication networks and systems for power utility automation – Part 90-7: Object models for power converters in distributed energy resources (DER) systems*
Communication	IEC 60870-5-101	*Telecontrol equipment and systems – Part 5-101: Transmission protocols – Companion standard for basic telecontrol tasks*
Communication	IEC 60870-5-104	*Telecontrol equipment and systems – Part 5-104: Transmission protocols – Network access for IEC 60870-5-101 using standard transport profiles*
Communication	IEC 61850-8-1	*Communication networks and systems for power utility automation – Part 8-1: Specific communication service mapping (SCSM) – Mappings to MMS (ISO 9506-1 and ISO 9506-2) and to ISO/IEC 8802-3* IEC 61850 communication except Sample values
Communication, Information	IEC TR 61850-90-2	*Communication networks and systems for power utility automation – Part 90-2: Using IEC 61850 for the communication between substations and control centres*
Communication	IEC TR 61850-90-12	*Communication networks and systems for power utility automation – Part 90-12: Wide area network engineering guidelines*
Communication	IEC 61400-25-4	*Wind turbines – Part 25-4: Communications for monitoring and control of wind power plants – Mapping to communication profile*
Communication	IEC 61158 series	*Industrial communication networks – Fieldbus specifications*
Communication	IEC 61784-1	*Industrial communication networks – Profiles – Part 1: Fieldbus profiles*
Information	IEC 61131 series	*Programmable controllers*
Information	IEC 61499 series	*Function blocks*
Information	IEC 61968 series	*Application integration at electric utilities – System interfaces for distribution management* Common Information Model (System Interfaces For Distribution Management)
Information	IEC 61970 series	*Energy management system application program interface (EMS-API)* Common Information Model (System Interfaces For Energy Management)
Communication	IEC 61968-100	*Application integration at electric utilities – System interfaces for distribution management – Part 100: Implementation profiles* Defines profiles for the communication of CIM messages using Web Services or Java Messaging System
Communication	IEC 62351 series	*Power systems management and associated information exchange – Data and communications security* Cyber-security aspects (see 5.10.4)
Component	IEC 60904 series	*Photovoltaic devices*

Layer	Standard	Title and comments
Component	IEC 61194	*Characteristic parameters of stand-alone photovoltaic (PV) systems*
Component	IEC 61724	*Photovoltaic system performance monitoring – Guidelines for measurement, data exchange and analysis*
Component	IEC 61730 series	*Photovoltaic (PV) module safety qualification*
Component	IEC TS 61836	*Solar photovoltaic energy systems – Terms, definitions and symbols*
Component	IEC 61400-1	*Wind turbines – Part 1: Design requirements*
Component	IEC 61400-2	*Wind turbines – Part 2: Design requirements for small wind turbines*
Component	IEC 61400-3	*Wind turbines – Part 3: Design requirements for offshore wind turbines*
Component	IEC TS 62282	*Fuel cell technologies*
Component	IEC 62600 series	*Marine energy – Wave, tidal and other water current converters*
Component	Refer to 5.8.2.3	Refer to 5.8.2.3
Other specifications		
Communication	IEEE 1815	*Also known as DNP3*
Information	IEEE 1815-1	*Mapping of IEC 61850 data model over DNP3*

5.9.8.6.3 Coming standards

See Table 40. Refer to 5.2.5.3 for the definition of the criteria considered in this document for stating that a standard is “coming”.

Table 40 – DER management system – Coming standards

Layer	Standard	Title and comments
Information	IEC 61850-7-420	*Communication networks and systems for power utility automation – Part 7-420: Basic communication structure – Distributed energy resources logical nodes* IEC 61850 modelling for DER – New edition
Information	IEC TR 61850-90-9 [a]	*Use of IEC 61850 for electrical storage systems*
Information	IEC TR 61850-90-10 [a]	*IEC 61850 object models for scheduling*
Information	IEC TR 61850-90-15 [a]	*Hierarchical architecture of a DER system*
Information	IEC TR 61850-90-11 [a]	*Methodologies for modelling of logics for IEC 61850 based applications*
Communication	IEC 61850-8-2 [a]	*Communication networks and systems for power utility automation – Part 8-2: Specific communication service mapping (SCSM) – Mappings to Extensible Messaging Presence Protocol (XMPP)*
Communication	IEC 62351 series	*Power systems management and associated information exchange – Data and communications security* Cyber-security aspects (see 5.10.4)
Communication, information	IEC 61400-25 series	Wind turbines – Edition 2
Component	Refer to 5.8.2.4	Refer to 5.8.2.4
[a] Under preparation.		

5.9.8.7 Gaps

Mapping to communication protocols (IEC 61850-8 parts).

In addition, a systems configuration language (SCL) for DER (IEC 61850-6 parts) would address the configuration of DER plants.

For wind power, the mapping for communication protocols developed by IEC 61400-25 series could be used.

Electric connection points are often specific to certain customers and regions. This may also be subject to regulation, which makes it difficult to harmonize.

5.9.8.8 DER management system mapping

5.9.8.8.1 Preamble

The DER management system interacts with weather forecast system (wind farms and PV), related DSO systems (power quality control, DMS/SCADA, etc.) (tVPP) and the market (cVPP). In cases where the DER assets are owned or operated by the DSO, the DER management systems AS might be part of the DSOs DMS/SCADA system.

5.9.8.8.2 Component layer

The component architecture, as presented in Figure 31, covers all zones:

- the Process zone with the DERs, inverters and related sensors and actors;
- the Field zone with the DER unit controller;
- the Station zone with the DER plant controller;
- the Operation zone with the tVPP/EMS which may interact with the DSOs DMS in case of tVPP;
- the Enterprise zone with the cVPP which interacts with the market platform or directly with an energy retailer.

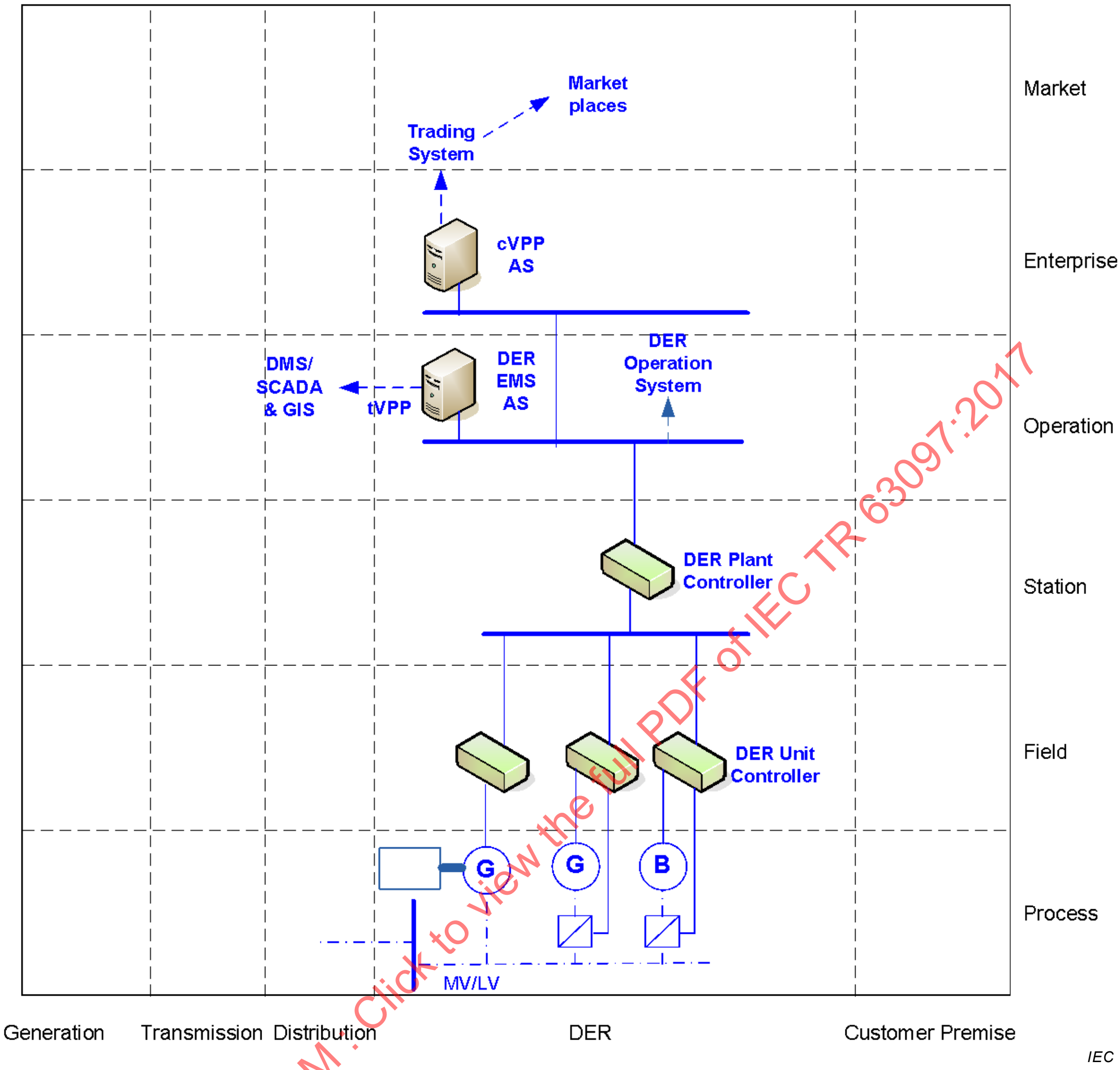


Figure 31 – DER management system – Component layer

5.9.8.8.3 Communication layer

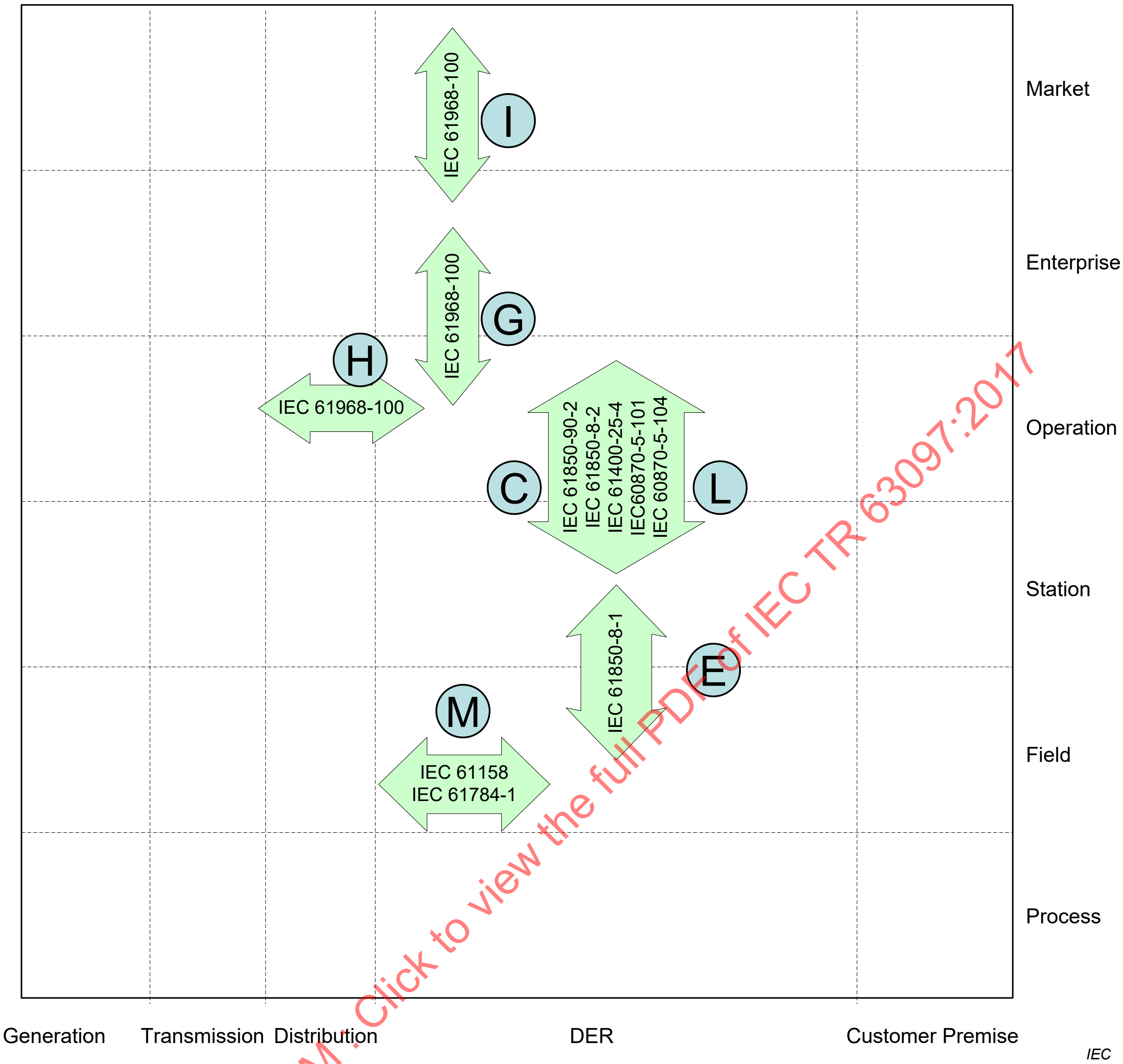
IEC 61850-8-1 defines the communication for any kind of data flows except sample values. IEC TR 61850-90-2 defines the communication to the control centre with IEC 61850-8-2 defining web-services mappings. For the field/station to operations communication the IEC 61850 communication protocols are used.

IEC 60870-5-101 and IEC 60870-5-104 can also be used for vertical communication as shown in Figure 32.

For the enterprise communication at the operation, enterprise and market zone the coming standard IEC 61968-100 will be used.

The IEC 61158 series defines industrial field bus communication and IEC 61968-100 communication at the operations and enterprise levels.

Refer to 5.10.4 for details on cyber-security standards and more specifically on where and how to apply the IEC 62351 series and/or other cyber-security mechanisms.



NOTE The letters in the blue disks refer to the network types defined in 5.10.1.2.

Figure 32 – DER management system- Communication layer

5.9.8.8.4 Information (Data) layer

The information layer of DER operation, as presented in Figure 33, is mostly based on the IEC 61850 information model.

IEC 61850-7-4 is the core part depicting this model which is extended by various standards for DER operations:

- IEC 61850-7-410: Hydroelectric power plants
- IEC 61850-7-420: DER logical nodes
- IEC 61400-25-2/-3: Wind turbines
- IEC TR 61850-90-7: PV inverters
- IEC TR 61850-90-9: Batteries
- IEC TR 61850-90-10: Scheduling functions
- IEC TR 61850-90-15: Multiple Use DER

Specific standards for DER EMS/VPP operation at the enterprise bus are currently not defined.

Note that for market operations the OASIS EMIX and EnergyInterop and the IEC 62325 series specifications (available and coming) may apply. However the details for the whole DER domain are still under discussion and further investigation is needed.

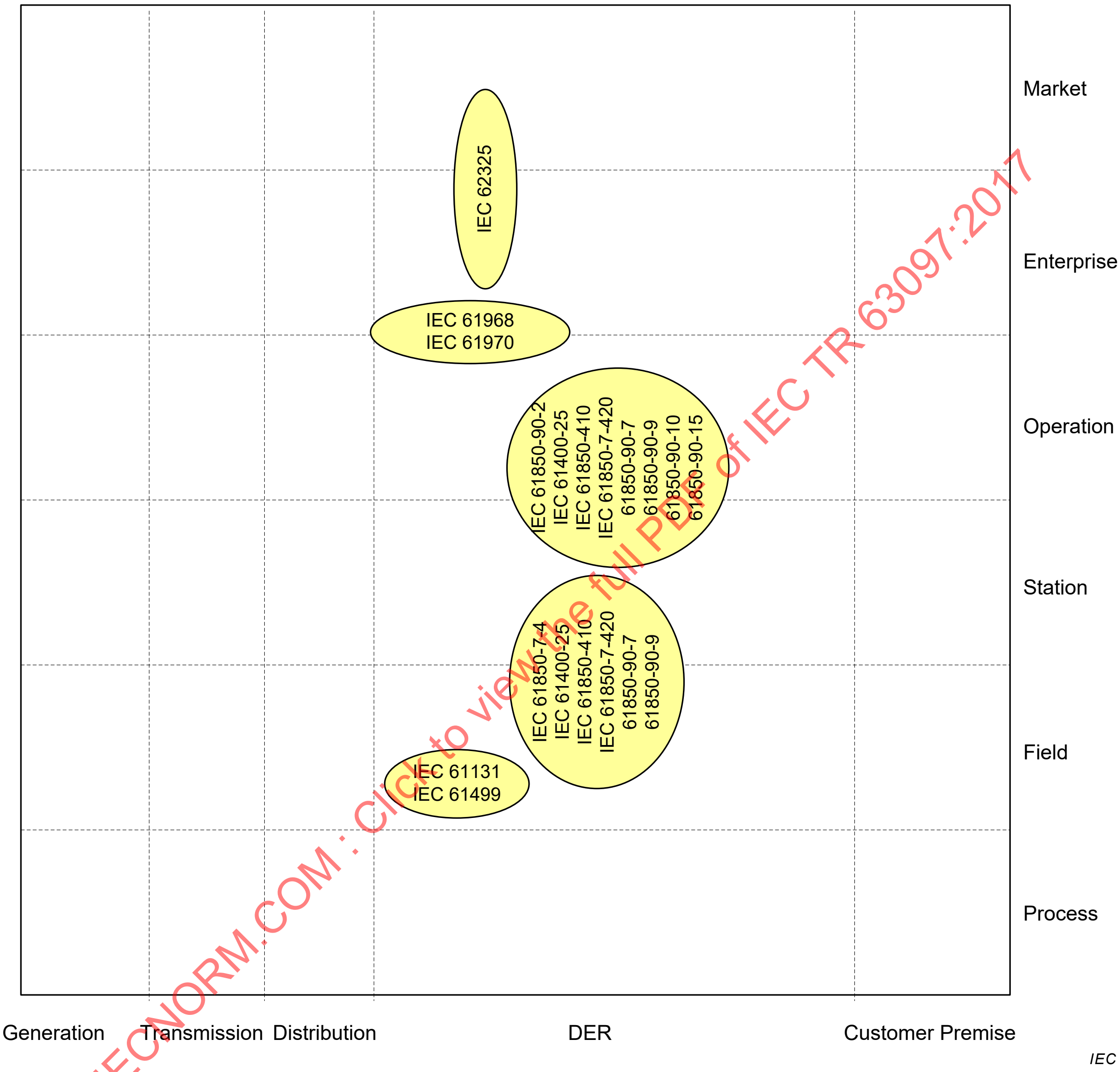


Figure 33 – DER management system – Information layer

5.9.9 Electrical energy storage management system

5.9.9.1 Description

The electric grid operates as an enormous just-in-time production and delivery system, with power generated at the same time it is consumed, and with little storage of electrical energy. This means that the transmission and distribution system have to be built to accommodate maximum power flow rather than average power flow, resulting in under-utilization of assets. Energy storage can enhance network reliability, enable a more efficient use of base load generation, and support a higher penetration of renewable energy resources.

Electric storage can be achieved on the large, medium and small scale and one can distinguish between real electric storage (storage that can input electricity into the power system) and energy buffers (storage that acts as a part of demand response systems like flywheels, hydrogen and heating reservoirs, etc.).

Energy storage already exists in many electrical power systems. Pumped hydro power plants represent most of this storage today. Pumped hydro allows the storage of enormous quantities of energy, although it requires a huge initial investment. Pumped water hydro power plants are subject to natural limitation. Their capacity cannot be extended beyond certain ranges depending on local conditions. Compressed air energy storage is a less widely implemented technology that uses off-peak renewable electricity to compress and store air, which can later be used to regenerate electricity.

Short-duration storage technologies such as ultra-capacitors and flywheels have uses in other applications, such as those in which power and energy requirements are not large but when the storage is expected to see a great deal of cycling. Such technologies can be used to address power-quality disturbances and frequency regulation, applications in which only a few kilowatts to megawatts are required for a few seconds or minutes.

Another means of storage is batteries. Lead-acid batteries are used for backup power in power plants. In larger scale applications sodium sulfur and vanadium redox flow batteries are more effective. Large-scale battery energy storage can be applied to peak shaving. The vanadium redox flow batteries also can be applied to improve the power quality.

Lithium-ion batteries are used for higher power requirements, cycling performance and for portable battery applications which, for example, enable plug-in hybrid electric vehicles (PHEV). This distributed energy storage could reduce the fluctuation in electrical load and generation by acting as a manageable load and discharging energy back to the grid when necessary.

Electrical storages can be connected directly into the distribution grid or can be integrated into a Building Automation System HBES/BACS. In the case of HBES/BACS the DERMS has an indirect influence on these storages by using the HBES/BACS network/communication.

Electrical storage should fulfil a number of functions in the grid including:

- serving as a spinning reserve;
- serving as a manageable load;
- power system stabilization;
- load levelling;
- load shedding;
- reactive power support.

Energy storage is a major element of Smart Grid.

5.9.9.2 Set of system capabilities

Table 41 provides a set of System Capabilities which may be supported by a substation automation system.

The meanings of the three last columns (AVAILABLE, COMING, Not yet) and of the “C”, “I”, “CI”, “X” conventions are given in 5.5.2.5.

Table 41 – Electrical energy storage management system – Capabilities

Cluster	System Capabilities	Supported by standards		
		AVAILABLE	COMING	Not yet
To be defined	To be defined			

5.9.9.3 Requirements

5.9.9.3.1 Product requirements

One major requirement for the different storage options is safety and material requirements (e.g. nanotechnology).

Safe operation and handling is a key requirement for batteries, compressed air and hydro power plants. For batteries, robustness and cyclic consistency is important. Safe operation with applied safety systems will ensure a robust and safe operation of the total energy storage system. Benchmarking parameters for batteries include self-discharge, start up time, lifetime, cycle profile, efficiency, power, energy content and required discharge time.

In order to function in a Smart Grid environment (including HBES/BACS), information about capacity of the storage unit and forecasts of pricing information will be essential. Optimal scheduling of the storage units will be a requirement.

5.9.9.3.2 Communication requirements

As for the other applications, communication is key for Energy Storage to function within the Smart Grid (including HBES/BACS). Therefore for the different forms of Energy Storage, protocols, data models and semantic information models have to be available to make full use of the potential benefit of Energy Storage.

Communication has to be available for the whole chain, power grid, power electronics, battery management (BMS), battery modules and cells.

The parameters that need to be communicated include:

- cell type;
- rating;
- start-up date;
- accumulated kWh;
- charging condition;
- temperature (cells and surroundings);
- load history;
- availability;
- manufacturer;
- etc. (list not complete).

Security of indoor/outdoor installations as well as handling specifications are requirements.

5.9.9.4 Standards context

5.9.9.4.1 Available standards

See Table 42. Refer to 5.2.5.3 for the definition of the criteria considered in this document for stating that a standard is “available”.

Table 42 – Electrical energy storage management system – Available standards

Layer	Standard	Title and comments
Information, Communication	IEC 61850-7-410	*Communication networks and systems for power utility automation – Part 7-410: Basic communication structure – Hydroelectric power plants – Communication for monitoring and control* (including pumped hydro)
Information Communication	IEC PAS 62746-10-1	*Systems interface between customer energy management system and the power management system – Part 10-1: Open Automated Demand Response (OpenADR 2.0b Profile Specification)*
Communication, Information	IEC TR 62746-2	*Systems interface between customer energy management system and the power management system – Part 2: Use cases and requirements*
Communication, Information	IEC TS 62746-3	*Systems interface between customer energy management system and the power management system – Part 3: Architecture*
Information, Communication	IEC TR 62939-1	*Smart Grid user interface – Part 1: Interface overview and country perspectives*
Information, Communication	(refer to 5.9.13.5)	refer to the DR management systems depicted in 5.9.13
Information, Communication	(refer to 5.9.8.6)	refer to the DER system depicted in 5.9.8
Information, Communication	(refer to 5.9.10.5)	refer to the AMI system depicted in 5.9.9
Information, Communication	IEC 61158 series	*Industrial communication networks – Fieldbus specifications*
Information, Communication	IEC 62541 series	*OPC unified architecture*
Information, Communication	IEC TR 62837	*Energy efficiency through automation systems*
Communication	IEC 62439 series	*Industrial communication networks – High availability automation networks*
Information, Communication	IEC 62443 series	*Industrial communication networks – Network and system security*
Information, Communication	IEC 61970	*Energy management system application program interface (EMS-API)* Common Information Model (CIM) / Energy Management
Information, Communication	IEC 61968	*Application integration at electric utilities – System interfaces for distribution management* Common Information Model (CIM) / Distribution Management
Information, Communication	IEC 62351 series	*Power systems management and associated information exchange – Data and communications security* Cyber-security aspects (see 5.10.4)
Information, Communication	IEC 62325 series	*Framework for energy market communications*
Process	IEC 60364 series	*Low-voltage electrical installations*

NOTE Standards related to clock management, safety, or EMC are mentioned in further dedicated subclauses.

5.9.9.4.2 Coming standards

See Table 43. Refer to 5.2.5.3 for the definition of the criteria considered in this document for stating that a standard is “coming”.

Table 43 – Electrical energy storage management system – Coming standards

Layer	Standard	Title and comments
Information	IEC TR 61850-90-9 [a]	Battery Storage systems
Information	IEC 61850-8-2 [a]	*Communication networks and systems for power utility automation – Part 8-2: Specific communication service mapping (SCSM) – Mapping to Extensible Messaging Presence Protocol (XMPP)* Mapping of IEC 61850 over web protocols
Information Communication	IEC 62746	System interfaces and communication protocol profiles relevant for systems connected to the Smart Grid
Information, Communication	IEC TR 62939-1	*Smart Grid user interface – Part 1: Interface overview and country perspectives*
Information, Communication	(refer to 5.9.13.5)	refer to the DR management systems depicted in 5.9.13
Information, Communication	(refer to 5.9.8.6)	refer to the DER system depicted in 5.9.8
Information, Communication	(refer to 5.9.10.5)	refer to the AMI system depicted in 5.9.9

[a] Under preparation.

5.9.9.5 Gaps

There is no standard for other bulk energy storage devices other than for hydro (IEC 61850-7-410).

Profiles have to be developed to decide on the amount and kind of data that need to be exchanged. These data have to be acquired in a standardized way. Testing and verification procedures for immobile and mobile batteries and battery stacks are needed. Batteries may require some sort of classification regarding their (charging) history, in order to make battery status easily accessible.

5.9.10 Advanced metering infrastructure

5.9.10.1 Description

Advanced metering infrastructure (AMI) integrates Smart Grid infrastructure with smart metering. AMI refers to systems that measure, collect, analyse and control energy distribution and usage, with the help of advanced energy distribution automation devices such as distribution network monitoring and controlling devices, network switching devices, load/source-shedding devices, electricity meters, gas meters and/or water meters, through various communication media on request or on a pre-defined schedule. This infrastructure includes hardware, software, communications, energy distribution-associated systems, customer-associated systems and meter data management (MDM) software.

The bidirectional communication network between the Smart Grid and metering devices and business systems allows collection and distribution of information to customers, suppliers, distribution network companies, utility companies and service providers. This enables these businesses to either participate in, or provide, demand response solutions, products and services.

Smart meters are the visible face of a new ICT infrastructure promoted by governments in many regions and countries of the world to improve energy efficiency. Smart metering systems allow electricity consumers to play an active role in the functioning of the electricity markets, and allow distribution networks to play an active role in the functioning of electricity systems, becoming “Smart Grids”.

Smart metering systems represent the gateway for customer access to the new grid and, together with new, value-added energy services they may have a critical and positive effect on energy and power demand, demand response / load management and integration of distributed energy generation. There are many potential benefits attributed to smart metering systems for various stakeholders:

- for energy end-users: better billing, decreasing energy use and energy costs through better information and increasing energy awareness, facilitation of supplier switch;
- for metering companies or Distribution System Operators (DSOs): decreasing meter operation costs through remote data exchange;
- for grid operators: preparing their grid for the future through better information and control;
- for energy suppliers: introducing new, customer oriented services and reducing customer care and call centre costs;
- for governments: reaching energy saving and efficiency targets and improving the operation of the free market.

Society as a whole may benefit through lower and more efficient energy usage and the integration of distributed/renewable energy sources.

Smart metering is a revolutionary development that will radically change the way electricity markets work and generation and distribution are managed. The concept of Automatic Meter Reading (AMR) is rapidly evolving towards Smart multi-energy metering / multi-functional Advanced (Multi-)Metering Infrastructure (AMI). Smart metering systems will cover at least the following key applications:

- remote data retrieval for billing and other metrological or fiscally relevant purposes concerning energy usage and, where available, energy generation;
- collection of additional data regarding the operation of the meter and the network, including power quality, outage information, technical and non-technical losses;
- sending configuration data to energy end-users, including contractual parameters, tariff schedules, pricing and operational information, time synchronization, firmware updating, etc.;
- supporting advanced tariff and payment options;
- remote enabling/disabling of supply, including flexible load limitation where and when system conditions require;
- communication towards in-home systems, including appliances and local generation units, for the purposes of load management, cost control, etc.;
- interface to home automation systems.

Some of these applications – including bi-directional energy metering, time-of-use metering, tariff- and load control, remote reading, and prepayment – have been provided by metering systems for a long time. They have gradually grown more sophisticated and the development of electronics, information and communication technologies allows all these advanced functions to be integrated in a single, cost-effective, multi-function device. However, in some scenarios a multi-part approach may prove to be useful.

The availability of all these advanced functions will allow energy suppliers and energy service and meter service companies to provide new services that create value for energy end-users and to increase operational efficiency and other benefits for all stakeholders.

In order to realize the full potential benefits of smart metering / AMI, nearly 100 % of industrial, commercial and domestic energy users should be equipped with smart meters. Nationwide large-scale roll-outs, such as the deployment of over 30 million smart electricity meters in Italy, have demonstrated the feasibility and the benefits that can be obtained.

5.9.10.2 Smart metering processes and use cases

Table 44 (according to IEC 62056-1-0) gives an overview of the use cases supported by the smart metering standards. The use cases are clustered into business process. This clustering solely serves for illustration purposes; it may vary from utility to utility.

Table 44 – Supported business processes and use cases

Business process	Use case[a]
Contracting and billing	Obtain meter readings on demand
	Obtain scheduled meter reading
	Set and maintain contractual[b] parameters in the meter
	Execute supply control
	Execute load control
Customer support	Provide information to the energy consumer
Infrastructure maintenance	Meter commissioning and registration
	Meter supervision
	Maintenance of the security system
	Manage events and alarms
	Firmware update
	Clock synchronization
	Disconnection and re-connection of the consumer's premises
	Quality of supply supervision

[a] There are no commonly agreed names for the smart metering use cases within the standardization community. In order to consider the universal scope of the IEC standards, generic and self-explanatory names are used here.

[b] Considering credit mode or debit mode (pre-payment) operation of the meter.

The detailed requirements of the different use cases depend on the market and on the legal environment the smart metering system is operating in. The supporting standards are designed to offer enough flexibility to consider the different market needs and different legal environments.

In order to facilitate achieving interoperability, security and efficiency, the standards have to consider all aspects of data exchange in a smart metering system, including the functions to be supported, the data models (semantics), the data presentation (syntax), and the communication protocols for transporting the data over the interfaces using various communication technologies.

5.9.10.3 Privacy and data security

5.9.10.3.1 General

In order to be accepted by the consumer, a smart metering system has to provide suitable protection of the privacy of the consumption data. In addition, data which are relevant for billing need to be protected against tampering from the source to the destination. Attention needs to be given to address the vulnerability of the AMI infrastructure against cyber-attacks. In particular, sensitive applications such as pre-payment and tariff setting, disconnection and reconnection of the supplies, etc. need to be protected against misuse.

5.9.10.3.2 Legislative framework and standards

The requirements concerning the protection of the privacy of the consumer data are up to national regulation. The smart metering standards need to provide the tools to ensure privacy according to the national regulation in a scalable, interoperable way.

5.9.10.3.3 General security policy and concepts

5.9.10.3.3.1 Principles

The following principles need to be considered in the secure design of a smart metering system:

- efficient end-to-end security considers the entire smart metering architecture comprising systems and processes;
- security of the smart metering infrastructure is linked to security of Smart Grid and home automation networks;
- the security standards need to support scalable implementations considering legislation, the type of applications and the processing resources of the components;
- the lifetime of the system components has to be considered in the design of the security measures;
- cryptographic algorithms provide a wide range of scalable security for systems, sub-systems and components;
- besides technical measures, organizational measures are also necessary to provide the required overall security.

Many security considerations are already covered in existing standards.

Establishing and executing security policies are outside the scope of the standards. However, the standards have to provide the tools to support different security policies.

5.9.10.3.3.2 Security concept

A security concept refers mainly to an architecture model, which represents data flows between role-based data processing functions. Requirements for the security concept result from the overall security objectives in combination with the derived security services and best practice. As additional constraints, legal requirements (e.g. metrology and data privacy) influence the application of security services to dedicated system elements and their interfaces.

The smart metering business processes and use cases (5.9.10.2) have to be protected by the appropriate security concepts. In addition the processes to establish and to maintain security (installation, security activation, key management) have to also be protected.

There are four major security services to support the security objectives. They have to be integrated into the smart metering system covering all networks and access points involved.

Security service	Security objective
Integrity	To prevent modification of information by unauthorized parties.
Authentication	To determine the identity of a communication party or the origin of the data.
Confidentiality	To prevent the disclosure of information to unauthorized parties
Non-repudiation	To ensure that a party cannot repudiate/refute the validity of data.

These security services can be realized with different, scalable cryptographic methods and/or techniques as described in the corresponding standards. The actual choice of the method/technique depends on the security requirements.

5.9.10.3.3.3 Security policy

The security policy addresses all security constraints on the system components, their functions and on the information flow between the system components. Further, all security constraints to access the system from external systems and users are considered.

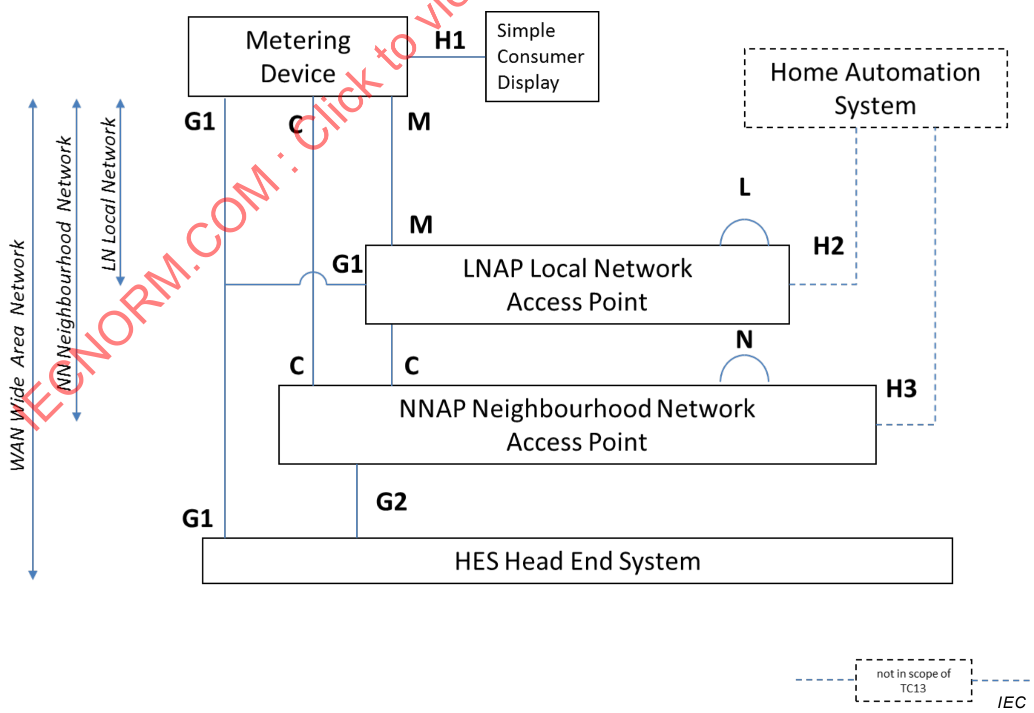
The organization owning the business processes is responsible for the definition and the execution of the appropriate security policy. The smart metering standards have to define a comprehensive set of methods/techniques to implement and to maintain the appropriate security policy. The combination of the policy and the methods determines the level of the achieved overall security.

5.9.10.4 Smart metering reference architecture

Figure 34 shows the smart metering reference architecture (according to IEC 62056-1-0) enabling the data exchange necessary to support the use cases of Table 44. The different system components and their interfaces are identified. The partitioning between the different components is purely based on communication aspects, i.e. components and interfaces are specified wherever a transition from one communication medium to another may be considered.

A comprehensive set of smart metering standards have to support all interfaces identified in Figure 34. All specifications of communication protocols, data access methods or data structures describe only the “outside view”, i.e. how the data and the communication protocols behave on the interface. The behaviour within the components (“inside view”) is implementation specific and is therefore not covered by the standards.

A practical realization of a smart metering system will typically contain a subset of the components and interfaces shown in Figure 34. Components and interfaces which are not exposed and are therefore not accessible do not need to fulfil any standards.



NOTE This architecture has been developed under the smart metering standardization mandate M/441 of the European commission.

Figure 34 – The smart metering reference architecture

EXAMPLE 1 “PLC system”:

A PLC system typically uses the C interface between the Metering device and the NNAP (Data Concentrator). The communication between the NNAP and the HES is defined by the G2 interface.

EXAMPLE 2 “IP communication via GPRS”:

Typically uses the G1 interface between the meter and the HES.

EXAMPLE 3 “Hand Held Unit for local meter access”:

This typically uses interface M.

5.9.10.5 List of standards

5.9.10.5.1 Available standards

Refer to 5.2.5.3 for the definition of the criteria considered in this document for stating that a standard is “available”.

Table 45 lists the available standards supporting the set (or a subset) of the use cases listed in Table 44. In addition, the interfaces (as defined in the reference architecture of Figure 34) covered by the standards are listed. Further, the table shows which “layer” of the SGAM (information, communication, component) is covered by the standard.

Table 45 – AMI system – available standards for smart metering

Available standards	Layer	M	H1	H2/H3	C	G1	G2	L	N
IEC									
IEC 62056-1-0	information communication component	X	X	X	X	X	X	X	X
IEC 61334-4-32	communication				X				
IEC 61334-4-511	communication				X				
IEC 61334-4-41	communication	X	X		X	X	X	X	X
IEC 61334-4-512	communication				X				
IEC 61334-5-1	communication				X				
IEC 61334-61	communication	X	X		X	X	X	X	X
IEC 62056-3-1	communication	X			X				
IEC 62056-4-2	communication	X	X		X				
IEC 62056-4-6	communication	X	X		X				
IEC 62056-4-7	communication				X	X	X		
IEC 62056-5-3	communication	X	X		X	X	X		
IEC 62056-6-1	information	X			X	X	X		
IEC 62056-6-2	information	X			X	X	X		
IEC 62056-7-6	communication	X	X		X				
IEC 62056-8-3	communication				X				
IEC 62056-9-7	communication					X			
IEC TS 61850-80-4	information	X			X	X	X		
ISO/IEC 14908 series	information communication	X	X	X	X			X	X

Available standards	Layer	M	H1	H2/H3	C	G1	G2	L	N
ITU-T									
ITU-T G.9901	communication				X				
ITU-T G.9902	communication				X				
ITU-T G.9903	communication				X				
ITU-T G.9904	communication				X				
CENELEC/CEN									
EN 50065-1	communication	X	X	X	X	X		X	X
EN 50090-3-1	information		X	X					
EN 50090-3-2	information		X	X					
EN 50090-3-3	information		X	X					
EN 50090-4-1	communication		X	X					
EN 50090-4-2	communication		X	X					
EN 50090-4-3	communication		X	X					
EN 50090-5-1	communication		X	X					
EN 50090-5-2	communication		X	X					
EN 50090-5-3	communication		X	X					
EN 50090-7-1	communication		X	X					
EN 13321 series	communication information		X	X					
EN 13757-1	communication	X	X	X	X				
EN 13757-2	communication	X	X	X	X				
EN 13757-3	communication information	X	X	X	X				
EN 13757-4	communication	X	X	X	X				
EN 13757-5	communication	X	X	X	X				
CLC TS 50568-4	communication		X	X	X				
CLC TS 50568-8	communication		X	X	X				
CLC TS 52056-8-4	communication				X				
CLC TS 52056-8-5	communication				X				
CLC TS 52056-8-7	communication								
IEEE									
IEEE 1377	information communication	X			X	X	X	X	X

5.9.10.5.2 Coming standards

Refer to 5.2.5.3 for the definition of the criteria considered in this document for stating that a standard is “coming”.

Table 46 lists the “coming”. standards supporting the set (or a subset) of the use cases listed in 5.9.10.2. In addition, the interfaces (as defined in the reference architecture of 5.9.10.3) covered by the standards are listed. Further, the table shows which “layer” of the SGAM (information, communication, component) is covered by the “coming” standard.

Table 46 – AMI system – Coming standards for smart metering

Coming standards	Layer	M	H1	H2/H3	C	G1	G2	L	N
IEC									
IEC 62056-3-1	communication	X			X				
IEC 62056-5-3	communication	X	X		X	X	X		
IEC 62056-5-8	communication					X	X		
IEC TS 62056-6-9	information	X			X	X	X		
IEC 62056-6-1	information	X			X	X	X		
IEC 62056-6-2	information	X			X	X	X		
CENELEC/CEN									
prTR 50491-10	information communication		X	X					
prEN 50491-11	information communication		X	X					
prEN 50491-12	information communication		X	X					
prTS 50567-1	communication				X				
prTS 50567-2	communication				X				
prTS 50568-2	communication								
prTS 50568-5	communication		X	X	X		X		
prTS 50568-6	communication		X	X	X		X		
prTS 50568-9	communication						X		
prTS 50586	communication	X		X	X				

5.9.10.6 Mapping to the SGAM architecture

5.9.10.6.1 Preamble

The smart metering reference architecture specified in Figure 34 is mapped into the SGAM architecture. Note that in the architecture in Figure 34 the Head End System is at the bottom of the diagram, in contrast to the order of the component layers in the SGAM architecture diagrams.

Both in the diagrams of 5.9.10.6 and in similar ones in 5.9.13 to 5.9.15, the split of the “customer premises” domain on the right is intended to illustrate a typical market model where assets in the home/building are not owned/operated by the electricity service supplier. However, market models vary, for example regarding meter ownership and operation, and are subject to national structures and regulation, so this representation should not be seen as universal.

5.9.10.6.2 Component layer

The exact composition of the AMI will depend on the configuration chosen. Figure 35 shows the components that may be part of the AMI. Meters for different media (Electricity, Gas, Heat and Water) represent the end devices on process and field level. We distinguish between meters at (residential) customer premises (which are subject to national metrological approvals) and meters used in industrial, commercial environments or for grid automation purposes. The meter may have an interface to a simple display unit or, it may be interfaced to a proper home automation system.

Meters and home/building automation end devices may be interconnected via LNAPs (Local Network Access Point).

The NNAP (Neighbourhood Network Access Point) is typically located at distribution station level. The NNAP may be part of a simple communication gateway or of a data concentrator offering comprehensive data processing features.

The meters are connected (directly or via LNAP and/or NNAP) to the HES (Head End System). The HES manages the data exchange with the meters and supervises the WAN/LAN communication.

The MDM (Meter Data Management) system interfaces to the ERP systems and to the market systems. In particular, the MDM accepts metering tasks (e.g. data acquisition, command distribution, etc.) from the “superior” systems and returns the validated results. The communication with the AMI endpoints is done via the HES.

The components of the AMI are depicted diagrammatically in Figure 35 below.

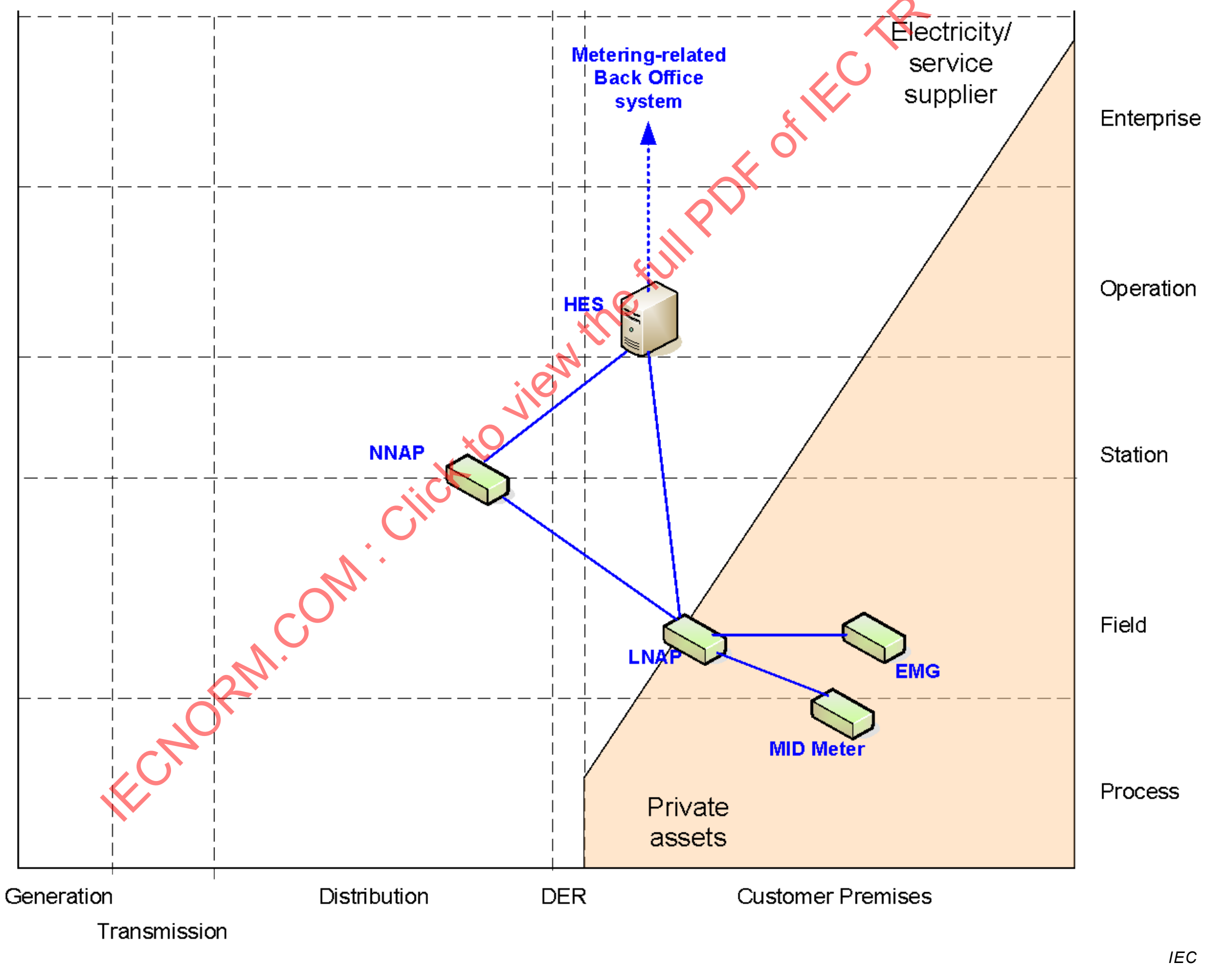
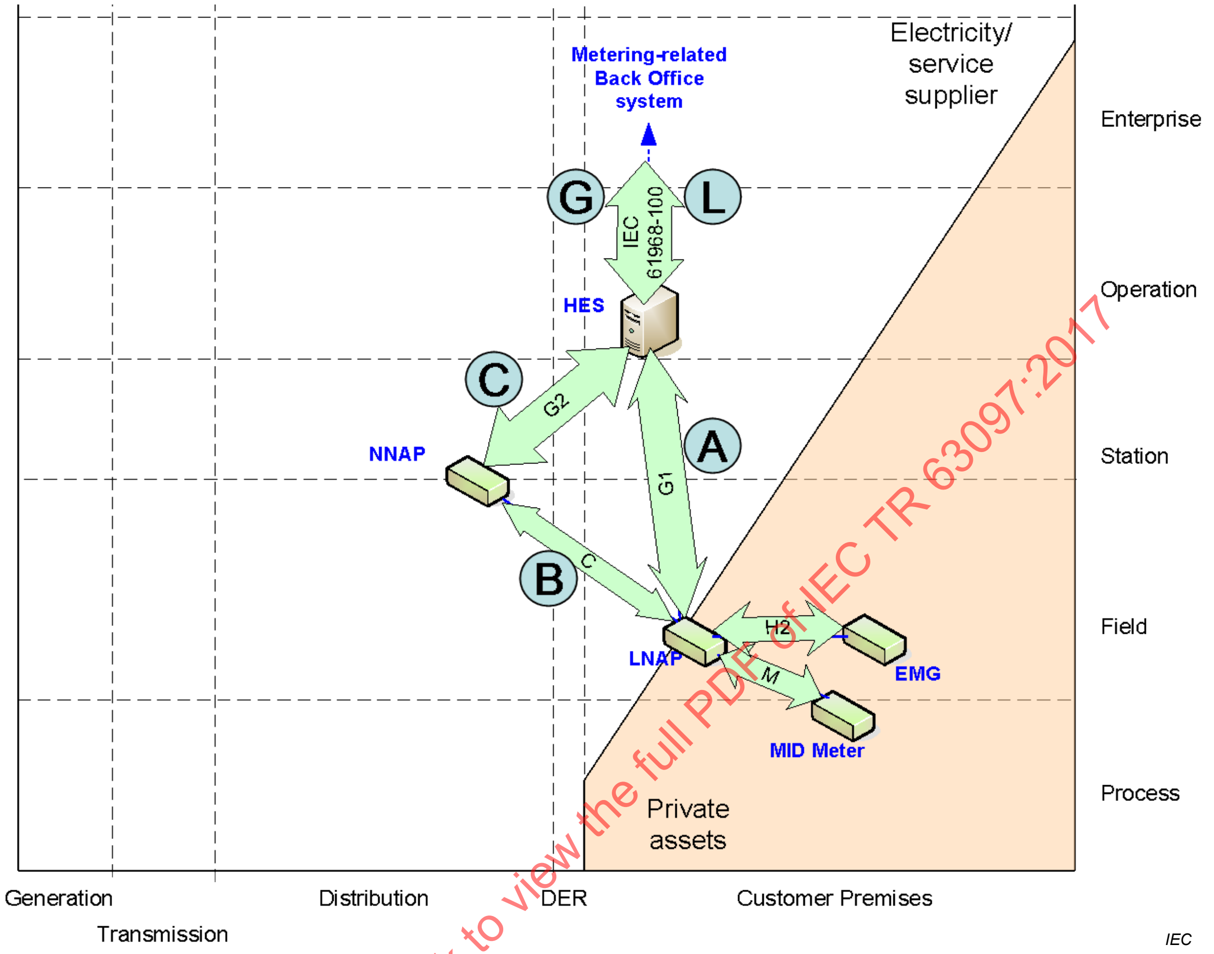


Figure 35 – Smart metering architecture (example) mapped to the SGAM component layer

5.9.10.6.3 Communications layer

The smart metering architecture in Figure 34 identifies the principal interfaces as M, C, G and H.

Figure 36 shows a mapping of this smart metering architecture into the SGAM communication layer.



NOTE The letters in the blue disks refer to the interfaces defined Figure 34 and are defined in 5.10.1.2. The standards supporting these interfaces are listed in Table 45 and Table 46 of 5.9.10.5.

Figure 36 – Smart metering architecture (example) mapped to the SGAM communication layer

5.9.10.6.4 Information (Data) layer

Figure 37 shows a mapping of the smart metering architecture into the SGAM information layer.

The COSEM information model for smart metering covering the customer premises on process and on field level is defined by the data models of IEC 62056-6-1 and IEC 62056-6-2. The application layer (DLMS) of IEC 62056-5-3 provides all the necessary services and security concepts to securely support the use cases defined in Table 44.

The information exchange between the Enterprise system and the Head End System (HES) is based on the IEC 61968 series (CIM model). The mapping between the COSEM model (IEC 62056-6-2) and the CIM model is described in the "coming" specification IEC TS 62056-6-9.

Smart metering data for distribution automation use cases on field level uses the IEC 61850 standards. The mapping between the COSEM model (IEC 62056-6-2) and the IEC 61850 model is described in the "coming" specification IEC TS 61850-80-4.

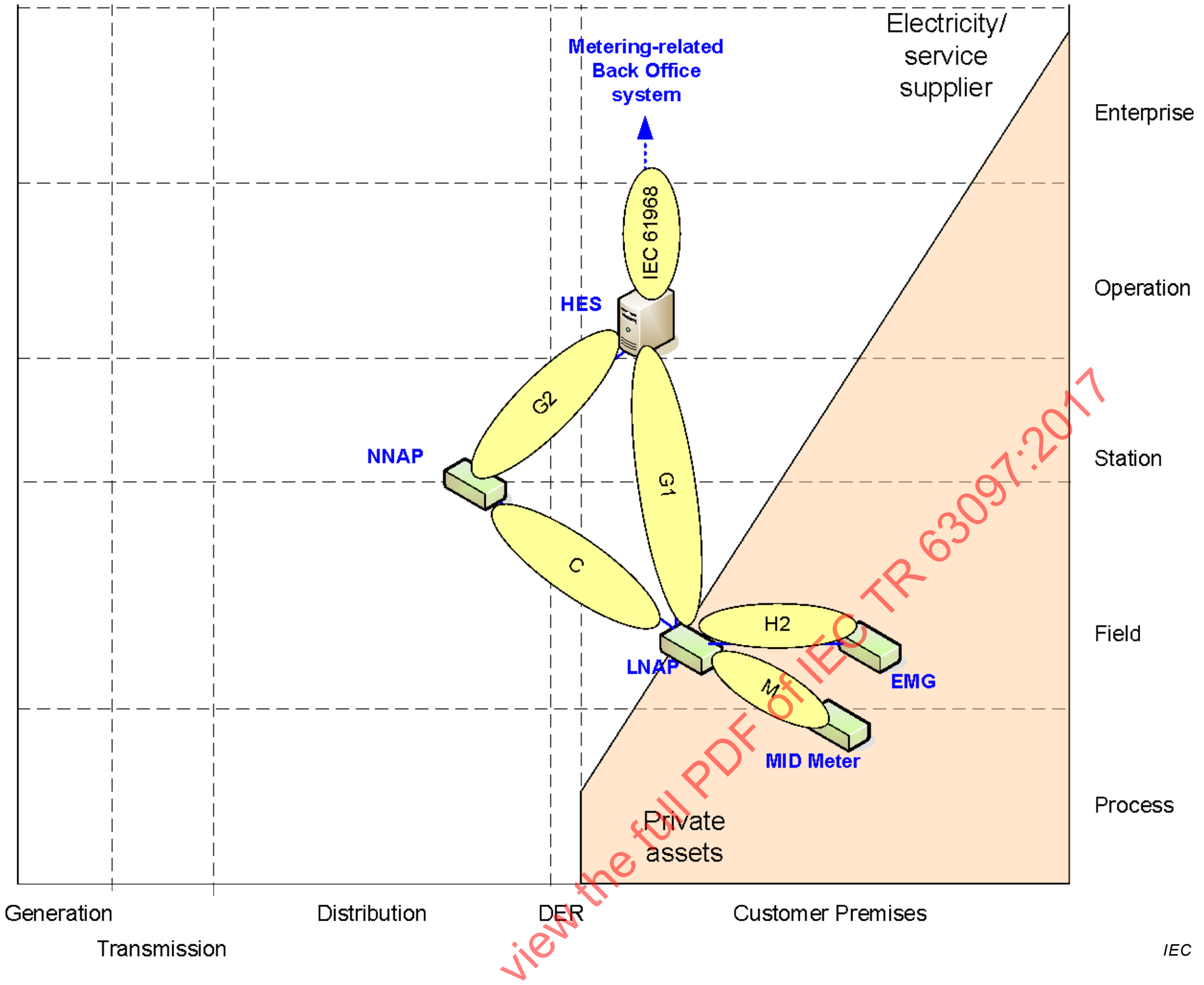


Figure 37 – Smart metering architecture (example) mapped to the SGAM information layer

5.9.11 Metering-related back office system

5.9.11.1 Description

Metered data feed many operation or enterprise level applications. In order to simplify the presentation, all these applications have been packed under a single "system" banner called "metering-related back office system".

Figure 38 shows the typical application hosted by such systems.

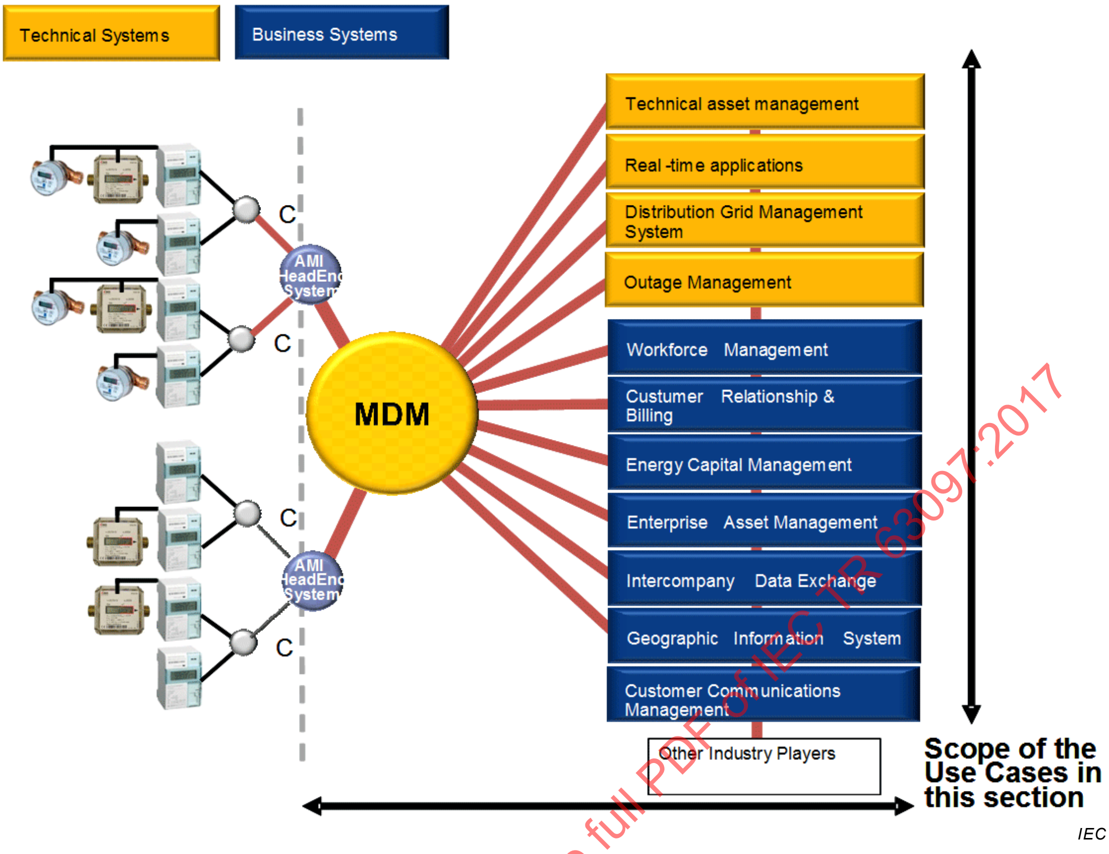


Figure 38 – Typical applications hosted by a metering-related back office system

5.9.11.2 System summary

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.

5.9.11.3 Set of System Capabilities

Table 47 provides a set of generic use cases which may be supported by a metering-related back office system.

The meanings of the three last columns (AVAILABLE, COMING, Not yet) and of the “C”, “I”, “CI”, “X” conventions are given in 5.5.2.5.

Work is in progress to integrate these System Capabilities with those identified for the AMI in 5.9.9.

Table 47 – Metering-related back office system – Capabilities

Cluster	System Capabilities	Supported by standards		
		AVAILABLE	COMING	Not yet
Monitor AMI event	Install, configure and maintain the metering system	CI		
	Manage power quality data	CI		
	Manage outage data	CI		
	Manage the network using metering system data	CI		
	Manage interference to metering system	CI		
	Enable and disable the metering system	CI		
	Display messages	CI		
	Facilitate DER for network operation	CI		
	Facilitate demand response actions	CI		
	Interact with devices at the premises	CI		
	Manage efficiency measures at the premise using metering system data	CI		
	Demand side management	CI		
Billing	Obtain meter reading data	CI		
	Support prepayment functionality	CI		
	Manage tariff settings on the metering system	CI		
	Consumer move-in/move-out	CI		
	Supplier change	CI		

5.9.11.4 List of standards

5.9.11.4.1 General

Here is the summary of the standards which are relevant to support metering-related back office systems.

5.9.11.4.2 Available standards

See Table 48. Refer to 5.2.5.3 for the definition of the criteria considered in this document for stating that a standard is “available”.

Table 48 – Metering-related back office system – Available standards

Layer	Standard	Comments
Information, Communication	IEC 62056-1-0	*Electricity metering data exchange – The DLMS/COSEM suite – Part 1-0: Smart metering standardisation framework*
Information, Communication	IEC 62056-1-1	*Electricity metering data exchange – The DLMS/COSEM suite – Part 1-1: Template for DLMS/COSEM communication profile standards*
Communication	IEC 61968 series	*Application integration at electric utilities – System interfaces for distribution management*
Information	IEC 61968-9	*Application integration at electric utilities – System interfaces for distribution management – Part 9: Interfaces for meter reading and control*
General	IEC TR 62357-1	*Power systems management and associated information exchange – Part 1: Reference architecture*
Communication	IEC 62351 series	*Power systems management and associated information exchange – Data and communications security* Cyber-security aspects (see 5.10.4)
Communication	IEC 61968-100	*Application integration at electric utilities – System interfaces for distribution management – Part 100: Implementation profiles*

5.9.11.4.3 Coming standards

See Table 49. Refer to 5.2.5.3 for the definition of the criteria considered in this document for stating that a standard is “coming”.

Table 49 – Metering-related back office system – Coming standards

Layer	Standard	Title and comments
Information	IEC TS 62056-6-9	*Electricity metering data exchange – The DLMS/COSEM suite – Part 6-9: Mapping between the Common Information Model message profiles (IEC 61968-9) and DLMS/COSEM (IEC 62056) data models and protocols*
Communication	IEC 62351 series	*Power systems management and associated information exchange – Data and communications security* Cyber-security aspects (see 5.10.4)

5.9.11.5 Metering-related back office systems mapping

5.9.11.5.1 Preamble

Metering-related back office systems are widely different in nature, but have as their common element use of the AMI system.

5.9.11.5.2 Component layer

Metering-related back office systems may be understood as comprising such systems as the head-end system, meter data management system, asset and workforce management systems, distribution management systems (including SCADA), geographic information systems and outage management, inter-company data exchange, customer information and relationship management systems and consumer internet portals.

The components which may be envisaged in such systems are shown in Figure 39.

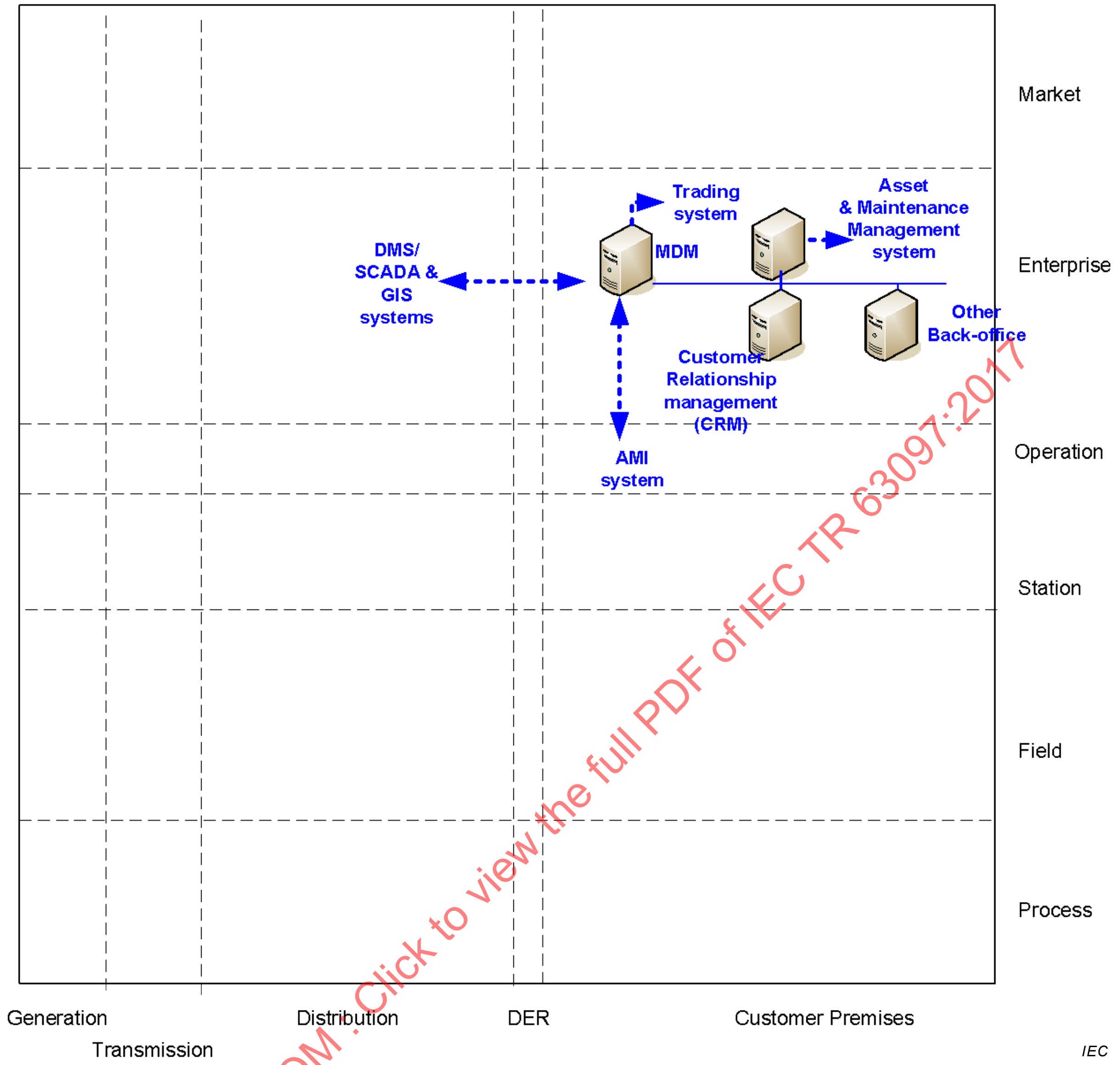
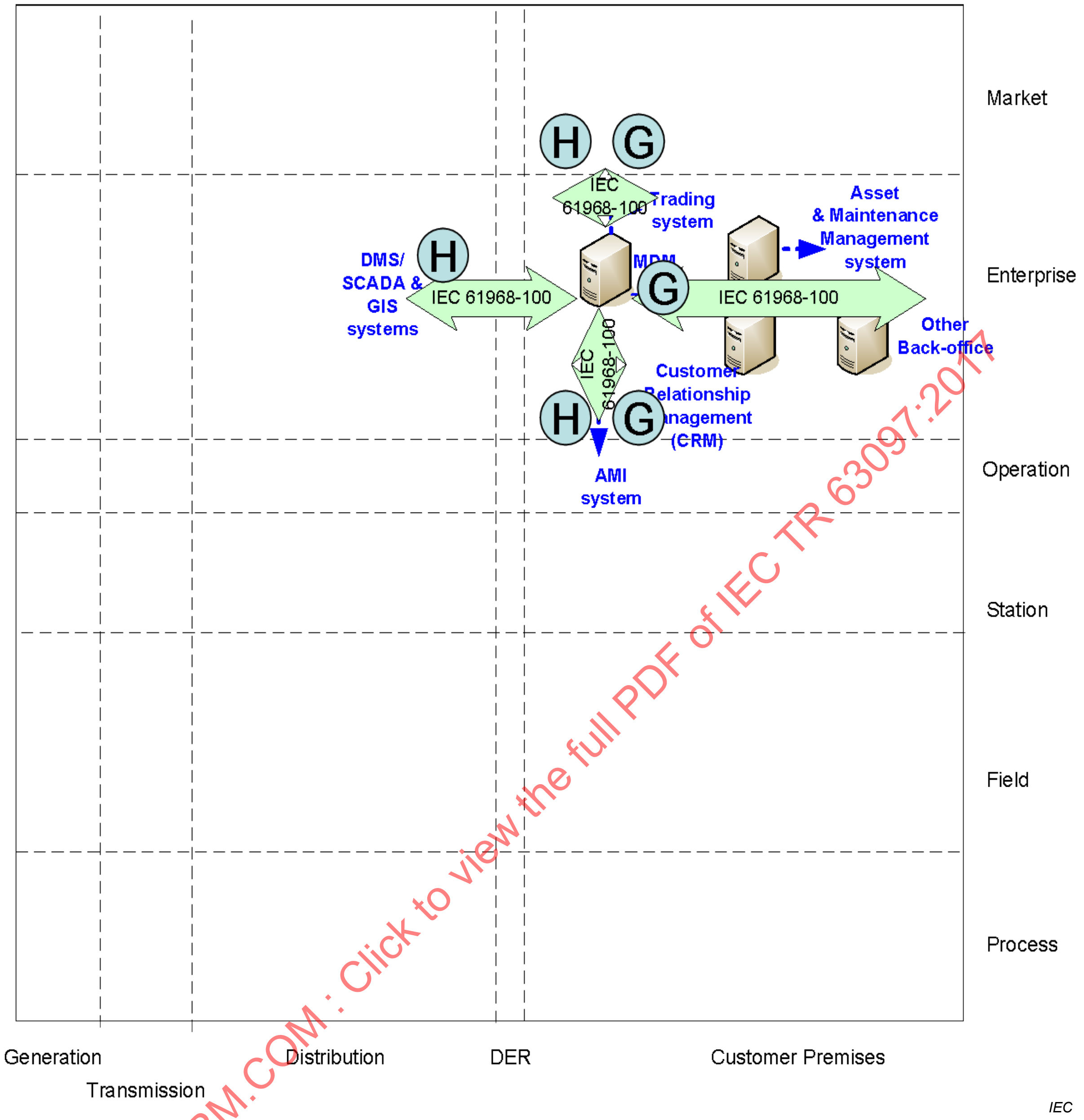


Figure 39 – Metering-related back office system – Component layer

5.9.11.5.3 Communications layer

See Figure 40. The main communication standard likely to be applicable to such back office systems is IEC 61968-100.

Refer to 5.10.4 for details on cyber-security standards and more specifically on where and how to apply the IEC 62351 series and/or other cyber-security mechanisms.



NOTE The letters in the blue disks refer to the network types defined in 5.10.1.2.

Figure 40 – Metering-related back office system – Communication layer

5.9.11.5.4 Information (Data) layer

The main information model standard is IEC 61968-9 (CIM for metering) as shown in Figure 41.

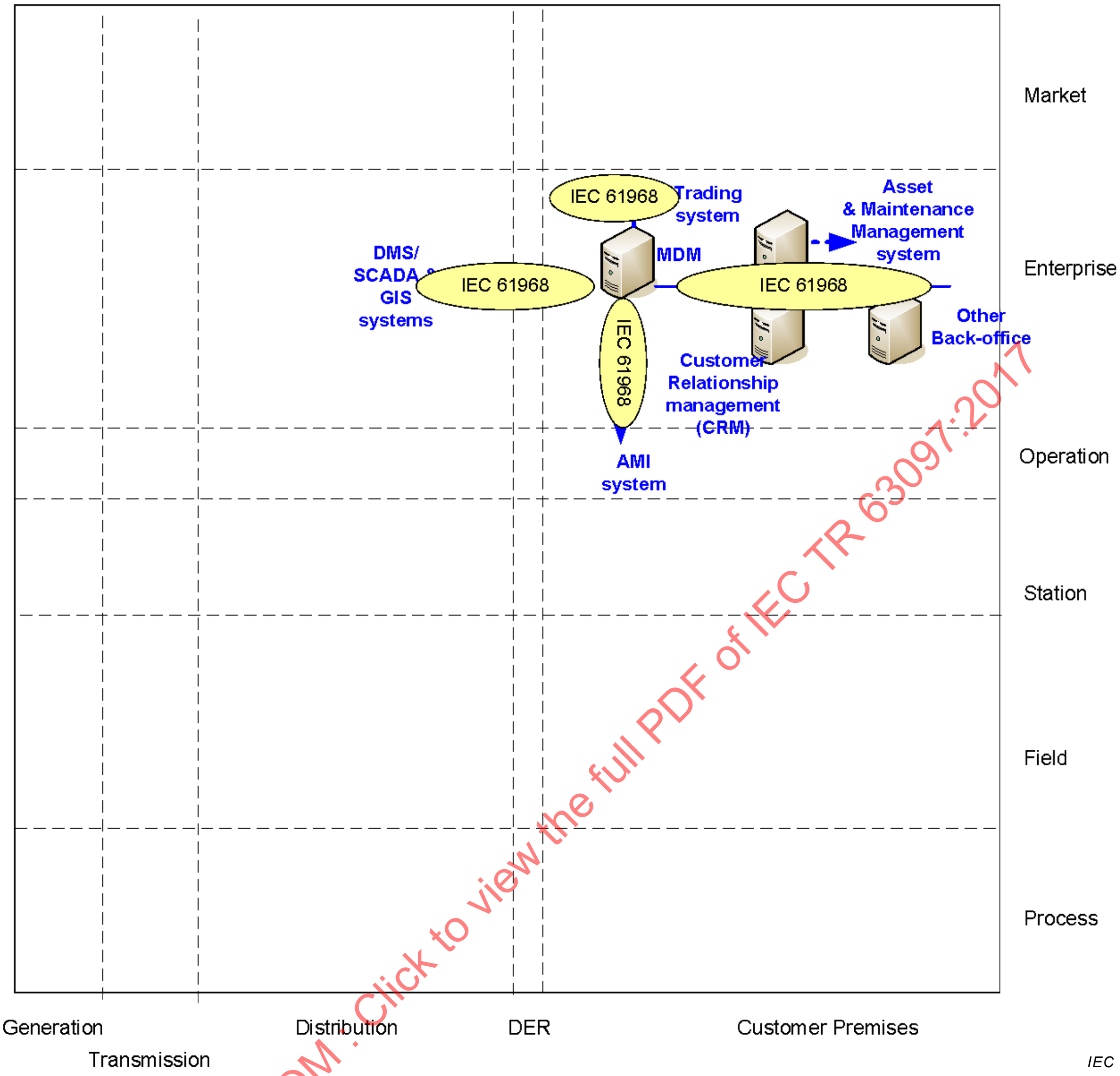


Figure 41 – Metering-related back office system – Information layer

5.9.12 Marketplace system

5.9.12.1 System summary

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. Several kinds of marketplaces can be differentiated depending on the product sold on the marketplace:

- wholesale electricity marketplace operated by power exchanges;
- marketplaces for products needed for grid reliability (transmission capacity, ancillary services, balancing energy) operated by Transmission System Operators;
- forward capacity markets to secure adequacy of supply;
- retail marketplaces, for instance to sell or purchase flexibility.

Furthermore markets can be differentiated based on geographical coverage starting from local markets (i.e. within a micro-grid area) to regional, countrywide and cross-country markets.

The marketplace systems are accessed by so-called market participants who can be electricity power producers, suppliers, industrial consumers, virtual power plants, aggregators, DER operators, etc.

5.9.12.2 Set of System Capabilities

Table 50 provides a set of System Capabilities relevant to market systems.

The meanings of the three last columns (AVAILABLE, COMING, Not yet) and of the “C”, “I”, “CI”, “X” conventions are given in 5.5.2.5.

Table 50 – Marketplace system – Capabilities

Cluster	System Capabilities	Supported by standards		
		AVAILABLE	COMING	Not yet
Operate wholesale electricity market	Receive energy offers and bids			X
	Clear day-ahead market			X
	Clear intraday market			X
	Clear real-time market			X
	Publish market results			X
Grid reliability using market-based mechanisms	Manage (auction/resale/curtailment) transmission capacity rights on interconnectors	CI		
	Consolidate and verify energy schedules	CI		
	Operate (register/bidding/clearing/publishing) Ancillary Services Markets	CI		
	Solve balancing issues through Balancing Market	CI		
	Solve grid congestion issues through Balancing Market	CI		
Market Settlements	Perform measurement and validation	CI		
	Perform settlements	CI		
Secure adequacy of supply	Operate Capacity Markets			X
Flexibility markets	Register Flexibility Markets			X

5.9.12.3 List of standards

5.9.12.3.1 General

The summary of the standards which appear relevant to support marketplace systems are listed hereafter.

5.9.12.3.2 Available standards

See Table 51. Refer to 5.2.5.3 for the definition of the criteria considered in this document for stating that a standard is “available”.

Table 51 – Marketplace system – Available standards

Layer	Standard	Title and comments
Information	IEC 61968 series IEC 61970 series	*Application integration at electric utilities – System interfaces for distribution management* *Energy management system application program interface (EMS-API)* Common Information model
Information	IEC 62325-301	*Framework for energy market communications – Part 301: Common information model (CIM) extensions for markets*
Information	IEC 62325-351	*Framework for energy market communications – Part 351: CIM European market model exchange profile*
Information	IEC 62325-450	*Framework for energy market communications – Part 450: Profile and context modelling rules*
Information	IEC 62325-451-1	*Framework for energy market communications – Part 451-1: Acknowledgement business process and contextual model for CIM European market*
Information	IEC 62325-451-2	*Framework for energy market communications – Part 451-2: Scheduling business process and contextual model for CIM European market*
Information	IEC 62325-451-3	*Framework for energy market communications – Part 451-3: Transmission capacity allocation business process (explicit or implicit auction) and contextual models for European market*
Information	IEC 62325-451-4	*Framework for energy market communications – Part 451-4: Settlement and reconciliation business process, contextual and assembly models for European market*
Information	IEC 62325-451-5	*Framework for energy market communications – Part 451-5: Problem statement and status request business processes, contextual and assembly models for European market*
Information	IEC 62325-503	*Framework for energy market communications – Part 503: Market data exchanges guidelines for the IEC 62325-351 profile*
Communication	IEC 62351 series	*Power systems management and associated information exchange – Data and communications security* Cyber-security aspects (see 5.10.4)
Information	ENTSO-E Harmonized Role Model	Joint ENTSO-E, ebIX®[9], EFET
Information	ENTSO-E Market Data Exchange Standard (MADES)	
Communication	ENTSO-E Scheduling System (ESS)	Latest revision V3R3
Communication	ENTSO-E Reserve Resource Planning (ERRP)	Latest revision V4R1
Communication	ENTSO-E Capacity Allocation and Nomination (ECAN)	Latest revision V5R0
Communication	ENTSO-E Settlement Process (ESP)	Latest revision V1R2
Communication	ENTSO-E acknowledgement process	Latest revision V5R1

9 ebIX® is a trademark of the European forum for energy Business Information eXchange. This information is given for the convenience of users of this document and does not constitute an endorsement by IEC.

5.9.12.3.3 Coming standards

See Table 52. Refer to 5.2.5.3 for the definition of the criteria considered in this document for stating that a standard is "coming".

Table 52 – Marketplace system – Coming standards

Layer	Standard	Title and comments
Information	IEC 62325 series	*Framework for energy market communications*
Information	IEC 62325-351	*Framework for energy market communications – Part 351: CIM European market model exchange profile*
Information	IEC 61970-301	*Energy management system application program interface (EMS-API) – Part 301: Common information model (CIM) base*
Communication	IEC 62351 series	*Power systems management and associated information exchange – Data and communications security* Cyber-security aspects (see 5.10.4)

5.9.12.4 Marketplace system mapping

5.9.12.4.1 Preamble

Most of the System Capabilities listed previously involve a central marketplace operator (whether the operator of a power exchange or TSO) and market participants. Hence those are mostly links between IT systems located at the market, enterprise and in some cases operation levels.

5.9.12.4.2 Component layer

As shown in Figure 42, the following components are involved:

- Trading systems at enterprise zone. Trading systems are used at various areas such as Generation and DER.
- Operation systems at operation zone. They interact with trading systems to translate commercial/contractual positions into physical orders to be transmitted to lower zones (Process, Fields).

Figure 42 summarizes the way components are linked.

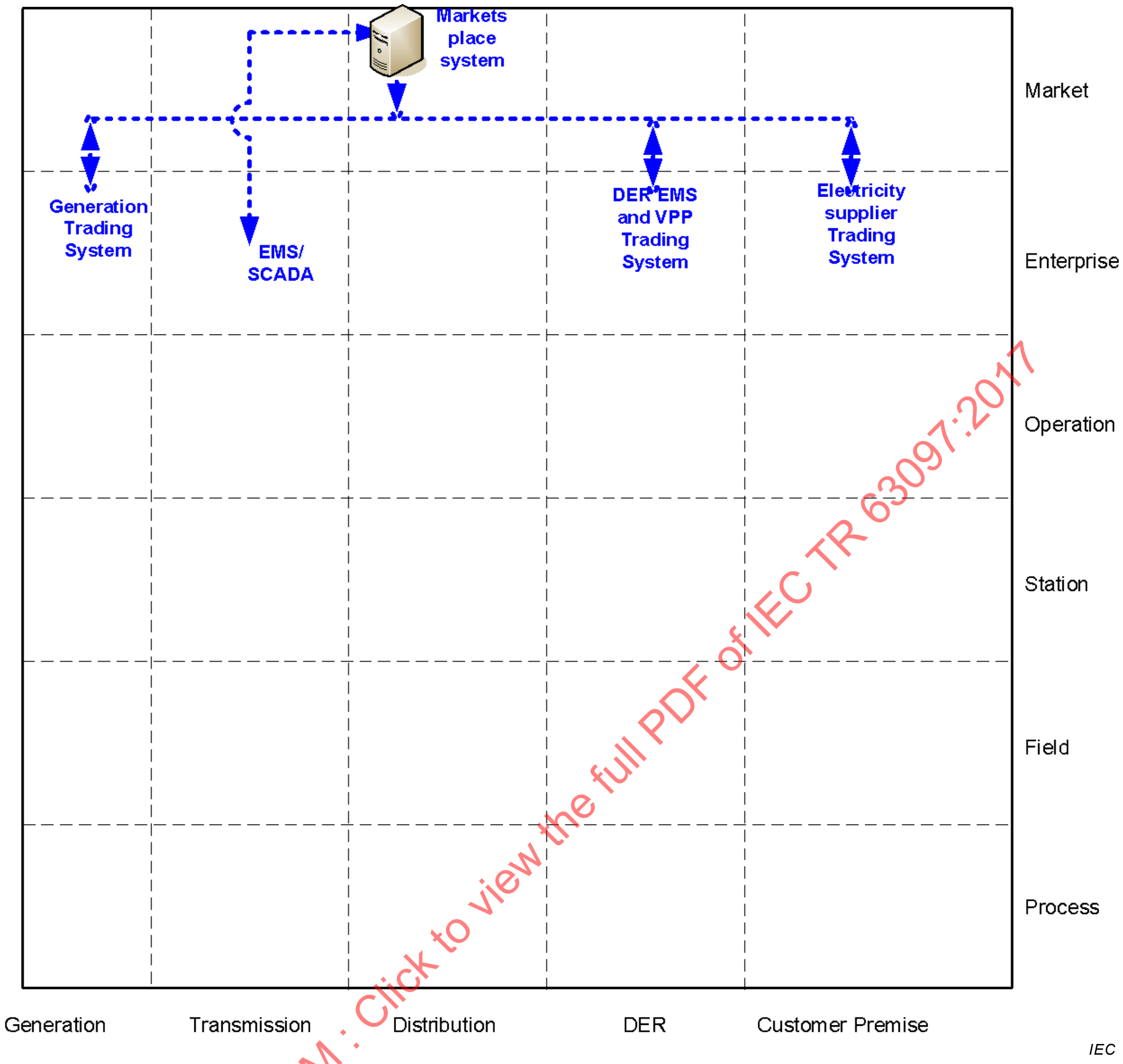


Figure 42 – Marketplace system – Component layer

5.9.12.4.3 Communication layer

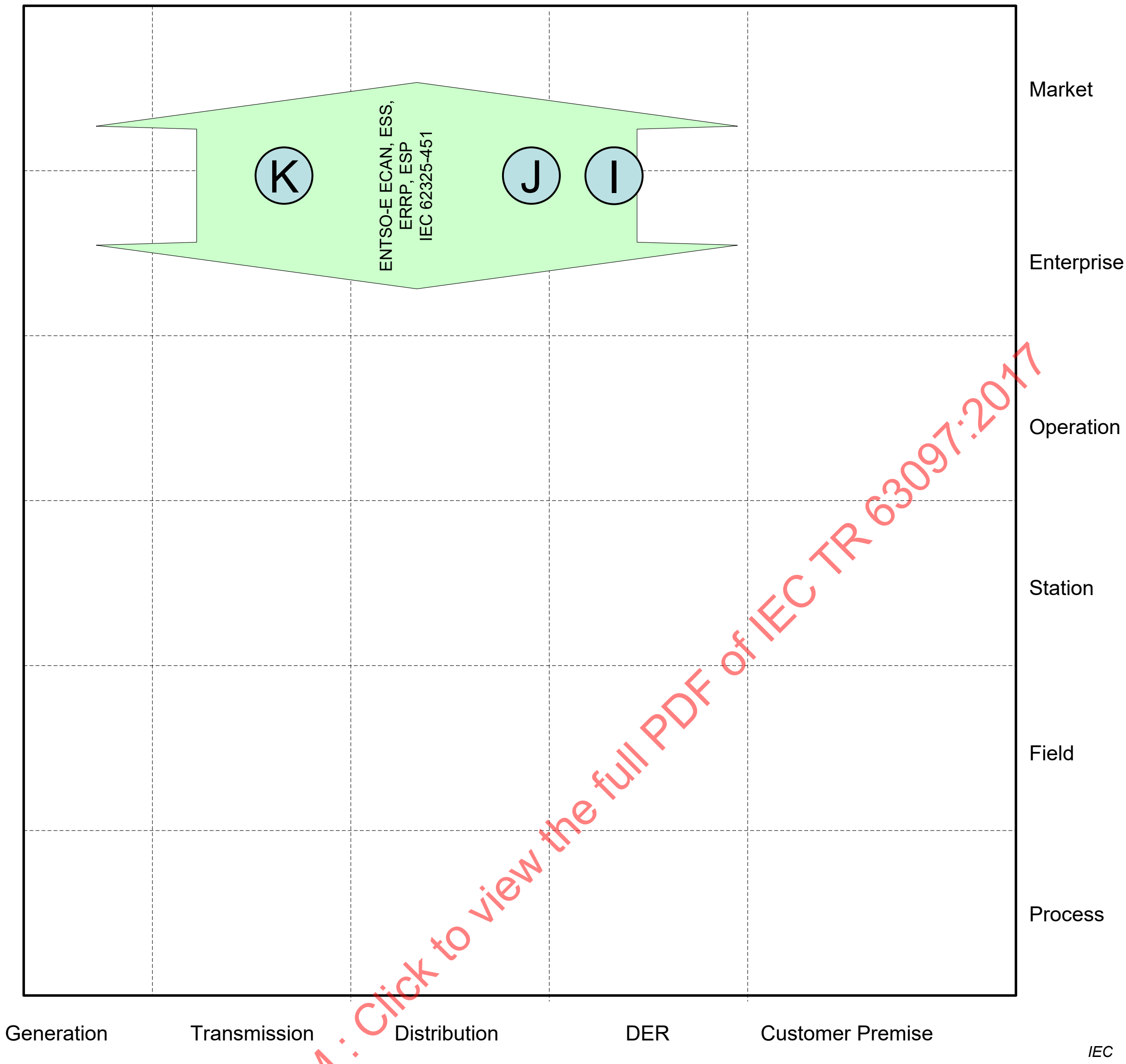
Markets involve data exchange between the central marketplace systems and market participants IT systems (trading systems).

The communication layer, as shown in Figure 43, is mostly around IEC 62325-450 and IEC 62325-451-1.

Worldwide standards such as SOA, XML, SOAP, etc. are leveraged as much as possible according to Enterprise Service Bus pattern.

Refer to 5.10.4 for details on cyber-security standards and more specifically on where and how to apply the IEC 62351 series and/or other cyber-security mechanisms.

This set of standards can be positioned this way on the communication layer of SGAM.



NOTE The letters in the blue disks refer to the network types defined in 5.10.1.2.

Figure 43 – Marketplace system – Communication layer

5.9.12.4.4 Information (Data) layer

Markets involve information exchange between the central market place systems and market participants IT systems (trading systems).

The information layer, as shown in Figure 44, is mostly around IEC 62325-301 and IEC 62325-351 using the ENTSO-E Market Data Exchange Standard (MADES) as a reference.

This set of standards can be positioned this way on the communication layer of SGAM.

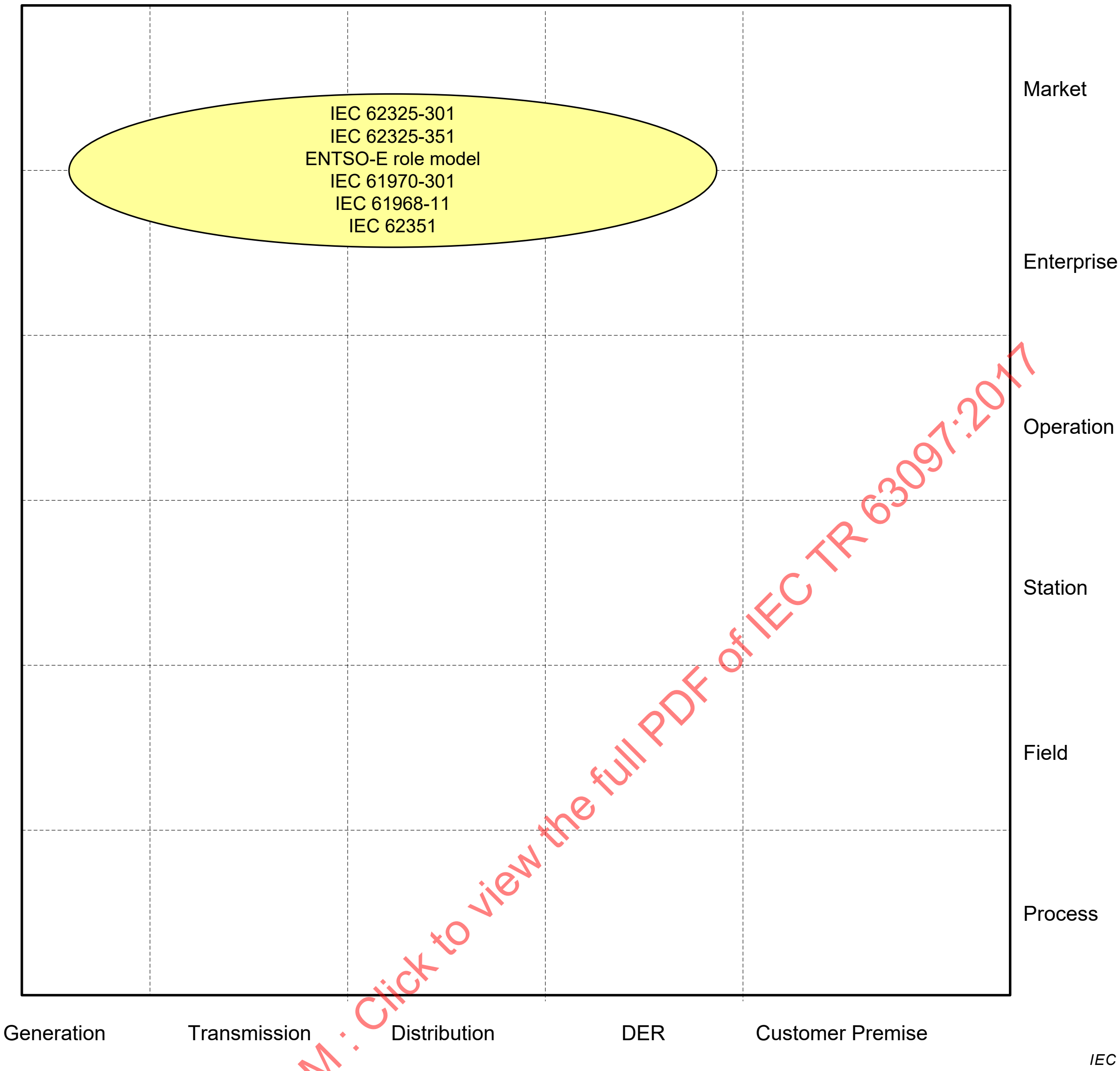


Figure 44 – Marketplace system – Information layer

5.9.13 Demand response / load management system

5.9.13.1 Description

Demand response or load management is a feature which is closely connected to DER (5.9.8), AMI systems (5.9.9), HBES/BACS (5.9.14) as well as Industrial Automation systems (5.9.15). Many of the standards and descriptions have already been addressed there.

To comply with the ambiguous goals of climate policies, in the future renewable energy resources will have a larger significance. Compared to the easy planning and adjustable power generation with fossil and nuclear fuel, renewable power generation can only in parts be planned and adjusted (e.g. solar, wind) or is subject to other restrictions (hydro). This means that in the future the share of “easily” adjustable power generation will decrease, which poses new challenges to a future energy management system.

One approach to the solution of this problem is the paradigm shift from “generation follows load” to “load adapts to generation”. Therefore load management will have a much higher significance in future. Load management has been performed in the past, e.g. large and small consumers (e.g. night storage heater). However it was limited to the prevention of peak loads and the respective load shedding of day and night load curves. These solutions, however, had only a limited influence on the control of individual loads.

Demand response (DR) is similar to dynamic demand mechanisms to manage customer consumption of electricity in response to supply conditions, for example, having electricity customers reduce their consumption at critical times or in response to market prices. The difference is that demand response mechanisms respond to explicit requests to shut off, whereas dynamic demand devices passively shut off when stress in the grid is sensed. Demand response is generally used to refer to mechanisms used to encourage consumers to reduce demand, thereby reducing the peak demand for electricity.

Load management / demand response can be performed in two respects:

- Energy management: this means the energy balance needs to be achieved in each demand period, generally 15 minutes to 60 minutes.
- Near real-time power management: this means energy needs to be balanced at all times.

The latter imposes significantly higher requirements on the control speed and can be realized only through fully automated, closed control loops. In all cases an integration of the consumer in the power grid automation requires a seamless communication. Area-wide smart meter utilization will be a major contributor to such a development. Load management and demand response solutions can be realized through an interface to control individual loads within the consumer premises.

An incentive can be set by a price signal, which is transmitted to the consumer, for example, a real time price signal. The consumer then still has the choice of whether he will change his own power consumption according to the set price incentives. In this case it is not important whether such a decision is taken by the consumer himself or an intelligent control system. The behaviour of such systems is not easily predictable, no matter which of the above systems is in place. Therefore these systems cannot support a real fast energy balancing and are therefore only capable of supporting energy management. Another problem with incentives is the choice of the optimal incentive. Normally incentive programs will follow monetary considerations. However since electrical energy is a basic necessity this will pose a conflict between social fairness and a sufficiently high price difference between times of high and low power availability.

Therefore, incentives will not be sufficient in the long run and have to be extended to direct intervening control mechanism. An integration of power grid automation and building and home automation offers the possibility to make full use of the flexibility and energy storage option of consumers for power grid balancing.

This power grid balancing requires load models for the optimizing software, in order to be able to predict the load behaviour of the overall system. These load profiles describe the limits of time flexibility of consumers and their energy storage potential. Only with this information available can a predictive load management be realized, which avoids a decreasing quality of energy supply for the consumer.

This approach consisting in aggregating individual capabilities of grid users, raises the question of considering a generic interface of any type of user.

The concept of Smart Grid user interface may then serve demand-response applications but also many other applications.

In that sense, and as represented in Figure 45, “The Smart Grid user interface (SGUI) is a bi-directional, logical, abstract interface that supports secure communications of information between an entity within the customer domain (e.g. energy management system, electrical load, electrical energy management storage system, generation source, or HBES subsystem) and an external energy service provider. Devices and applications will implement the SGUI between service providers and customers for the purpose of facilitating machine-to-machine communications. The SGUI needs to meet the needs of today's grid interactions (e.g. demand response, grid-aware energy management, EV charging equipment interactions) and those of the future (e.g. retail market transactions). In practice, the SGUI may be implemented in multiple levels with aggregation, both inside and outside of the customer facility. Implementations will have variations arising from complex system inter-relationships: diverse customer business and usage models with different types of equipment in different types of customer facilities controlled by a range of energy management systems."

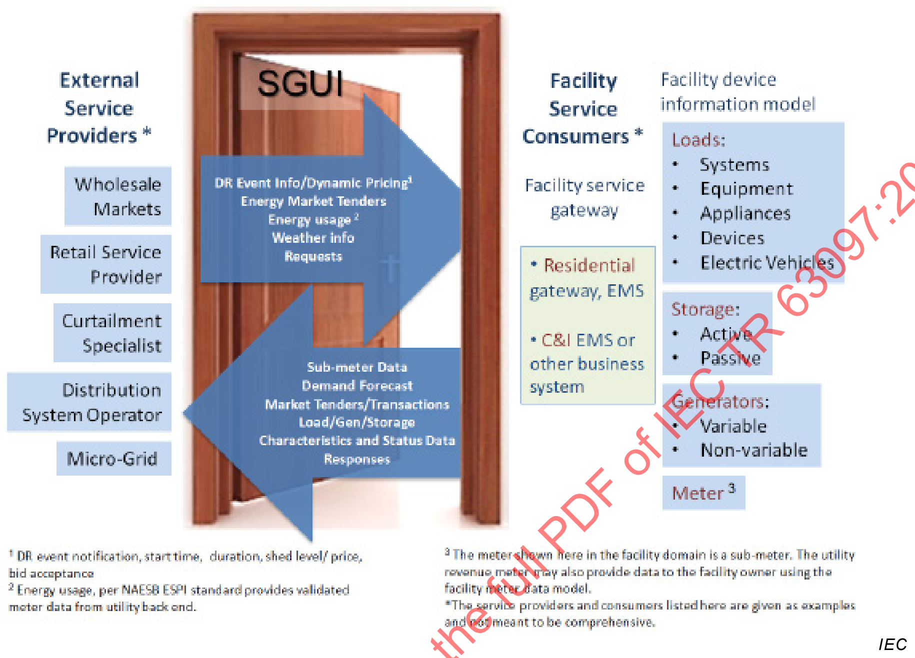


Figure 45 – SGUI representation

5.9.13.2 System summary

The demand response management system comprises all the needed components to perform the expected demand flexibility, and is mostly made of application servers, front-end communication processors and interfaces to the DR contributor, which can be of Home, Building, Industry or DER types. It may comprise the AMI itself, if the communication channel considered for getting connected to the DR contributor is the metering channel.

5.9.13.3 Set of System Capabilities

Table 53 provides a set of System Capabilities which may be supported by a demand response management system.

The meanings of the three last columns (AVAILABLE, COMING, Not yet) and of the "C", "I", "CI", "X" conventions are given in 5.5.2.5.

Table 53 – Demand response management system – Capabilities

Cluster	System Capabilities	Supported by standards		
		AVAILABLE	COMING	Not yet
Demand and production flexibility	Sending/Receiving metrological or price information for further action by consumer or CEM	CI	CI	
Demand and production flexibility	Direct load/generation control signals	C	CI	
Demand and production flexibility	Convey requests for ancillary services	C	CI	
Demand and production flexibility	Convey forward power usage projections	C	CI	
Demand and production flexibility	Convey user information	C	CI	
Demand and production flexibility	Managing energy consumption or generation of DERs via local DER energy management system bundled in a DR program	C	CI	
System and security management	Registration/de-registration of smart devices	C	CI	
	Enabling remote control of smart devices	C	CI	

5.9.13.4 Requirements

The main requirement for demand response is the active involvement of the consumer, which has to be achieved through a transparent pricing mechanism. Furthermore, information concerning current load and generation, a forecast of these quantities and a real-time measurement are requirements for demand response.

The availability of equipment for manageable loads (electricity heating, ventilation, smart appliances, e-cars, etc.), generation (DER, bulk wind and solar power, etc.) and storage (distributed like e-cars or bulk storage) is a prerequisite for demand response. The information exchange and control of these systems require an information exchange across several domains, e.g. from bulk generation down to smart appliances. A building operator will have significant influence on the choice of which manageable loads, sources and storage will be controlled within the building itself (and therefore be controlled through the Building Automation) and which loads, sources and storages will be directly controlled by the power grid.

Data models and protocols have to be available across all levels.

Connecting conditions have to be standardized, in order to allow a dynamic configuration of the overall system.

Furthermore security and data security are important. Failure to achieve security of the infrastructure is less severe than in the case of the transmission systems. However privacy issues may play an important role, since there are various local regulations and laws which need to be accommodated.

5.9.13.5 List of standards

5.9.13.5.1 General

Here is the summary of the principal standards which appear relevant to support demand response management systems:

The list below should also be read in conjunction with those “available” or “coming” cross-cutting standards supporting the telecommunication technologies detailed in 5.10.1, attached to the network types presented above (identified by their letter in the blue disks in Figure 36).

5.9.13.5.2 Available standards

See Table 54. Refer to 5.2.5.3 for the definition of the criteria considered in this document for stating that a standard is “available”.

Table 54 – Demand response management system – Available standards

Layer	Standard	Title and comments
Information, Communication	IEC 62325 series	*Framework for energy market communications*
Information, Communication	IEC 61968 series	*Application integration at electric utilities – System interfaces for distribution management*
Communication, Information	IEC PAS 62746-10-1	IEC PAS based on OpenADR[a]
Communication, Information	IEC TR 62746-2	*Systems interface between customer energy management system and the power management system – Part 2: Use cases and requirements*
Communication, Information	IEC TS 62746-3	*Systems interface between customer energy management system and the power management system – Part 3: Architecture*
Information, Communication	(refer to 5.9.8.6)	refer to the DER system depicted in 5.9.8
Information, Communication	(refer to 5.9.10.5)	refer to the AMI system depicted in 5.9.9
Information, Communication	(refer to 5.9.14.5)	refer to the HBES/HBAC system depicted in 5.9.14
Information, Communication	(refer to 5.9.15.5)	refer to the Industrial system depicted in 5.9.15
Information, Communication	IEC 62351 series	*Power systems management and associated information exchange – Data and communications security* Cyber-security aspects (see 5.10.4)
Information, Communication	ISO 16484 series	*Building automation and control systems (BACS)*
Information, Communication	ISO/IEC 14543-3 series	*Information technology – Home electronic system (HES) architecture*
Information, Communication	ISO/IEC 15045-1	*Information technology – Home electronic system (HES) gateway – Part 1: A residential gateway model for HES*
Information, Communication	ISO/IEC 15045-2	*Information technology – Home electronic system (HES) gateway – Part 2: Modularity and protocol*
Information	ISO/IEC 15067-3	*Information technology – Home electronic system (HES) application model – Part 3: Model of a demand-response energy management system for HES*
Information	ISO/IEC 18012-1	*Information technology – Home electronic system – Guidelines for product interoperability – Part 1: Introduction*
Information	ISO/IEC 18012-2,	*Information technology – Home electronic system – Guidelines for product interoperability – Part 2: Taxonomy and application interoperability model*
Information, Communication	IEC TR 62939-1	*Smart Grid user interface – Part 1: Interface overview and country perspectives*
Information	ISO 17800	*Facility Smart Grid information model* An information model to represent the Smart Grid related energy information within the facility, and specifically the information that may need to be communicated to/from electric grid service providers across the SGUI.
Information, Communication	ISO 16484-5	*Building automation and control systems (BACS) – Part 5: Data communication protocol*

Layer	Standard	Title and comments
Regional/national standards and Technical Specifications		
Information, Communication	EN 13321 series	*Open data communication in building automation, controls and building management – Home and building electronic systems*
Information, Communication	EN 50090 series	*Home and building electronic systems (HBES)*
Information, Communication	EN 50491	*General requirements for Home and Building Electronic Systems (HBES) and Building Automation and Control Systems (BACS)*
Information	(China): GB/Z 20965	*Information technology -- Home Electronic System (HES) architecture*
Information, Communication	OASIS Energy Interoperation 1.0	*Demand response (DR) and distributed energy resources (DER) communications as well as price communication and market transactions.*
Information, Communication	OpenADR 2.0	*A profile on the OASIS Energy Interoperation standard and serves DR and DER communications as well as price distribution for both wholesale and retail markets.*
Information, Communication	IEEE 2030.5	Smart energy Profile 2.0. *Customer premises communications of pricing, demand response signals, messaging, and energy usage to inhome devices.*
Information, Communication	NAESB Energy Services Provider Interface (ESPI) standard and "Green Button" application	The Green Button defines energy usage information for electricity meters as well as gas and water.
Information, Communication	(US) ANSI/CEA-2045:	*Modular Communication Interface.* Details mechanical, electrical, and logical characteristics of a residential appliance socket interface that allows communication devices to be separated from end devices.
Information	EN 50491-12	(CENELEC)Smart Grid interface and framework for Customer Energy Management
	AS/NZS 4755	Framework for demand response capabilities and supporting technologies for electrical products Demand response standard for appliances, under consideration in IEC TC 59
[a] IEC PAS 62746-10-1 is first proposed over simple HTTP transport layer, or over XMPP – refer to 5.10.1.4.		

5.9.13.5.3 Coming standards

See Table 55. Refer to 5.2.5.3 for the definition of the criteria considered in this document for stating that a standard is "coming".

Table 55 – Demand response management system– Coming standards

Layer	Standard	Title and comments
Information, Communication	IEC 62325 series	*Framework for energy market communications*
Information Communication	IEC 62746 series[a]	System interfaces and communication protocol profiles relevant for systems connected to the Smart Grid
Information, Communication	(refer to 5.9.10.5)	refer to the AMI system depicted in 5.9.9
Information, Communication	(refer to 5.9.8.6)	refer to the DER system depicted in 5.9.8
Information, Communication	(refer to 5.9.14.5)	refer to the HBES/HBAC system depicted in 5.9.14
Information, Communication	(refer to 5.9.15.5)	refer to the Industrial system depicted in 5.9.15
Communication	IEC 62351 series	*Power systems management and associated information exchange – Data and communications security* Cyber-security aspects (see 5.10.4)
Regional/national standards and Technical Specifications		
Information	prEN 50491-12	(fits CLC TR 50572 type H2/H3 needs) – Smart Grid – Application specification. Interface and framework for customer energy management
[a] Under preparation.		

5.9.13.6 Gaps

Profiles between Power Automation, Building Automation and Metering are missing.

5.9.13.7 Demand response / load management mapping

5.9.13.7.1 General

Flexibility can be effected directly by an enterprise (any authorized actor) by means of a suitable WAN communication management system linking the enterprise's user management system with the energy management gateway at the customer premises level, and thence to Customer Energy Management System (CEM), smart appliances or generation equipment. Alternatively the AMI can be used, with communications routed via utility's HES, NNAP and LNAP (dependent on the AMI configuration used).

5.9.13.7.2 Preamble

The demand response management system may utilize the AMI as the channel to the home/building and the reference architecture diagram included as Figure 34 in 5.9.10.3.

Figure 46, Figure 47 and Figure 48 give examples of a mapping of a typical configuration based on the smart metering reference architecture on the SGAM.

Note that the Energy Management Gateway and the Customer Energy Management System may be integrated.

Both in the figures in 5.9.13.7 and in similar ones in 5.9.10.6, the split of the "customer premises" domain on the right is intended to illustrate a typical market model where assets in the home/building are not owned/operated by the electricity service supplier. However Member State market models vary, e.g. as regards meter ownership and operation, and are subject to national structures and regulation, so this representation should not be seen as definitive.

The blue zone indicates that such a system may rely on the AMI system to carry some data.

5.9.13.7.3 Component layer

The principal functional components used for flexibility purposes, as shown in Figure 46, are the CEM and HAN, and – if utilizing the AMI – the smart meter, the LN and LNAP, NN and NNAP, the WAN, MDM and HES, as indicated below.

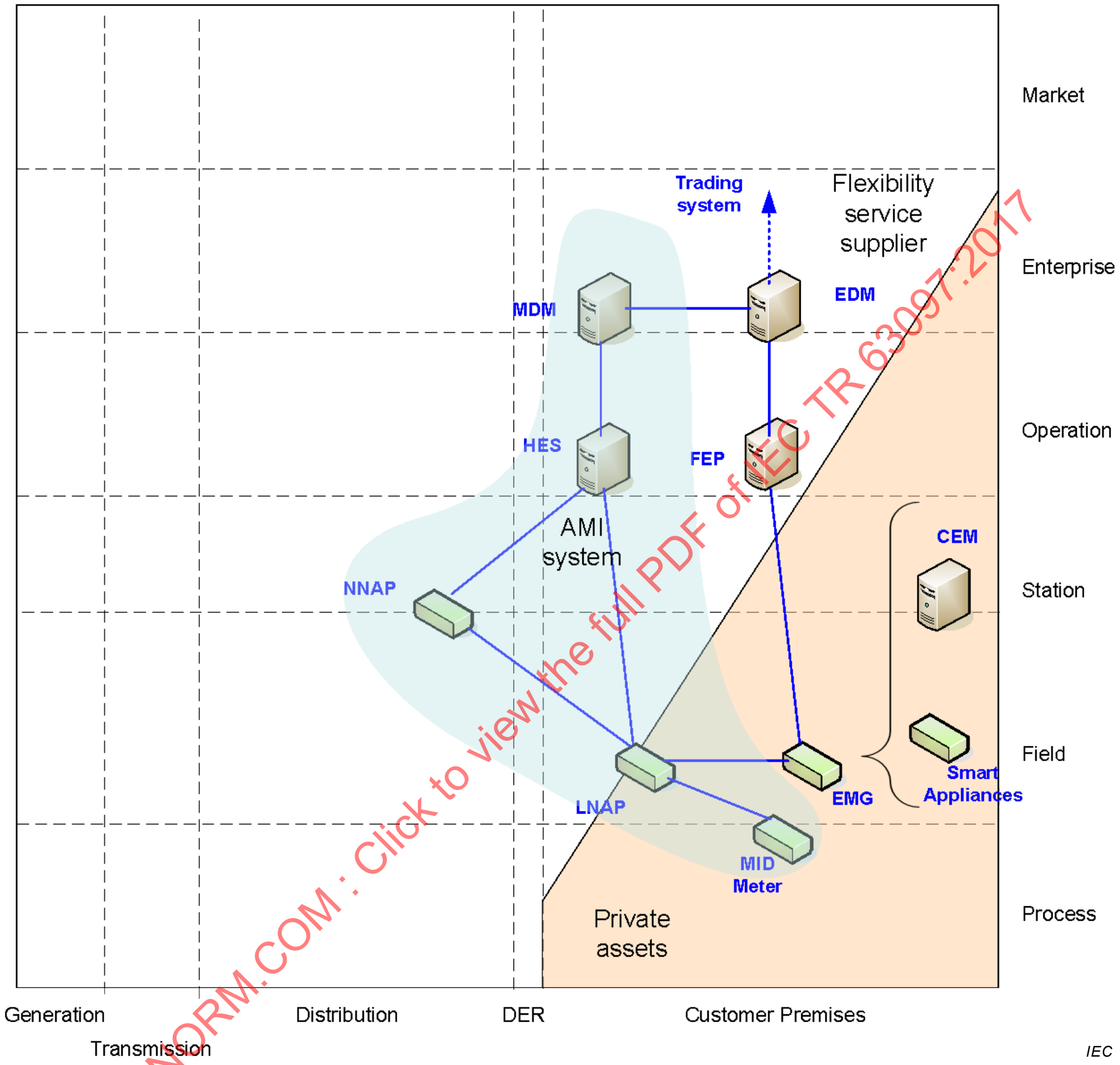
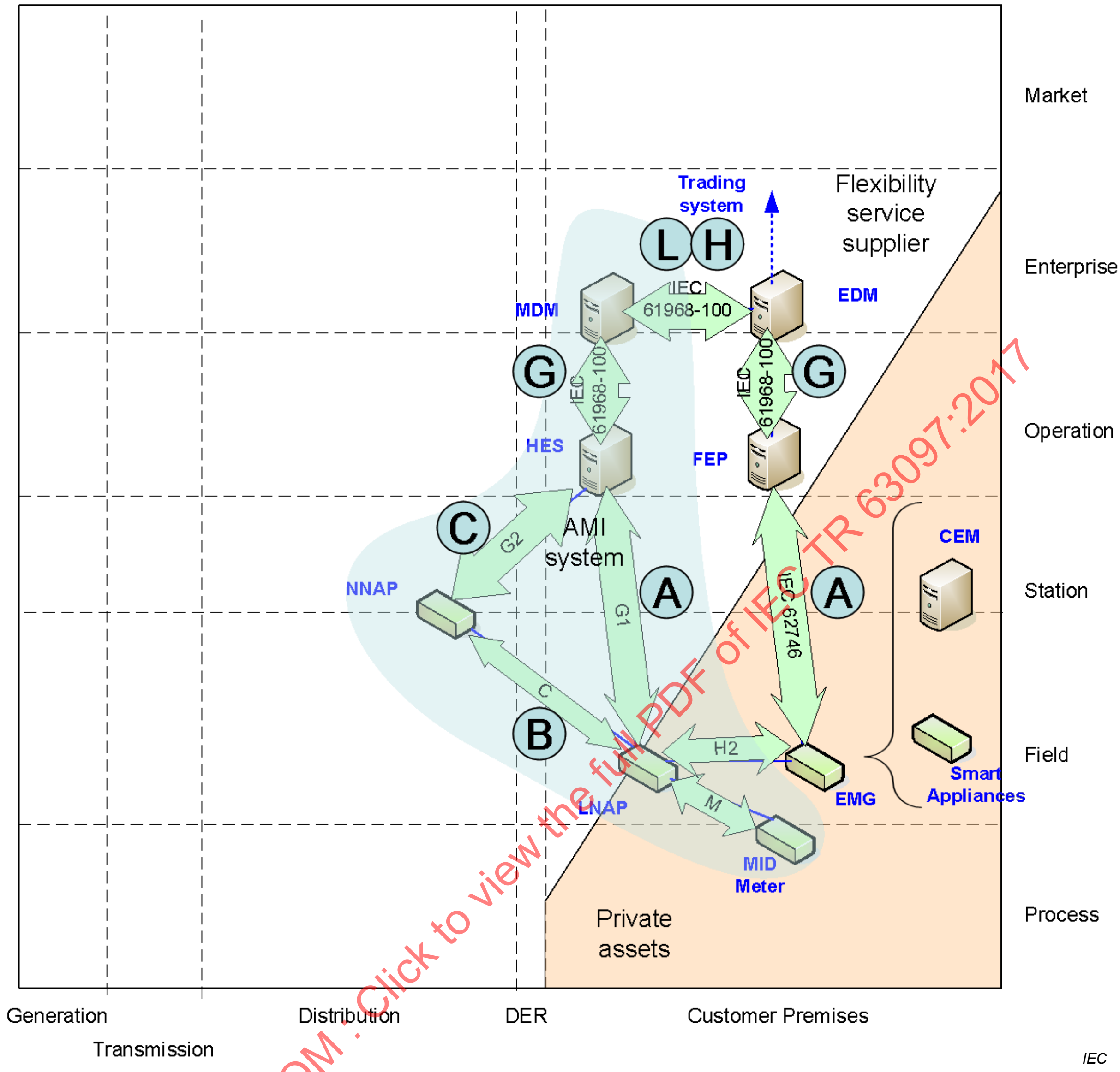


Figure 46 – Demand response management system (example) – Component layer

5.9.13.7.4 Communications layer

Work is underway in IEC TC 57 and IEC PC 118, as well as in IEC TC 13 as soon as smart metering is used. Figure 47 shows a possible mapping of communication standards for this application.

Refer to 5.10.4 for details on cyber-security standards and more specifically on where and how to apply the IEC 62351 series and/or other cyber-security mechanisms.



NOTE The letters in the blue disks refer to the network types defined in 5.10.1.2.

Figure 47 – Demand response management system (example) – Communication layer

5.9.13.7.5 Information (Data) layer

Figure 48 shows how information level standards may be mapped to support the considered system (as an example).

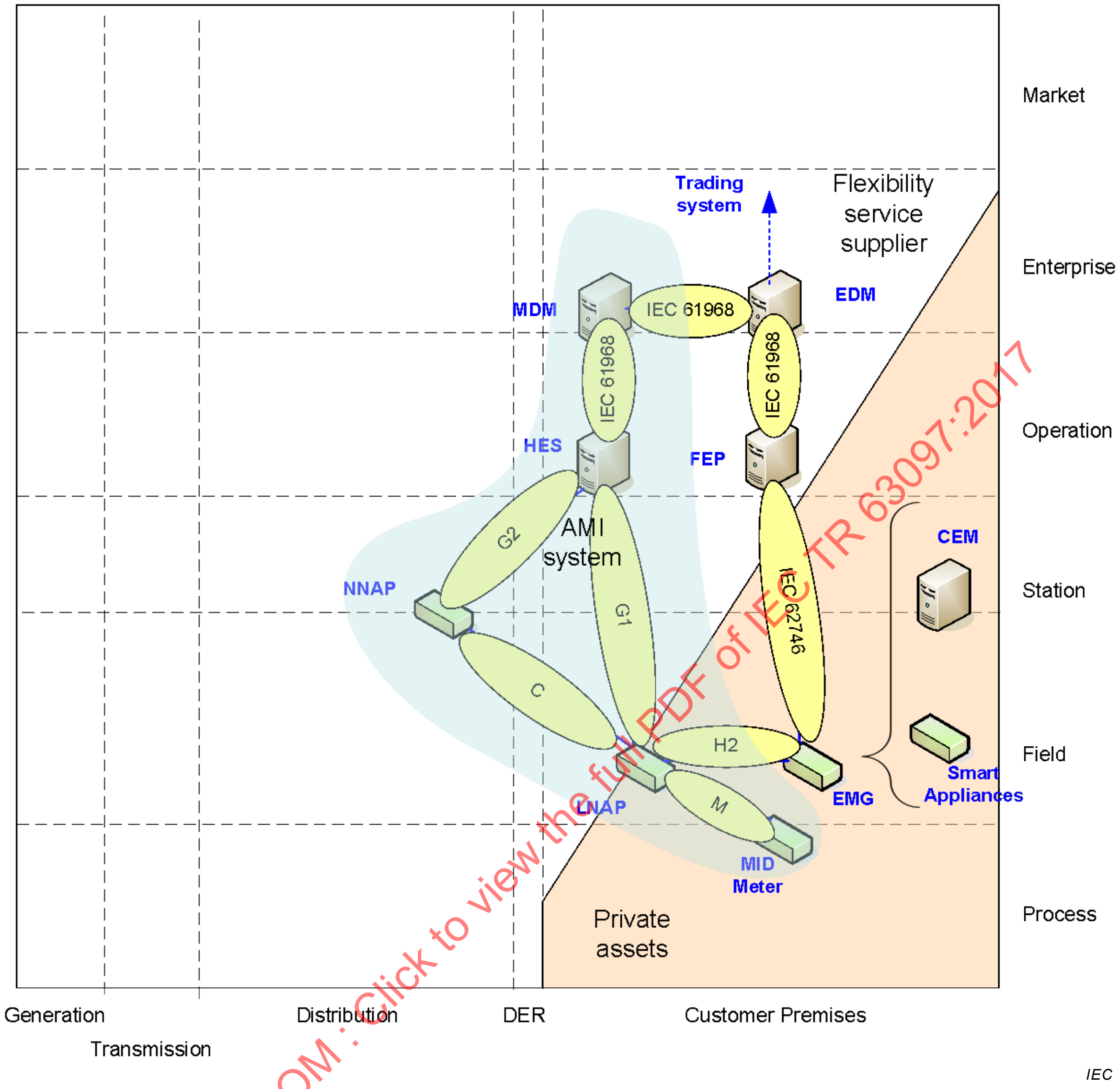


Figure 48 – Demand response management system (example) – Information layer

5.9.14 HBES/BACS system

5.9.14.1 Description

The term "building automation and control" (BAC) refers to the equipment, software and services for automatic control, monitoring, optimization, operation and management used for energy-efficient, economical, and reliable operation of building services. The term was ultimately defined in ISO 16484-2.

According to ISO 16484-2, "building automation and control" refers to the instrumentation, control and management technology for all building structures, plant, outdoor facilities and other equipment capable of automation. In addition to automation, operation and management with software and services (BAC functions), this also includes the required field devices, control panels, cables and wiring and the associated networks for the transfer of information. Room automation is also covered by the term. These categories of equipment can be linked to the building automation and control system via special interfaces (ISO 16484-2).

Within the Smart Grid, buildings become an active element within the power grid rather than a pure unpredictable consumer of electrical energy. Since the HBES/BACS controls and monitors all technical installations in a building, it also controls and monitors local electrical resources such as local generation plants, as well as storages such as heating or cooling reservoirs. Therefore, distributed energy resources (DER such as Solar photovoltaic (PV) power supply systems) or storages (e-cars) will become more important in the future and will also be managed by HBES/BACS. HBES/BACS will then communicate with external systems such as the DR management system (refer to 5.9.13), the AMI system (refer to 5.9.9), the ADMS (refer to 5.9.5) and potentially other remote services systems (not described here).

Because DERs are possibly part of such HBES/BACS systems, standards related to this domain (refer to 5.9.8) may also be of interest.

One of the main tasks of BAC is to optimize overall energy costs by using energy optimization functions (to reduce the consumption of kWh) and by considering the best energy tariff and contractual power limitations by using load management function (to reduce the cost per kWh).

Relating to Smart Grid, HBES/BACS will get smarter tariff information as important input parameters for the load management function. On the other hand HBES/BACS have to also handle the electrical resources as well as electrical and thermal storages as integrated components of the load management to optimize the cost per kWh from the grid and to reduce power consumption from the grid.

ADMS (refer to 5.9.5) as well as DR management system (refer to 5.9.13) may require energy consumption and production forecast information from HBES/BACS as well as actual potential switchable loads and feed-in power values. Such information flow may use the AMI system (refer to 5.9.9) for that purpose.

Typical information flows from external to HBES/BACS:

- actual consumption value;
- consumption values of different elapsed periods;
- tariff information for consumption and energy feed-in;
- actual maximum power value (Peak Demand Limiting);
- charging period information (Peak Demand Limiting);
- forecast value;
- etc. (list not complete).

Typical information flows from HBES/BACS to external:

- actual controllable loads and resources;
- actual feed-in power value;
- forecast value;
- etc. (list not complete).

5.9.14.2 System summary

A building automation and control system (HBES/BACS) is thus a system which 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. These functions are defined in ISO 16484-3.

In our specific case, we will only consider the needed/potential elements to be considered when focusing on the interface with the Grid.

5.9.14.3 Set of System Capabilities

Table 56 provides a set of System Capabilities which may be supported by a demand response management system.

The meanings of the three last columns (AVAILABLE, COMING, Not yet) and of the “C”, “I”, “CI”, “X” conventions are given in 5.5.2.5.

Table 56 – HBES/BACS system – Capabilities

Cluster	System Capabilities	Supported by standards		
		AVAILABLE	COMING	Not yet
Demand and production flexibility	Refer to 5.9.13			
Remote services	Enable energy efficiency analysis Enable remote asset management			
	Enable monitoring power quality			
	Enable remote optimization of operation			
System and security management	Registration/de-registration of users	C	CI	
	Enabling remote control of users	C	CI	

5.9.14.4 Requirements

One of the most specific system requirements to consider is related to the protection of privacy, as soon as detailed information related to privacy may be conveyed through such interface.

5.9.14.5 List of standards

5.9.14.5.1 General

Here is the summary of the principal standards which appear relevant to support interface of HBES/BACS systems to the grid.

The list below should also be read in conjunction with:

- those “available” or “coming” cross-cutting standards supporting the telecommunication technologies detailed in 5.10.1, attached to the network types presented above (identified with their letter in the blue disks in Figure 47);
- those already identified for interfacing DR management systems – refer to 5.9.13 (demand flexibility is one set of Capabilities to consider) and AMI systems (refer to 5.9.9);
- those already identified for DER management systems (refer to 5.9.8).

5.9.14.5.2 Available standards

See Table 57. Refer to 5.2.5.3 for the definition of the criteria considered in this document for stating that a standard is “available”.

As for AMI system, which may participate in the building-up of such a system, we will rely on the CLC TR 50572 set of standards definition.

Table 57 – HBES/BACS system – Available standards

Layer	Standard	Comments
Information, Communication	IEC 62325 series	*Framework for energy market communications*
Information, Communication	IEC 61968 series	*Application integration at electric utilities – System interfaces for distribution management*
Information, Communication	IEC 60870 series	*Telecontrol equipment and systems*
Information Communication	IEC PAS 62746-10-1	*Systems interface between customer energy management system and the power management system – Part 10-1: Open Automated Demand Response (OpenADR 2.0b Profile Specification)*
Communication, Information	IEC TR 62746-2	*Systems interface between customer energy management system and the power management system – Part 2: Use cases and requirements*
Communication, Information	IEC TS 62746-3	*Systems interface between customer energy management system and the power management system – Part 3: Architecture*
Information, Communication	IEC TR 62939-1	*Smart Grid user interface – Part 1: Interface overview and country perspectives*
Information, Communication	(refer to 5.9.13.5)	refer to the DR management systems depicted in 5.9.13
Information, Communication	(refer to 5.9.8.6)	refer to the DER system depicted in 5.9.8
Information, Communication	(refer to 5.9.10.5)	refer to the AMI system depicted in 5.9.9
Information, Communication	IEC 62351 series	*Power systems management and associated information exchange – Data and communications security* Cyber-security aspects (see 5.10.4)
Information, Communication	ISO 16484 series	*Building automation and control systems (BACS)*
Information, Communication	ISO/IEC 14543	*Residential communication architecture, protocols, network configuration and network management that could carry smart grid signals*
Information, Communication	ISO/IEC 14543-3 series	*Information technology – Home Electronic System (HES) architecture*
Information, Communication	ISO/IEC 14908 series	(LON) Control network protocol stack
Information, Communication	ISO/IEC 15067-3	Smart Grid application specifications for demand response, distributed energy resources and local storage
Information, Communication	ISO/IEC 15045	Gateway to link a home network and an external network including Smart Grid communications
Information, Communication	ISO/IEC 18012	Product interoperability to provide seamless operation of home system products including energy management complying with a diversity of communication protocols
Information	IEC 62394	(ECHONET) direct control of household appliances within home, including remote control through the home gateway appliances (ECHONET) device object Interface for equipment maintenance
Communication	ISO/IEC 24767	(ECHONET) ISO/IEC 24767-1, ISO/IEC 24767-2: Secure communication layer, Secure communication for home appliances
Information, Communication	IEC 63480 IEC 62480	(ECHONET) Middleware adapter interface
Communication	ISO/IEC 14543-4	(ECHONET) ISO/IEC 14543-4-1: communication middleware – upper section (ECHONET) ISO/IEC 14543-4-2: communication middleware – lower section
Communication	IEC 62457	(ECHONET) Application of TCP/IP to home network – cooperation with AV/PC equipment
Component	IEC 60364 series	*Low-voltage electrical installations*
Information, Communication	ISO 16484-5	*Building automation and control systems (BACS) – Part 5: Data communication protocol*

Layer	Standard	Comments
Information, Communication	ISO 17800	*Facility Smart Grid information model.* An information model to represent the Smart Grid related energy information within the facility, and specifically the information that may need to be communicated to/from electric grid service providers across the SGUI.
Other specifications		
Information, Communication	EN 13321 series	Open data communication in building automation, controls and building management – Home and building electronic systems
Information, Communication	EN 50090 series	Home and building electronic systems (HBES)
Information, Communication	EN 50491	General requirements for Home and Building Electronic Systems (HBES) and Building Automation and Control Systems (BACS)
Information, Communication	(China): GB/Z 20965	Information technology -- Home Electronic System (HES) architecture
Information, Communication	NAESB Energy Services Provider Interface (ESPI) standard and "Green Button" application.	The Green Button defines energy usage information for electricity meters as well as gas and water.
Information, Communication	ANSI/CEA-2045: Modular Communication Interface	Details mechanical, electrical, and logical characteristics of a residential appliance socket interface that allows communication devices to be separated from end devices.
Information, Communication	IEEE 1547	Standard for Interconnecting Distributed Resources with Electric Power Systems. Distributed generation and Micro-grid
Information, Communication	AS/NZS 4755	Framework for demand response capabilities and supporting technologies for electrical products Demand response standard for appliances, under consideration in IEC TC 59
Information, Communication	Zigbee Home Automation	Standard for interoperable products enabling smart homes that can control appliances, lighting, environment, energy management and security

5.9.14.5.3 Coming standards

See Table 58. Refer to 5.2.5.3 for the definition of the criteria considered in this document for stating that a standard is "coming".

Table 58 – HBES/BACS system– Coming standards

Layer	Standard	Title and comments
Information, Communication	IEC 62325 series	*Framework for energy market communications*
Information Communication	IEC 62746 series	System interfaces and communication protocol profiles relevant for systems connected to the Smart Grid
Information, Communication	(refer to 5.9.13.5)	refer to the DR management systems depicted in 5.9.13
Information, Communication	(refer to 5.9.8.6)	refer to the DER system depicted in 5.9.8
Information, Communication	(refer to 5.9.10.5)	refer to the AMI system depicted in 5.9.9
Communication	IEC 62351 series	*Power systems management and associated information exchange – Data and communications security* Cyber-security aspects (see 5.10.4)
Component	IEC 63044 series	*Home and Building Electronic Systems (HBES) and Building Automation and Control Systems (BACS)*
Information	ISO 17800	Derived from AHSRAE SPC 201 mentioned above
Other specifications		
Information	prEN 50491-12	(fits CLC TR 50572 type H2/H3 needs) – Smart Grid – Application specification. Interface and framework for customer energy management

5.9.14.6 Gaps

Definition of the required interface(s) and communication protocol(s) between Demand-Response and Load management systems and HBES/BACS.

Definition of profiles (common semantic/data model/interworking standard) between Demand-Response and Load management systems and HBES/BACS.

5.9.14.7 HBES/BACS system mapping

5.9.14.7.1 Preamble

There are many different cases in which HBES/BACS systems may be architectured, and also many possibilities for having such systems interfaced to the Grid (operator, supplier, flexibility service provider). The drawings given in 5.9.14.7 are just here to depict the typical usage of the considered standards.

5.9.14.7.2 Component layer

The Smart Home and Building automation component architecture (shown here Figure 49 within a "private asset") may be interfaced according to the following schema (Figure 49).

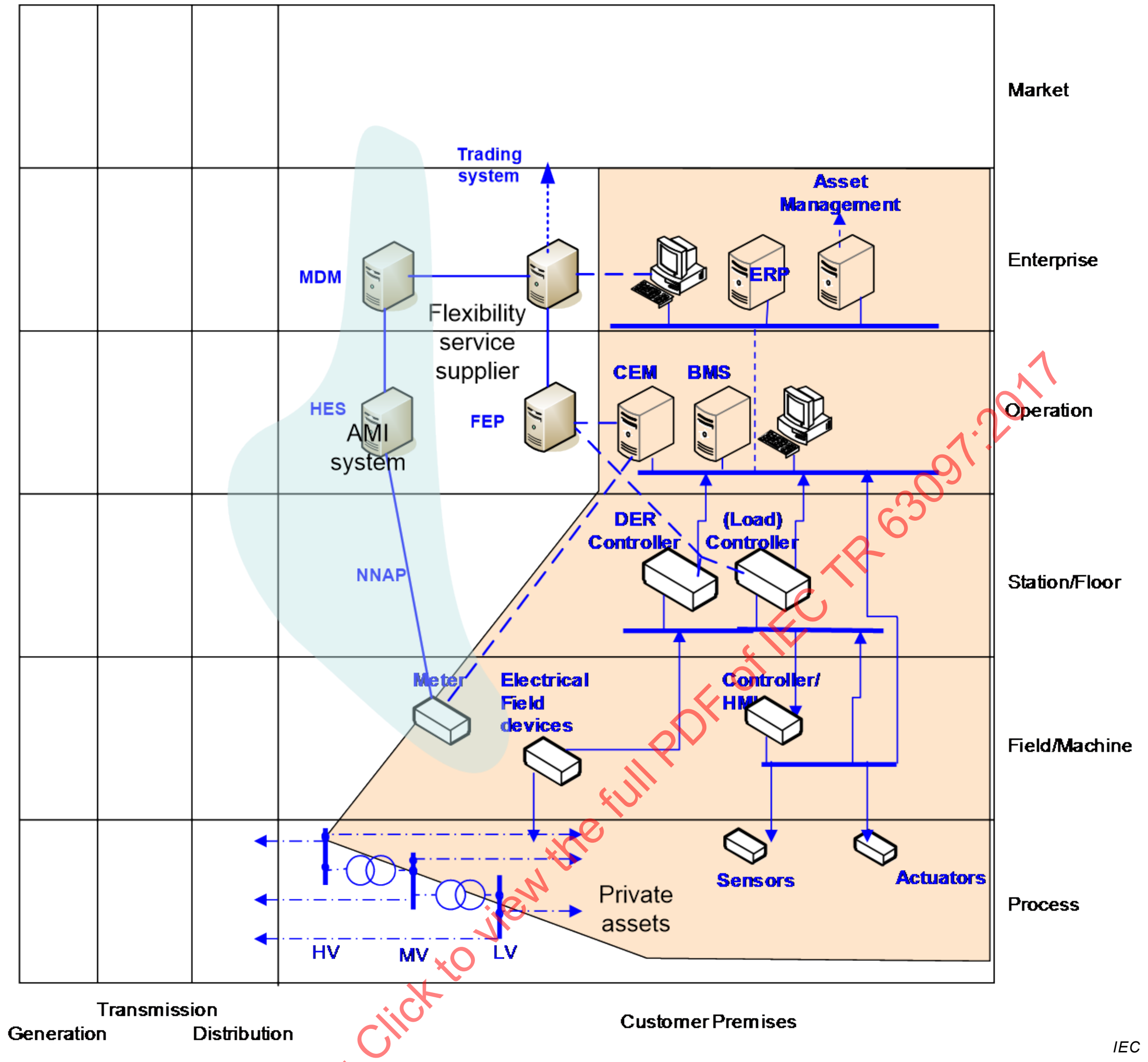
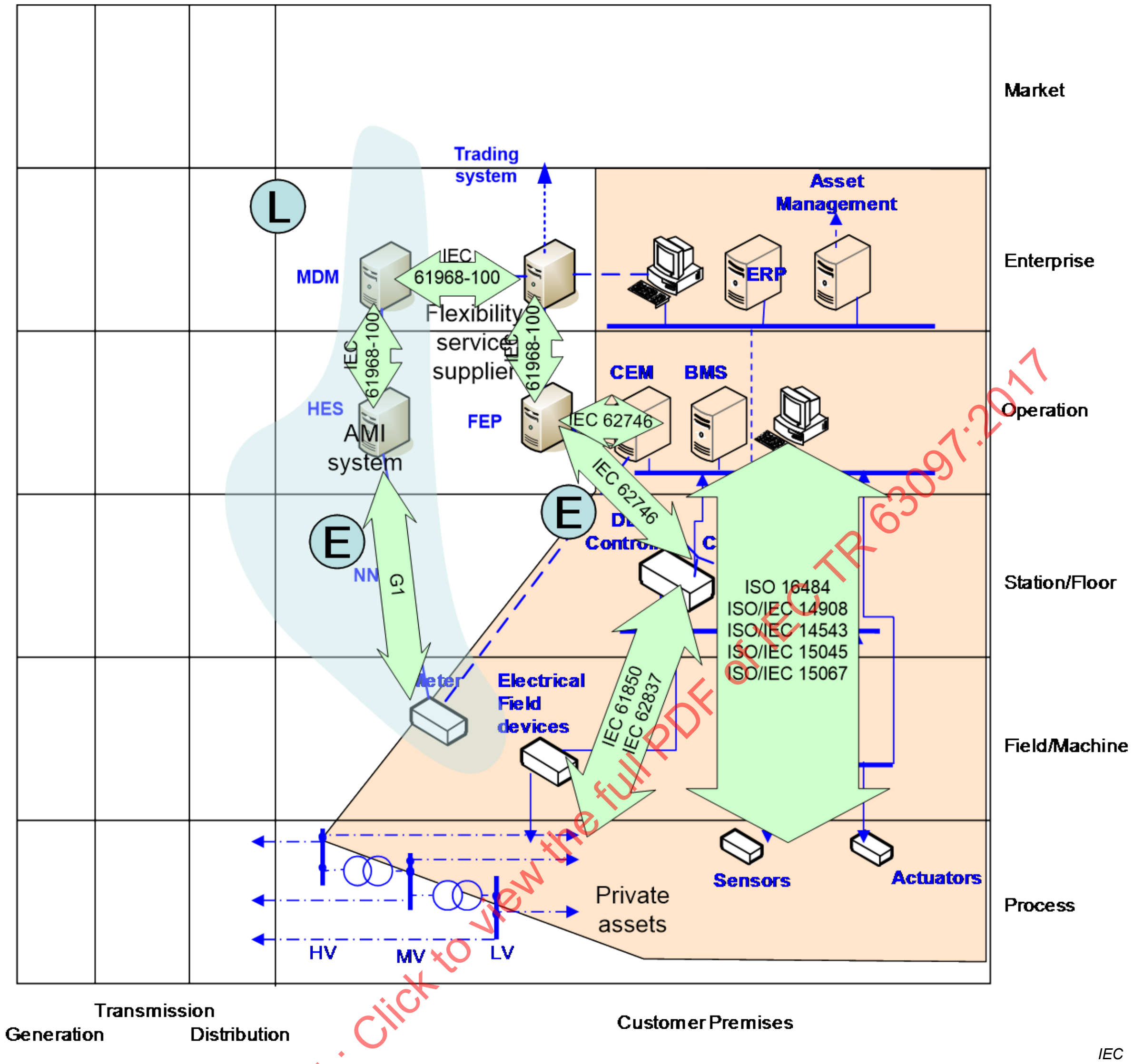


Figure 49 – HBES/BACS system (example) – Component layer

5.9.14.7.3 Communication layer

Refer to 5.10.4 for details on cyber-security standards and more specifically on where and how to apply the IEC 62351 series and/or other cyber-security mechanisms.

This set of standards can be positioned as shown in Figure 50 on the communication layer of SGAM.



NOTE The letters in the blue disks refer to the network types defined in 5.10.1.2.

Figure 50 – HBES/BACS system (example) – Communication layer

5.9.14.7.4 Information (Data) layer

This set of standards can be positioned as shown in Figure 51 on the information layer of SGAM.

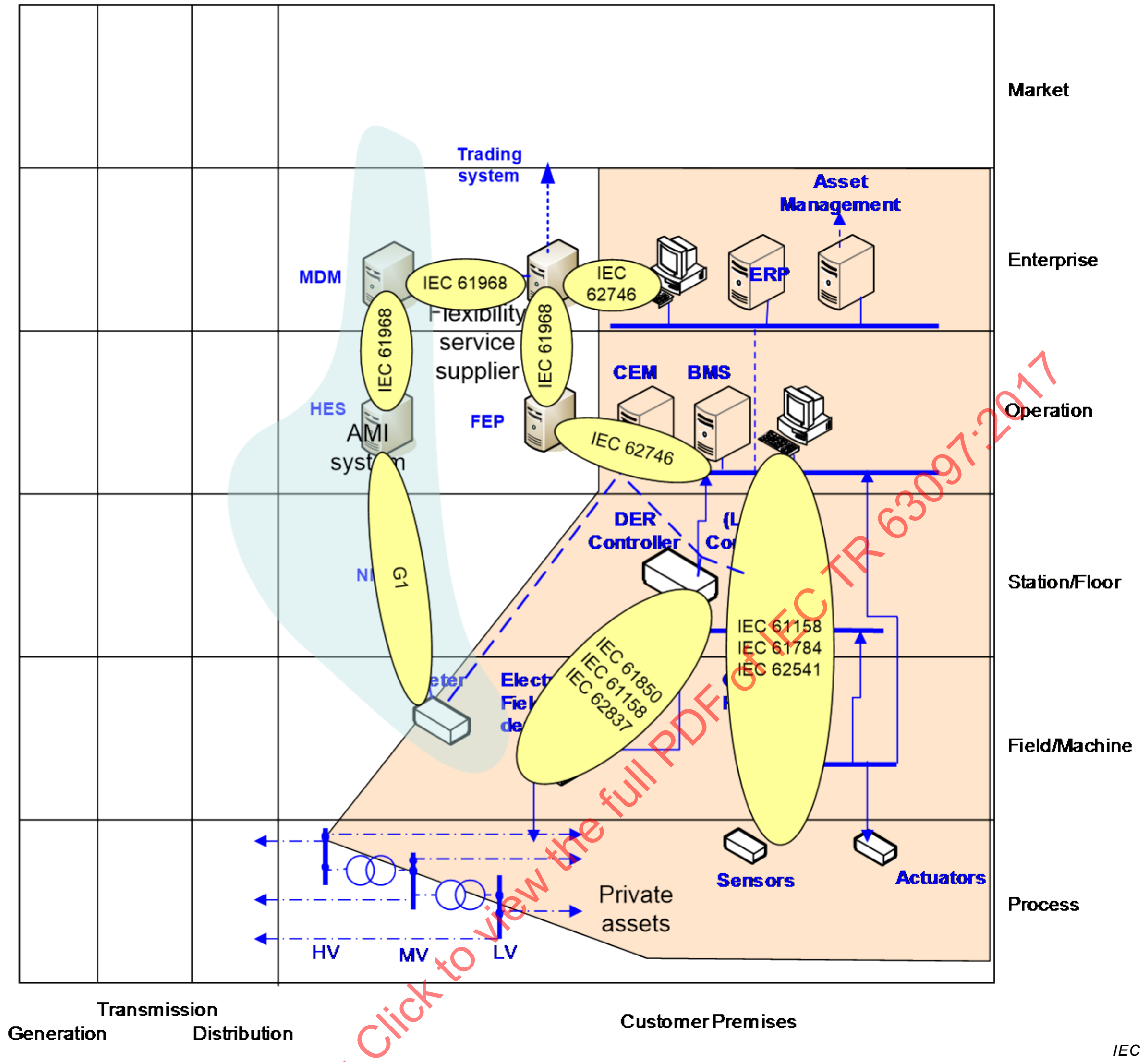


Figure 51 – HBES/BACS system (example) – Information layer

5.9.15 Industrial automation system

5.9.15.1 Description

The ongoing changes in the electrical energy infrastructure will also offer new opportunities for industrial automation. Energy efficiency and the minimization of a plant's impact on the environment are common goals across the industry. While designers will tend to specify low power consumption devices and equipment, overall plant efficiency and environmental stewardship will continue to dominate design decisions. In addition, the availability of the Smart Grid will allow industry to better match how it generates and uses electrical energy, resulting in reduced costs and impacts on the environment while enhancing efficiency, safety and production quality.

The Smart Grid promises to make available to industry the ability to better access dynamic energy tariffs and to better co-ordinate electricity consumption and in some cases electricity supply to the grid. Many industries generate significant amounts of electricity internally, for example using co-generation equipment, and industry world-wide consumes about 40 % of the total electricity generated by traditional electric utilities. The availability of "smarter" interfaces to the grid will enable a better management of industrial energy resources by providing industrial process automation the necessary added flexibility. This can be used by industry to reduce energy costs by aligning consumption to periods when energy prices are low and to create new revenue sources by selling energy to the grid.

The objective of 5.9.15 is not then to provide a complete overview of industrial automation systems, but to focus on their interaction with the Smart Grids and identify the standards needed to allow industrial facilities, and the industrial automation systems within such industrial facilities, to communicate with the Smart Grid for the purpose of planning, negotiating, and managing the flow of electrical power and related information between them.

It is recognized that a wide range of industrial facilities will interface with the Smart Grid. This section addresses arrangements where the industrial facility or a facility-contracted intermediate party, remains responsible for the operation of facility internal energy resources. For these industries, energy arrangements are primarily made to support internal production (manufacturing) by the facility. In some cases a facility may enter into agreements with an intermediate party to take responsibility for management of their internal energy resources and this party would then implement the interface to the Smart Grid. Such parties would understand the consequences of such control and may rely on a detailed understanding of internal facility operations.

Other arrangements will exist, for example where the industrial facility offers energy generation or storage resources primarily for the benefit of the grid, allocates responsibility for the operation of these resources to the grid, and the grid takes responsibility, and assumes any corresponding liability, for such operation. These latter arrangements were addressed in 5.9.8.

The industrial arrangements identified in 5.9.15 have to address the unique requirements which can be summarized as follows.

Many industries have significant options for production scheduling given sufficient notice, but they can seldom respond to unplanned energy shortages by simply reducing their short term demand across the board. Unlike typical consumer applications where loads can be reduced, for example by acting on heating, ventilation, cooling and lighting, it is often critical that energy supply be kept in planned conditions once industrial production has started to ensure that production quality, plant safety and security are maintained. Some types or phases of production, once started, cannot be stopped immediately without damage to equipment. Thus the criteria used to respond to unplanned demand events and energy fluctuations have to differ from that of, for example, home and building automation, so that the consequences of unplanned changes can be factored into operations and into the design of the industrial plant itself.

Some industrial facilities can postpone or reduce production at times of predicted energy shortage if given sufficient notice. Industrial facilities can be designed to adjust the production quantity, for example, through parallelism, and the scheduling of activities across shifts. Industrial facilities could choose to reduce production if the current energy cost makes the incremental cost of production exceed the incremental product's value. Industry could choose to operate energy intensive operations during periods when energy costs are low. Simple time-of-day pricing would not always provide the flexibility needed to allow full exploitation of the scheduling.

Many larger industries have significant internal energy generation and/or storage capabilities. A plant with in-house hydroelectric generation could draw energy from the grid during off-peak times and use the corresponding saved hydroelectric power to supply energy to the grid at peak times, thus providing the equivalent of pumped energy storage. Plants with co-generation facilities could also assist the grid in meeting normal and emergency energy demands. These situations can only be addressed if the Grid operator and Industry can dynamically negotiate and plan such arrangements on a short-term basis.

Notwithstanding the above opportunities, it is emphasized that the owner of the industrial facility will expect, and will demand, that they retain full responsibility for the operation of all of their equipment, including energy generation, use and storage equipment, within the facility. Direct control of energy resources within the facility has to be retained by the facility operator to ensure that all safety, production quality and environmental targets are met.

Seldom will the external electrical grid entity desire to accept the liability associated with the direct control of facility equipment.

5.9.15.2 System summary

The Industrial Automation and Control System (IACS) refers to the system and all the elements needed for industrial-process measurement and control. However, the following only considers the elements needed to interface to the Grid.

5.9.15.3 Set of System Capabilities

Use cases (and associated "stories") have been depicted within IEC TS 62872 and are summed up in Table 59.

IEC TS 62872 also includes an assessment of standards meeting the deduced requirements.

The meanings of the three last columns (AVAILABLE, COMING, Not yet) and of the "C", "I", "CI", "X" conventions are given in 5.5.2.5.

Table 59 – Industrial automation system – Use cases

Cluster	Use cases	Supported by standards		
		AVAILABLE	COMING	Not yet
Connecting industry grid users	Facility and Smart Grid obtain current and past energy information	IEC 62872		
	Facility provides energy consumption and supply plan to Smart Grid.	IEC 62872		
	Smart Grid provides stable (long term) price schedule to facility	IEC 62872		
	Smart Grid provides dynamic (short term) pricing to facility	IEC 62872		
	Facility informs Smart Grid about upcoming consumption and supply	IEC 62872		
	Smart Grid informs facility of blackout notice	IEC 62872		
	Smart Grid requests facility to alter consumption or supply	IEC 62872		
	Facility and Smart Grid negotiate price schedule	IEC 62872		

5.9.15.4 Specific requirements

These have been depicted in IEC TS 62872. Of critical importance for Industrial facilities is ensuring that the facility is secure. Typically the security requirements resulting from the application of IEC 62443 series will prohibit connections between the Smart Grid and layers below the Operations Level (see Figure 52, these Levels are defined in IEC 62264 series). As indicated previously, direct control of the energy resource within the facility (if permitted), which may require a connection below the Operations Level, is addressed by the DER standards identified in 5.9.8. In Figure 52 to Figure 54, a single interface is shown between the Smart Grid and a Factory Energy Management System (FEMS) within the Industrial facility. In the IEC TS 62872 model, the FEMS is considered an abstract entity which may include components at various Levels of the facility architecture while ensuring that all interactions with the Smart Grid conform to the security and other policies in effect at the facility.

5.9.15.5 Standards context

5.9.15.5.1 Available standards

See Table 60. Refer to 5.2.5.3 for the definition of the criteria considered in this document for stating that a standard is “available”.

Table 60 – Industrial automation system – Available standards

Layer	Standard	Title and comments
General	IEC 62264 series	*Enterprise-control system integration* (defines Architecture)
General	IEC TR 62794	*Industrial-process measurement, control and automation – Reference model for representation of production facilities (digital factory)*
Business, Function	IEC 61508 series	*Functional safety of electrical/electronic/programmable electronic safety-related systems*
Business, Function	IEC 61511 series	*Functional safety – Safety instrumented systems for the process industry sector*
Business, Function, Information, Communications	IEC 62443 series	*Industrial communication networks – Network and system security*
Information, Communication	IEC TS 62872	*Industrial-process measurement, control and automation system interface between industrial facilities and the Smart Grid*
Communication	IEC 61158 series	*Industrial communication networks – Fieldbus specifications*
Communication	IEC 61784 series	*Industrial communication networks – Profiles*
Information, Communication	IEC 61588	*Precision clock synchronization protocol for networked measurement and control systems*
Component	IEC 61918	*Installation of communication networks – Installation of communication networks in industrial premises*
Function, Information	IEC 61499 series	*Function blocks*
Function, Information	IEC 61804 series	*Function blocks (FB) for process control*
Information, Communication	IEC 62541 series	*OPC unified architecture*
Information Communication	IEC PAS 62746-10-1	*Systems interface between customer energy management system and the power management system – Part 10-1: Open Automated Demand Response (OpenADR 2.0b Profile Specification)*
Communication, Information	IEC TR 62746-2	*Systems interface between customer energy management system and the power management system – Part 2: Use cases and requirements*
Communication, Information	IEC TS 62746-3	*Systems interface between customer energy management system and the power management system – Part 3: Architecture*
Information, Communication	IEC TR 62939-1	*Smart Grid user interface – Part 1: Interface overview and country perspectives*
Information, Communication	(refer to 5.9.13.5)	refer to the DR management systems depicted in 5.9.13
Information, Communication	(refer to 5.9.8.6)	refer to the DER system depicted in 5.9.8
Information, Communication	(refer to 5.9.10.5)	refer to the AMI system depicted in 5.9.9
Business, Function	IEC TR 62685	*Industrial communication networks – Profiles – Assessment guideline for safety devices using IEC 61784-3 functional safety communication profiles (FSCPs)*
Business, Function	IEC TR 62837	*Energy efficiency through automation systems*
Communication	IEC 62439 series	*Industrial communication networks – High availability automation networks* based on the ISO/IEC 8802-3 (Ethernet) technology
Component	IEC 61131 series	*Programmable controllers*

Layer	Standard	Title and comments
Information	IEC 61987 series	*Industrial-process measurement and control – Data structures and elements in process equipment catalogues*
Information, Communication	IEC 61970 series	*Energy management system application program interface (EMS-API)* Common Information Model (CIM) / Energy Management
Information, Communication	IEC 61968 series	*Application integration at electric utilities – System interfaces for distribution management*
Information, Communication	IEC 61850 series	*Communication networks and systems for power utility automation*
Information, Communication	IEC 62351 series	*Power systems management and associated information exchange – Data and communications security* Cyber-security aspects (see 5.10.4)
Information, Communication	IEC 62056 series	*Electricity metering data exchange – The DLMS/COSEM suite*
Information, Communication	IEC 62325 series	*Framework for energy market communications*
Component	IEC 60364 series	*Low-voltage electrical installations*

NOTE Additional standards related to clock management, safety, or EMC are mentioned in further dedicated subclauses.

5.9.15.5.2 Coming standards

See Table 61. Refer to 5.2.5.3 for the definition of the criteria considered in this document for stating that a standard is “coming”.

Table 61 – Industrial automation system – Coming standards

Layer	Standard	Title and comments
Information, Communication	IEC TS 62872 [a]	*Industrial-process measurement, control and automation system interface between industrial facilities and the Smart Grid* Resulting from NP 65/519/NP
Information Communication	IEC 62746 [a]	System interfaces and communication protocol profiles relevant for systems connected to the Smart Grid
Information, Communication	(refer to 5.9.13.5)	refer to the DR management systems depicted in 5.9.13
Information, Communication	(refer to 5.9.8.6)	refer to the DER system depicted in 5.9.8
Information, Communication	(refer to 5.9.10.5)	refer to the AMI system depicted in 5.9.9
[a] Under preparation.		

5.9.15.6 Gaps

The gaps are being identified in IEC TS 62872.

5.9.15.7 Industrial automation system mapping

5.9.15.7.1 Preamble

Many different architectures are used to represent industrial facilities, although the architecture described in the IEC 62264 series has been used extensively and is consistent with the architecture used in this SGAM document. Figure 52, Figure 53 and Figure 54 depict the typical usage of the considered standards.

5.9.15.7.2 Component layer

The industrial automation component architecture (shown here within a “private asset”) may be interfaced according to the following schema (Figure 52).

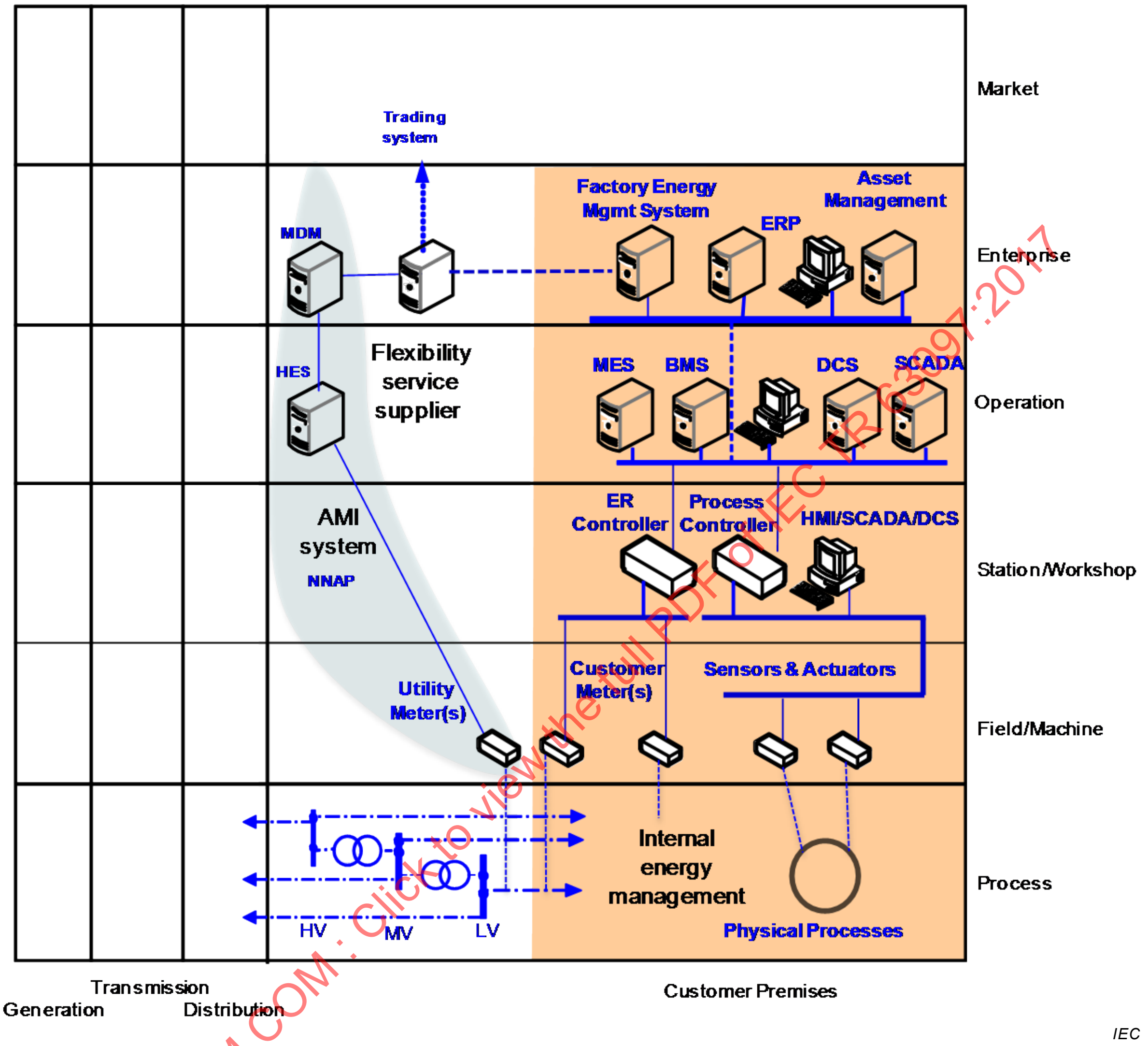
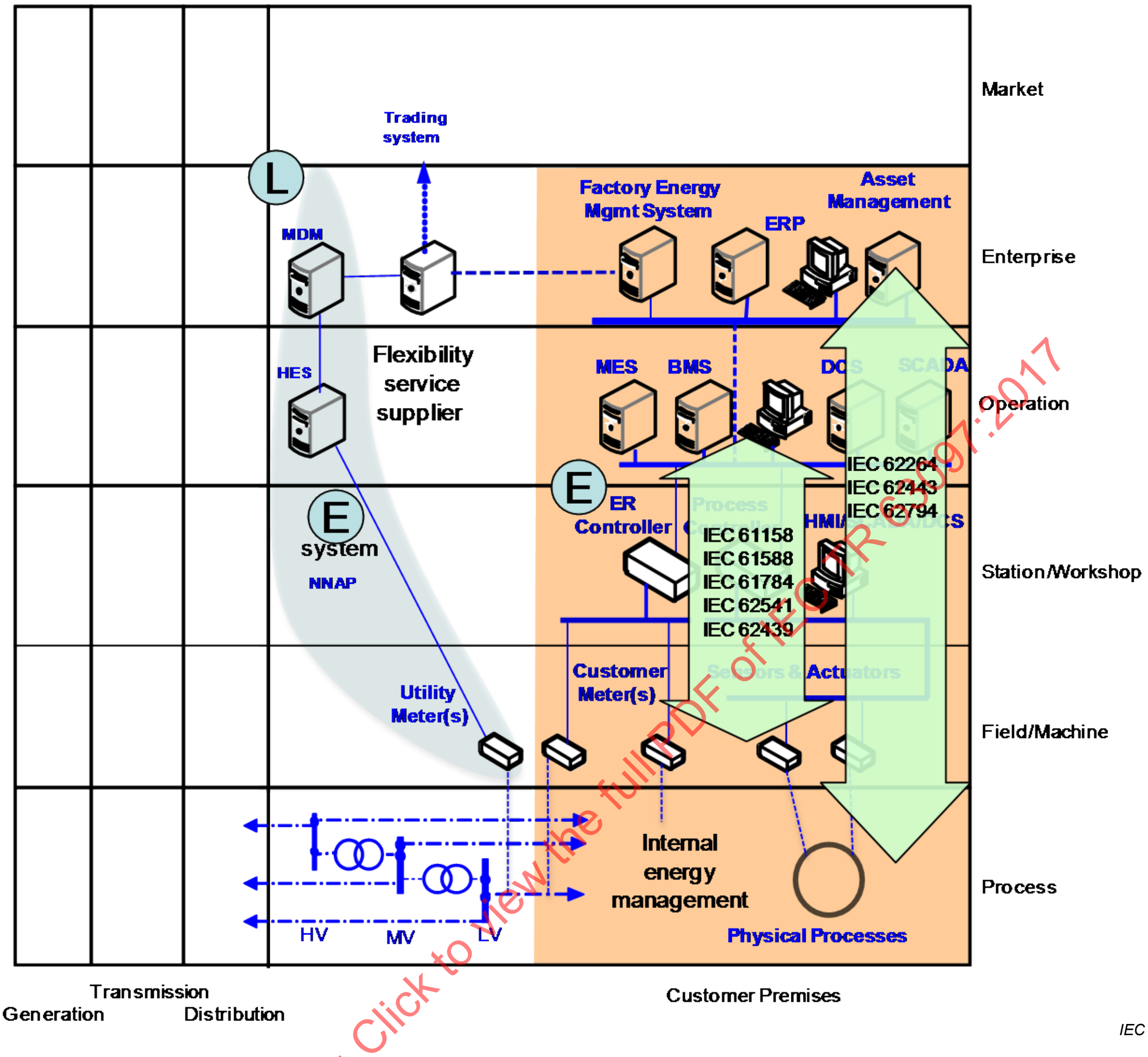


Figure 52 – Industrial automation system (example) – Component layer

5.9.15.7.3 Communication layer

System security for industrial systems is defined by the IEC 62443 series with some parts being updated in co-operation with ISO/IEC JTC 1/SC 27.

This set of standards can be positioned as shown in Figure 53 on the communication layer of SGAM.



NOTE The letters in the blue disks refer to the network types defined in 5.10.1.2.

Figure 53 – Industrial automation system (example) – Communication layer

5.9.15.7.4 Information (Data) layer

See Figure 54.

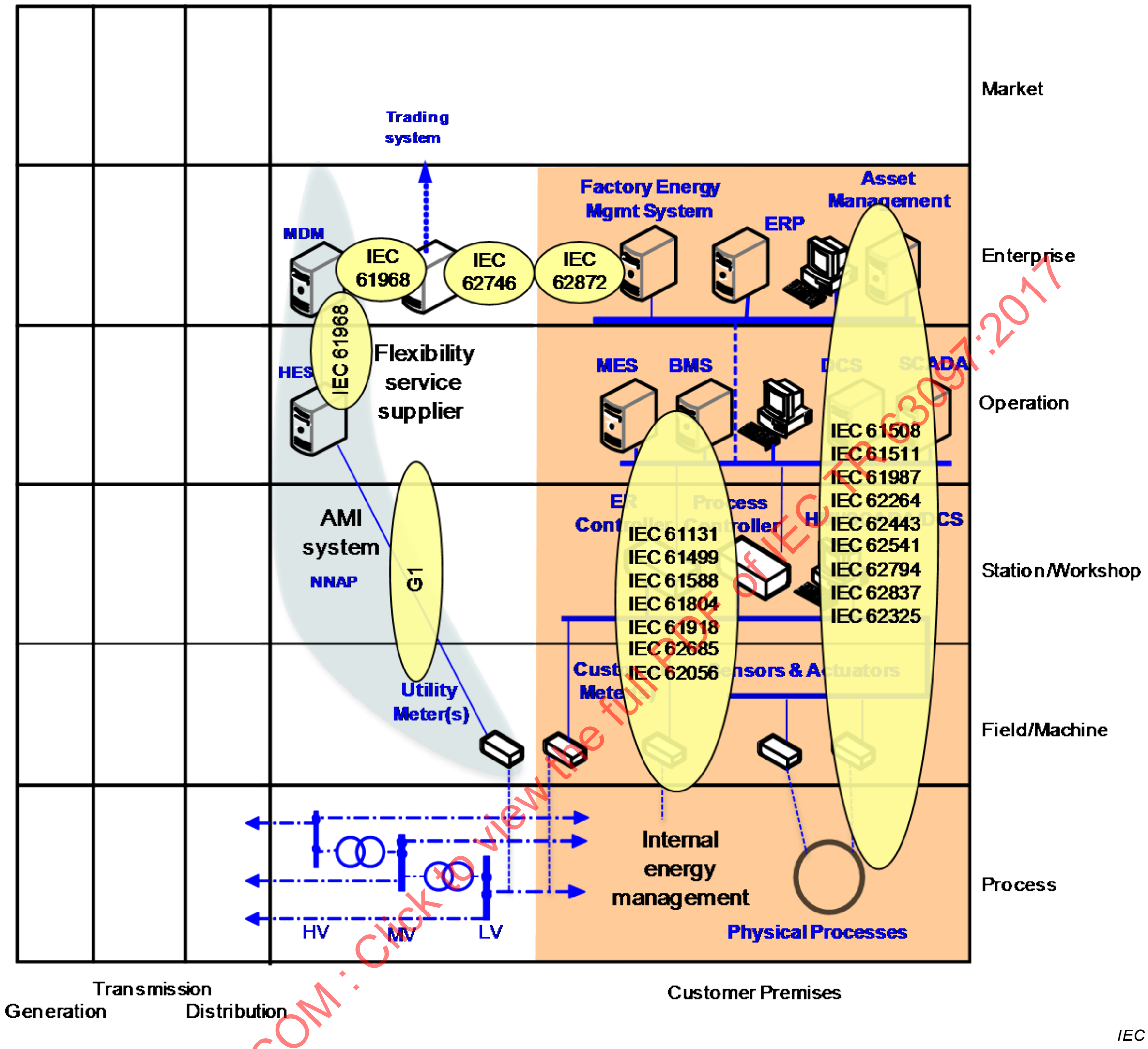


Figure 54 – Industrial automation system (example) – Information layer

5.9.16 E-mobility system

5.9.16.1 Description

E-Mobility is one option for a Smart Grid with respect to the integration of energy storage and therefore the integration of renewable energies. Furthermore it would serve the conservation of individual mobility in times of decreasing fossil fuel supply. The full scope of its capability, however, can only be achieved by seamless integration into a Smart Grid architecture. E-Mobility provides a large, flexible load and storage capacity for the Smart Grid. This however depends on the use case, some of which are not capable of contributing to these advantages. Basic charging (charging the car at a plug existing today) does not offer the full scope of possibilities from a Smart Grid perspective. Battery swapping scenarios only contribute insofar as the batteries serve Smart Grid functions within the swapping station, not in the car itself.

A seamless integration can be provided through bidirectional power flow, utilization of manageable loads and maximum information exchange between onboard and grid automation, including price information.

E-Mobility will serve the following functions:

- a primary, secondary, tertiary reserve;
- a manageable load;
- power system stabilization;
- power quality;
- load levelling;
- load shedding;
- individual mobility (not relevant for Smart Grid);
- energy conservation (increased efficiency compared to combustion engines) under the constraint of fulfilling environmental constraints.

Total electrification of the vehicle will furthermore promote the role of IEC standards in the vehicle domain. This has to urgently be dealt with, however it is not within the scope of a Smart Grid discussion.

5.9.16.2 Requirements

5.9.16.2.1 Product requirements

Battery technology needs standardization. Batteries and associated power electronics need to fulfil minimum requirements for lifecycle and cyclic stability in order to function as part of the power grid system.

Safety requirements need to be fulfilled in an overall perspective. In particular, application and design concepts for the use of batteries need to conform to safety requirements. This is also true for low voltage installations for the charging infrastructure. Physical connector interface dimensions for vehicle and power supply side need to be standardized.

EMC requirements need to be met.

An important requirement is the availability of pricing information for new business models as well as the interface for load and generation balancing functionalities/system functions.

5.9.16.2.2 Communication requirements

At a first glance, bidirectional communication is not a necessary requirement for E-Mobility, especially in the basic case of simple home charging.

However such a scenario would prevent taking any benefits from E-mobility to Smart Grid application.

In order to achieve the advantages of E-mobility in the Smart Grid environment, a bi-directional connection needs to be possible between the individual charging management of the vehicle with the automation on distribution grid level. This includes charging and discharging depending on the load situation of the power net and therefore requires bidirectional communication and even control capabilities over the individual e-car through distribution management systems of the power net. A connection or extension of the already existing energy automation and the respective communication standards (e.g. IEC 61850/IEC 61968) is therefore absolutely necessary.

5.9.16.3 Standards context

5.9.16.3.1 Available standards

See Table 62. Refer to 5.2.5.3 for the definition of the criteria considered in this document for stating that a standard is “available”.

Table 62 – E-mobility system – Available standards

Layer	Standard	Title and comments
Information, Communication	IEC 61968 series	*Application integration at electric utilities – System interfaces for distribution management* Common Information Model (CIM) / Distribution Management
Information, Communication	IEC 61970 series	*Energy management system application program interface (EMS-API)*
Information, Communication	IEC 61850-7-420	*Communication networks and systems for power utility automation – Part 7-420: Basic communication structure – Distributed energy resources logical nodes*
Information	IEC TR 61850-90-8	*IEC 61850 object models for electric mobility*
Information, Communication	ISO 15118 series	*Road vehicles – Vehicle to grid communication interface* Communication protocol between electric vehicle and grid
Communication	IEC 62351 series	*Power systems management and associated information exchange – Data and communications security* Cyber-security aspects (see 5.10.4)
Communication	IEC 62443 series	*Industrial communication networks – Network and system security*
Information, Communication, Component	IEC 61851 series	*Electric vehicle conductive charging system*
Component	IEC 61851-1	*Electric vehicle conductive charging system – Part 1: General requirements*
Component	IEC 61851-21	*Electric vehicle conductive charging system – Part 21: Electric vehicle requirements for conductive connection to an a.c./d.c. supply*
Component	IEC 61851-22	*Electric vehicle conductive charging system – Part 22: AC electric vehicle charging station*
Component	IEC 61851-23	*Electric vehicle conductive charging system – Part 23: DC electric vehicle charging station*
Communication	IEC 61851-24	*Electric vehicle conductive charging system – Part 24: Digital communication between a d.c. EV charging station and an electric vehicle for control of d.c. charging*
Component	IEC TR 60783	*Wiring and connectors for electric road vehicles*
Component	IEC TR 60784	*Instrumentation for electric road vehicles*
Component	IEC TR 60785	*Rotating machines for electric road vehicles*
Component	IEC TR 60786	*Controllers for electric road vehicles*
Component	IEC 60364 series	*Low-voltage electrical installations*
Component	IEC 60364-4-41	*Low-voltage electrical installations – Part 4-41: Protection for safety – Protection against electric shock*
Component	IEC 60364-5-53	*Electrical installations of buildings – Part 5-53: Selection and erection of electrical equipment – Isolation, switching and control*
Component	IEC 60364-5-55	*Electrical installations of buildings – Part 5-55: Selection and erection of electrical equipment – Other equipment* Clause 551: Low-voltage generating set
Component	IEC 60364-7-712	*Electrical installations of buildings – Part 7-712: Requirements for special installations or locations – Solar photovoltaic (PV) power supply systems*

Layer	Standard	Title and comments
Component	IEC 60364-7-722	*Electrical installations of buildings – Part 7-722: Requirements for special installations or locations – Supplies for electric vehicles*
Component	ISO 8713	*Electrically propelled road vehicles – Terminology*
Component	IEC 61894	*Preferred sizes and voltages of battery monoblocs for electric vehicle applications*
Component	IEC 61980 series	*Electric vehicle wireless power transfer systems (WPT)*
Component	IEC 61982 series	*Secondary batteries (except lithium) for the propulsion of electric road vehicles – Performance and endurance tests*
Component	IEC 62196 series	*Plugs, socket-outlets, vehicle couplers and vehicle inlets – Conductive charging of electric vehicles*
Component	ISO 6469	*Electrically propelled road vehicles – Safety specifications*
Other specifications		
Component	SAE J standards	*J2836 (use cases), J2847 (requirements), and J2931 (protocol) to address: Utility programs, DC Charging, Reverse power flow, Diagnostics, Customer to PEV and HAN, and wireless power flow.*
Information, Communication	IEEE 2030.5	*Smart Energy Profile 2.0*
Information, Communication	OCPP	*Open Charge Point Protocol.*

NOTE Standards related to clock management, safety, or EMC are mentioned in further dedicated subclauses.

5.9.16.3.2 Coming standards

See Table 63. Refer to 5.2.5.3 for the definition of the criteria considered in this document for stating that a standard is “coming”.

Table 63 – E-mobility system – Coming standards

Layer	Standard	Title and comments
Component	IEC 60364-7-722	*Low-voltage electrical installations – Part 7-722: Requirements for special installations or locations – Supplies for electric vehicles*

5.9.16.4 Gaps

- Determination of data model, protocol, etc. in ISO/TC 22/SC 31 (ISO 15118-1, -2 and -3).
- Matching of these data models with information models of IEC TC 57.
- Inclusion and harmonization with IEC 61850 and IEC 61968 series and relevant standards of other SDOs, if any.
- Finalize IEC 61851 series for preferred plug and socket option (1/3-phase, 400 V, 63 A) within IEC 62192-2.

5.9.16.5 E-mobility system mapping

5.9.16.5.1 Preamble

There are many different cases in which E-mobility systems may be architectured, and also many possibilities for having such systems interfaced to the Grid (operator, supplier, E-mobility service provider). Figure 55 to Figure 57 are just here to depict possible usages of the considered standards.

5.9.16.5.2 Component layer

The E-mobility system component architecture may be interfaced following Figure 55.

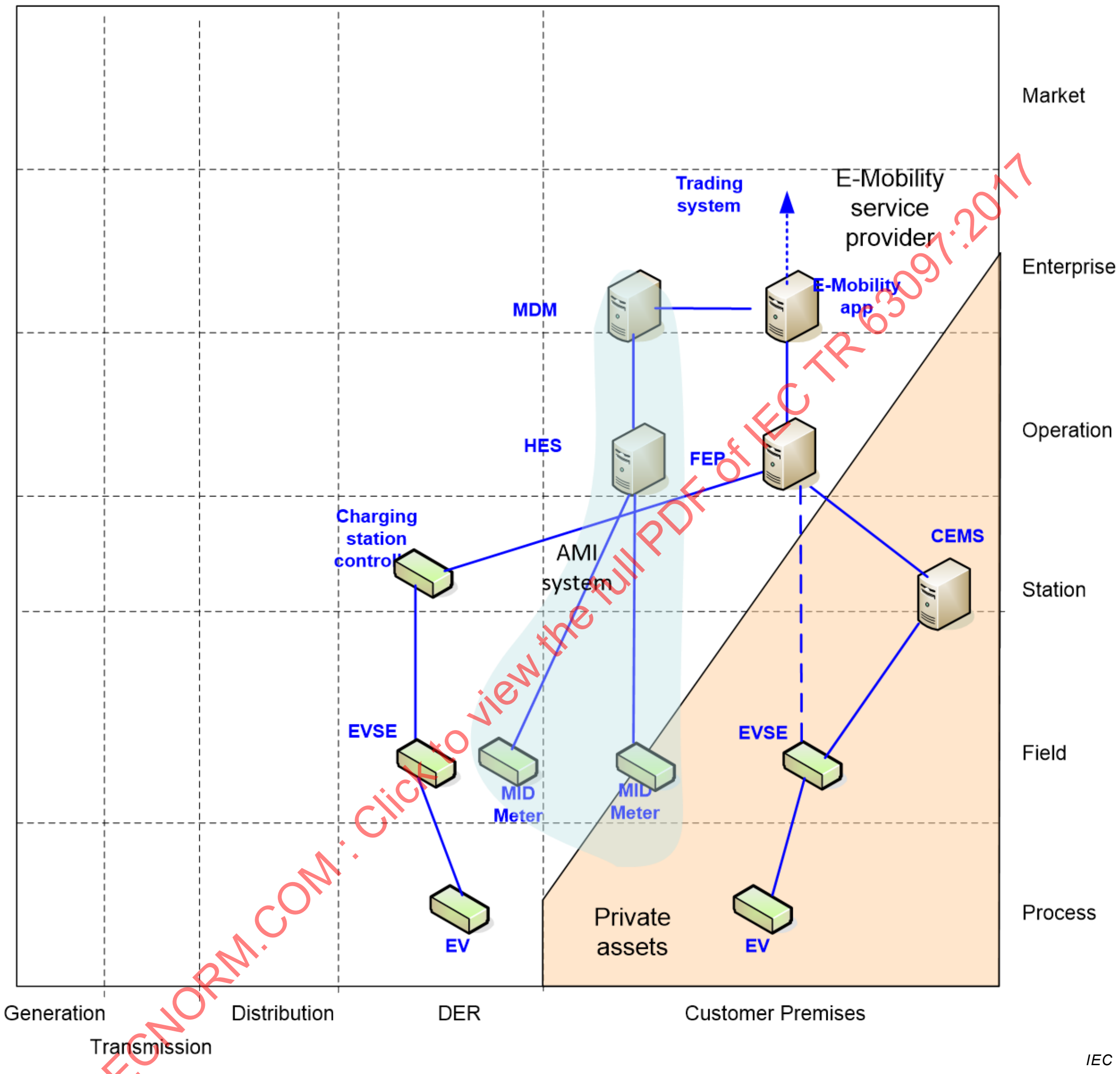


Figure 55 – E-mobility system (example) – Component layer

5.9.16.5.3 Communication layer

Refer to 5.10.4 for details on cyber-security standards and more specifically on where and how to apply the IEC 62351 series and/or other cyber-security mechanisms.

This set of standards can be positioned on the communication layer of SGAM as shown in Figure 56.

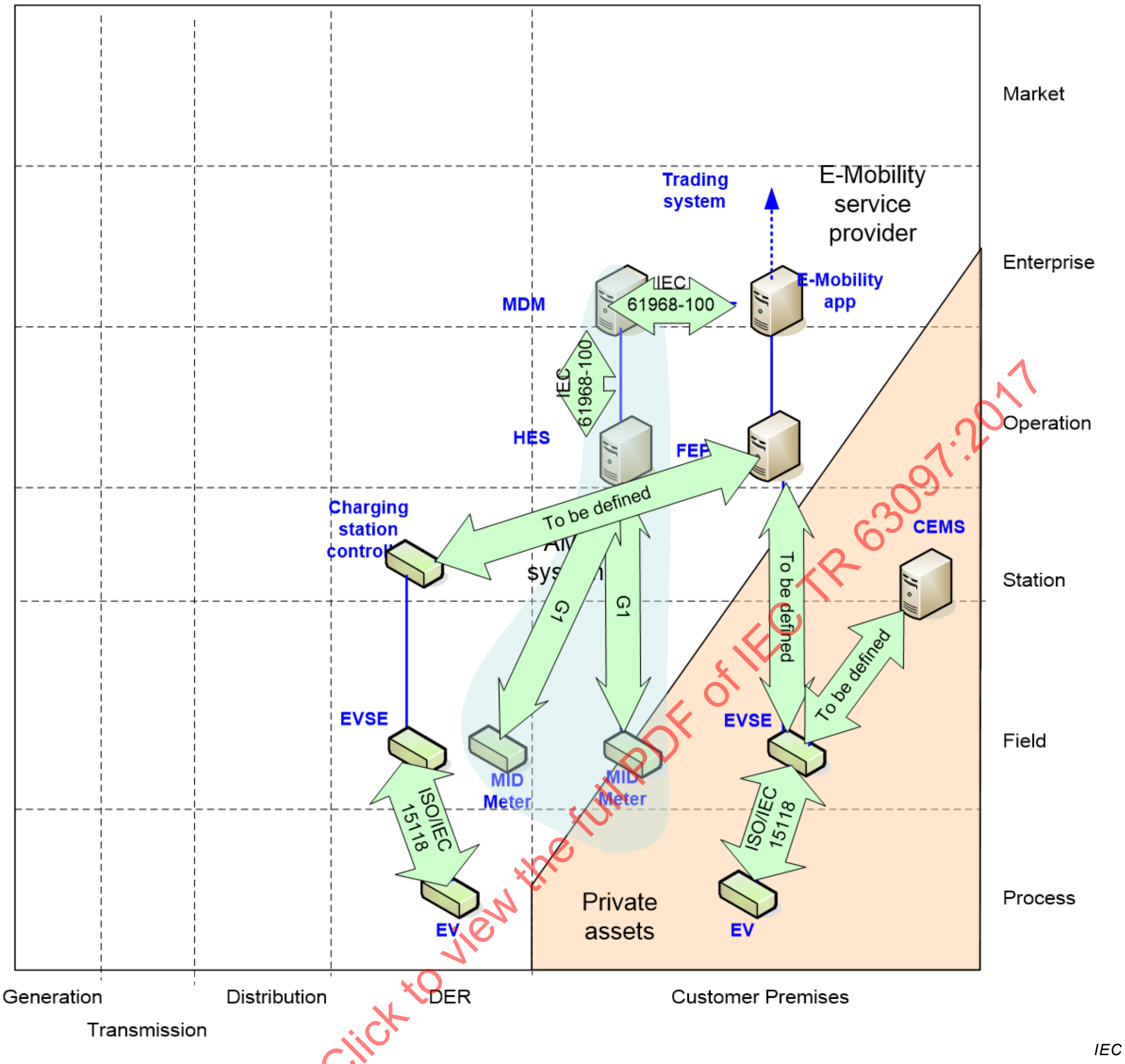


Figure 56 – E-mobility system (example) – Communication layer

5.9.16.5.4 Information (Data) layer

See Figure 57.

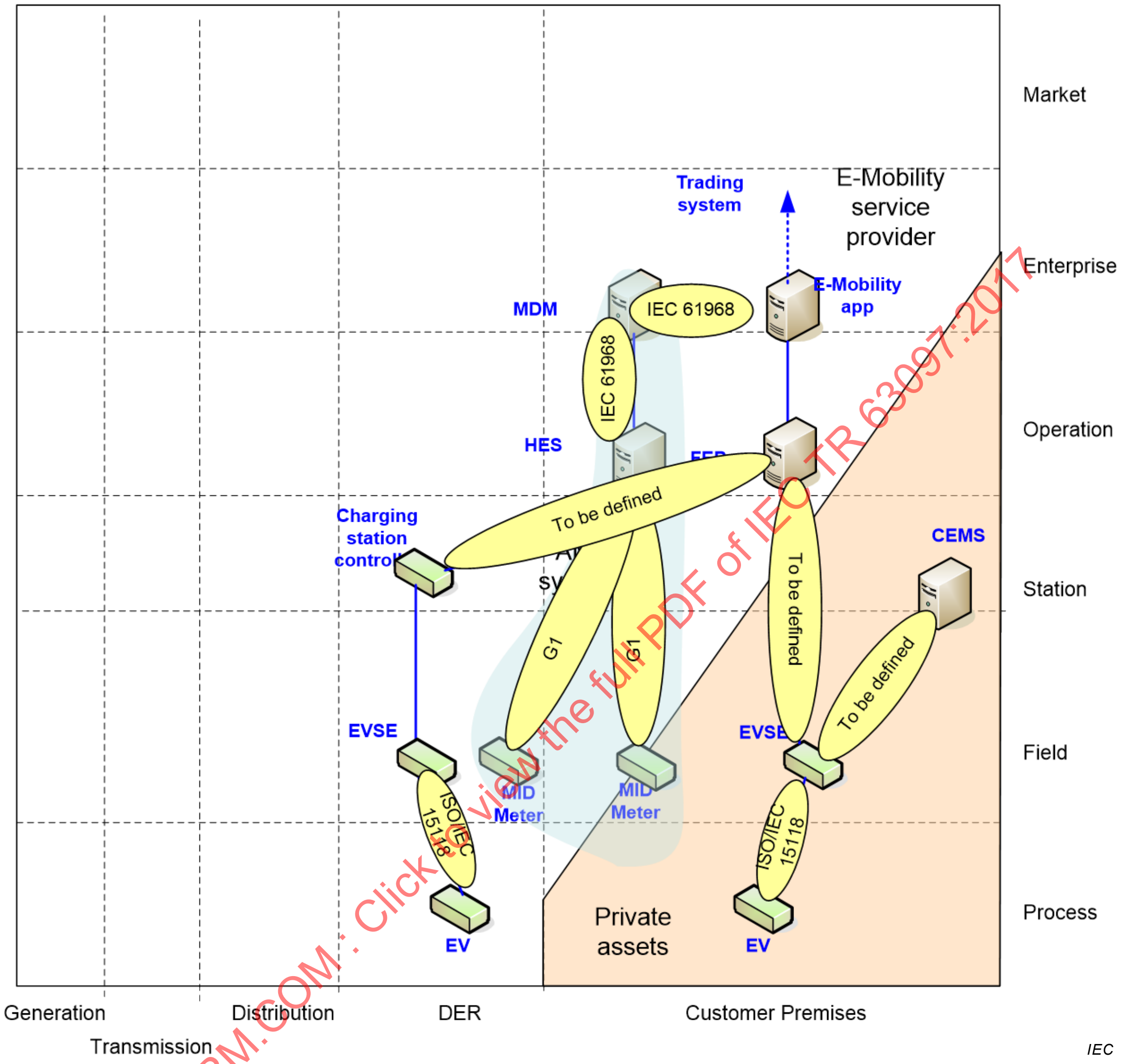


Figure 57 – E-mobility system (example) – Information layer

5.9.17 Assets management and condition monitoring system

5.9.17.1 Description

The power grid faces a number of challenges: in view of the steadily growing demand for energy, network capacities need to be expanded, availability improved, and congestion and outages avoided. All this needs to be performed in the most cost-efficient way possible, in consuming as little as possible of CAPEX (capital expenditure) then taking maximum benefits of already installed assets, and in consuming as little as possible of OPEX (operational expenditure). This means extending average life cycles and minimizing maintenance costs.

The Smart Grid vision therefore includes solutions like Condition Monitoring in order to make full use of existing infrastructure. Condition Monitoring provides all the technical information required to maintain availability and at the same time maximize performance, including loading and lifetime benefits. The Condition Monitoring solution surveys every link in the energy supply chain. Accurate monitoring of all primary components of a substation makes optimized loading and performance possible and helps to increase the lifetime of the line.

Additionally Condition Monitoring systems contribute to network optimization down to each element in terms of efficiency and reliability. It provides valuable information and reliable diagnostics. Failures can be predicted, unscheduled downtime is thus reduced, and equipment life is extended to a significant degree. This feature is called condition-based maintenance. In addition, capacity data analysis can provide recommendations on how to maximize asset performance and can lever existing overloading capabilities, especially of transformers and overhead lines. This optimizes grid operation and grid asset management.

Assets management and Condition Monitoring System includes the following elements.

- Transformer Monitoring: The main components monitored are cooling, bushings, tap changer and oil quality.
- GIS Monitoring: The main parameters for GIS monitoring are SF6 pressure, density and partial discharge.
- Circuit Breaker Monitoring: In order to monitor the performance of the circuit breaker, key parameters, such as the contact separation speed and the operation time of the circuit breaker, need to be recorded. This can be achieved by a range of transducers providing signal input. The signals need to be digitized at a frequency that provides sufficient sample points to allow accurate and early assessment of a developing problem.
- Isolator- and Earthing-Switch Monitoring.
- Overhead Line Monitoring: The main parameters are OHL tension and ampacity.
- Cable Monitoring: Assessment of an installed cable can be achieved, for example, through the line impedance phase shift and the hot-spot detector signature. The first indicator is used both for local and global aging assessment. For local fault detection, the two indicators work together, where the phase shift is used as a real-time early warning of a developing fault and the hot-spot detector quantifies and localizes the fault along the cable.
- Surge Arrester Monitoring.
- Current Transformer and Voltage Transformer Monitoring.
- Balance of Plant Monitoring: Monitoring of supplementary BoP equipment, especially batteries and diesel engines.
- Secondary Equipment Monitoring.
- Predictive diagnoses and prognoses.

Unlike “islanded”, individual condition monitoring systems for each asset, which have already been available on the market for some time, advanced Condition Monitoring makes a combination of individual modules possible on a common communication platform.

5.9.17.2 System summary

Condition Monitoring Management system refers to the information system and all the elements needed to support the team in charge of managing the system assets along its total lifecycle. It is used to help maximize the value of the related assets over their lifecycles, and help prepare future plans (long-term planning, mid-term optimization, extension, refurbishment) and also the associated maintenance work.

Such a system is usually made of one or many interconnected IT systems, possibly connected to field communicating devices or sub-systems, through the use of LAN/WAN communication systems.

The Application covers the different business processes containing the different maintenance methods (corrective, periodic and condition based) and maintenance models of related assets.

Asset and maintenance management systems are used in the Generation, Transmission, Distribution and DER domain.

5.9.17.3 Set of System Capabilities

The System Capabilities in Table 64 might be supported by an asset and maintenance management system.

The meanings of the three last columns (AVAILABLE, COMING, Not yet) and of the “C”, “I”, “CI”, “X” conventions are given in 5.5.2.5.

Table 64 – Assets management and Condition Monitoring System – Capabilities

Cluster	System Capabilities	Supported by standards		
		AVAILABLE	COMING	Not yet
Monitoring the grid flows	Producing, exposing and logging time-stamped events	CI		
Maintaining grid assets	Monitoring assets conditions	C	CI	I
	Supporting periodic maintenance (and planning)	CI	C	I
	Optimize field crew operation	C	C	I
	Archive maintenance information	CI	C	I
System and security management	Discover a new component in the system		C	I
	Distributing and synchronizing clocks	CI		

NOTE For some domains, standards are already available or under development (i.e. Distribution) while for other domains standards are under development or are not yet available (i.e. Transmission, DER).

5.9.17.4 Requirements

Measuring and testing procedures have to be available for all components.

The main requirement is uniform data models for the individual components. These data have to be transported through common communication channels.

Calculation models for predictive diagnosis have to be standardized to allow for uniform diagnosis across an environment, which is characterized by multi-vendor equipment.

5.9.17.5 List of standards

5.9.17.5.1 General

Here is the summary of the standards which appear relevant to transmission asset management systems:

5.9.17.5.2 Available standards

See Table 65. Refer to 5.2.5.3 for the definition of the criteria considered in this document for stating that a standard is “available”.

Table 65 – Assets management and Condition Monitoring System – Available standards

Layer	Standard	Title and comments
Information	IEC 61360	*Common Data Dictionary* available from <http://std.iec.ch/iec61360>
Information	IEC TR 61850-90-3	*Communication networks and systems for power utility automation – Part 90-3: Using IEC 61850 for condition monitoring diagnosis and analysis*
Information	IEC TS 61850-80-1	*Communication networks and systems for power utility automation – Part 80-1: Guideline to exchanging information from a CDC-based data model using IEC 60870-5-101 or IEC 60870-5-104*
Communication, information	IEC TR 61850-90-2	*Communication networks and systems for power utility automation – Part 90-2: Using IEC 61850 for the communication between substations and control centres*
Information, communication	IEC 61400-25 series	*Wind turbines – Communications for monitoring and control of wind power plants*
Information	IEC 61968-4	*Application integration at electric utilities – System interfaces for distribution management – Part 4: Interfaces for records and asset management*
Information	IEC 61968 series	*Application integration at electric utilities – System interfaces for distribution management* CIM Distribution
Information	IEC 61968-6	*Application integration at electric utilities – System interfaces for distribution management – Part 6: Interfaces for maintenance and construction*
Information	IEC 61970 series	*Energy management system application program interface (EMS-API)* CIM Transmission
Communication	IEC 61850-8-1	*Communication networks and systems for power utility automation – Part 8-1: Specific communication service mapping (SCSM) – Mappings to MMS (ISO 9506-1 and ISO 9506-2) and to ISO/IEC 8802-3* IEC 61850 communication except Sample values
Communication	IEC 60870-5-101	*Telecontrol equipment and systems – Part 5-101: Transmission protocols – Companion standard for basic telecontrol tasks*
Communication	IEC 60870-5-104	*Telecontrol equipment and systems – Part 5-104: Transmission protocols – Network access for IEC 60870-5-101 using standard transport profiles*
Communication	IEC 61968-100	*Application integration at electric utilities – System interfaces for distribution management – Part 100: Implementation profiles* Defines profiles for the communication of CIM messages using Web Services or Java Messaging System.
Component	IEC 60076 series	*Power transformers*
Component	IEC 62271-1 series	*High-voltage switchgear and controlgear*
Component	IEC 62271-2 series	*High-voltage switchgear and controlgear* assemblies
Component	IEC 61897	*Overhead lines – Requirements and tests for Stockbridge type aeolian vibration dampers*

5.9.17.5.3 Coming standards

See Table 66. Refer to 5.2.5.3 for the definition of the criteria considered in this document for stating that a standard is “coming”.

Table 66 – Assets management and Condition Monitoring System – Coming standards

Layer	Standard	Title and comments
Information, communication	IEC 61400-25 series	*Wind turbines – Communications for monitoring and control of wind power plants* Edition 2 – Set of standards more specific to wind turbines and wind farms
Communication	IEC 61850-8-2 [a]	*Communication networks and systems for power utility automation – Part 8-2: Specific communication service mapping (SCSM) – Mapping to Extensible Messaging Presence Protocol (XMPP)* IEC 61850 communication mapping on Web-services
[a] Under preparation.		

5.9.17.6 Gaps

There are no standards or guides for diagnosis and prediction models.

There are no standard ways for identifying equipment nameplates, and their components.

5.9.17.7 Assets management and Condition Monitoring System mapping

5.9.17.7.1 Preamble

A single entity of an Asset and maintenance management system is shown as an overlay that can be applied to the specific domains. It should be noted that the specific standards especially at the information layer may be different for the different domains.

The Asset Management System interacts with the domain management and operation systems (e.g. EMS, DMS), GIS and SCADA systems. Condition monitoring and field force management is shown as part of the Asset Management System with the related interaction with the field components.

Most information regarding maintenance and condition of components is captured by the field force workers and the laptops they use in the field. Detailed condition assessment (information) models of assets are not (yet) available in standards.

Generation distinctive feature: an important part of condition monitoring is related to rotating machines vibration monitoring. Appropriate information and communication solutions are different than those that are used for control, monitoring and common condition monitoring. The existing standard IEC 61400-25-6 is an excellent example of the possibility to use existing wind turbines control and monitoring solutions to support common condition monitoring, but of the necessity to extend these solutions to fully support wind turbines condition monitoring. The same reasoning is applicable to the generation using other fuels.

The consequence is that components dedicated to condition monitoring may coexist in parallel with control and monitoring components down to the Field zone.

5.9.17.7.2 Component layer

The Asset Management component architecture ranges from the process to the Enterprise zone as shown in Figure 58.

- At the Enterprise zone the Asset Management system itself is located.
- At the Operation zone the Condition Monitoring systems are located.

- The Station and Field zones provide the communication with the sensors that monitor the assets and with the field force.
- The assets are located at the Process zone.

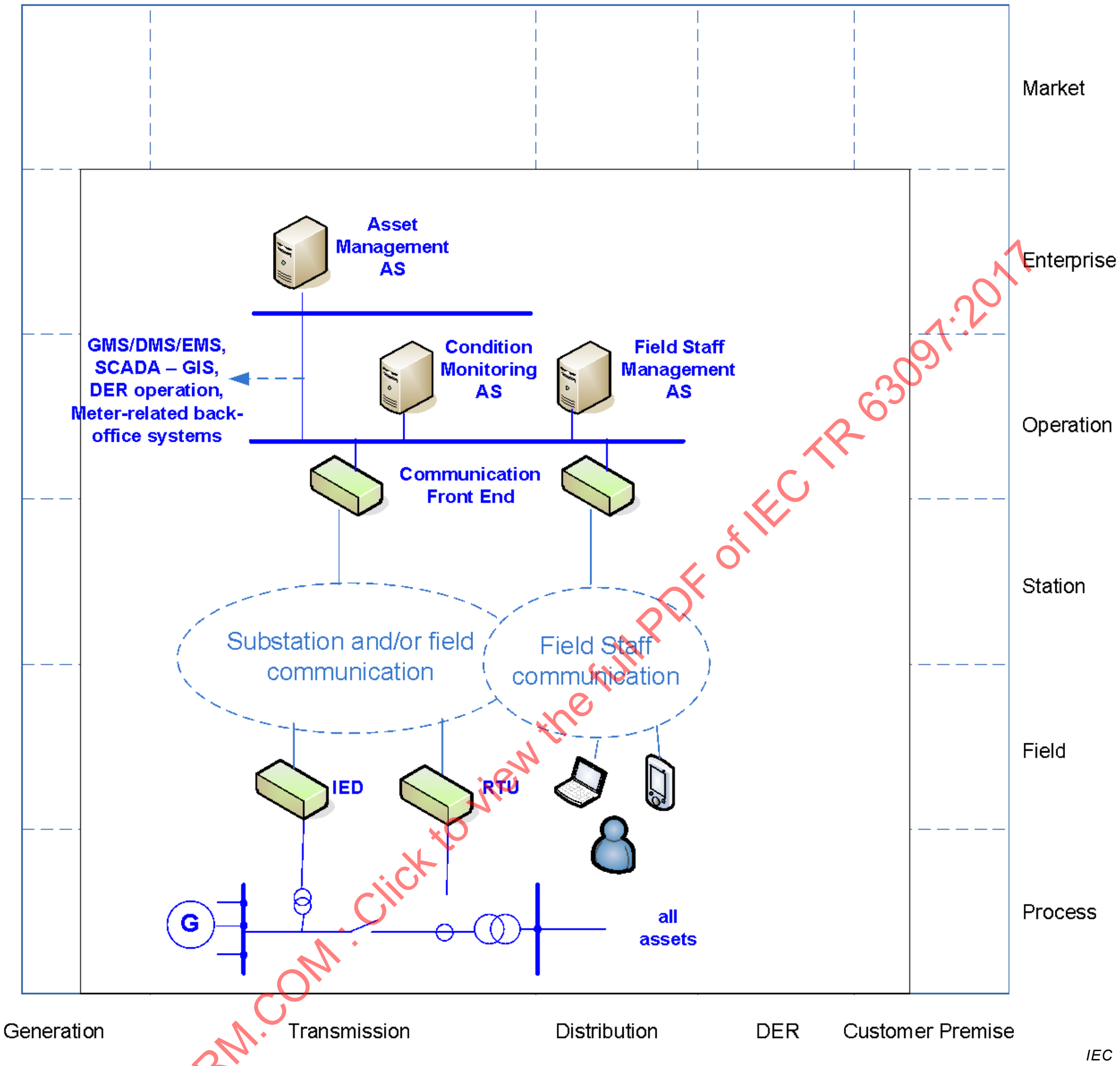
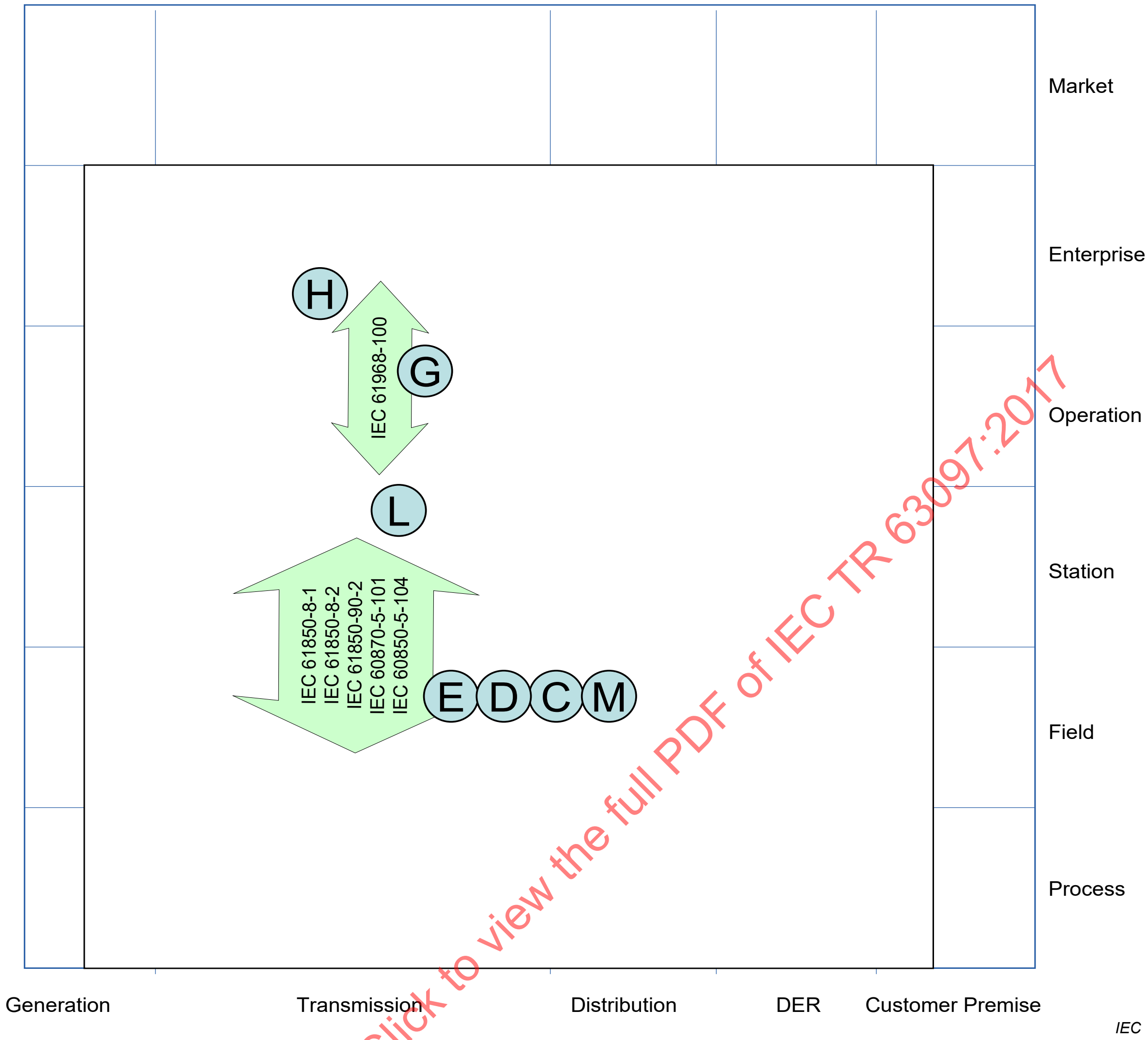


Figure 58 – Assets management and Condition Monitoring System – Component layer

5.9.17.7.3 Communication layer

See Figure 59. The communication between the field, station and operations is done via IEC 61850 or through IEC 60870-5-101 or IEC 60870-5-104. For the enterprise bus communication between the operation and enterprise zone components, the coming standard IEC 61968-100 is used. Note that IEC 61968-100 is defined for the IEC 61968 series information models, but the same web services approach can be applied to the IEC 61970 information models. For field force communication the substation to operations communication infrastructure and dedicated networks (e.g. mobile networks) can be used.



NOTE The letters in the blue disks refer to the network types defined in 5.10.1.2.

Figure 59 – Assets management and Condition Monitoring System – Communication layer

5.9.17.7.4 Information (Data) layer

For the condition monitoring information exchange between the field/station and operations zone the coming standard IEC TR 61850-90-3 will be used. IEC 61968 and IEC 61970 standards in general apply for providing asset management related information. Specifically IEC 61698-4 and the coming standard IEC 61968-6 define CIM interfaces for asset and maintenance management for the distribution domain. For the other domains no specific asset and maintenance management standards exist.

Figure 60 sums up the relevant standards on the SGAM.

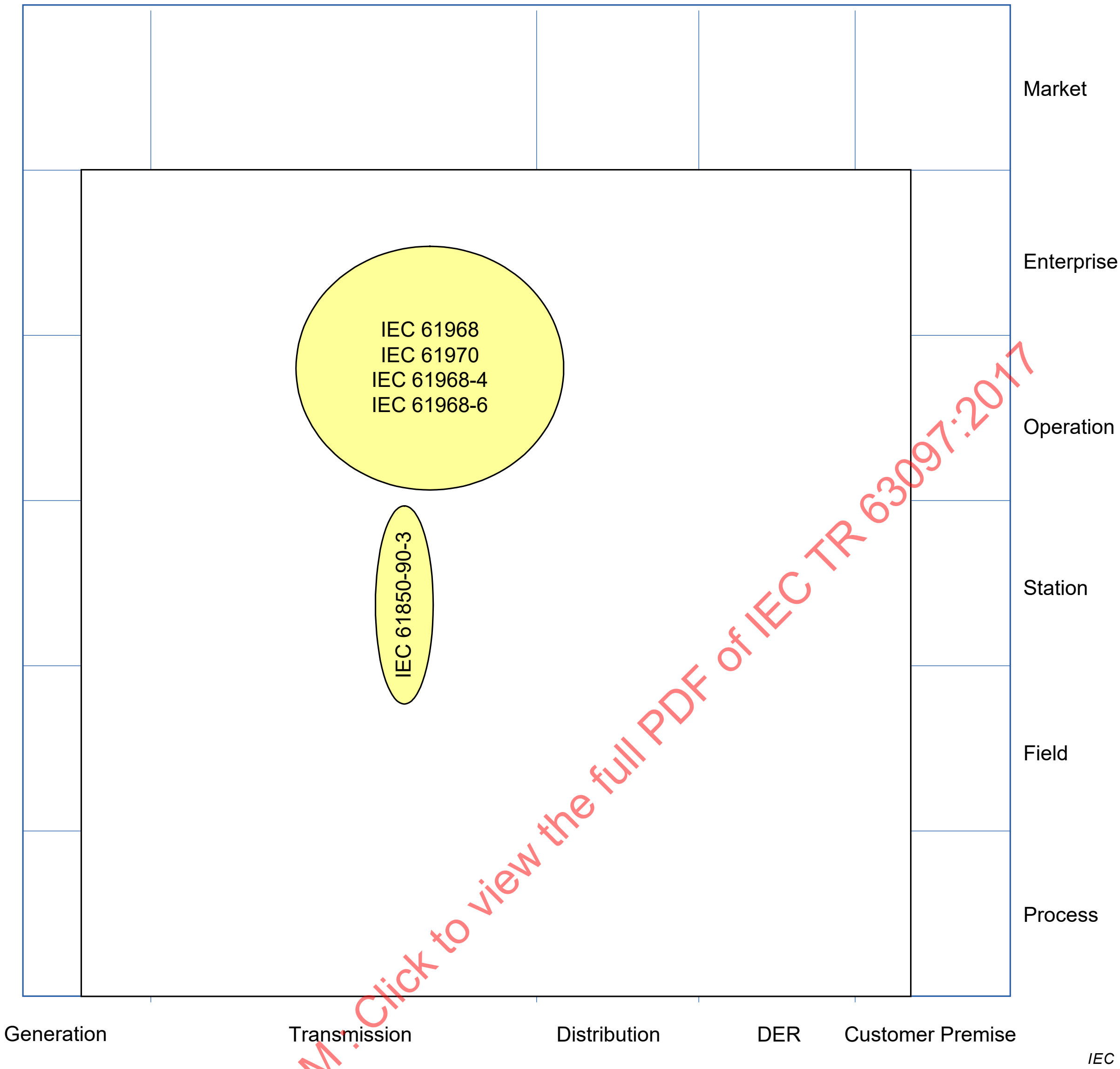


Figure 60 – Assets management and Condition Monitoring System – Information layer

5.9.18 Weather forecast system

5.9.18.1 Description – System summary

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 all connected other systems such as Distribution management systems, Transmission management systems, DER/Generation management systems, EMS or VPPs systems for DER, etc. enabling in many cases optimized decision processes or automation.

It generally comprises a secured IT system, usually relying on an SOA infrastructure, possibly interconnected to international weather observation and/or connected to a number of weather sensors.

5.9.18.2 Set of System Capabilities

5.9.18.2.1 General

A weather forecast system is generally capable of providing forecast updates, in a solicited or unsolicited manner, such as:

a) general atmospheric forecast;

b) watches/warnings (future).

In addition, it may also provide weather observations which can be solicited or unsolicited, and may or will cover information such as:

- observed lightning (future);
- current conditions;
- storm approaching data (future) such as:
  - precipitation timer;
  - future lightning (currently US only);
  - storm corridors (currently US only).

Consequently Table 67 provides the list of System Capabilities possibly supported by a weather forecast and observation system.

The meanings of the three last columns (AVAILABLE, COMING, Not yet) and of the “C”, “I”, “CI”, “X” conventions are given in 5.5.2.5.

Table 67 – Weather forecast and observation system – Capabilities

Cluster	System Capabilities	Supported by standards		
		AVAILABLE	COMING	Not yet
Demand and production (generation) flexibility	Load forecasting	I		
Weather condition forecasting and observation	Wind forecasting	C	I	
	Solar forecasting	I		
	Temperature forecasting	I		
	Providing weather observations	I	I	
	Situational alerting		X	

5.9.18.2.2 Available standards

See Table 68. Refer to 5.2.5.3 for the definition of the criteria considered in this document for stating that a standard is “available”.

Web service related standards are described in 5.10.1.4.

Table 68 – Weather forecast and observation system – Available standards

Layer	Standard	Comments
Communication	ISO 19142	OpenGIS Web Feature Service 2.0 Interface Standard
Information	NCAR WXXM	Weather Exchange Model. The release V1.1 seems appropriate https://wiki.ucar.edu/display/NNEWD/WXXM
Information	WMO METCE	WMO (World Meteorological Organization) METCE (Weather Water and Climate exchange) .

5.9.18.2.3 Coming standards

See Table 69. Refer to 5.2.5.3 for the definition of the criteria considered in this document for stating that a standard is "coming".

Table 69 – Weather forecast and observation system – Coming standards

Layer	Standard	Comments
Information	IEC 61968-9	*Application integration at electric utilities – System interfaces for distribution management – Part 9: Interfaces for meter reading and control* Weather observation and forecast extensions, in CIM
Information	NCAR WXXM	Weather Exchange Model. Next release.
Information	WMO IWXXM	WMO (World Meteorological Organization) ICAO Meteorological Information Exchange Model

NOTE IEC TC 57 has also engaged a work to extend CIM to include an "Environmental Data" model.

5.9.18.3 Weather forecast system mapping

5.9.18.3.1 Preamble

A weather forecast system is not really attached to any SGAM domains or zones, so its mapping over SGAM is not providing real value.

However breaking down such a system using the SGAM layers is useful:

5.9.18.3.2 Component layer

A weather forecast system mostly acts as a server as shown in Figure 61. The clients of the weather forecast services are any type of Smart Grids system already described above.

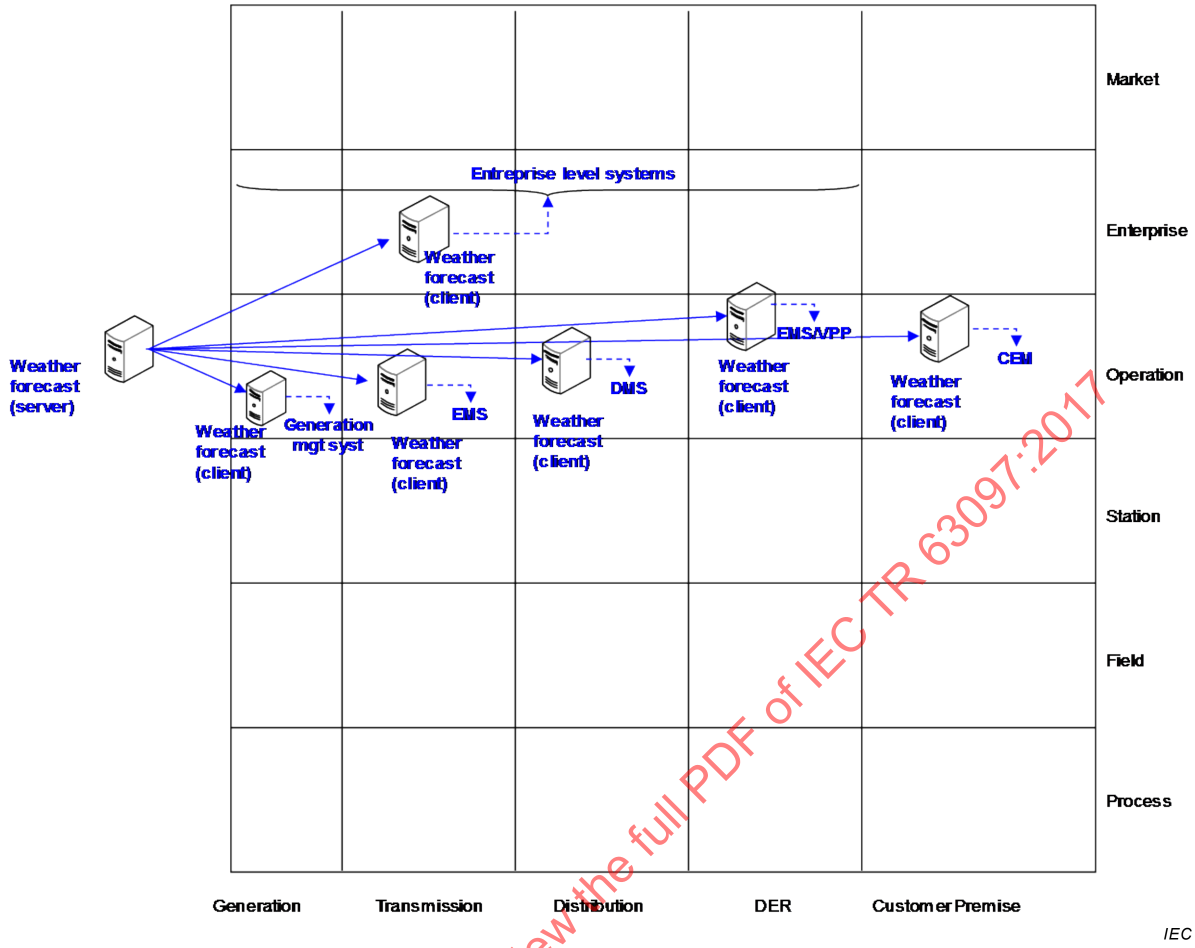
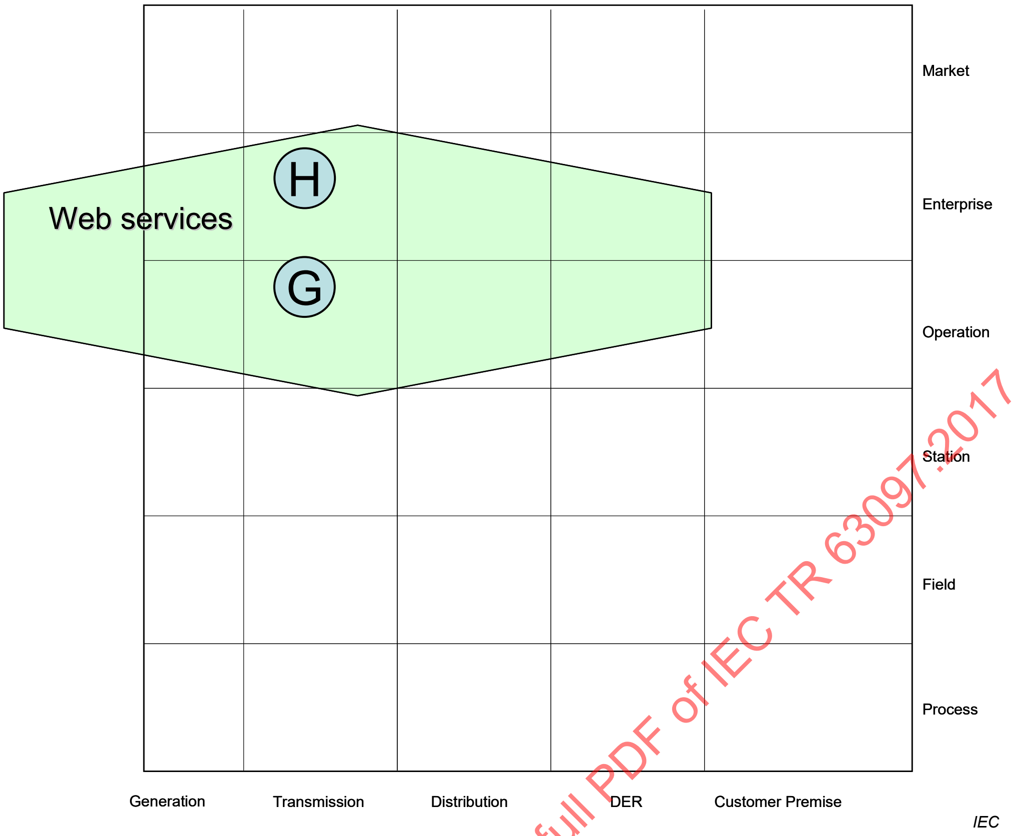


Figure 61 – Weather forecast and observation system – Component layer

5.9.18.3.3 Communication layer

See Figure 62. The most common communication protocol used for handling exchange with a weather forecast system for a request/response based service is web services (refer to 5.10.1.4 for further details).

Supporting subscribe and publish service for unsolicited data may request to get a network connection available from registration to receiving the data.



NOTE The letters in the blue disks refer to the network types defined in 5.10.1.2.

Figure 62 – Weather forecast and observation system – Communication layer

5.9.18.3.4 Information (Data) layer

Even if not perfect, WXXM 1.1 XML interface standard provides a good basis as shown in Figure 63, GML inheritance may not be needed and some data types may be lacking.

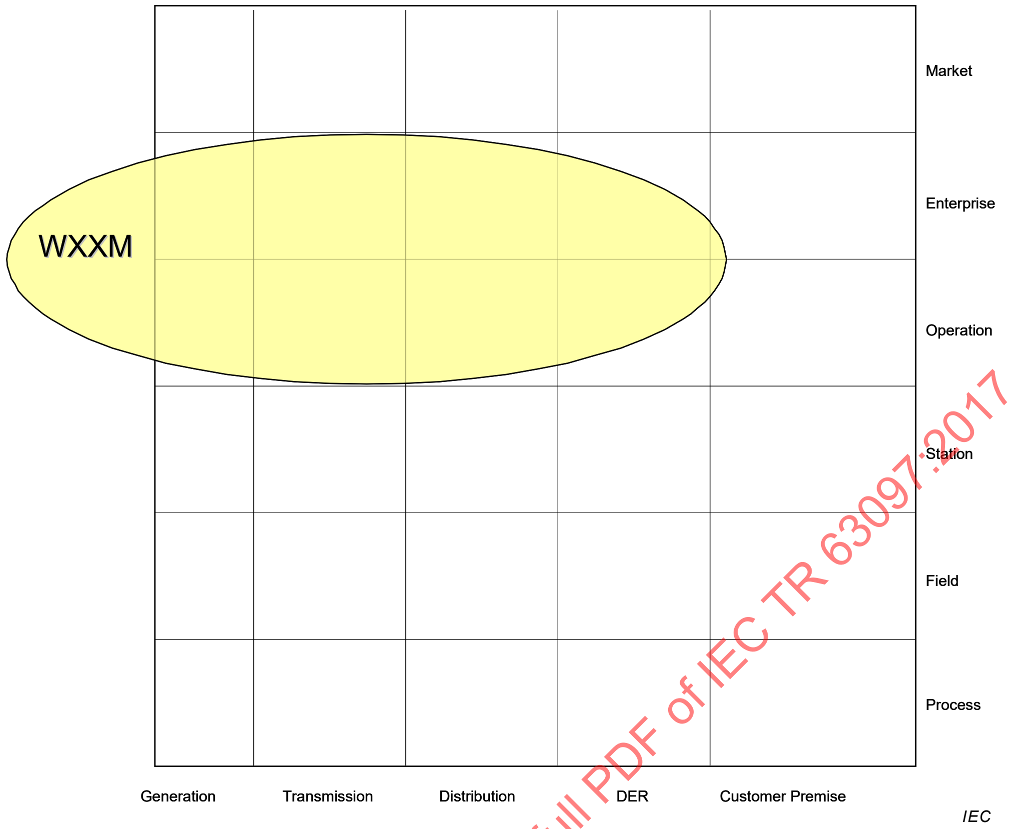


Figure 63 – Weather forecast and observation system – Information layer

In the future, Extended WXXM or WMO METCE by adding a Smart Grid (SG) Weather Exchange Model Extension may be considered. The use of the SG Weather Exchange Model Extension will enable the geospatial aspect of the data and provide area capabilities rather than just point.

Business rules that need to be taken into consideration include but are not limited to the following.

- Data elements have to be optional and not required to allow businesses to entitle users with different combinations of data elements. The data elements have also to be able to be specified in the request and meta-data provided about units of measure and other supporting request information.
- Multiple locations may be requested and returned.
- Request modifiers have to be defined to allow selection of datasets to be queried. If this does not fit in to the extension then a request schema has to be created. Currently the schema defines the request as well as the response.

5.9.19 Micro-grid systems

5.9.19.1 Description

Within the context of the IEC roadmap a micro-grid is defined as follows:

"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 to enable it to operate in both grid connected or island mode."

Based on local DERs and micro-grid primary devices, a micro-grid system needs to maintain its stability, voltage, frequency and reliability.

While in the grid connected mode, a micro-grid system may interface to an EMS or DMS to perform various grid support functions such as:

a) Peak Management;
b) Responsive Reserves;
c) Ancillary Services;
d) Grid Voltage Support (VARS);
e) Backup Emergency Power.

While in the island mode, a micro-grid system may be called on to perform the following functions:

1) Islanding on requests;
2) Islanding on emergency;
3) Grid Synchronizing and (re-) Connection;
4) Balancing Supply and Demand;
5) Black Start in islanding mode;
6) Network Configuration;
7) Active/Reactive Power Compensation/Voltage Control;
8) Economic Dispatch;
9) Load Control.

From a domain perspective, micro-grids may cover three main domains: Distribution, DER and Customer premises, and then encompass systems from these same domains. Figure 64 outlines the components, subsystems, and interfaces which make up a micro-grid system. With these interfaces defined, a set of standards can be identified.

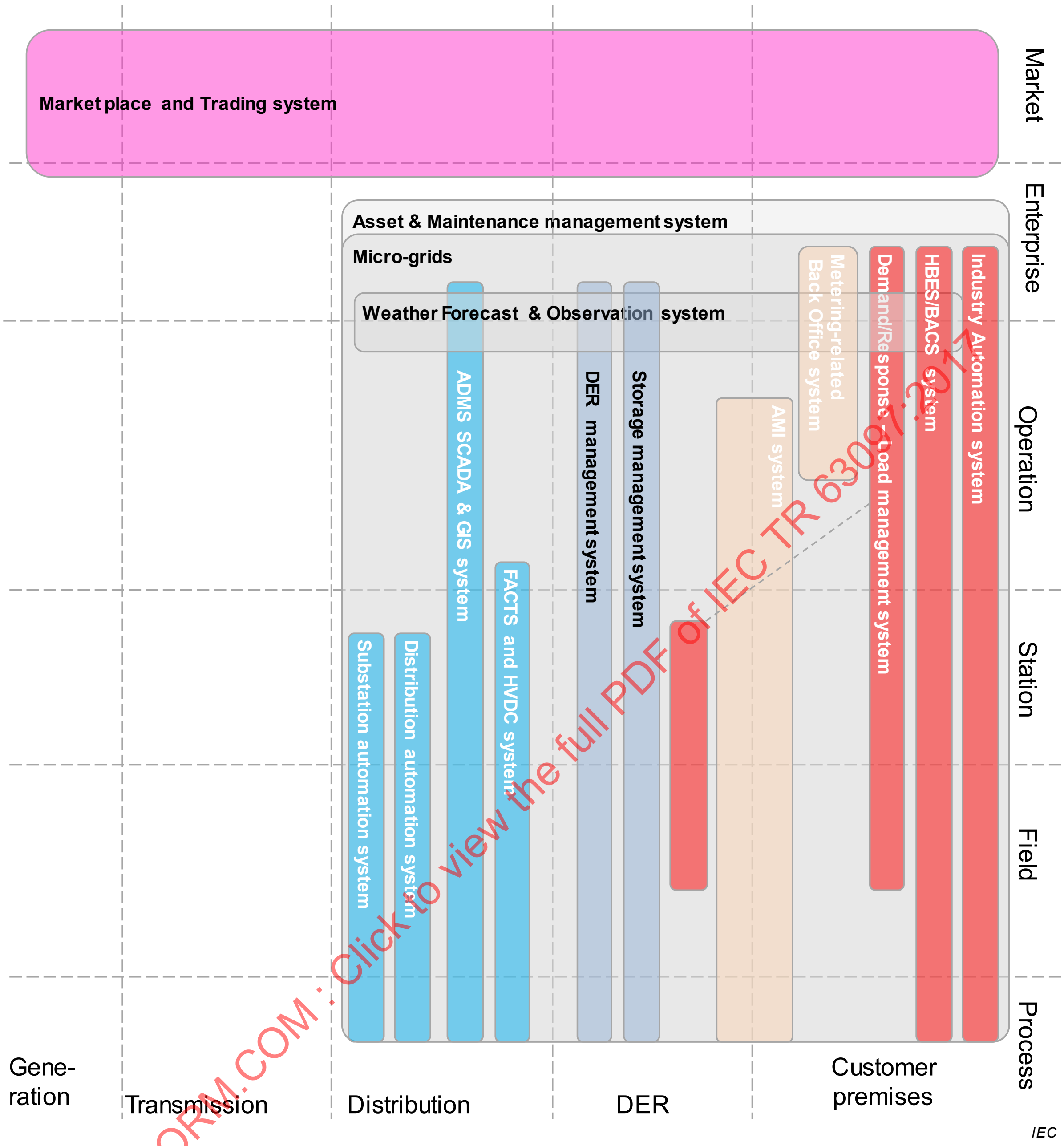


Figure 64 – Micro-grids – possible domains and systems breakdown

5.9.19.2 System summary

A micro-grid system refers to the real-time information system and all the elements needed to support all the relevant operational activities and functions needed to run a micro-grid. It improves the information made available to operators at control room, as well as to micro-grid users. It improves the overall efficiency of operation of the micro-grid, and it may optimize the use of related assets.

Such a system is usually made of one or many interconnected IT systems, connected to field communicating devices or sub-systems, through the use of communication systems. It may also include the components needed to enable field crew to operate the micro-grid from the field.

A micro-grid system provides the following major functions:

- SCADA, real time monitoring and control of the micro-grid;

- capabilities to distribute electricity to any micro-grid users;
- capabilities to protect and maintain the related micro-grid assets;
- automation capabilities to ensure balance of demand and supply;
- automation capabilities to handle islanding, connection and disconnection.

It may also include “commercial related activities”, and then may also include:

- trading capabilities;
- electricity supply and associated metering-related back office capabilities.

5.9.19.3 Set of System Capabilities

Table 70 provides a set of System Capabilities which may be supported by an industrial automation system.

The meanings of the three last columns (AVAILABLE, COMING, Not yet) and of the “C”, “I”, “CI”, “X” conventions are given in 5.5.2.5.

Table 70 – Industrial automation system – Capabilities

Cluster	System Capabilities	Supported by standards		
		AVAILABLE	COMING	Not yet
Handling Micro-grid scenarios	Islanding on requests	C		I
	Islanding on emergency	C		I
	Grid Synchronizing and (re-)Connection	C		I
	Balancing Supply and Demand	C		I
	Black Start in islanding mode	C		I

5.9.19.4 Specific requirements

5.9.19.5 Standards context

5.9.19.5.1 Available standards

Refer to 5.2.5.3 for the definition of the criteria considered in this document for stating that a standard is “available”.

Web service related standards are described in 5.10.1.4.

Rather than duplicating lists of standards, reference is made to the corresponding systems which can be included in a micro-grid (see Table 71).

Table 71 – Micro-grid systems – Available standards

Layer	Standard	Comments
Information, Communication	(refer to 5.9.5.5)	refer to the ADMS systems depicted in 5.9.5
Information, Communication	(refer to 5.9.6.4)	refer to Distribution Automation systems depicted in 5.9.6
Information, Communication	(refer to 5.9.7.5)	refer to Substation Automation systems depicted in 5.9.7
Information, Communication	(refer to 5.9.8.6)	refer to the DER system depicted in 5.9.8
Information, Communication	(refer to 5.9.10.5)	refer to the AMI system depicted in 5.9.9
Information, Communication	(refer to 5.9.11.4)	refer to Metering related back office systems depicted in 5.9.11
Information, Communication	(refer to 5.9.13.5)	refer to the DR management systems depicted in 5.9.13
Information, Communication	(refer to 5.9.14.5)	refer to Smart Home and Building systems depicted in 5.9.14
Information, Communication	(refer to 5.9.15.5)	refer to Industrial Automation systems depicted in 5.9.15
Information, Communication	(refer 5.9.9)	refer to Electrical Energy Storage management systems depicted in 5.9.9
Information, Communication	(refer to 5.9.16.3)	refer to E-mobility systems depicted in 5.9.16
Information, Communication	(refer to 5.9.17)	refer to Assets management systems depicted in 5.9.17
Information, Communication	(refer to 5.9.18)	refer to Weather forecast systems depicted in 5.9.18

5.9.19.5.2 Coming standards

See Table 72. Refer to 5.2.5.3 for the definition of the criteria considered in this document for stating that a standard is “coming”.

Table 72 – Micro-grid systems – Coming standards

Layer	Standard	Comments
Information, Communication	(refer to 5.9.5.5)	refer to the ADMS systems depicted in 5.9.5
Information, Communication	(refer to 5.9.6.4)	refer to Distribution Automation systems depicted in 5.9.6
Information, Communication	(refer to 5.9.7.5)	refer to Substation Automation systems depicted in 5.9.7
Information, Communication	(refer to 5.9.8.6)	refer to the DER system depicted in 5.9.8
Information, Communication	(refer to 5.9.10.5)	refer to the AMI system depicted in 5.9.9
Information, Communication	(refer to 5.9.11.4)	refer to Metering-related back office systems depicted in 5.9.11
Information, Communication	(refer to 5.9.13.5)	refer to the DR management systems depicted in 5.9.13
Information, Communication	(refer to 5.9.14.5)	refer to Smart Home and Building systems depicted in 5.9.14
Information, Communication	(refer to 5.9.15.5)	refer to Industrial Automation systems depicted in 5.9.15
Information, Communication	(refer 5.9.9)	refer to Electrical Energy Storage management systems depicted in 5.9.9
Information, Communication	(refer to 5.9.16.3)	refer to E-mobility systems depicted in 5.9.16
Information, Communication	(refer to 5.9.17)	refer to Assets management systems depicted in 5.9.17
Information, Communication	(refer to 5.9.18)	refer to Weather forecast systems depicted in 5.9.18

5.9.19.6 Gaps

The IEC and other SDOs as well as industry associations have identified the following gaps.

a) Demand response – Focus on an extended field and station zone data modelling standard (part of IEC 61850) to support demand response, DER, VPP and home/building/industry automation and unified languages for tariff information for demand response (refer to 5.9.13).

b) CIM and IEC 61850 – Focus on giving high priority to the works needed in the area of harmonization of CIM and IEC 61850, supporting electronic form of IEC 61850 data model at IEC level based on UML language (refer to 5.10.3).

c) Web Services – Focus on standard communication technology to be used either within back office systems (such as monitoring and control centres) or field systems (such as feeder automation or integration of distributed Energy Resources or active customers) (refer to 5.10.1).

d) Connecting DERs to Grid – Focus on the harmonization/adaptation of the electrical connection to the grid and installation rules addressing the operation of the grid in presence of high ratio of DER (refer to 5.9.8).

In addition, as shown in 5.9.19, the specific micro-grids Capabilities need to be effectively supported by the adequate information model, both at CIM and IEC 61850 levels, which is still missing.

5.9.19.7 Micro-grid system mapping

In order not to duplicate information already depicted in this document, the best is to rely on the already described mapping of the underlying systems micro-grids are composed of: to be found from 5.9.5 to 5.9.18.

5.10 Cross-cutting technologies and systems

5.10.1 Communication network

5.10.1.1 Description

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

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

The functional requirements (response times) and the environment where the communications system is installed have a big influence, and therefore are a key criterion to choose the right technology. 5.10.1 cannot enter the level of details needed to compare each level of performance of each criterion; however, the selection proposed below is more or less pre-supposed to meet the performance levels requested by the proposed domain of use. Case by case, a check remains necessary to verify the adequacy.

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

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

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

Wireless communications may have to comply with local or regional regulations (such as the Telecommunication Directive 99/05/CE for Europe).

For Smart Grid communication architecture/technology, products based on specifications from industry consortia (e.g. the IETF, IEEE, W3C) have been deployed widely, notably in the area of IP protocols and web services. In 5.10.1, the list of standards/specifications takes into account the ones which fulfil market requirements. The SGCG RAWG report, Annex F provides further detailed information on standards pertaining to Smart Grid communications.

The remainder of 5.10.1 is structured as follows:

- 5.10.1.2 provides an overview of communications networks (layer 1 to layer 3 according to the OSI layers). Standards/specifications listed in 5.10.1.2 are grouped according to standards families where each family has applicability statement to Smart Grid communications sub-networks.
- 5.10.1.3 introduces a mapping of these standards families over the SGAM.
- 5.10.1.4 provides a list of higher level communication protocol standards/specifications (layer 4 and above) used to support Smart Grid applications.

NOTE 5.10.1.2 to 5.10.1.4 have not been written to specifically include the Smart Metering related standards. Some specific requirement and standards may be needed to implement a smart metering AMI system.

5.10.1.2 Communication network type breakdown

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

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

- (A) Subscriber access network:

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

- (B) Neighbourhood network:

  networks at the distribution level between distribution substations and end users. They are 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.

- (C) AMI backhaul network:

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

- (D) Low-end intra-substation network:

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

- (E) Intra-substation network:

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

- (F) Inter-substation network:

  networks that interconnect substations with each other and with control 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.

- (G) Intra-control centre / intra-data centre network:

  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.

- (H) Backbone network:

  inter-enterprise or campus networks, including backbone internet network, as well as inter-control centre networks.

- (L) Operation backhaul network:

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

- (M) Industrial fieldbus area network:

  networks that interconnect process control equipment mainly in power generation (bulk or distributed) in the scope of Smart Grids.

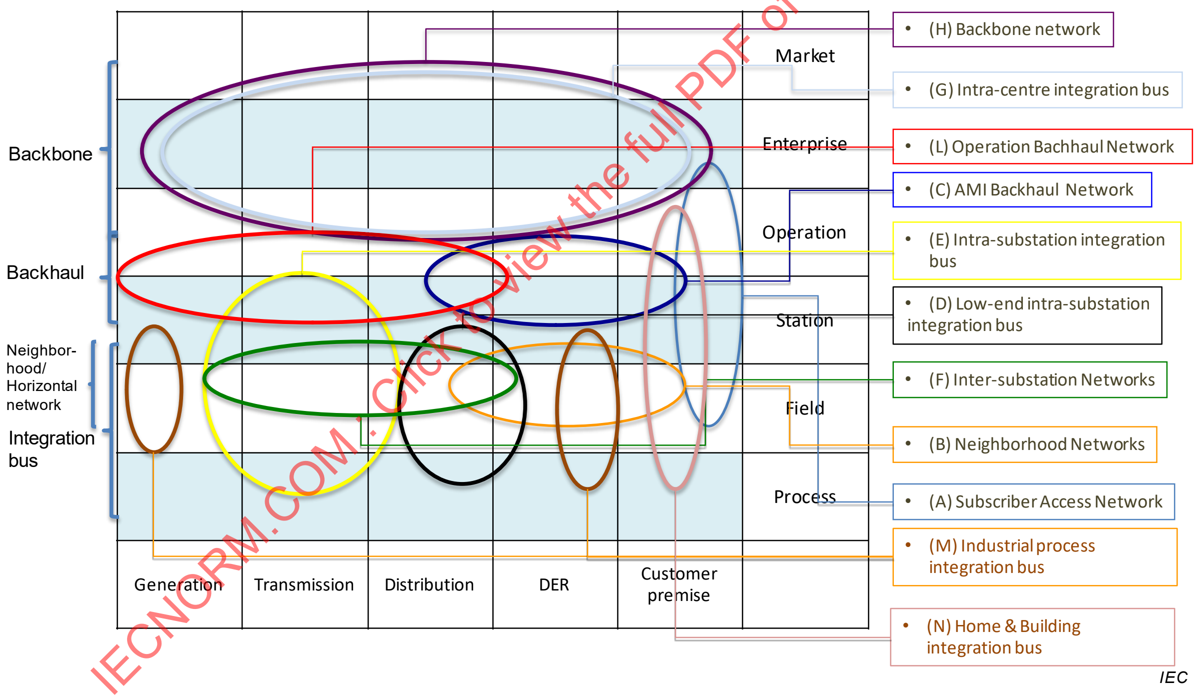
- (N) Home and building integration bus network:

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

5.10.1.3 Mapping of communication network type over the SGAM

5.10.1.3.1 General

Figure 65 provides a mapping of the different Smart Grid networks to the SGAM model.



NOTE 1 Where a circle is tangent to a zone, this means that the corresponding network type can support the interface with the tangent zone.

NOTE 2 These areas are a mapping example and cannot be normative to all business models.

NOTE 3 It is assumed that that sub-networks depicted here are interconnected (where needed) to provide end-to-end connectivity to applications they support. VPNs, gateways and firewalls could provide means to ensure network security or virtualization.

Figure 65 – Mapping of communication networks on SGAM

5.10.1.3.2 Applicability of communication standards to Smart Grid networks

Table 73 provides an applicability statement indicating the standardized communication technologies to the Smart Grid sub-networks depicted in 5.10.1.2. As mentioned in [2], the choice of a technology for a sub-network is left to implementations, which need to take into account a variety of deployment constraints.

Each line in Table 73 identifies a family of communication standards and thus indicates for these standards families the most appropriate type(s) of usage, as defined in 5.10.1.2.

Table 73 – Applicability statement of the communication technologies to the Smart Grid sub-networks

		Subscriber Access Network	Neighborhood network	Multi-services backhaul Network	Low-end intra-substation network	Intra-substation network	Inter substation network	Intra-Control Centre / Intra-Data Centre network	Backbone Network	Operation Backhaul Network	Home and Building integration bus Network	Industrial Fieldbus Area Network
		A	B	C	D	E	F	G	H	L	N	M
IEEE protocols (MAC-PHY)												
	IEEE 1901.2 Narrow band PLC		■	▨							■	
	IEEE 1901 Broad band PLC	■	■	■							■	
	IEEE 802.15.4 wireless Low Power	▨	■								■	▨
	IEEE 802.11 (WIFi)	▨	■	■	■	■	▨				■	▨
	IEEE 802.3/1 (Ethernet)				■	■		■	▨		■	▨
	IEEE 802.16 (Wimax)	■	■	■							▨	
IETF protocols (Layer 3, 4 and above)												
	IPv4	■	■	■	■	■	■	■	■	■	■	▨
	IPv6	■	■	■	■	■	■	■	■	■	■	▨
	RPL / 6LowPan / 6TiSCH		■								■	
	IP MPLS / MPLS TP			▨			■	■	■	■		
	XMPP		■	■			■			■	■	
ITU Protocols												
	SDH/OTN	▨	▨	■	▨	▨	■	■	■	■	▨	
	DSL/PON	■	■	■			▨	■	■			
	DWDM	▨	▨	▨	▨	▨	■	■	■	■	▨	
	Narrow band PLC (Medium & Low voltage)		■	▨							■	
	Narrow band PLC (High & very High voltage)					▨	■					
	Broadband PLC	■	■	■							■	
ANSI standards												
	SONET / SONET NG	▨	▨	■	■	■	■	■	■	■	▨	
ETSI / 3GPP Protocols												
	ETSI TS 102 887 Wireless (IEEE 802.15.4g)	▨	■								■	
	GSM / GPRS / EDGE	▨	■	▨								
	3G / WCDMA / UMTS / HSPA	■	■	■					▨	▨		
	ETSI TS 103 908		■	▨							■	
	4G LTE/LTE-A	■	■	■			■		■	▨		
EN standards												
	EN 61334		■								▨	
	EN 14908		■	▨							■	■
	EN 50090		■	▨							■	
	EN 13757		▨								▨	■
IEC standards												
	IEC 61158 & IEC61784											■
	IEC 61850		▨	▨	■	■	■			▨		
	IEC 62439		▨	▨	■	■	■			▨		■
	IEC 60870-5									■		
Higher layer comm protocol		■	■	■			■	■	■	■	■	

Legend	■	Mostly used
	▨	May be used

NOTE Refer to the set of protocols presented in 5.10.1.3.3.

5.10.1.3.3 List of standards

5.10.1.3.3.1 General

The standards that follow are those that reference communication protocols (mostly focusing on L1, L2, L3 of the OSI protocol stack) for Smart Grid Communications. Many standards are part of wider multipart standards.

Only standards which are relevant for the communication, according the OSI Layer model, are listed in 5.10.1.3.3.

5.10.1.3.3.2 Available standards

See Table 74. Refer to 5.2.5.3 for the definition of the criteria considered in this document for stating that a standard is "available".

Table 74 – Communication – Available standards

Layer	Category (ies)	Standard	Title and comments
General		ISO/IEC 7498-1	(1994) *Information technology – Open Systems Interconnection – Basic Reference Model: The Basic Model*
General		ITU-T I.322	(02/99) *Generic protocol reference model for telecommunication networks*
Communication	IEEE 802.1	ISO/IEC 15802 IEEE 802.1	A list of standards is available at <**Error! Hyperlink reference not valid.**http://standards.ieee.org/about/get/802/802.1.html>
Communication	IEEE 802.3	ISO/IEC 8802-3 IEEE 802.3	A list of standards is available at <**Error! Hyperlink reference not valid.**http://standards.ieee.org/about/get/802/802.3.html>
Communication	IEEE 802.11	ISO/IEC 8802-11 IEEE 802.11	A list of standards is available at <**Error! Hyperlink reference not valid.**http://standards.ieee.org/about/get/802/802.11.html>
Communication	DSL/PON	ITU-T G.991.1	*High bit rate digital subscriber line (HDSL) transceivers*
Communication	DSL/PON	ITU-T G.991.2	*Single-pair high-speed digital subscriber line (SHDSL) transceivers*
Communication	DSL/PON	ITU-T G.992.1	*Asymmetric digital subscriber line (ADSL) transceivers*
Communication	DSL/PON	ITU-T G.992.2	*Splitterless asymmetric digital subscriber line (ADSL) transceivers*
Communication	DSL/PON	ITU-T G.992.3	*Asymmetric digital subscriber line transceivers 2 (ADSL2)*
Communication	DSL/PON	ITU-T G.992.4	*Splitterless asymmetric digital subscriber line transceivers 2 (splitterless ADSL2)*
Communication	DSL/PON	ITU-T G.993.1	*Very high speed digital subscriber line transceivers (VDSL)*
Communication	DSL/PON	ITU-T G.993.2	*Very high speed digital subscriber line transceivers 2 (VDSL2)*
Communication	DSL/PON	ITU-T G.993.5	*Self-FEXT cancellation (vectoring) for use with VDSL2 transceivers*
Communication	DSL/PON	ITU-T G.994.1	*Handshake procedures for digital subscriber line (DSL) transceivers*
Communication	DSL/PON	ITU-T G.995.1	*Overview of digital subscriber line (DSL) Recommendations*
Communication	DSL/PON	ITU-T G.996.1	*Test procedures for digital subscriber line (DSL) transceivers*

Layer	Category (ies)	Standard	Title and comments
Communication	DSL/PON	ITU-T G.996.2	*Single-ended line testing for digital subscriber lines (DSL)*
Communication	DSL/PON	ITU-T G.997.1	*Physical layer management for digital subscriber line (DSL) transceivers*
Communication	DSL/PON	ITU-T G.998.1	*ATM-based multi-pair bonding*
Communication	DSL/PON	ITU-T G.998.2	*Ethernet-based multi-pair bonding*
Communication	DSL/PON	ITU-T G.998.3	*Multi-pair bonding using time-division inverse multiplexing*
Communication	DSL/PON	ITU-T G.999.1	*Interface between the link layer and the physical layer for digital subscriber line (DSL) transceivers*
Communication	DSL/PON	ITU-T G.998.4	*Improved Impulse Noise Protection (INP) for DSL Transceivers*
Communication	DSL/PON	ITU-T G.983.1	*Broadband optical access systems based on Passive Optical Networks (PON)*
Communication	DSL/PON	ITU-T G.983.2	*ONT management and control interface specification for B-PON*
Communication	DSL/PON	ITU-T G.983.3	*A broadband optical access system with increased service capability by wavelength allocation*
Communication	DSL/PON	ITU-T G.983.4	*A broadband optical access system with increased service capability using dynamic bandwidth assignment*
Communication	DSL/PON	ITU-T G.983.5	*A broadband optical access system with enhanced survivability*
Communication	DSL/PON	ITU-T G.984.1	*Gigabit-capable passive optical networks (GPON): General characteristics*
Communication	DSL/PON	ITU-T G.984.2	*Gigabit-capable Passive Optical Networks (G-PON): Physical Media Dependent (PMD) layer specification*
Communication	DSL/PON	ITU-T G.984.3	*Gigabit-capable Passive Optical Networks (G-PON): Transmission convergence layer specification*
Communication	DSL/PON	ITU-T G.984.4	*Gigabit-capable passive optical networks (G-PON): ONT management and control interface specification*
Communication	DSL/PON	ITU-T G.984.5	*Gigabit-capable Passive Optical Networks (G-PON): Enhancement band*
Communication	DSL/PON	ITU-T G.984.6	*Gigabit-capable passive optical networks (GPON): Reach extension*
Communication	DSL/PON	ITU-T G.984.7	*Gigabit-capable passive optical networks (GPON): Long reach*
Communication	DSL/PON	ITU-T G.987.1	*10-Gigabit-capable passive optical networks (XG-PON): General requirements*
Communication	DSL/PON	ITU-T G.987.2	*10-Gigabit-capable passive optical networks (XG-PON): Physical media dependent (PMD) layer specification*
Communication	DSL/PON	ITU-T G.987.3	*10-Gigabit-capable passive optical networks (XG-PON): Transmission convergence (TC) layer specification*
Communication	SDH/OTN	ITU-T G.707	*Network node interface for the synchronous digital hierarchy (SDH)*
Communication	SDH/OTN	ITU-T G.7042	*Link capacity adjustment scheme for virtual concatenated signals.*
Communication	SDH/OTN	ITU-T G.7041	*Generic Framing Procedure (GFP)*
Communication	SDH/OTN	ITU-T G.709	*Interfaces for the Optical Transport Network (OTN)*
Communication	SDH/OTN	ITU-T G.798	*Characteristics of optical transport network hierarchy equipment functional blocks*
Communication	SDH/OTN	ITU-T G.781	*Synchronization layer functions*
Communication	SDH/OTN	ITU-T G.872	*Architecture of optical transport networks*

Layer	Category (ies)	Standard	Title and comments
Communication	SDH/OTN	ITU-T G.783	*Characteristics of synchronous digital hierarchy (SDH) equipment functional blocks*
Communication	SDH/OTN	ITU-T G.803	*Architecture of transport networks based on the synchronous digital hierarchy (SDH)*
Communication	EN 50090	ISO/IEC 14543-3 series	*Information technology – Home electronic system (HES) architecture* KNX – Standard for applications in home and building control
Communication	IEC 60870-5	IEC 60870-5-4 IEC 60870-5-3 IEC 60870-5-2 IEC 60870-5-1	*Telecontrol equipment and systems – Part 5: Transmission protocols*
Communication	IEC 60870-5	IEC 60870-5-101	*Telecontrol equipment and systems – Part 5-101: Transmission protocols – Companion standard for basic telecontrol tasks*
Communication	IEC 60870-5	IEC 60870-5-102	*Telecontrol equipment and systems. Part 5-102: Transmission protocols – Companion standard for the transmission of integrated totals in electric power systems*
Communication	IEC 60870-5	IEC 60870-5-103	*Telecontrol equipment and systems – Part 5-103: Transmission protocols – Companion standard for the informative interface of protection equipment*
Communication	IEC 60870-5	IEC 60870-5-104	*Telecontrol equipment and systems – Part 5-104: Transmission protocols – Network access for IEC 60870-5-101 using standard transport profiles*
Communication	Narrow band PLC (Medium and Low voltage)	IEC 61334	*Distribution automation using distribution line carrier systems*
Communication	IEC 61158 series	IEC 61158 series	*Industrial communication networks – Fieldbus specifications*
Communication	IEC 61158 series	IEC 61784 series	*Industrial communication networks – Profiles*
Communication	IEC 61850	IEC 61850-8-1	(Ed. 2.0 2011) *Communication networks and systems for power utility automation – Part 8-1: Specific communication service mapping (SCSM) – Mappings to MMS (ISO 9506-1 and ISO 9506-2) and to ISO/IEC 8802-3*
Communication	IEC 61850	IEC 61850-9-2	(Ed. 2.0:2011) *Communication networks and systems for power utility automation – Part 9-2: Specific communication service mapping (SCSM) – Sampled values over ISO/IEC 8802-3*
Communication	IEC 61850	IEC PAS 61850-9-3	*Communication networks and systems for power utility automation – Part 9-3: Precision time protocol profile for power utility automation*
Communication	IEC 61850	IEC TR 61850-90-4	*Communication networks and systems for power utility automation – Part 90-4: Network engineering guidelines*
Communication	IEC 61850	IEC TR 61850-90-1	(Ed. 1.0:2010) *Communication networks and systems for power utility automation – Part 90-1: Use of IEC 61850 for the communication between substations*
Communication	IEC 61850	IEC TR 61850-90-5	(Ed. 1.0:2012) *Communication networks and systems for power utility automation – Part 90-5: Use of IEC 61850 to transmit synchrophasor information according to IEEE C37.118*
Communication, information	IEC 61850	IEC TR 61850-90-2	*Communication networks and systems for power utility automation – Part 90-2: Using IEC 61850 for communication between substations and control centres*

Layer	Category (ies)	Standard	Title and comments
Communication	IEC 61850	IEC TR 61850-90-12	*Communication networks and systems for power utility automation – Part 90-12: Wide area network engineering guidelines*
Communication, Information	IEC 61850	IEC 61850-7-1	(Ed. 2.0:2011) *Communication networks and systems for power utility automation – Part 7-1: Basic communication structure – Principles and models*
Communication	IEC 61968	IEC 61968-100	*Application integration at electric utilities – System interfaces for distribution management – Part 100: Implementation profiles*
Communication	IEC 62439 series	IEC 62439 series	*Industrial communication networks – High availability automation networks:* *Part 1: General concepts and calculation methods,* *Part 2: Medium Redundancy Protocol (MRP),* *Part 3: Parallel Redundancy Protocol (PRP) and High-availability Seamless Redundancy (HSR),* *Part 4: Cross-network Redundancy Protocol (CRP),* *Part 5: Beacon Redundancy Protocol (BRP),* *Part 6: Distributed Redundancy Protocol (DRP),* *Part 7: Ring-based Redundancy Protocol (RRP),* the common Rapid Spanning Tree Protocol (RSTP) specified in the IEEE 802.1D-2004 (and later) standard
Communication, Information	IEC 62541 series	IEC 62541 series	*OPC unified architecture*
Communication	Narrow band PLC (High and very High voltage)	IEC 62488-1 (Formerly EN 60663)	*Power line communication systems for power utility applications – Part 1: Planning of analogue and digital power line carrier systems operating over EHV/HV/MV electricity grids*
Communication	Broadband PLC	ISO/IEC 12139-1	*Information technology – Telecommunications and information exchange between systems – Powerline communication (PLC) – High speed PLC medium access control (MAC) and physical layer (PHY) – Part 1: General requirements*
Communication	ISO/IEC 14908	ISO/IEC 14908-1	Information technology – Control network protocol – Part 1: Protocol stack
Communication	ISO/IEC 14908	ISO/IEC 14908-2	*Information technology – Control network protocol – Part 2: Twisted pair communication*
Communication	ISO/IEC 14908	ISO/IEC 14908-3	*Information technology – Control network protocol – Part 3: Power line channel specification*
Communication	ISO/IEC 14908	ISO/IEC 14908-4	*Information technology – Control network protocol – Part 4: IP communication*
Communication	Broadband PLC	ITU-T G.9960 (PHY) ITU-T G.9961 (DLL) ITU-T G.9962 (MIMO) ITU-T G.9963 (MIMO G.hn) ITU-T G.9964 (PSD)	*Unified high-speed wireline-based home networking:* *ITU-T G.9960 (PHY)* *ITU-T G.9961 (DLL)* *ITU-T G.9962 (MIMO)* *ITU-T G.9963 (MIMO G.hn)* *ITU-T G.9964 (PSD)*
Communication	Narrow band PLC	ITU-T G.9901	*Narrowband orthogonal frequency division multiplexing power line communication transceivers – Power spectral density specification* (common for all 3 technos G.9902, G.9903, G.9904)

Layer	Category (ies)	Standard	Title and comments
Communication	Narrow band PLC	ITU-T G.9902	*Narrowband orthogonal frequency division multiplexing power line communication transceivers for ITU-T G.hnem networks*
Communication	Narrow band PLC	ITU-T G.9903	*Narrowband orthogonal frequency division multiplexing power line communication transceivers for G3-PLC networks*
Communication	Narrow band PLC	ITU-T G.9904	*Narrowband orthogonal frequency division multiplexing power line communication transceivers for PRIME networks*
Communication	Narrow band PLC (Medium and Low voltage)	ITU-T G.9905	*ITU-T G.9905 (Routing)*
Communication	Narrowband wireless"	ITU-T G.9959	*ITU-T G.9959 (Z-Wave) Short range narrowband digital radio communication transceivers – PHY & MAC layer specifications*
Communication	G.fast	ITU-T G.9700	*Fast access to subscriber terminals (FAST) – Power spectral density specification (G.fast PSD)*
Communication	G.fast	ITU-T G.9701	*Fast access to subscriber terminals – G.fast PHY*
Other specifications			
Communication	DSL/PON	IEEE 802.3ah	802.3 application for EPON – *Ethernet Passive Optical Network standard*
Communication	DSL/PON	IEEE 802.3av	802.3av application for 10G-EPON – *10 Gbit/s Ethernet Passive Optical Network standard*
Communication	IEEE 802.15.4	IEEE 802.15.4	*IEEE Standard for Local and metropolitan area networks--Part 15.4: Low-Rate Wireless Personal Area Networks (LR-WPANs)*
Communication	IEEE 802.16	IEEE 802.16	A list of standards is available at <http://standards.ieee.org/about/get/802/802.16.html>
Communication	Broadband PLC	IEEE 1901	*Broadband over Power Line Networks*
Communication	Broadband PLC	IEEE 1901.2	*Standard for Low Frequency (less than 500 kHz) Narrow Band Power Line Communications for Smart Grid Applications*
Communication	IP MPLS	IETF RFC 5654	*Requirements of an MPLS Transport Profile*
Communication	IP MPLS	IETF RFC 5921	*A Framework for MPLS in Transport Networks*
Communication	IP MPLS	IETF RFC 3031	*Multiprotocol Label Switching Architecture*
Communication	IP MPLS	IETF RFC 3032	*MPLS Label Stack Encoding*
Communication	IP MPLS	IETF RFC 4090	*Fast Reroute Extensions to RSVP-TE for LSP Tunnels, http://www.ietf.org/rfc/rfc4090.txt*
Communication	IP MPLS	IETF RFC 6178	*Label Edge Router Forwarding of IPv4 Option Packets*
Communication	IPv4, IPv6	IETF RFC 791	*Internet Protocol*
Communication	IPv4, IPv6	IETF RFC 2460	*Internet Protocol, Version 6 (IPv6) Specification*
Communication	IPv4, IPv6	IETF RFC 4944	*Transmission of IPv6 Packets over IEEE 802.15.4 Networks -. http://www.rfc-editor.org/rfc/rfc4944.txt*
Communication	IPv4, IPv6	IETF RFC 6272 [10]	*Internet Protocols for the Smart Grid. http://www.rfc-editor.org/rfc/rfc6272.txt*
Communication	IPv4, IPv6	IETF RFC 6282	*Compression Format for IPv6 Datagrams over IEEE 802.15.4-Based Networks*
Communication	IPv4, IPv6, IP MPLS	IETF RFC 5086	*Structure-Aware Time Division Multiplexed (TDM) Circuit Emulation Service over Packet Switched Network (CESoPSN)*

10 RFC 6272 is an informational RFC. It is listed in Table 74 because it makes reference to several standard track RFCs which are relevant for Smart Grids

Layer	Category (ies)	Standard	Title and comments
Communication	IPv4, IPv6, IP MPLS	IETF RFC 4553	*Structure-Agnostic Time Division Multiplexing (TDM) over Packet (SAToP)*
Communication	RPL/6LowPan	IETF RFC 4919	*IPv6 over Low-Power Wireless Personal Area Networks (6LoWPANs): Overview, Assumptions, Problem Statement, and Goals*
Communication	RPL/6LowPan	IETF RFC 6550	*(ROLL) RPL IPv6 Routing Protocol for Low-Power and Lossy Network.* A list of Internet RFCs is available under: http://tools.ietf.org/wg/roll draft-ietf-roll-minrank-hysteresis-of -11 (2012-06-30) RFC Ed Queue draft-ietf-roll-security-framework draft-ietf-roll-p2p-measurement draft-ietf-roll-p2p-rpl draft-ietf-roll-trickle-mcast
Communication	RPL/6LowPan	IETF RFC 6551	*(ROLL) Routing metrics*
Communication	RPL/6LowPan	IETF RFC 6552	*(ROLL) Objective Function Zero*
Communication	RPL/6LowPan	IETF RFC 6206	*(ROLL) Trickle*
Communication	RPL/6LowPan	IETF RFC 6775	*Neighbor Discovery Optimization for IPv6 over Low-Power Wireless Personal Area Networks (6LoWPANs)*
Communication	EN 50090	EN 50090-2-1	*System overview – Architecture (1994)*
Communication	EN 50090	EN 50090-3-1	*Aspects of application – Introduction to the application structure (1994)*
Communication	EN 50090	EN 50090-3-2	*Aspects of application – User process for HBES Class 1 (2004)*
Communication	EN 50090	EN 50090-4-1	*Media independent layers – Application layer for HBES Class 1 (2004)*
Communication	EN 50090 Narrow band PLC (Medium and Low voltage)	EN 50090-4-2	*Media independent layers – Transport layer, network layer and general parts of datalink layer for HBES Class 1 (2004)*
Communication	EN 50090	EN 50090-4-3	*Media independent layers -Communication over IP*
Communication	EN 50090	EN 50090-5-1	*Media and media dependent layers-Power line for HBES Class 1 (2005)*
Communication	EN 50090	EN 50090-5-2	*Media and media dependent layers-Network based on HBES Class1, Twisted Pair (2004)*
Communication	EN 50090	EN 50090-7-1	*System management-Management procedures (2004)*
Communication	EN 13757	EN 13757-4	*Communication systems for meters and remote reading of meters – Part 4: wireless meter readout (radio meter reading for operation in SRD bands)*
Communication	EN 13757	EN 13757-5	*Communication systems for meters and remote reading of meters – Part 5: wireless relaying*
Communication	EN 13321	EN 13321-2	*EN 13321-2:2012-02: Open Data Communication in Building Automation, Controls and Building Management – Home and Building Electronic System Part 2: KNXnet/IP Communication*
Communication	*DLMS/COSEM*	CLC TS 50568-4	*CENELEC/TS 50568-4 'Electricity metering data exchange – The Smart Metering Information Tables and Protocols (SMITP) suite – Part 4: Physical layer based on SMITP B-PSK modulation and SMITP Data Link Layer'*
Communication	*DLMS/COSEM*	CLC TS 50568-8	*CENELEC/TS 50568-8 'Electricity metering data exchange – The DLMS/COSEM suite – Part 8: PLC profile based on SMITP B-PSK modulation – Including: The original-SMITP PLC profile based on SMITP B-PSK modulation, the original-SMITP Local data exchange profile and the original-SMITP IP profile*

Layer	Category (ies)	Standard	Title and comments
Communication	*DLMS/COSEM*	CLC TS 50590	*CENELEC/TS 50590 – Electricity metering data exchange – CX 1 Lower layer specification – Part X: Physical layer, data link layer and network layer*
Communication	EN 14908 Narrow band PLC (Medium and Low voltage)	ETSI TS 103 908	*Power Line channel in the EN 50065-1 CENELEC A-Band*
Communication	ETSI TS 102 887	ETSI TS 102 887	– *Electrocompatibility and radio spectrum Matters (ERM); Short Range Devices; Smart Metering Wireless Access Protocol (SMEP). Part 1; PHY Layer* – *Electrocompatibility and radio spectrum Matters (ERM); Short Range Devices; Smart Metering Wireless Access Protocol (SMEP). Part 2; MAC Layer*
Communication	LTE/LTE-A	ETSI TS 136 300 / 3GPP TS 36.300	*LTE Evolved Universal Terrestrial Radio Access (E-UTRA) and Evolved Universal Terrestrial Radio Access Network (E-UTRAN); Overall description; Stage 2 http://www.3gpp.org/ftp/Specs/html-info/36300.htm (ITU-R endorsement)*
Communication	LTE/LTE-A	ETSI TS 136 201 / 3GPP TS 36.201	*Evolved Universal Terrestrial Radio Access (E-UTRA); LTE physical layer; General description. (ITU-R endorsement)*
Communication	LTE/LTE-A	ETSI TS 136 211 / 3GPP TS 36. 211	*Evolved Universal Terrestrial Radio Access (E-UTRA); Physical channels and modulation. (ITU-R endorsement)*
Communication	LTE/LTE-A	ETSI TS 136 212 / 3GPP TS 36.212	*Evolved Universal Terrestrial Radio Access (E-UTRA); Multiplexing and channel coding. (ITU-R endorsement)*
Communication	LTE/LTE-A	ETSI TS 136 213 / 3GPP TS 36.213	*Evolved Universal Terrestrial Radio Access (E-UTRA); Physical layer procedures. (ITU-R endorsement)*
Communication	LTE/LTE-A	ETSI TS 136 214 / 3GPP TS 36.214	*Evolved Universal Terrestrial Radio Access (E-UTRA); Physical layer; Measurements.*
Communication	LTE/LTE-A	ETSI TS 136 216 / 3GPP TS 36.216	*Evolved Universal Terrestrial Radio Access (E-UTRA); Physical layer for relaying operation (ITU-R endorsement)*
Communication	LTE/LTE-A	ETSI TS 123 401 / 3GPP TS 23.401	*General Packet Radio Service (GPRS) enhancements for Evolved Universal Terrestrial Radio Access Network (E-UTRAN) access*
Communication	3G / WCDMA / UMTS / HSPA	ETSI TS 121 101	*Overview of Technical Specifications and Technical Reports for a UTRAN-based 3GPP system (3GPP TS 21.101)*
Communication	GSM / GPRS / EDGE	ETSI TS 141 101	*Overview of Technical Specifications and Technical Reports for a GERAN-based 3GPP system (3GPP TS 41.101)*
Communication	LTE/LTE-A, GSM/GPRS/EDGE, 3G/WCDMA/UMTS/HSPA	ETSI TS 122 368 / 3GPP TS 22.368	*Service requirements for Machine-Type Communications (MTC); Stage 1*
Communication	LTE/LTE-A, GSM/GPRS/EDGE, 3G/WCDMA/UMTS/HSPA	ETSI TS 123 682 / 3GPP TS 23.682	*Architecture Enhancements to facilitate communications with Packet Data Networks and Applications*
Communication	LTE/LTE-A	ETSI TS 123 402 / 3GPP TS 23.402	*Architecture Enhancements for Non-3GPP Accesses (Release 10)*
Communication	LTE/LTE-A, GSM/GPRS/EDGE, 3G/WCDMA/UMTS/HSPA	ETSI TS 129 368/ 3GPP TS 29.368	*Tsp interface protocol between the MTC Interworking Function (MTC-IWF) and Service Capability Server (SCS)*

Layer	Category (ies)	Standard	Title and comments
Communication	GSM/GPRS/EDGE	ETSI EN 301 502	*Global System for Mobile communications (GSM);Harmonized EN for Base Station Equipment covering the essential requirements of article 3.2 of the R&TTE Directive*
Communication	GSM/GPRS/EDGE,	ETSI EN 301 511	*Global System for Mobile communications (GSM);Harmonized EN for mobile stations in the GSM 900 and GSM 1800 bands covering essential requirements under article 3.2 of the R&TTE directive*
Communication	LTE/LTE-A, 3G/WCDMA/UMTS/HSPA	ETSI EN 301 908	*Parts 1,2,3,6,7,3,11,13, 14,15,18 – IMT cellular networks; Harmonized EN covering the essential requirements of article 3.2 of the R&TTE Directive*
Communication	CDMA2000/UMB	ETSI EN 301 908	*Parts 4, 5, 12, 16, 17 – IMT cellular networks; Harmonized EN covering the essential requirements of article 3.2 of the R&TTE Directive*
Communication	M2M	ETSI TR 101 531	*Machine-to-Machine communications (M2M); Reuse of Core Network Functionality by M2M Service Capabilities –*
Communication	M2M	ETSI TR 102 935	*Machine-to-Machine communications (M2M);. Applicability of M2M architecture to Smart Grid Networks*
Communication	M2M	ETSI TR 102 966	*Machine-to-Machine communications (M2M); Interworking between the M2M Architecture and M2M Area Network technologies*
Communication	M2M	ETSI TR 103 167	*Machine-to-Machine Communications (M2M); Threat analysis and counter-measures to M2M service layer*
Communication	M2M	ETSI TS 101 584	*Machine-to-Machine Communications (M2M);. Study on Semantic support for M2M Data*
Communication	M2M	ETSI TS 102 689	*Machine-to-Machine communications (M2M); M2M service requirements*
Communication	M2M	ETSI TS 103 092	*Machine-to-Machine communications (M2M); OMA DM compatible Management Objects for ETSI M2M*
Communication	M2M	ETSI TS 103 093	*Machine-to-Machine communications (M2M); BBF TR-069 compatible Management Objects for ETSI M2M*
Communication	M2M	ETSI TS 103 104	*Machine-to-Machine communications (M2M); Interoperability Test Specification for CoAP Binding of ETSI M2M Primitives*
Communication	M2M	ETSI TS 103 107	*ETSI TS 103 107 Machine-to-Machine communications (M2M); Service layer interworking with 3GPP2 networks*
Communication	M2M	ETSI TS 103 603	*Machine-to-Machine communications (M2M); Service layer interworking with 3GPP networks*

5.10.1.3.3.3 Coming standards

See Table 75. Refer to 5.2.5.3 for the definition of the criteria considered in this document for stating that a standard is “coming”.

Table 75 – Communication – Coming standards

Layer	Standard	Title and comments
Communication	IEC 61850-8-2 [a]	*Communication networks and systems for power utility automation – Part 8-2: Specific communication service mapping (SCSM) – Mapping to Extensible Messaging Presence Protocol (XMPP)*
Communication	IEC/IEEE 61850-9-3	*Communication networks and systems for power utility automation – Part 9-3: Precision time protocol profile for power utility automation*
Information Communication	IEC 62746 series	*Systems interface between customer energy management system and the power management system*
Other specifications		
Communication	prEN 50491-12	*Smart Grid interface and framework for Customer Energy Management*
Communication	CLC prTS 50586	*CENELEC/prTS 50586: OSGP (Open Smart Grid Protocol) – Communication protocols, data structures and procedures*
Communication	prEN 50412-4	*(pr) Broadband PLC – LRWBS – Power line communication apparatus and systems used in low-voltage installations in the frequency range 1,6 MHz to 30 MHz*

[a] Under preparation.

5.10.1.4 Higher layer communication protocols

5.10.1.4.1 General

Smart Grid applications and standards rely heavily on Web Services for the higher layers protocols. Web Services are defined to be the methods to communicate between applications over communication networks, generally IP based. Two major classes of Web Services can be distinguished (the pros/cons of each class are beyond the scope of this document):

- RESTfull Web Services (Representational State Transfer): Applications are fully defined via representations (e.g. XML) of resources that can be manipulated using a uniform interface that is composed of four basic interactions, i.e. CREATE, UPDATE, DELETE and READ. Each of these operations is composed of request and response messages. The most common implementation of REST is HTTP, whereby the REST operations are mapped into the HTTP methods: CREATE is mapped on HTTP POST, READ on HTTP GET, UPDATE on HTTP PUT and DELETE on HTTP DELETE. However other implementations are possible: CoAP (Constrained Application Protocol), XMPP (Extensible Messaging and Presence Protocol), etc.
- SOAP/RPC based Web Services: Applications expose interfaces that are described in machine processable format, the Web Service Description Language (WSDL). It is also possible for applications to interact through SOAP interfaces which provide a means to describe message format. These messages are often transported over HTTP and encoded using XML.

More information on these two classes of Web Services is provided by the W3C at the following address: <http://www.w3.org/TR/ws-arch/#relwwwrest>

NOTE 5.10.1.4 focuses on Web Service as a general technology for information exchange between Smart Grid applications over communication networks. Other more system-specific solutions like MMS/ACSE are part of the relevant standards (e.g. IEC 61850-8-1) of the specific systems listed in 5.9. Also the specific usage of web services is defined by the system relevant upcoming standards in 5.9 (i.e. IEC 61850-8-2, IEC 61968-100).

5.10.1.4.2 List of standards

5.10.1.4.2.1 Available standards

See Table 76. Refer to 5.2.5.3 for the definition of the criteria considered in this document for stating that a standard is "available".

Table 76 – Higher level communication protocols – Available standards

Layer	Category (ies)	Standard	Title
Communication	HTTP	IETF RFC 2616	*Hypertext Transfer Protocol -- HTTP/1.1*
Communication	REST	ETSI TS 102 690	*Machine-to-Machine communications (M2M); Functional architecture*
Communication	REST	ETSI TS 102 921	*Machine-to-Machine communications (M2M); mIa, dIa and mId interfaces*
Communication	Secured communication	W3C XML Digital Signature	XML Signature Syntax and Processing
Communication	Secured communication	W3C XML Encryption	XML Encryption Syntax and Processing
Communication	SOAP	W3C RECsoap12-part1-20070427	*SOAP Version 1.2 Part 1: Messaging Framework*
Communication	SOAP	W3C REC-soap12-part2-20070427	*SOAP Version 1.2 Part 2: Adjuncts, Section 7: SOAP HTTP Binding,*
Communication	SOAP	OASIS, wsdd-soapoverudp-1.1-spec-pr-01	*OASIS Standard, SOAP-over-UDP*
Communication	SOAP	W3C, RECws-addr-soap-20060509,	*Web Services Addressing 1.0 – SOAP Binding*
Communication	Web Services (general)	W3C WD-ws-arch-20021114	*W3C, Web Services Architecture*
Communication	Web Services (general)	IETF RFC 5246	*The TLS Protocol, Version 1.2*
Communication	Web Services (general)	W3C, REC-ws-addrcore-20060509	*Web Services Addressing 1.0*
Communication	Web Services (general)	OASIS, wsdd-discovery-1.1-spec-os	*Web Services Dynamic Discovery (WS-Discovery)*
Communication	Web Services (general)	W3C, SUBM-WSEventing-20060315	*Web Services Eventing (WS-Eventing)*
Communication	WSDL	W3C, NOTEwsdl-20010315	*Web Services Description Language (WSDL) 1.1,*
Communication	WSDL	W3C, SUBM-wsdl11soap12-20060405	*WSDL 1.1 Binding Extension for SOAP 1.2*
Communication	XML	W3C REC-xml-20001006	*W3C, Extensible Markup Language (XML) 1.0*
Communication	XML	W3C REC-xml-names	*Name spaces in XML*
Communication	XMPP	IETF RFC 6120	*Extensible Messaging and Presence Protocol*
Communication	XMPP	IETF RFC 6121	*Extensible Messaging and Presence Protocol: Instant Messaging and Presence*
Communication	XMPP	IETF RFC 6122	*Extensible Messaging and Presence Protocol: Address Format*
Communication	XMPP	IEC PAS 62746-10-1	*Systems interface between customer energy management system and the power management system – Part 10-1: Open Automated Demand Response (OpenADR 2.0b Profile Specification)*

5.10.1.4.2.2 Coming standards

See Table 77. Refer to 5.2.5.3 for the definition of the criteria considered in this document for stating that a standard is “coming”.

Table 77 – Higher level communication protocols – Coming standards

Layer	Standard	Comments
Communication	CoAP draft-ietf-core-coap-11	Constrained Application Protocol (CoAP). More information available at: <http://datatracker.ietf.org/doc/draft-ietf-core-coap/>
Communication	draft-ietf-6tisch-architecture	Architecture for IPv6 over the TSCH mode of IEEE 802.15.4e
Communication	draft-ietf-6tisch-6top-interface	Architecture for IPv6 over the TSCH mode of IEEE 802.15.4e
Communication	draft-ietf-6tisch-coap	Architecture for IPv6 over the TSCH mode of IEEE 802.15.4e
Communication	draft-ietf-6tisch-minimal	Architecture for IPv6 over the TSCH mode of IEEE 802.15.4e

5.10.1.5 Gaps

The integration and migration of technology standard IPv6 to existing communication standards is necessary.

Seamless wireless communication standards for AMI applications are not yet defined. These could include WiFi, Mobile WiMAX, GPRS, etc.

5.10.2 Communication network management system

5.10.2.1 System description

Communication Network management systems are concerned with the management of the communication networks used for Smart Grid communication. These are for example wide area (WAN), local area (LAN), access and neighbourhood area (NAN) networks. For more details on communication networks see 5.10.1.

When communicating devices, including the communication functions of end devices, have the ability to be managed remotely regarding their communication capabilities, they are usually called “managed devices”, and the network having this property is called “managed network”.

A managed network consists of two key components:

- manager device with network management system;
- managed device with agent.

A network management system executes applications that monitor and control managed devices. The network management systems provide the bulk of the processing and memory resources required for network management. One or more network management systems may exist on any managed network and different management systems might be used for different network domains and zones.

Various network management standards exist for the different communication network technologies. 5.10.2 focuses on management of the IP layer and can only provide a rough overview. For other communication network technologies and more details, refer to the specific technologies.

It should be noted that the responsibility for network management usually is with the network owner. A distribution network operator, for example, will manage its own enterprise and control centre LAN while in case of leased line or VPN services the management of the underlying network providing these services is the responsibility of the communication service provider who owns the underlying network.

5.10.2.2 Set of System Capabilities

Possibly any use case which is supported by communicating features is concerned with managing the health of the communication system it is using.

Practically any IP based system may support a communication network management system encompassing part or all communicating devices.

5.10.2.3 List of standards

5.10.2.3.1 Available standards

See Table 78. Refer to 5.2.5.3 for the definition of the criteria considered in this document for stating that a standard is "available".

Table 78 – Communication network management – Available standards

Layer	Standard	Comments
Information, Communication	IEC TS 62351-7	*Power systems management and associated information exchange – Data and communications security – Part 7: Network and system management (NSM) data object models* Cyber-security aspects (see 5.10.4)5.10.4)
Communication, Information	IEC TR 61850-90-4	*Communication networks and systems for power utility automation – Part 90-4: Network engineering guidelines* for IEC 61850 based systems (including Ethernet technology, network topology, redundancy, traffic latency, traffic management by multicast and VLAN). This document also proposes a data model /SCL extension to expose information related to network management onto IEC 61850, mostly based on SNMP tags
Other specifications		
Information, Communication	IETF RFC 5343, IETF RFC 5590, IETF RFC 4789 IETF RFC 3584	SNMPv3. Internet-standard protocol for managing devices on IP networks, and co-habitation with former SNMP releases
Communication	IETF RFC 768	UDP/IP

5.10.2.3.2 Coming standards

None.

5.10.2.4 Mapping on SGAM

5.10.2.4.1 Preamble

It is mostly not possible to map a communication network management system onto the SGAM, as such systems are independent from the Smart Grid domains and zones and have their own architectural structure. It is therefore shown as a simple overlay on the SGAM.

5.10.2.4.2 Component layer

The managed devices can be any type of communication device, including end devices (e.g. routers, access servers, switches, bridges, hubs, IP telephones, IP video cameras and computer hosts). Most communicating end devices which serve a Smart Grid function such as IEDs, controllers, computers, HMIs, should be "manageable" from a communication point of view.

A managed device is a network node that implements an SNMP interface that allows unidirectional or bidirectional access to node-specific information. Managed devices exchange node-specific information with the network management system. An agent is a network-management software module that resides on a managed device. An agent has local knowledge of management information and translates that information to or from an SNMP specific form.

The resulting architecture is shown in Figure 66.

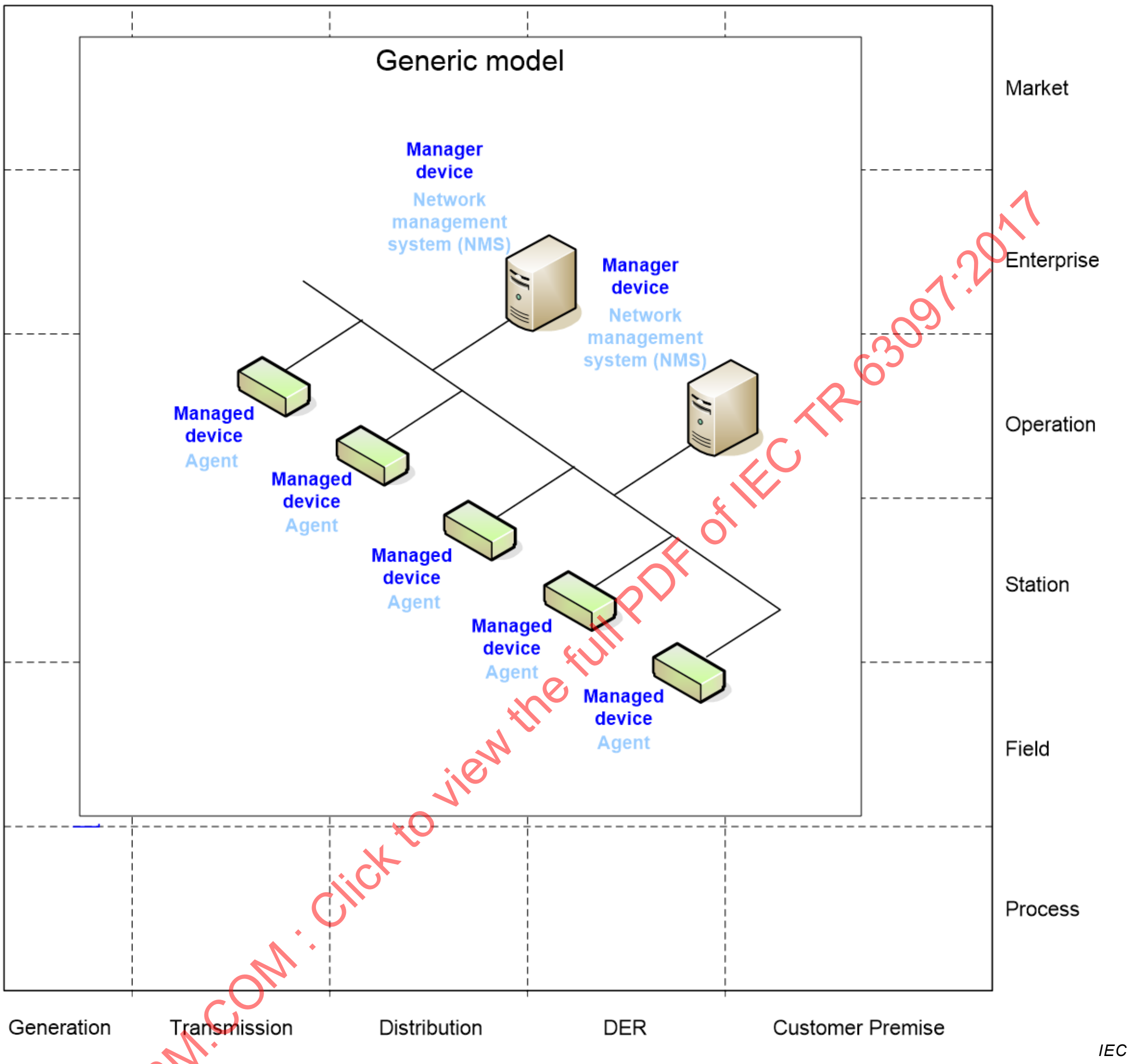
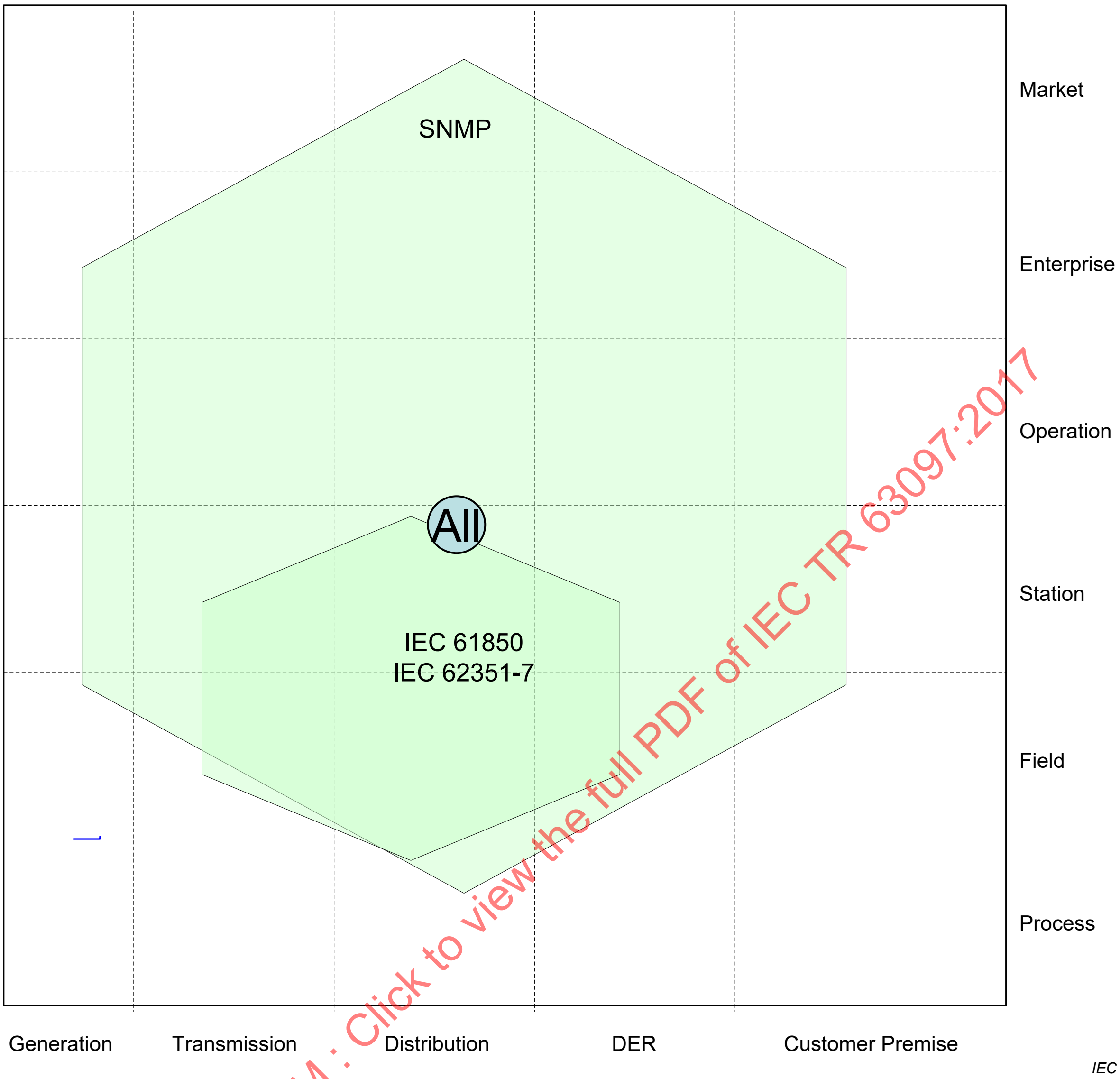


Figure 66 – Communication network management – Component layer

5.10.2.4.3 Communication layer

See Figure 67.



NOTE The letters in the blue disk refer to the network types defined in 5.10.1.2.

Figure 67 – Communication network management – Communication layer

5.10.2.4.4 Information (Data) layer

See Figure 68.

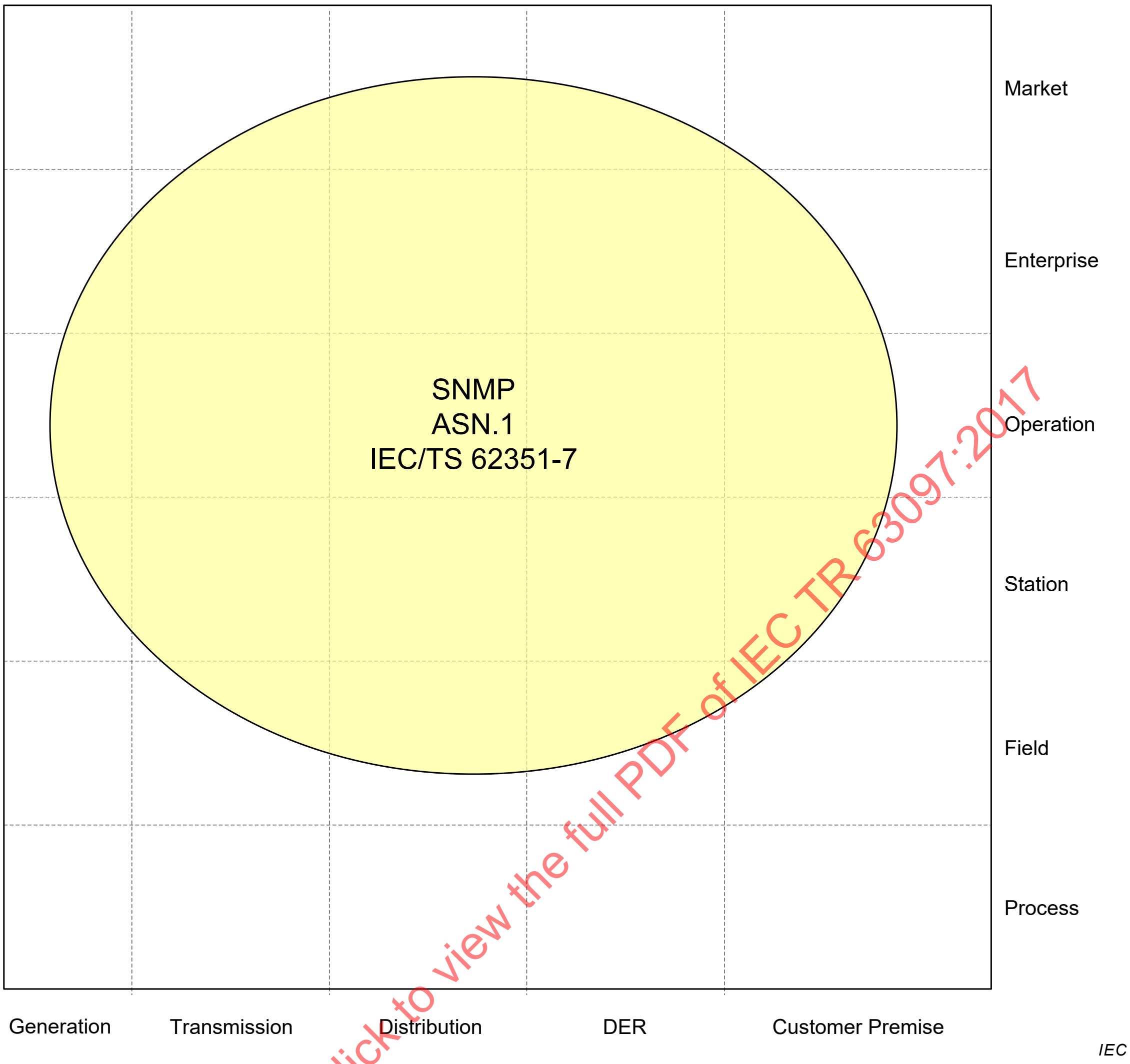


Figure 68 – Communication network management – Information layer

5.10.3 Data modelling

5.10.3.1 Description

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

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

Currently the IEC framework relies on three main pillars, as far as data modelling is concerned, represented in Figure 69.

Figure 69 also represents the three harmonizations (i.e. the definition of unified shared semantic sub-areas, or formal transformation rules) which need to be performed in order to enable an easy bridging of these semantic domains:

- harmonization between CIM and IEC 61850, mostly to seamlessly connect the field to operation and enterprise level;
- harmonization between CIM and COSEM, mostly to seamlessly interconnect electricity supply and grid operation;

- harmonization between COSEM and IEC 61850, where smart metering may co-habit with Power Utility Automation systems.

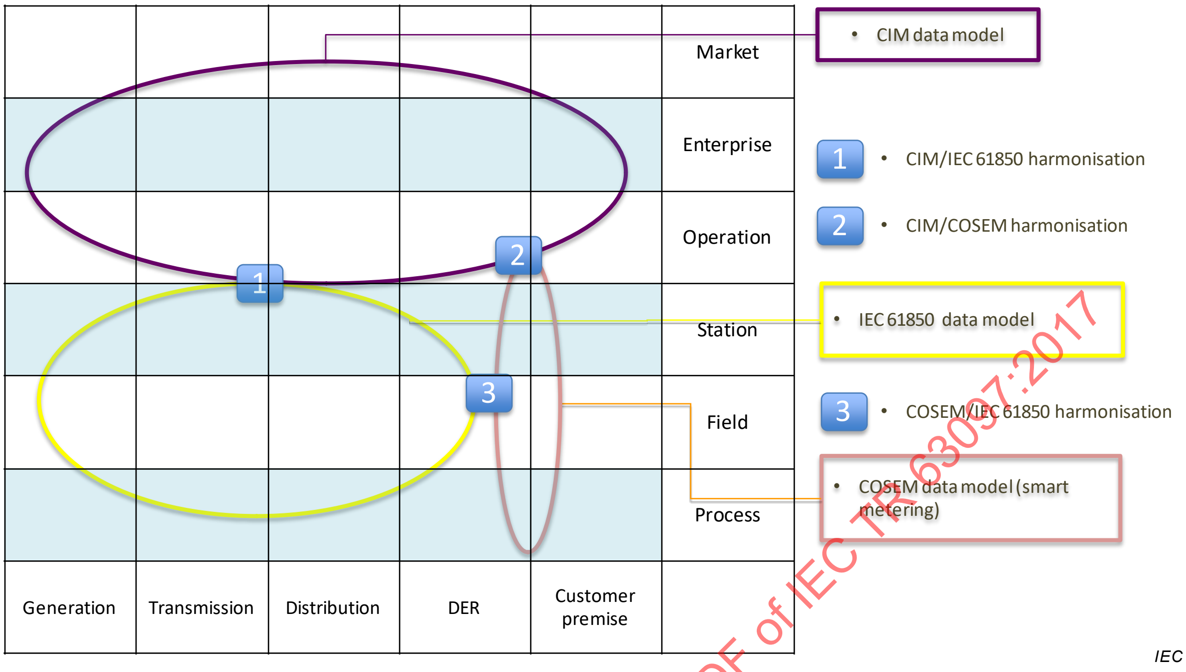


Figure 69 – Data modelling and harmonization work mapping

5.10.3.2 List of standards

5.10.3.2.1 Available standards

See Table 79.

Table 79 – Data modelling – Available standards

Layer	Standard	Title and comments
Information	IEC 61850 series	*Communication networks and systems for power utility automation*
Information	IEC 62056 series	*Electricity metering data exchange – The DLMS/COSEM suite*
Information	IEC 61970 series	*Energy management system application program interface (EMS-API)* Part of the CIM family
Information	IEC 61968 series	*Application integration at electric utilities – System interfaces for distribution management* Part of the CIM family
Information	IEC 62361 series	*Power systems management and associated information exchange – Interoperability in the long term*
Information	IEC TS 61850-80-4	*Communication networks and systems for power utility automation – Part 80-4: Translation from the COSEM object model (IEC 62056) to the IEC 61850 data model*

5.10.3.2.2 Coming standards

See Table 80.

Table 80 – Data modelling – Coming standards

Layer	Standard	Title and comments
Information	IEC TS 62056-6-9	*Electricity metering data exchange – The DLMS/COSEM suite – Mapping between the Common Information Model message profiles (IEC 61968-9) and DLMS/COSEM (IEC 62056) data models and protocols*
Information	IEC TS 62361-102[a]	*Power systems management and associated information exchange – Interoperability in the long term – Part 102: CIM – IEC 61850 harmonization*
[a] Under preparation.		

5.10.3.3 Gaps

In case of multi-utility support, the data models for gas and water supply domains are not yet considered in IEC 61970 and IEC 61850 series.

Currently no complete mapping exists between IEC 61850 and IEC 61970 series.

A seamless Smart Grid communication requires a mapping of intersystem-to-subsystem communication. Currently standardized mappings of established domain standards (e.g. from IEC 61850 to Home and Building Automation domain) are not yet specified.

5.10.4 Security and privacy

NOTE The content of 5.10.4 is mostly derived from [4].

5.10.4.1 Description

Cyber security is an important success criterion for a secure, efficient and reliable operation of the Smart Grid. The most important goal of cyber security is the protection of all relevant assets in the scope of the Smart Grid from any type of hazards such as deliberate cyber security attacks, inadvertent mistakes, equipment failures, information theft and natural disasters. These hazards predominantly concern the IT and telecommunication infrastructure. In order to achieve an adequate level of protection, classical security objectives such as confidentiality, integrity, availability, non-repudiation and privacy need to be assured by the implementation of security controls. Cyber security issues are already addressed in the scope of the critical infrastructure protection efforts. As recognized there, any vulnerability could be exploited in order to attack the stability of the underlying systems with a fatal impact on energy supply and reliability. Because of the nature of the Smart Grid as a huge network of interconnected sub-networks and its inherent complexity, the aforementioned risks could quickly be increased. This comes along with a vast number of systems, interfaces, operational modes and policies implemented by the stakeholders involved which leads to more vulnerabilities and a higher probability that these will be exploited. In addition, new functionalities like smart metering introduce stronger requirements for data protection and privacy. The following bullets state the risks more precisely.

- The architecture of the Smart Grid will be complex with a very high number of endpoints, participants, interfaces and communication channels and with different levels of protection in the underlying systems. In general, it is always a challenge and requires effort to achieve an adequate level of protection for such a complex system.
- The introduction of Smart Metering systems and processes will increase the number of endpoints dramatically and will move them to private households. Physical security is hard to achieve in these scenarios and time and motivation to penetrate the systems are in plentiful supply.

- Many components of the Smart Grid can be characterized as legacy where security has never been an important requirement.
- The majority of network connections and communications paths in the scope of the Smart Grid will be based on Internet-technologies / IP-networks. This infrastructure comes along with high flexibility and many existing systems, but also introduces a higher vulnerability because of the mal-ware (e.g. worms, viruses) which already exists in this ecosystem and the potential risk of this spreading quickly, which could have fatal consequences.
- A higher number of attack scenarios based on very different objectives, ranking from industrial espionage and terrorism to privacy breaches, can be anticipated.

5.10.4.2 Cyber security standardization landscape

The relevant documents are non-exhaustively listed below.

The set of security standards is split into "requirements standards" (type 1) and "solution standards" (type 2 and type 3) as listed below.

- "Requirement standards" considered (Mostly the 'What'):
  – ISO/IEC 15408, *Information technology – Security techniques – Evaluation criteria for IT security*
  – ISO/IEC 18045, *Information technology – Security techniques – Methodology for IT security evaluation*
  – ISO/IEC 19790, *Information technology – Security techniques – Security requirements for cryptographic modules*
  – 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*
  – IEC 62443-2-4, *Security for industrial automation and control systems – Part 2-4: Security program requirements for IACS service providers*
  – IEC 62443-3-3, *Security for industrial automation and control systems – Part 3-3: System security requirements and security levels*
  – IEC 62443-4-2, *Security for industrial automation and control systems – Part 4-2: Technical security requirements for IACS components*
  – IEEE 1686, *Substation Intelligent Electronic Devices (IED) Cyber Security Capabilities*
  – IEEE C37.240, *Cyber Security Requirements for Substation Automation, Protection and Control Systems*
- "Solution standards" considered (Mostly the 'How'):
  – ISO 15118-2, *Road vehicles – Vehicle-to-Grid Communication Interface, Part 2: Network and application protocol requirements*
  – IEC 62351-x, *Power systems management and associated information exchange – Data and communication security*
  – IEC 62056-5-3, *Electricity metering data exchange – The DLMS/COSEM suite – Part 5-3: DLMS/COSEM application layer*
  – IETF RFC 6960, *Online Certificate Status Protocol*
  – IETF draft-ietf-core-coap (RFC 7252): *CoAP Constrained Application Protocol*
  – IETF I-D draft-weis-gdoi-iec62351-9: *IEC 62351 Security Protocol support for the Group Domain of Interpretation (GDOI)*
  – IETF RFC 7030: *Enrollment over Secure Transport*

NOTE 1 5.10.4 has not been written to specifically include the Smart Metering related standards. Some specific requirement and standards may be needed to implement a smart metering AMI system.

NOTE 2 The standards stated above have been analysed in the context of dedicated use cases. The use cases addressed were:

- Transmission Substation;
- Distribution Control Room;
- Consumer Demand Management;
- DER Control.

One way to better position the above documents is to consider two axes as illustrated in Figure 70. The first one is their relevance for Organizations (Smart Grid operators) and products and services (product manufacturer and service providers). The second one is their relevance from a technical point of view and their relevance from an organizational point of view.

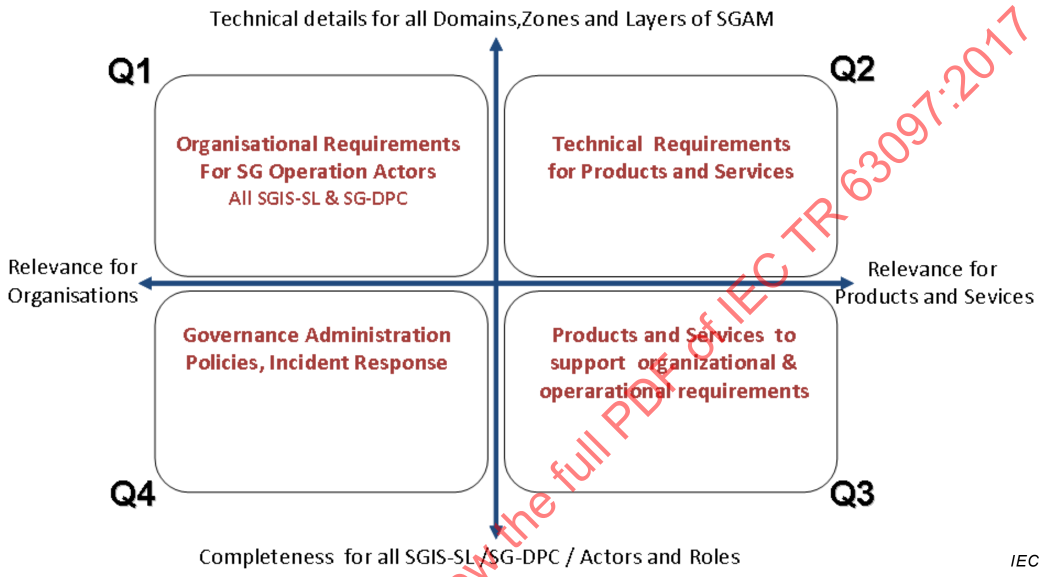


Figure 70 – Smart Grid information security standards areas

Figure 71 below shows the mapping of the selected standards to the standards areas under the following terms:

- Details for Operation: The standard addresses organizational and procedural means applicable for all or selected actors. It may have implicit requirements for systems and components without addressing implementation options.
- Relevance for Products: The standard directly influences component and/or system functionality and needs to be considered during product design and/or development. It addresses technology to be used to integrate a security measure.
- Design Details: The standard describes the implementation of security means in details sufficient to achieve interoperability between different vendor’s products for standards on a technical level and/or procedures to be followed for standards addressing organizational means.
- Completeness: The standard addresses not only one specific security measure but addresses the complete security framework, including technical and organizational means.

Using this representation the security standards landscape based on the documents listed above can be established as illustrated in Figure 71.

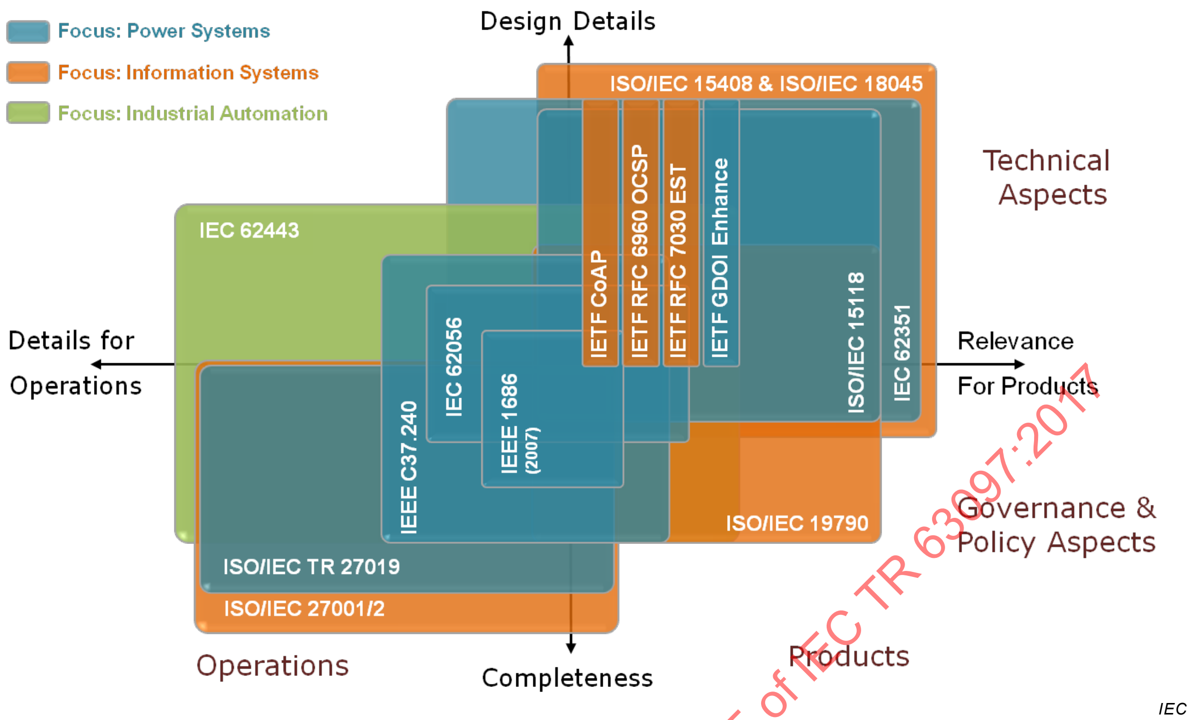


Figure 71 – Current Smart Grid information security standard landscape analysed

Figure 72 shows the applicability and scope of each of the standards from a somewhat different perspective. The differentiation in the drawing is as follows.

- Guideline: The document provides guidelines and best practice for security implementations. This may also comprise pre-requisites to be available for the implementation.
- Requirement: The document contains generic requirements for products, solutions or processes. No implementation specified.
- Realization: The document defines implementation of security measures (specific realizations). Note, if distinction possible, the level of detail of the document raises from left to right side of the column.
- Vendor: Standard addresses technical aspects relevant for products or components.
- Integrator: Standard addresses integration aspects, which have implications on the technical design, is relevant for vendor processes (require certain features to be supported), or requires product interoperability (e.g. protocol implementations).
- Operator: Standard addresses operational and/or procedural aspects, which are mainly focused on the service realization and provisioning on an operator site.

The colour code from Figure 71 is kept also in Figure 72. Some of the standards only cover partly a certain vertical area. The interpretation of partial coverage is that the standard may not provide explicit requirements for the vendor/integrator/operator. Standards covering multiple horizontal areas address requirements and also provide solution approaches on an abstract level. For the implementation additional standards or guidelines may be necessary.

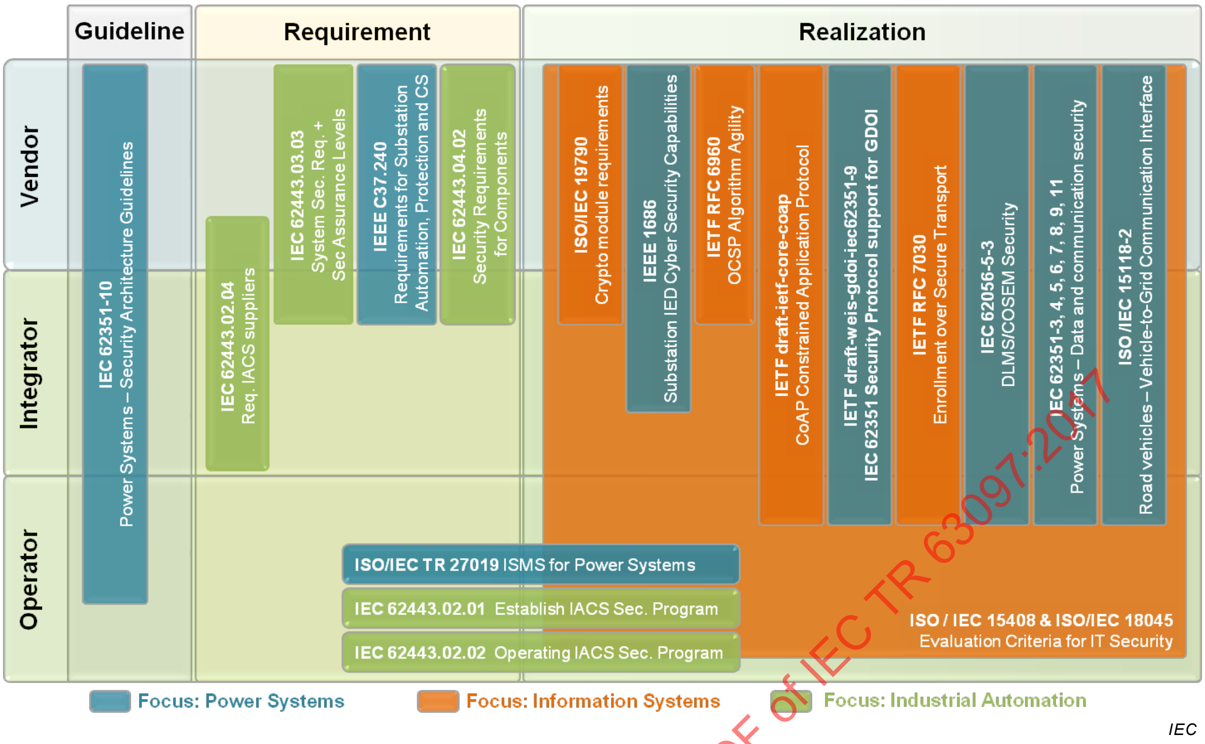


Figure 72 – Security standard applicability

The conclusion of this study is key information for the Smart Grid information security landscape. As shown above (Figure 71 and Figure 72) there are several standards available and mature to be utilized in Smart Grid applications. Nevertheless there is still a need for investigating further standards and their coverage of Smart Grid specific needs. Hence, this exercise (standards gap analysis) is a continuous process, which will require further investigation into existing and upcoming standards addressing the evolution of the Smart Grid information security needs. This evolution is especially driven through new use cases, incorporating communication interactions between new Smart Grid roles and entities.

5.10.4.3 List of standards

5.10.4.3.1 Available standards

See Table 81. Refer to 5.2.5.3 for the definition of the criteria considered in this document for stating that a standard is “available”.

Table 81 – Security – Available standards

Layer/type	Standard	Title and comments
General	IEC TS 62351-1	*Power systems management and associated information exchange – Data and communications security – Part 1: Communication network and system security – Introduction to security issues* Does not provide a dedicated technical solution, rather explains the applicability of the IEC 62351 series
General	IEC TS 62351-2	*Power systems management and associated information exchange – Data and communications security – Part 2: Glossary of terms* Does not provide a dedicated technical solution, rather explains the glossary of the IEC 62351 series
Component, communication, information, function	IEC TS 62351-3	*Power systems management and associated information exchange – Data and communications security – Part 3: Communication network and system security – Profiles including TCP/IP* Depends on the usage of TCP/IP
Component, communication, information, function	IEC TS 62351-4	*Power systems management and associated information exchange – Data and communications security – Part 4: Profiles including MMS* Depends on the usage of TCP/IP and MMS
Component, communication, information, function	IEC TS 62351-5	*(Ed 2) Power systems management and associated information exchange – Data and communications security – Part 5: Security for IEC 60870-5 and derivatives* Depends on the usage of IEC 60870-5 and serial protocols
Component, communication, information, function	IEC TS 62351-6	*Power systems management and associated information exchange – Data and communications security – Part 6: Security for IEC 61850;* Depends on the usage of GOOSE and SMV
Component, communication, information, function	IEC TS 62351-7	*Power systems management and associated information exchange – Data and communications security – Part 7: Network and system management (NSM) data object models* Depends on the usage of network management protocols/functions
Component, communication, information, function	IEC TS 62351-8	*Power systems management and associated information exchange – Data and communications security – Part 8: Role-based access control* Defines Role-Based Access Control and associated credentials to be used in the context of IEC 62351
Component, communication, information, function	IEC TR 62351-10	*Power systems management and associated information exchange – Data and communications security – Part 10: Security architecture guidelines* Provides an overview about and motivation of application of security in power systems
Component, communication, information, function	IEC 62443-3-3	*Industrial communication networks – Network and system security – Part 3-3: System security requirements and security levels* Describes System Security Requirements and Security Levels for industrial communication networks
Communication, Information, function	ISO 15118-2	*Road vehicles – Vehicle-to-Grid Communication Interface – Part 2: Network and application protocol requirements* Describes the communication interface between an electric vehicle and the charging spot including security
Communication, Information, function	IEC TR 61850-90-5	*Communication networks and systems for power utility automation – Part 90-5: Use of IEC 61850 to transmit synchrophasor information according to IEEE C37.118* Describes exchanging synchrophasor data between PMUs, WAMPAC (Wide Area Monitoring, Protection, and Control), and between control centre applications; Contains a comprehensive security model for the underlying routable profile; GDOI is used for key management
Communication, Information, function	IEC 62056-5-3	*Electricity metering data exchange – The DLMS/COSEM suite – Part 5-3: DLMS/COSEM application layer* Describes the COSEM application layer, including security

Layer/type	Standard	Title and comments
Communication, Information, function	IEC 61400-25 series	*Wind energy generation systems – Communications for monitoring and control of wind power plants* Set of standards describing also web service mapping for wind power
Information, function	ISO/IEC 27001	*Information technology – Security techniques – Information security management systems – Requirements* Describes requirements for information security management
Information, function	ISO/IEC 27002	*Information technology – Security techniques – Code of practice for information security controls*
Information, function	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 industry*
Other specifications		
Communication	IETF RFC 2617	HTTP Authentication: Basic and Digest Access Authentication
Communication	IETF RFC 2759	EAP MS-CHAP2
Communication, Information	IETF RFC 2865	RADIUS (Remote Authentication Dial In User Service)
Communication, Information, function	IETF RFC 3711	SRTP, to protect video surveillance data or customer service (VoIP)
Communication, Information	IETF RFC 3748	EAP Base Protocol (includes EAP MD5)
Communication, Information	IETF RFC 3923	End-to-End Signing and Object Encryption for XMPP
Communication, Information, function	IETF RFC 4210	Certificate Management Protocol
Communication, Information, function	IETF RFC 4211	Certificate Request Message Format
Communication, Information, function	IETF RFC 4301	IPSec, may be used to realize VPNs, Or for any other type of IPSec based security mechanisms
Communication, Information, function	IETF RFC 4302	IPSec, may be used to realize VPNs, Or for any other type of IPSec based security mechanisms
Communication, Information, function	IETF RFC 4303	IPSec, may be used to realize VPNs; Or for any other type of IPSec based security mechanisms
Communication	IETF RFC 4422	SASL Security
Communication, Information, function	IETF RFC 4962	AAA, Network Access, e.g. for service or remote access
Communication	IETF RFC 5106	EAP IKEv2
Communication	IETF RFC 5216	EAP TLS
Communication, Information, function	IETF RFC 5246	TLS, can be applied whenever point-to-point TCP/IP needs to be protected
Communication, Information, function	IETF RFC 5247	EAP Framework, Framework for key management, can be used for any type of endpoint, Network Access, e.g. for service or remote access
Communication, Information, function	IETF RFC 5272	Certificate Management over CMS
Communication, Information, function	IETF RFC 5274	CMC Compliance Requirements
Communication, Information, function	IETF RFC 5280	Internet X.509 Public Key Infrastructure Certificate and Certificate Revocation List (CRL) Profile, Base specification for X.509 certificates and certificate handling
Communication	IETF RFC 5281	EAP TTLSv1.0
Communication, Information, function	IETF RFC 6272	Identifies the key infrastructure protocols of the Internet Protocol Suite for use in the Smart Grid
Communication, Information, function	IETF RFC 6347	DTLS, Alternative to TLS in UDP-based; meshed-type of networks; can be applied whenever point-to-point UDP/IP needs to be protected

Layer/type	Standard	Title and comments
Communication, Information, function	IETF RFC 6407	GDOI, used, e.g., to provide key management for IEC 61850-90-5
Communication	IETF RFC 6749	The OAuth 2.0 Authorization Framework
Communication	IETF RFC 6750	The OAuth 2.0 Authorization Framework: Bearer Token Usage
Communication, Information	IEEE 802.1X	Specifies port based access control, allowing the restrictive access decisions to networks based on dedicated credentials. It defines the encapsulation of EAP over IEEE 802, also known as EAP over LAN or EAPOL. Includes also the key management, formally specified in IEEE 802.1AF
Communication, Information	IEEE 802.1AE	Specifies security functionality in terms of connectionless data confidentiality and integrity for media access independent protocols. Specifies a security frame format similar to Ethernet
Communication, Information	IEEE 802.1AR	Specifies unique per-device identifiers and the management and cryptographic binding of a device to its identifiers
General	IEEE 1686	defines functions and features that must be provided in substation intelligent electronic devices to accommodate critical infrastructure protection programs
Communication, Information, function	ETSI TCRTR 029	General overview of features specified on ETSI side
Communication, Information, function	ETSI ETR 332	
Communication, Information, function	ETSI ETR 237	
Communication, Information, function	ETSI ES 202 382	
Communication, Information, function	ETSI ES 202 383	
Communication, Information, function	ETSI EG 203 387	
Communication, Information, function	ETSI TS 102 165-1	
Communication, Information, function	ETSI TS 102 165-2	
Communication, Information, function	ETSI EG 202 549	
Communication, Information, function	ETSI TR 185 008	
Communication, Information, function	ETSI TR 187 012	
Communication, Information, function	ETSI TS 187 016	
Communication, Information, function	ETSI TR 102 419	
function	ETSI TS 101 456	Electronic signatures
function	ETSI TR 102 437	Electronic signatures
function	ETSI TS 102 042	Electronic signatures
function	ETSI TR 102 572	Electronic signatures
function	ETSI TS 102 573	Electronic signatures
function	ETSI TS 102 689	Requirements
function	ETSI TS 102 690	Architecture
function	ETSI TS 102 921	Protocols
function	ETSI TR 103 167	Threat Analysis

Layer/type	Standard	Title and comments
communication , information	ETSI TS 100 920	Communication, information for mobile (3GPP, GSM, CDMA…) telecommunication infrastructures
Communication, Information	ETSI TS 133 203	
Communication, Information	ETSI TS 133 210	
Communication, Information	ETSI TS 133 234	
Communication, Information	ETSI TS 133 310	
Communication, Information	ETSI TS 102 225	Communication, information for mobile (3GPP, GSM, CDMA…) telecommunication infrastructures. Secure packet protocol for remote administration of security element
Communication, Information	ETSI TS 102 226	Communication, information for mobile (3GPP, GSM, CDMA…) telecommunication infrastructures. Remote administration of Security element
Communication, Information	ETSI TS 102 484	Communication, information for mobile (3GPP, GSM, CDMA…) telecommunication infrastructures. Local Secure Channel to security element
Communication, Information	ETSI TS 187 001	Communication, information for fixed (IP based…) telecommunication infrastructures. Security Requirements
Communication, Information	ETSI TS 187 003	Communication, information for fixed (IP based…) telecommunication infrastructures. Threat Analysis
Communication, Information	ETSI TR 187 002	Communication, information for fixed (IP based…) telecommunication infrastructures. Security Architecture
Communication, Information	W3C XML Digital Signature	Provide security features for XML encoded data
Communication, Information	W3C XML Encryption	Provide security features for XML encoded data

5.10.4.3.2 Coming standards

See Table 82. Refer to 5.2.5.3 for the definition of the criteria considered in this document for stating that a standard is “coming”.

Table 82 – Security – Coming standards

Layer/type	Standard	Title and comments
Component, communication, information, function	IEC 62351-6 [a]	*Power systems management and associated information exchange – Data and communications security – Part 6: Security for IEC 61850* Depends on the usage of GOOSE and SMV (Edition 2)
Component, communication, information, function	IEC 62351-9	*Power systems management and associated information exchange – Data and communications security – Part 9: Cyber security key management for power system equipment* Defines management of necessary security credentials and parameters in the context of IEC 62351
Component, communication, information, function	IEC 62351-11	*Power systems management and associated information exchange – Data and communications security – Part 11: Security for XML documents* Focus on XML Security for files to ensure that the receiver gets information about the sensitivity of the data received
Component, communication, information, function	IEC 62443 series	*Industrial communication networks – Network and system security*
Other specifications		
General	IEEE P2030	Provides a Guide for Smart Grid Interoperability of Energy Technology and Information Technology Operation with the Electric Power System

[a] Under preparation.

5.10.5 Authentication, Authorization, Accounting systems

5.10.5.1 Description

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.

Authentication is the process to authenticate an identity (a user or a system). The process verifies that the person or system is really the one it claims to be by verifying evidence. This is usually done using credentials such as login/passwords, one-time-passwords, digital certificates, etc.

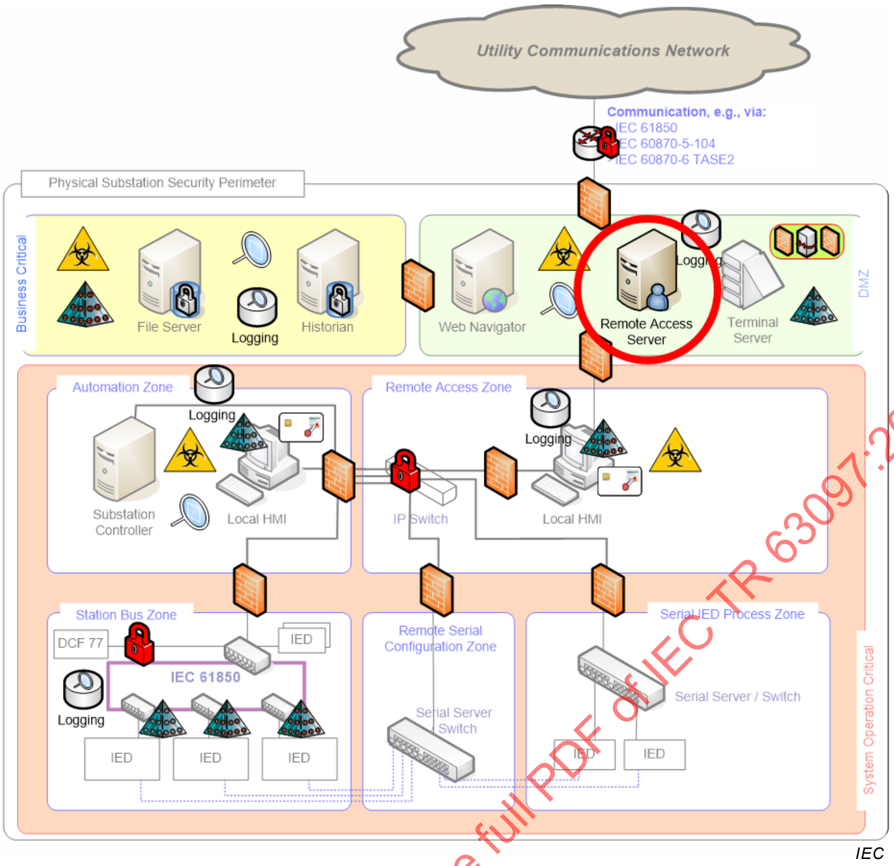
Authorization is the process to identify what a given identity is allowed to perform on a given system. It describes what the “rights” of the identity over the system are. In other words it describes to what extent the identity is allowed to manipulate the system. For example, the rights of an Operating System user on the file system (what can be read, what can be modified, what can be executed) or access rights of a system over the network (what the system is allowed to connect to).

Accounting is the process that measures the resources consumed by the identity for billing, auditing and reporting. Accounting systems are also used to record events. Usually the following type of information is recorded: Identity, Authentication success/failure, Authorization success/failure, what is accessed, when the access starts, when the access stops and any other relevant information related to the service delivered.

When it comes to technically looking at an AAA system, it is difficult to do the exercise without a context. Even if the same kinds of actions are performed, the way they are performed and they can be described depends on the context and the technical architecture used in that context. Analysing the way a user is granted access locally to an operating system is different, even if there are similarities, from analysing the way a user can remotely access a system or the way a system can access a system on Local Area Network or over the Internet through a Virtual Private Network.

The choice has been made in 5.10.5 to consider the scenario of a remote access to a Substation Automation System as defined in 5.9.7.

Figure 73 is taken from IEC TR 62351-10 and shows such a substation automation scenario. As shown in Figure 73, access is controlled using a remote access server (circled in red).



SOURCE: IEC TR 62351-10:2012, Figure 14.

Figure 73 – AAA Example in a substation automation use case

Access protection for zones or subnets is typically done by using AAA (Authentication, Authorization, and Accounting). AAA builds basically on three components: the supplicant (the person or component that wants to access the substation), the authenticator (the ingress access switch) and the authentication server (performing the actual authentication, authorization, and accounting).

In case of AAA there exist supporting standards like the EAP (Enhanced Authentication Protocol) framework defined by the IETF. EAP allows authentication and key establishment and can be mapped to protocols like IEEE 802.1x for the communication between the supplicant and the authenticator or RADIUS (Remote Authentication Dial In User Service) for the communication between authenticator and authentication server as depicted in Figure 74.

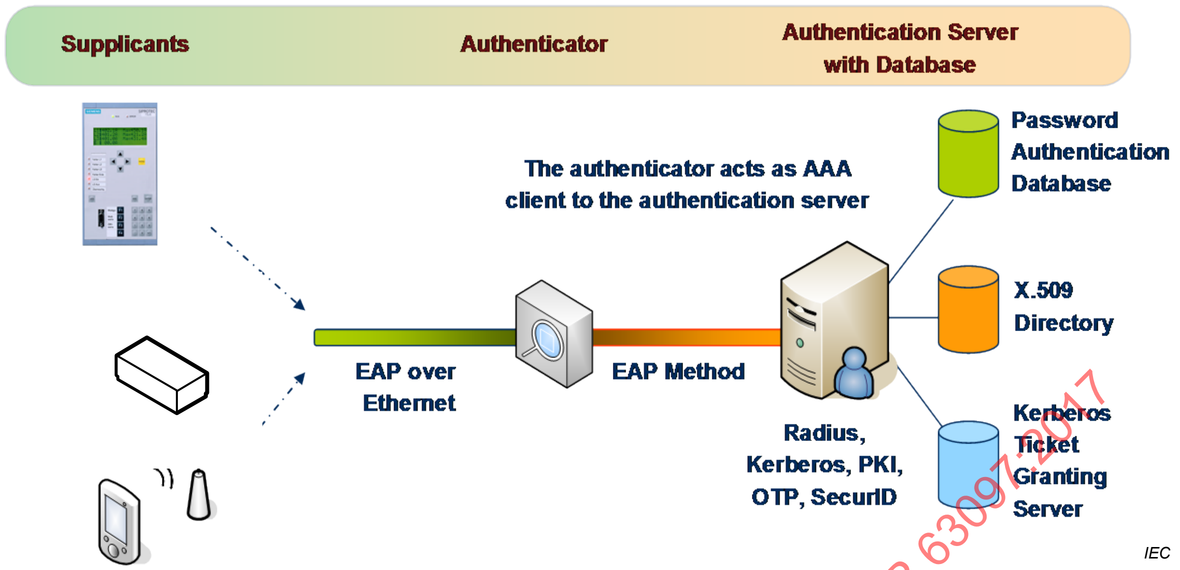


Figure 74 – EAP Overview

There are further means for the communication between the authenticator and the authentication server. One example is TACACS+ (Terminal Access Controller Access-Control System). In contrast to RADIUS, it uses TCP for communication.

The current approach used for remotely accessing a substation often relies on the application of a VPN connection based on IPSec. This termination of the VPN in the substation is connected with the AAA infrastructure to ensure that only authenticated and authorized connections are possible. This is often achieved by using a dedicated component, a VPN gateway.

In the future, the security may be enhanced especially for connections using IEC 61850 or IEC 60870-5-104. For these protocols IEC 62351 series means can be directly applied to protect the communication, allowing for an end-to-end security relationship terminating in the substation. Hence, this protection does not necessarily require a specific VPN connection to protect the communication. It is expected that VPN connections will still provide a value as there are other connections, for example Voice over IP, which can be protected using the VPN tunnel.

Additional possibilities, which may be used to further support remote access control, are provided by IEC TS 62351-8 (RBAC, Role based Access Control) in conjunction with IEC 61850 series. IEC TS 62351-8 allows fine grained role based access control using X.509 certificates and corresponding private keys. This allows extension of access control also within the substation. Hence, it allows further restriction of access or rights for operative or management actions within the substation.

NOTE IEC TS 62351-8 may be used in conjunction with LDAP to fetch RBAC specific credentials from a repository.

5.10.5.2 Set of System Capabilities

Table 83 provides a set of System Capabilities which may be supported by an AAA system for a Remote Access Solution (in that example applied to a Substation Automation System).

The meanings of the three last columns (AVAILABLE, COMING, Not Yet) and of the "C", "I", "CI", "X" conventions are given in 5.5.2.5.

Table 83 – AAA systems – Capabilities

Cluster	System Capabilities	Supported by standards		
		AVAILABLE	COMING	Not yet
Access Control (Substation Remote Access Example)	Local access to devices residing in a substation, with substation local authentication and authorization	x		
	Local access to devices residing in a substation, with higher level support (e.g. control centre) for authentication and authorization	x		
	Remote access to devices residing in a substation, with substation local authentication and authorization using a separate VPN	x		
	Remote access to devices residing in a substation, with higher level support (e.g. control centre) for authentication and authorization using a separate VPN	x		
	Remote access to devices residing in a substation, with substation local authentication and authorization using communication protocol inherent security means	(x)	x	
	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	(x)	x	
System and security management	User Management			
	Role Management			
	Rights/Privileges Management			
	Certificate Management			
	Events Management		x	

Access control based on authentication of persons or components in these System Capabilities can be provided by different means like:

- Username and Password;
- X.509 Certificates and corresponding private keys;
- Security Tokens (like one-time-password-generators, smart cards, RFID token, etc.)

Note that authentication means can also be directly derived from the used EAP method.

Depending on the use case, these means may be applied just locally, requiring the authorization handling to be performed locally as well. This may include the local management of accessing peers (persons or devices), roles, and associated rights. Moreover, these means may be used as part of the communication protocols on different OSI layers. A further option is to delegate the access control from the station level to the operation level. This leads to access control decisions by an AAA server residing in a control centre for example.

5.10.5.3 List of standards

5.10.5.3.1 General

5.10.5.3.2 and 5.10.5.3.3 provide a summary of standards which appear relevant to support AAA systems.

5.10.5.3.2 Available standards

Refer to 5.2.5.3 for the definition of the criteria considered in this document for stating that a standard is "available".

Table 84 provides an overview of applicable standards for AAA.

NOTE The list is not exhaustive.

Table 84 – AAA system – Available standards

Layer	Standard	Title and comments
Information	IEC TS 62351-8	Definition of Role Based Access Credentials
Communication	IEC TS 62351-3 IEC TS 62351-4 IEC TS 62351-8	Protection of TCP-based IEC 61850 or IEC 60870-5-104 communication using TLS together with RAC credentials
Information, Communication	IEC TR 61850-90-4	*Communication networks and systems for power utility automation – Part 90-4: Network engineering guidelines*
Information, Communication	IEC TR 61850-90-2	*Communication networks and systems for power utility automation Part 90-2: Using IEC 61850 for the communication between substations and control centres*
Other specifications		
Information	IETF RFC 4962	Guidance for Authentication, Authorization, and Accounting (AAA) Key Management
Information	IETF RFC 2865	RADIUS (Remote Authentication Dial In User Service)
Communication	IETF RFC 2759	EAP MS-CHAP2
Communication	IETF RFC 3748	EAP Base Protocol (includes EAP MD5)
Communication	IETF RFC 4764	EAP PSK (Pre-Shared Key)
Communication	IETF RFC 5106	EAP IKEv2
Communication	IETF RFC 5216	EAP TLS
Communication	IETF RFC 5281	EAP TTLSv1.0

5.10.5.3.3 Coming standards

See Table 85. Refer to 5.2.5.3 for the definition of the criteria considered in this document for stating that a standard is "coming".

Table 85 – AAA system – Coming standards

Layer	Standard	Title and comments
Communication	IEC 61850-8-2 [a]	*Communication networks and systems for power utility automation – Part 8-2: Specific communication service mapping (SCSM) – Mapping to Extensible Messaging Presence Protocol (XMPP)* IEC 61850 Specific communication service mapping (SCSM) – Mappings to web-services
[a] Under preparation.		

5.10.5.4 Mapping on SGAM

5.10.5.4.1 Preamble

It is important to consider that, from a standard point of view, there are a lot of similarities between distribution substation automation systems, transmission and generation substations, especially when it comes to remote access. For an easy reading of the document only the distribution substation automation is mapped as an example use case. The general approach can also be applied to other scenarios like transmission or generation, and also to remotely access smart metering systems like data collection points, which constitute the first layer of data accumulation.

Considering that this system does not interact with the “Enterprise” and “Market” zones of the SGAM, only the “Process”, “Field”, “Station” and “Operation” zones will be shown.

5.10.5.4.2 Component layer

The base representation of the component layer is provided by the substation automation use case. The additional component used here is the AAA server. The AAA server allows the storage of the authentication information and access rights of dedicated users (or roles) or components necessary to access to the substation. The AP (Access Point) is the ingress equipment supporting authentication and access control communicating with the AAA authentication server. The AAA authentication server may reside on station level or in the control centre (typical). This is shown in Figure 75 by the two AAA authentication servers connected with the access switch with dotted lines. The AP may be the switch already available or an additional component (like a VPN Gateway) as marked in red in Figure 75.

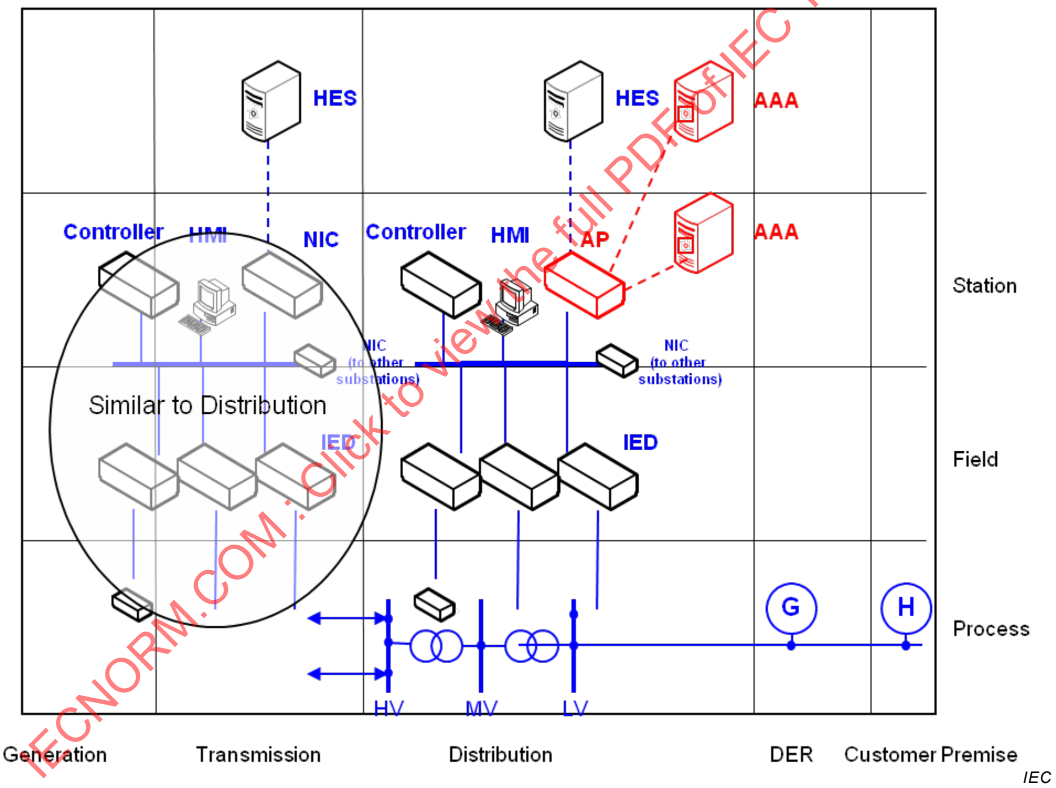


Figure 75 – Mapping of standards used in the AAA example on SGAM – Component layer

5.10.5.4.3 Communication layer

As stated before, there are two main options for remotely accessing a substation. Either using a separate VPN connection or protocol specific security features.

For the VPN connection IPSec is assumed to be applied. Network access control is often performed, before the IPSec connection is actually established (e.g. using EAP (Encapsulated Authentication Protocol) on OSI layer 2. Examples can be given by dial-up connections using PPP.

EAP is a container protocol allowing the transport of different authentication methods which provide different functionality. The base protocol is defined in RFC 3748. EAP allows the specification of dedicated methods to be used within the container. The functionality supported ranges from plain unilateral authentication to mutual authentication with session key establishment. From the cryptographic strength of the authentication, there is also a range from plain passwords to X.509 certificate based authentication.

Examples for EAP authentication methods include (not complete) for instance: EAP-MD5, EAP-MS-CHAP2, EAP-TLS, EAP-TTLS, EAP-FAST, EAP-PSK, EAP-PAX, EAP-IKEv2, EAP-AKA, EAP-MD5, EAP-LEAP, EAP-PEAP, EAP-SIM, EAP-Double-TLS, EAP-SAKE and EAP-POTP. These methods are typically defined in separate IETF documents.

While EAP is typically used for network access authentication, there may be the need to further distinguish access within the substation. For example to access certain protection devices or a substation controller, also considering the role of the accessing entity. IEC TS 62351-8 provides a solution to support role based access control based on specific credentials, which can be applied in the context of applied security protocols. An example is given by the application of these credentials in TLS, which can be used according to IEC TS 62351-3 and IEC TS 62351-4 to protect the IEC 61850 series communication performed over TCP connections. This approach may be followed within a substation but also to access the substation from outside, without relying on a VPN connection. In fact, in the latter case, TLS provides the secure channel and thus works as a VPN.

For the use case shown here, two protocol families build the base namely IEC 61850 and IEC 60870-5. Especially for the outside communication the TCP based variants are applied allowing an easy application of IEC 62351 series functionalities. Note that the main focus here is on IEC TS 62351-8 as it supports the access control functionality.

- Within the substation, IEC 61850-8-1 (for any kind of data flows except sample values) and IEC 61850-9-2 (for sample values) are used to support the selected set of generic Capabilities.

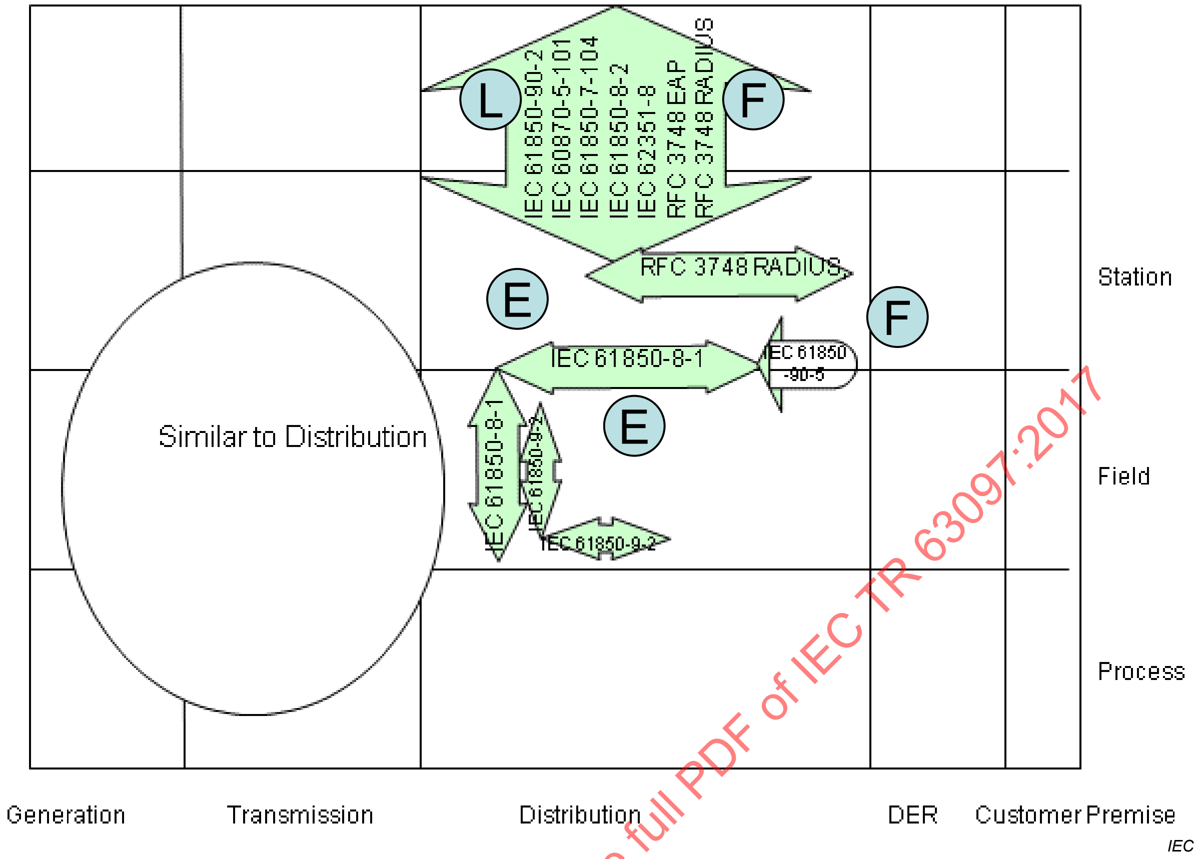
  IEC TR 61850-90-4 provides detailed guidelines for communication inside a substation.

  IEC 61850 is used for connecting protection relays.

- Outside the substation, “vertical communications” uses IEC 60870-5-104 or IEC 61850, while horizontal communications can rely on IEC TR 61850-90-5 (full mapping over UDP) or IEC TR 61850-90-1 (tunnelling).

Future vertical communication may rely on IEC TR 61850-90-2 (guideline for using IEC 61850 to control centres) to provide a seamless architecture, based on IEC 61850. A new mapping of IEC 61850 over the web services technology (IEC 61850-8-2) is under preparation, in order to enlarge (in security) the scope of application of IEC 61850 outside the substation, while facilitating its deployment.

This set of standards can be positioned as shown in Figure 76 on the communication layer of SGAM.



NOTE The letters in the blue disks refer to the network types defined in 5.10.1.2.

Figure 76 – Mapping of standards used in the AAA example on SGAM – Communication layer

5.10.5.4.4 Information (Data) layer

The information layer of substation automation is mostly based on the IEC 61850 series information model. Security is added by the definition of the security credential formation within IEC TS 62351-8 as shown in Figure 77. In addition, the IETF documents connected with network access (EAP, RADIUS, etc.) also define the necessary information elements.

For the sake of simplicity, only the security specific data models are referenced here:

- IEC TS 62351-8: Role Based Access Control, definition of credential formats
- RFC 3748: EAP, additionally the RFCs handling/defining EAP methods
- RFC 2865: RADIUS

For protocols, which are not IEC 61850 native, such as the IEC 60870-5-101 or IEC 60870-5-104, a mapping of IEC 61850 information model is possible using IEC TS 61850-80-1, enabling users of these technologies to use the power of data modelling (and then more seamless integration) without changing communication technologies.

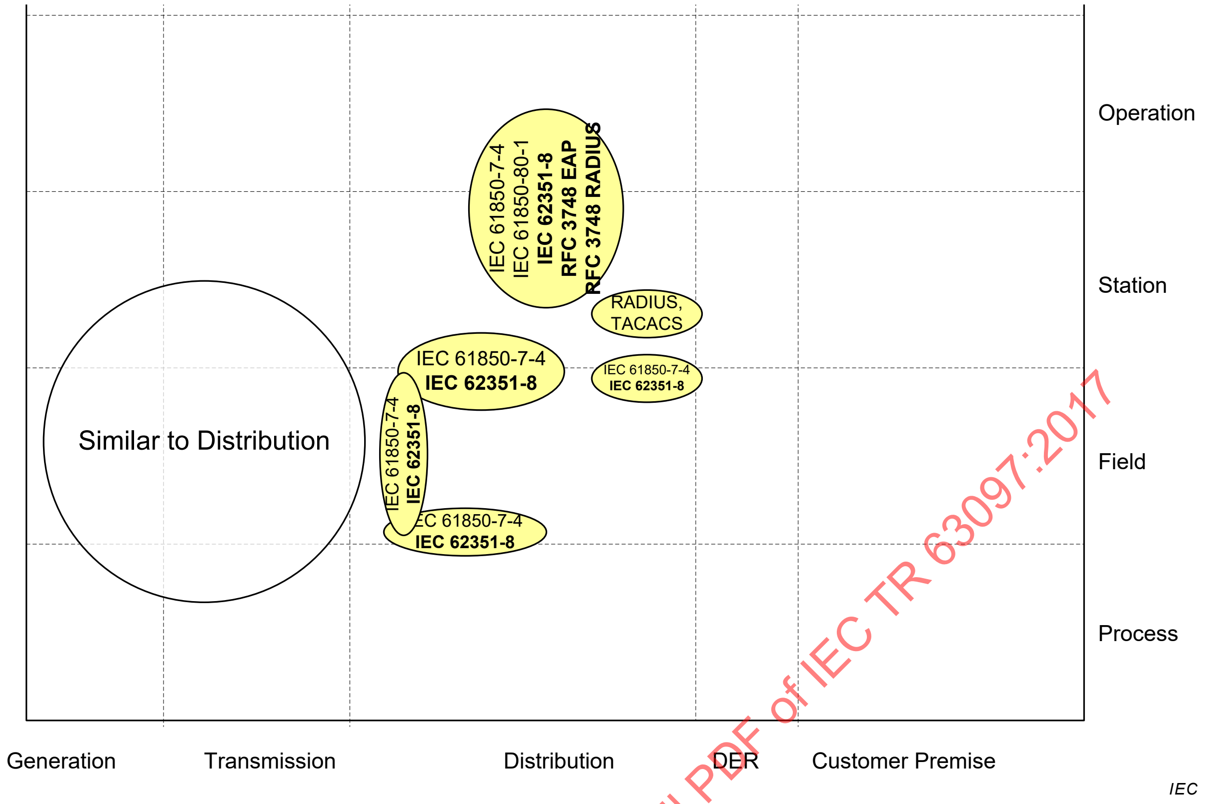


Figure 77 – Mapping of standards used in the AAA example on SGAM – Information layer

5.10.6 Clock reference system

5.10.6.1 Description

Many Smart Grid systems need a unified global time and then synchronized clocks, distributed among all the components in order to support specific Capabilities, such as accurate time stamping for events logging, alarming but also more and more to perform very time-critical algorithms based on digital time-stamped measurement samples, such as the "Sample values" specified by the IEC 61850 series.

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. It is usually made of a collection of one or many clock servers, transmission systems, relay stations, tributary stations and data terminal equipment capable of being synchronized.

The clock reference system will be highly dependent on the needed clock accuracy, from seconds accuracy (for example for DER process control), to millisecond(s) for electricity related events, down to sub-microsecond for digital samples.

Clock reference may be local reference time (the important point being that all components' clocks share the same time reference) or absolute reference time (the important point being that all clocks refer to the same absolute time reference). The last case may also be considered even if the requirement is only to get a same local reference time within the system, when it may be of easier deployment to rely on the absolute reference time, provided for example by the GPS system, rather than distributing a local reference time.

5.10.6.2 Set of System Capabilities

Table 86 lists a set of System Capabilities which is supported by a clock reference system and the indication how the current or coming set of standards supports it.

Time information may be associated to mostly any Smart Energy system capabilities, and the system described below in 5.10.6 may be associated to mostly systems as described in 5.9.

The meanings of the three last columns (AVAILABLE, COMING, Not yet) and of the “C”, “I”, “CI”, “X” conventions are given in 5.5.2.5.

Table 86 – Clock reference system – System Capabilities

Cluster	System Capabilities	Supported by standards		
		AVAILABLE	COMING	Not yet
System and security management	Distributing and synchronizing clocks	I	C	

5.10.6.3 List of standards

5.10.6.3.1 Available standards

See Table 87. Refer to 5.2.5.3 for the definition of the criteria considered in this document for stating that a standard is “available”.

Table 87 – Clock reference system – Available standards

Layer	Standard	Title and comments
Information	ISO 8601	*Data elements and interchange formats – Information interchange – Representation of dates and times.* Coordinated Universal Time (UTC)
Communication	IEC 60870-5-5	*Telecontrol equipment and system – Part 5-5: Transmission protocols – Basic application functions* including time synchronization basic application
Communication	IEC 61588 (IEEE 1588)	*Precision clock synchronization protocol for networked measurement and control systems* PTP (Precision clock synchronization protocol)
Communication	IEC PAS 61850-9-3	*Communication networks and systems for power utility automation – Part 9-3: Precision time protocol profile for power utility automation*
Communication	IEC TR 61850-90-5	*Communication networks and systems for power utility automation – Part 90-5: Use of IEC 61850 to transmit synchrophasor information according to IEEE C37.118*
Communication	IEC TR 61850-90-4	Network Engineering Guidelines for IEC 61850 based systems (including clock synchronization guidelines)
Communication	IEC 62439-3	Time management for PRP network mechanism
Communication	IETF RFC 5905	*NTP – Network Time protocol*
Communication	IETF RFC 4330	*SNTP – Simplified Network Time protocol*
Communication	IEEE C37.118	*PTP profile – IEEE standard for Synchrophasors for Power Systems*
Communication	IEEE C37.238:2011	*PTP Profile – IEEE standard for Power System Applications*
Communication	IRIG 200-98	*IRIG Time codes*

5.10.6.3.2 Coming standards

See Table 88. Refer to 5.2.5.3 for the definition of the criteria considered in this document for stating that a standard is "coming".

Table 88 – Clock reference system – Coming standards

Layer	Standard	Title and comments
Communication	IEC/IEEE 61850-9-3	*Communication networks and systems for power utility automation – Part 9-3: Precision time protocol profile for power utility automation*

5.10.6.4 Mapping on SGAM

5.10.6.4.1 Preamble

Mapping such a clock reference system onto the SGAM is not really easy, such system being independent from the domains and the zones, and in general re-using some existing communication capabilities of the concerned systems.

However, clock accuracy requirements may be different depending on the system or the part of the system which is under consideration and then their implementation request different mechanisms of even time model to support the expected functionalities.

Except for high accuracy, in many cases, clock synchronization does not require specific capabilities of the communication network itself, used for distributing the time. However, and specifically when using PTP, all components used between the clock master and the "ordinary clocks" have to comply with PTP specification, to achieve the expected performance.

5.10.6.4.2 Component layer

See Figure 78.

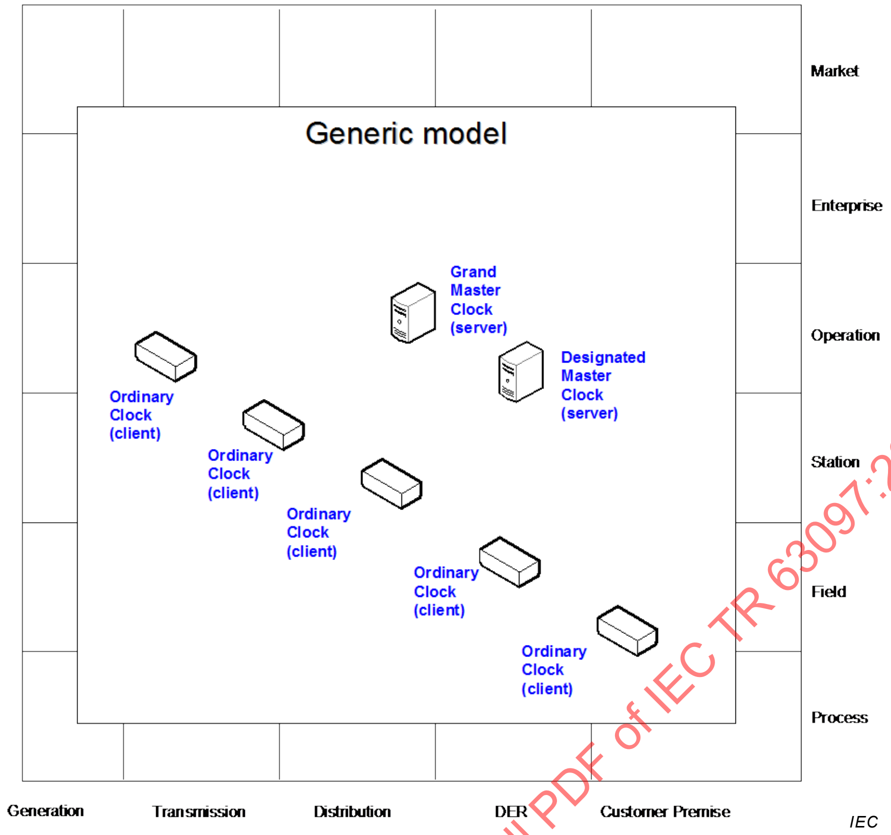
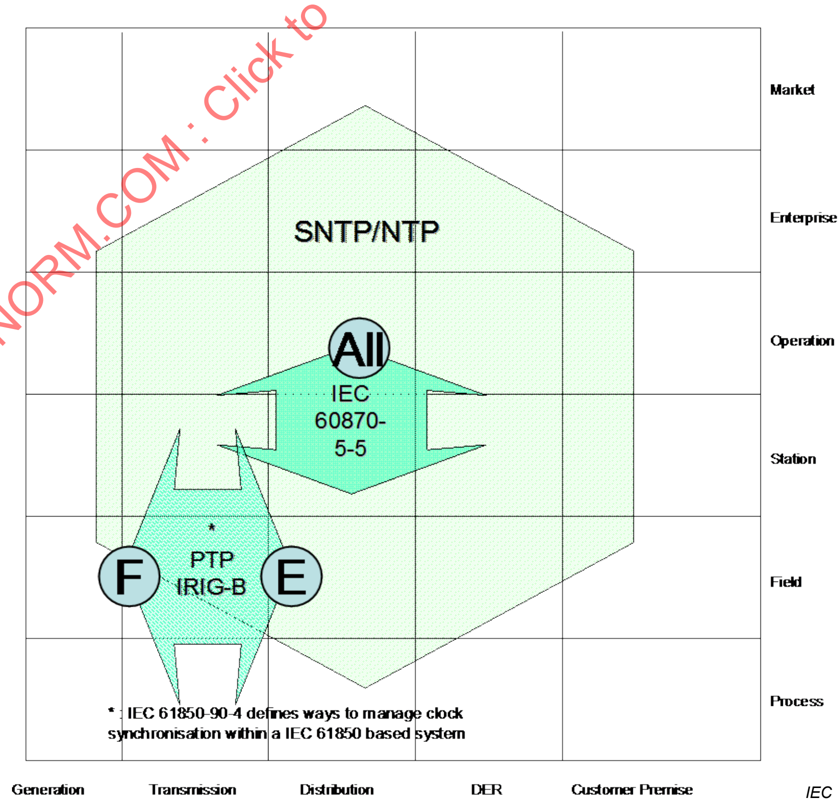


Figure 78 – Clock reference system – Component layer

5.10.6.4.3 Communication layer

See Figure 79.



NOTE The letters in the blue disks refer to the network types defined in 5.10.1.2.

Figure 79 – Clock reference system – Communication layer

5.10.6.4.4 Information (Data) layer

See Figure 80.

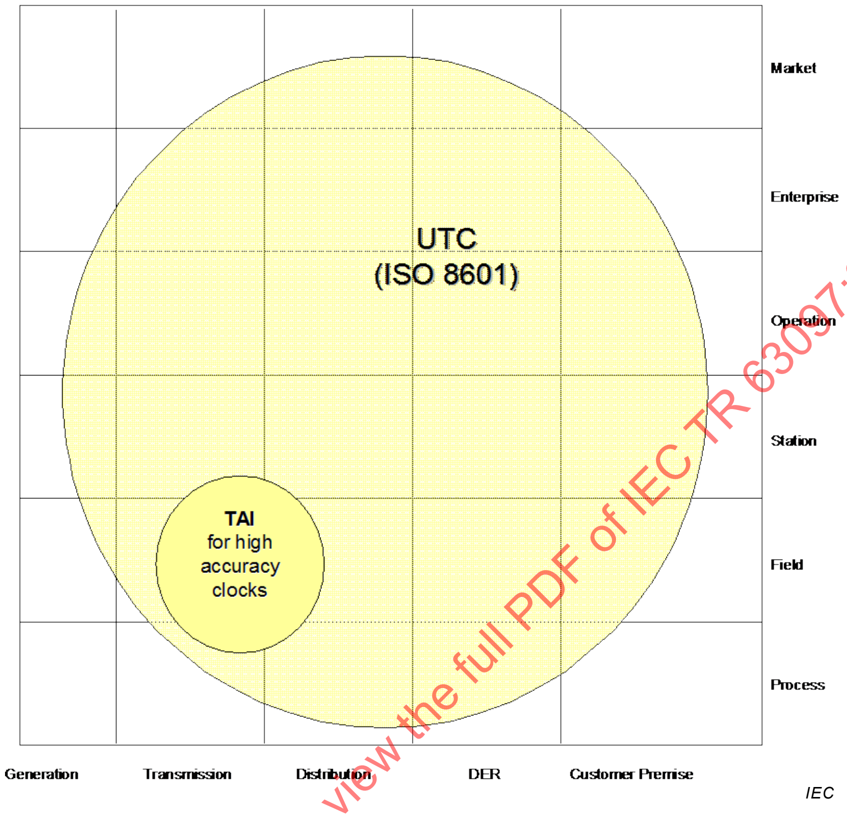


Figure 80 – Clock reference system – Information layer

5.10.7 EMC and Power Quality

5.10.7.1 Definitions

Electromagnetic compatibility is the ability of an equipment or system to function satisfactorily in its electromagnetic environment without introducing intolerable electromagnetic disturbances to anything in that environment.

Power quality encompasses characteristics of the electric current, voltage and frequencies at a given point in an electric power system, evaluated against a set of reference technical parameters.

NOTE These parameters might, in some cases, relate to the compatibility between electricity supplied in an electric power system and the loads connected to that electric power system.

Standards exist in some countries for the characteristics of electricity supplied to customers (at the entry point of user's installation), up to 150 kV, and are used for contractual relationship and for regulation. The specified levels are generally close to the Compatibility levels given in EMC standards, used as reference for product EMC requirements (Emission limits and Immunity levels).

A Technical Specification was published in 2015: IEC TS 62749, *Assessment of power quality – Characteristics of electricity supplied by public networks*

5.10.7.2 Power Quality

5.10.7.2.1 Power Quality related to Network operation

Power quality usually refers to the obligations of the Network Operators.

IEC 62749, *Assessment of power quality – Characteristics of electricity supplied by public networks*, provides insights on the subject.

The power quality levels given in standards can be used for customer relationship or for reporting towards the Authorities. When comparable, the specified levels are close to the Compatibility levels given in the EMC standards. They cover appropriately the huge majority of locations under acceptable economic conditions, despite the differences in situations, provided that:

- for mass-market products, emission requirements in standards are regularly and appropriately updated to take into account the development of markets and changes in technologies;
- for large installations, emission levels are effectively controlled, e.g. through connection agreements;
- network operators make use of appropriate methodologies and engineering practices, e.g. based on planning levels and IEC TR 61000-3-6, IEC TR 61000-3-7, IEC TR 61000-3-13 and/or IEC TR 61000-3-14.

The massive introduction of Distributed Energy Resources can impact the quality of supply experienced by network users in a number of ways. Examples being discussed in several publications include magnitude of the supply voltage, harmonic emission and resonances, increased level of flicker and single rapid voltage changes, increased number of interruptions due to incorrect operation of the protection, etc. Some impact is local, other impact is global; some impact is minor and occurs only for extreme locations, other impact is major and more general.

EN 50160:2010 specifies the characteristics of electricity supplied to customers (at the entry point of user’s installation), up to 150 kV.

5.10.7.2.2 Power quality (from bulk generation, etc.)

IEC 61000, *Electromagnetic compatibility (EMC)*

IEC 60038:2009, *IEC standard voltages*

IEC TR 62510, *Standardising the characteristics of electricity*

5.10.7.2.3 Power Quality in a Smart Grid context

A Smart Grid is expected to be flexible, and consequently Power Quality should be addressed in an appropriate way, considering high penetration of distributed energy resources (DER) and new ways of operating the networks (intentional islands, micro-grids, virtual power plants, etc.).

The following maintenance projects should be noted:

- IEC 61000-4-30:2015, *Electromagnetic compatibility (EMC) – Part 4-30: Testing and measurement techniques – Power quality measurement methods*
- CLC/TR 50422:2013, *Guide for the application of the European Standard EN 50160*

Draft Standards specifying connection of Distributed Energy Resources to the grid, such as EN 50438 Ed2 and CLC TS 50549, consider the contribution of DER to voltage control, by means of active and/or reactive power management.

5.10.7.3 EMC

5.10.7.3.1 General

Electromagnetic Compatibility is a prerequisite for all applications and products and is therefore not limited and not unique to Smart Grid.

For the Smart Grid to function properly and coexist with other electrical and electronic systems, it needs to be designed with due consideration for electromagnetic emissions and for immunity to various electromagnetic phenomena. EMC needs to be addressed effectively if the Smart Grid is to achieve its potential and provide its benefits when deployed.

The design and operation of a Smart Grid shall be consistent with relevant EMC standards and, in particular, with the EMC Compatibility Standards IEC 61000-2-2 (LV) and IEC 61000-2-12 (MV).

For a number of "smart" applications (e.g. Electric Vehicle or PLC in the metering domain), EMC will be a major issue. This will then include compliance with the IEC 61000 and CISPR series, besides specific product standards.

When designing a Smart Grid that utilizes equipment in the frequency range 9 kHz to 400 GHz, the user shall comply also with the emission requirements of CISPR 22 or CISPR 32.

In terms of equipment immunity, IT equipment used within a Smart Grid shall comply with the requirements of CISPR 24 or CISPR 35.

If no product standard comprising EMC part(s) exists, the requirements of the generic EMC standards apply according to its application:

IEC 61000-6-1, *Electromagnetic compatibility (EMC) – Part 6-1: Generic standards – Immunity standard for residential, commercial and light-industrial environments*

IEC 61000-6-2, *Electromagnetic compatibility (EMC) – Part 6-2: Generic standards – Immunity standard for industrial environments*

IEC 61000-6-3, *Electromagnetic compatibility (EMC) – Part 6-3: Generic standards – Emission standard for residential, commercial and light-industrial environments*

IEC 61000-6-4, *Electromagnetic compatibility (EMC) – Part 6-4: Generic standards – Emission standard for industrial environments*

IEC 61000-6-5, *Electromagnetic compatibility (EMC) – Part 6-5: Generic standards – Immunity for equipment used in power station and substation environments*

5.10.7.3.2 Immunity and emission in the frequency range from 2 kHz to 150 kHz

The change in the use of electricity, especially by the introduction of power electronics equipment (Active Infeed Converters (AIC) are contributing to many solutions for Smart Grids) in residential or commercial environments, is increasing the occurrence of voltage components above the frequency range of harmonics up to 150 kHz. This requires the consideration of this frequency range for ensuring EMC. It appeared to be advisable to urge EMC committees, as well as those product committees defining EMC requirements in their product standards (ISO/TC 22, IEC TC 13, IEC TC 57, IEC TC 205/SC 205A, etc.), to review the existing standards or develop new ones in view of covering the above-mentioned gap in EMC standardization.

Technical input in this domain can be found in several reports/publications such as CLC SC 205A Study Report on Electromagnetic Interference between Electrical Equipment/Systems in the Frequency Range below 150 kHz (SC205A/Sec0260/R, April 2010). Nevertheless, further studies are necessary before a full set of standards providing immunity and emission requirements can be established.

On the basis of the data available at present, basic publications such as those dealing with Compatibility Levels (IEC 61000-2-2 and IEC 61000-2-12) and immunity test methods (IEC 61000-4-19) are in progress. Emission limits and Immunity Levels will follow.

5.10.7.3.3 Immunity and emission requirements applicable to Distributed Energy Resources

IEC TR 61000-3-15, *Electromagnetic compatibility (EMC) – Part 3-15: Assessment of low frequency electromagnetic immunity and emission requirements for dispersed generation systems in LV network* was published in 2011. IEC TC 77/SC 77A WGs are requested to consider and assess the recommendations in IEC TR 61000-3-15.

The next step is to standardize how to give a limitation to the disturbance emissions by DER equipment and to fairly allocate the ability of HV, MV or LV networks to absorb disturbance emissions among present and possibly forthcoming connected equipment at sites in networks. Connected equipment may well be installation or other network(s). The work should originate from extension of IEC TR 61000-3-6, IEC TR 61000-3-7, IEC TR 61000-3-13 and IEC TR 61000-3-14.

5.10.7.4 List of standards

5.10.7.4.1 Available standards

See Table 89. Refer to 5.2.5.3 for the definition of the criteria considered in this document for stating that a standard is “available”.

Table 89 – EMC – Power Quality – Available standards

Layer/Type	Standard	Title and comments
EMC	IEC 61000 series	*Electromagnetic compatibility*
EMC	IEC TR 61000-3-6	*Electromagnetic compatibility (EMC) – Part 3-6: Limits – Assessment of emission limits for the connection of distorting installations to MV, HV and EHV power systems*
EMC	IEC TR 61000-3-7	*Electromagnetic compatibility (EMC) – Part 3-7: Limits – Assessment of emission limits for the connection of fluctuating installations to MV, HV and EHV power systems*
EMC	IEC TR 61000-3-13	*Electromagnetic compatibility (EMC) – Part 3-13 Limits – Assessment of emission limits for the connection of unbalanced installations to MV, HV and EHV power systems*
EMC	IEC TR 61000-3-14	*Electromagnetic compatibility (EMC) – Part 3-14: Assessment of emission limits for harmonics, interharmonics, voltage fluctuations and unbalance for the connection of disturbing installations to LV power systems*
EMC	IEC TR 61000-3-15	*Electromagnetic compatibility (EMC) – Part 3-15: Assessment of low frequency electromagnetic immunity and emission requirements for dispersed generation systems in LV network*
EMC	IEC 61000-4-16	*Electromagnetic compatibility (EMC) – Part 4-16: Testing and measurement techniques – Test for immunity to conducted, common mode disturbances in the frequency range 0 Hz to 150 kHz*
EMC	IEC 61000-4-19	*Electromagnetic compatibility (EMC) – Part 4-19: Testing and measurement techniques – Test for immunity to conducted, differential mode disturbances and signalling in the frequency range 2 kHz to 150 kHz at a.c. power ports*
EMC	IEC 61000-4-30	*Electromagnetic compatibility (EMC) – Part 4-30: Testing and measurement techniques – Power quality measurement methods*
EMC	IEC 61000-6-1	*Electromagnetic compatibility (EMC) – Part 6-1: Generic standards – Immunity standard for residential, commercial and light-industrial environments*
EMC	IEC 61000-6-2	*Electromagnetic compatibility (EMC) – Part 6-2: Generic standards – Immunity standard for industrial environments*
EMC	IEC 61000-6-3	*Electromagnetic compatibility (EMC) – Part 6-3: Generic Standards – Emission standard for residential, commercial and light-industrial environments*
EMC	IEC 61000-6-4	*Part 6-4: Electromagnetic compatibility (EMC) – Generic Standards – Emission standard for industrial environments*
EMC	IEC 61000-6-5	*Part 6-5: Electromagnetic compatibility (EMC) – Generic standards – Immunity for power station and substation environments*
EMC	IEC 61000-6-7	*Part 6-7: Electromagnetic compatibility (EMC) – Generic standards – Immunity requirements for equipment intended to perform functions in a safety-related system (functional safety) in industrial locations*
EMC	IEC 61326 series	*Electrical equipment for measurement, control and laboratory use – EMC requirements*
Power Quality	IEC TS 62749	*Assessment of power quality – Characteristics of electricity supplied by public networks*
Other specifications		
EMC	EN 55011	*Industrial, scientific and medical equipment – Radio-frequency disturbance characteristics – Limits and methods of measurement.*
EMC	EN 55022	*Information technology equipment – Radio disturbance characteristics – Limits and methods of measurement*
EMC	EN 55032	*Electromagnetic compatibility of multimedia equipment – Emission requirements*
EMC	EN 55024	*Information technology equipment – Immunity characteristics – Limits and methods of measurement*
EMC	EN 55035	*Electromagnetic compatibility of multimedia equipment – Immunity requirements IEC CISPR/I*