IEC Smart Grid Standardization Roadmap

Prepared by SMB Smart Grid Strategic Group (SG3)
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FOREWORD

Across the world many vendors, policy-makers and utilities have already, or are in the process of, implementing smart technologies into their transmission, distribution and customer systems, based on several factors such as implementing legislative and regulatory policy, realizing operational efficiencies and creating customer value. Smart Grid value realization by utility customers and society at large is, in part, linked to the pace of technology implementation that enables a secure, smart and fully connected electric grid.

Therefore, it can be said that the Smart Grid is the concept of modernizing the electric grid. The Smart Grid comprises everything related to the electric system in between any point of generation and any point of consumption.

IEC – Setting global standards for Smart Grids

The IEC is the most trusted international electrical standards development organization, providing a large catalogue of extremely well focused standards. With the creation of the **IEC Smart Grid Strategic Group** in 2008, it is also now seen as a 'beacon' for the electrical industry in terms of Smart Grid. This Smart Grid Strategic Group is now providing a “one-stop shop” for the large number of Smart Grid projects that are being launched worldwide.

The IEC Smart Grid Strategic Group has also prepared a web window allowing Smart Grid projects easy access to a first release of ready-to-use standards as well as guidance to make the most of them [www.iec.ch/smartgrid].

In addition, an action plan guiding the different IEC Technical Committees towards a comprehensive set of harmonized global standards, supporting the smart grid requirements, is fully underway.

Starting point:

During its autumn 2008 meeting in São Paulo, Brazil, the IEC Standardization Management Board (SMB) approved the creation of a Smart Grid Strategic Group, which is also referred to as **IEC SG3**. This group of experts from **14 nations** has since developed a framework for IEC Standardization which includes protocols and model standards to achieve interoperability of Smart Grid devices and systems and which is presented in this Roadmap document.

The Strategic Group widely engaged internal and external stakeholders, in order to offer a first release of such an IEC Standards Framework based on existing (or close to completion) IEC standards that can be used consistently for today’s projects.

Additionally, the IEC, in close coordination with the Smart Grid Strategic Group, has developed an interactive web window allowing Smart Grid **Project Managers**, **Executives** and **External SDOs**, easy access to a first release of ready-to-use standards as well as providing guidance to make the most of them.

Furthermore, SG3 is presently gathering information from actual industry ‘Use-Cases’, with the purpose of developing a target architecture which can be mapped and can aid in the development of a **“Generic Reference Architecture” for Smart Grid**. It is expected that this

Generic Reference Architecture will ultimately be used by anyone who references this IEC Smart Grid Technical Reference Roadmap document.

At long last, an action plan is now in place to involve the different IEC Technical Committees in order to manage their activities towards a joint goal of providing, in successive defined steps, a set of harmonized global standards supporting the Smart Grid requirements.

Is there a need to develop new standards?

Let's pick up the fruits already lying on the ground before grabbing the low hanging ones!

The Smart Grid is broad in its scope, so the potential standards landscape is also very large and complex. However, the opportunity today is that utilities, vendors and policy-makers are actively engaged. Technology is not a barrier to adoption. The fundamental issue is organization and prioritization to focus on those first aspects which provide the greatest customer benefit towards the goal of achieving an interoperable and secure Smart Grid.

Mature standards and best practices are already available and can be easily used to facilitate Smart Grid deployment. The main problem with adoption seems to be a lack of awareness of those standards by those involved in designing Smart Grid systems at a high level and a lack of clear best practices and regulatory guidelines for applying them.

Another major issue is that Smart Grid projects need to use standards developed separately by different groups or Technical Committees. Subtly they look similar but in fact they deal with concepts at many different levels that finally do not fit together.

Ultimately, Smart Grid interoperability certification will have to be subsequently addressed. Guidelines should then be developed, including mechanisms for interoperability enforcement and, where appropriate, leverage commercial certification activities.

Long-awaited Standards Framework

The projects cannot restart from scratch each time and recreate the same discoveries and costly mistakes. In addition, vendors might limit their investments in developing new innovative products if a global market does not emerge clearly.

A framework must be able to be used universally and seamlessly as a toolkit by the industry Smart Grid project managers. Such a framework must include best practice guidelines and a suite of standards:

- Smart Grid project guidelines describing major steps that can appear common sense but are still not always implemented (Requirements, Design, Integration, Testing, Validating), and how to define the boundaries and the appropriate level of interoperability.
- A suite of standards to be used at the User Requirements level, with generic use cases. This area is the newest and therefore the development of such standards can be directed more easily.
- A suite of standards to be used at the Technical Design and Specification level, covering electrotechnical and Information Technology aspects. This is where too many standards exist, and cross-cutting compatibility must be demonstrated in great detail. The value of a framework here is to provide a catalogue of compatible guaranteed short listed standards (or parts of standards).

Progressive releases of such a framework will need to be issued over time.

IEC Smart Grid Standardization Roadmap

The aim of this document is to draft a strategic, but nevertheless technically oriented, reference book which represents the standardization requirements for the IEC Smart Grid Roadmap based on the recent work of IEC SG3. As a living document, this roadmap will be subject to future changes, modifications and additions, (i.e. completion of the mapping of a Generic Reference Architecture for Smart Grid) and will be incorporated into future editions.

This roadmap presents an inventory of existing (mostly IEC) standards, and puts them into perspective regarding the different Smart Grid applications. Gaps between actual standards and future requirements are analyzed and recommendations for evolution are presented. Nevertheless, different national and international groups have delivered input which, after review and discussion in SG3, has been integrated in this version of the Roadmap.

1 Management Summary

Smart Grid is a term which embraces an enhancement of the power grid to accommodate the immediate challenges of the near future and provides a vision for a future power system in the long term. It is somewhat intangible in definition and relevant scope. However the main focus is on an increased observability and controllability of the power grid, including all its participating elements. 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 must 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. This framework will be at the core of new developments and benefits reached through the implementation of Smart Grid. The IEC, as the only international standardization organization in the field of electrotechnical standardization, is ideally positioned to contribute to the development of Smart Grid and its beneficial effects on society as a whole.

Within the IEC, SMB Strategic Group 3 “Smart Grid” has taken on the task of coordinating the standardization work towards Smart Grid. In a first step the relevant fields are described, the new requirements are derived and existing standards as well as future gaps are summarized.

In Clause 3 “Smart Grid Vision” a short definition of the Smart Grid is given. The main drivers: need for more energy; increased usage of renewable energy resources; sustainability; competitive energy prices; security of supply and aging infrastructure and workforce are named. The main elements/applications of Smart Grid are described.

In Clause 4 “IEC Smart Grid Standardization Roadmap” the main areas of Smart Grid are investigated. Besides the general topics of communication and security the following topics are included: HVDC/FACTS; Blackout Prevention/EMS; Advanced Distribution Management; Distribution Automation; Smart Substation Automation; Distributed Energy Resources; Advanced Meter Infrastructure; Demand Response and Load Management; Smart Home and Building Automation; Electric Storage; Electromobility and Condition Monitoring.

For each of the topics, recommendations for immediate actions are defined and described.

In Clause 5 “General Recommendations” the actions for the IEC as a whole are defined and described. These are:

Recommendation G-1

There is no single unified concept of what a "Smart Grid” is. Smart Grids can have multiple shapes. Furthermore legacy systems must be incorporated. Therefore existing mature domain communication systems should be used. The IEC should further standardize necessary interfaces and product requirements and must avoid standardizing applications and business models.

Recommendation G-2

The IEC should promote its excellent work on Smart Grid standardization. In particular, the potential of IEC/TR 62357 should be promoted. The IEC should take this chance to inform stakeholders about the possible applications of the TC 57 framework through white papers, promotions and workshops.

Recommendation G-3

Technical connection criteria are subject to standards, regulations and various local specifications. A harmonization of these criteria seems to be out of the scope of IEC standardization. General minimum requirements could be specified in TC 8, but the IEC should refrain from detailed standardization of these issues.

Recommendation G-4

The IEC should seek close cooperation with stakeholders in the domain “markets”. A lot of proprietary work is done in that field. The IEC should seek close cooperation with organizations such as UN/CEFACT and UN/EDIFACT as well as other important regulatory authorities and trade associations. An investigation of the most promising market data systems must be performed. This input is vital for an extension of the Smart Grid with market information.

Recommendation G-5

The IEC should acknowledge the work already done by NIST and the participants of the NIST roadmap effort. The IEC should actively offer support in the identified prioritized action fields where the IEC is involved and offer consultation in some areas, whereas NIST focuses on local or regional standards (e.g. AMI, DER) (see Figure 1).

The IEC should seek a close cooperation with the NIST roadmap activities.

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.

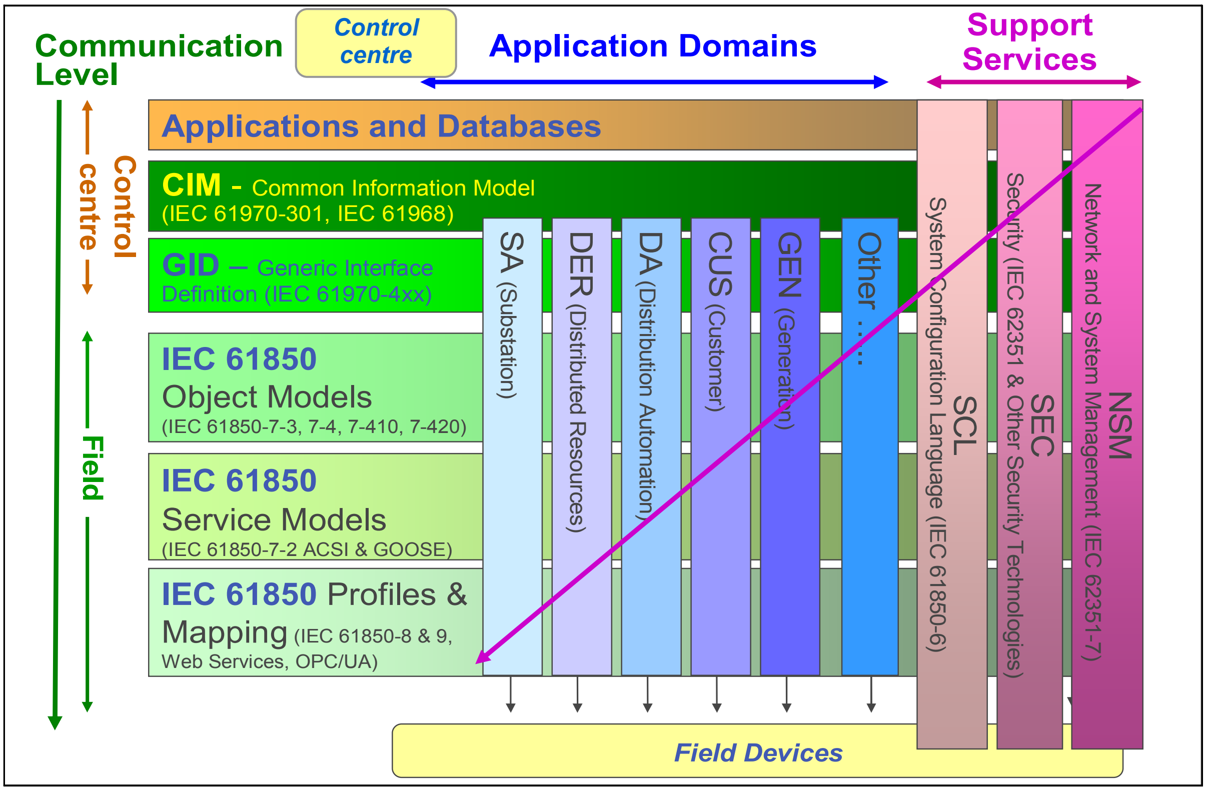


Figure 1 – IEC 61850 models and the Common Information Model (CIM)

These core standards include:

IEC/TR 62357 – Framework of power automation standards and description of the SOA (Service Oriented Architecture) concept

IEC 61850 – Substation automation and beyond

IEC 61970 – Energy Management System – CIM and GID definitions

IEC 61968 – Distribution Management System – CIM and CIS definitions

IEC 62351 – Security

The main focus of new activities are AMI (e.g. IEC 62051-62059; IEC/TR 61334); DER (e.g. IEC 61850-7-410: -420) and EV (e.g. IEC 61851). Furthermore there are areas which are not traditionally standardization topics such as market and service systems. These, however, also pose new requirements for IEC standardization. A close cooperation with the relevant organizations in these fields should be sought.

The survey has identified over 100 relevant standards and standard parts for Smart Grid. Twelve specific applications and six general topics have been analyzed. 44 recommendations for future work and actions have been defined.

The IEC, as the acknowledged international electrotechnical standardization organization, is well prepared to provide relevant standards for Smart Grid. The new challenges must be accepted. The IEC as an organization must enlarge its cooperation to sectors and organizations which have not been traditionally within the scope of the IEC. Through these efforts the IEC will be able to act as a one-stop shop for the standardization of Smart Grid.

2 Introduction

2.1 General

"Smart Grid" is one of the major trends and markets which involves 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. Furthermore, the way a power system is operated changes from the hierarchical top-down approach to a distributed control.

One of the main points about Smart Grid is an increased level of observability and controllability of a complex power system. This can only be achieved by an increased level of information sharing between the individual components and sub-systems of the power system. Standardization plays a key role in providing the ability of information sharing which will be required to enable the development of new applications for a future power system.

2.2 Purpose and Scope of the Document

The following document tries to identify existing standardization and potential gaps in the IEC portfolio which will be relevant for Smart Grid implementation.

The importance of these standards will vary in their relation to Smart Grid applications. A number of standards will form a core set of standards, which will be valid or necessary for nearly all Smart Grid applications. These standards will be considered priority standards. Their further promotion and development will be a key for the IEC to provide support for Smart Grid solutions. These standards are at the core of an IEC roadmap for the standardization of Smart Grid.

Besides these priority standards, the goal will also be to provide an overview of all the IEC standards capable of serving as a base for Smart Grid. The priority of these standards will be lesser compared to the priority standards mentioned above. However the collection should be comprehensive and also provide an overview of all the standardization involved.

Furthermore a whole framework of IEC standards and a roadmap of further actions are defined in order to help the Smart Grid vision to become a reality. With this the IEC will provide a necessary precondition for Smart Grid to become accepted by the market. Since Smart Grid investments are long-term investments, it is absolutely necessary to provide the stakeholders with a fixed set of standards which will provide the base for a sustainable future investment.

Care must be taken to concentrate standardization efforts on providing additional value to the Smart Grid implementation. This will be especially true for all 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. 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 Grid.

Standards from other SDOs are not the focus of this roadmap. Where further cooperation with another SDO may seem necessary to provide an optimal solution, standards other than IEC standards will be specified. A path of harmonization or incorporation may be evaluated.

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 Grid. One notable exception for the latter is the so-called NIST Interoperability roadmap. This effort, based on the Energy Act (2007) in the USA, is currently one of the most advanced efforts towards a comprehensive collection of standards. The IEC is supportive of most of the results and is ready to participate in future efforts to further develop standardization when there is international relevance.

3 Smart Grid Vision

3.1 Smart Grid Drivers

Efficient and reliable transmission and distribution of electricity is a fundamental requirement for providing societies and economics with essential energy resources.

The utilities in the industrialized countries are today in a period of change and agitation. On one hand large parts of the power grid infrastructure are reaching their designed end of life time, since a large portion of the equipment 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 renewable energy like solar, wind, biomasses and water.

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. Aging equipment, dispersed generation as well as load increase might lead to highly utilized equipment during peak load conditions. If the upgrade of the power grid should be reduced to a minimum, new ways of operating power systems have be found and established.

In many countries regulators and liberalization are forcing utilities to reduce costs for the transmission and distribution of electrical energy. Therefore new methods (mainly based on the efforts of modern information and communication techniques) to operate power systems are required to secure a sustainable, secure and competitive energy supply.

The key market drivers behind Smart Grid solutions are:

- Need for more energy
- Increased usage of renewable energy resources
- Sustainability
- Competitive energy prices
- Security of supply
- Ageing infrastructure and workforce

The utilities have to master the following challenges:

- High power system loading
- Increasing distance between generation and load
- Fluctuating renewables
- New loads (hybrid/e-cars)
- Increased use of distributed energy resources
- Cost pressure
- Utility unbundling
- Increased energy trading
- Transparent consumption & pricing for the consumer
- Significant regulatory push

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.

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.

3.2 Smart Grid Definitions

"Smart Grid" is today used as 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.

However smart technologies improve the observability and/or the controllability of the power system.

Thereby Smart Grid technologies help to convert the power grid from a static infrastructure to be operated as designed, to a flexible, "living" infrastructure operated proactively.

SG3 defines 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.

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.

European Technology Platform Smart Grid defines smart grid as follows [3]:

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

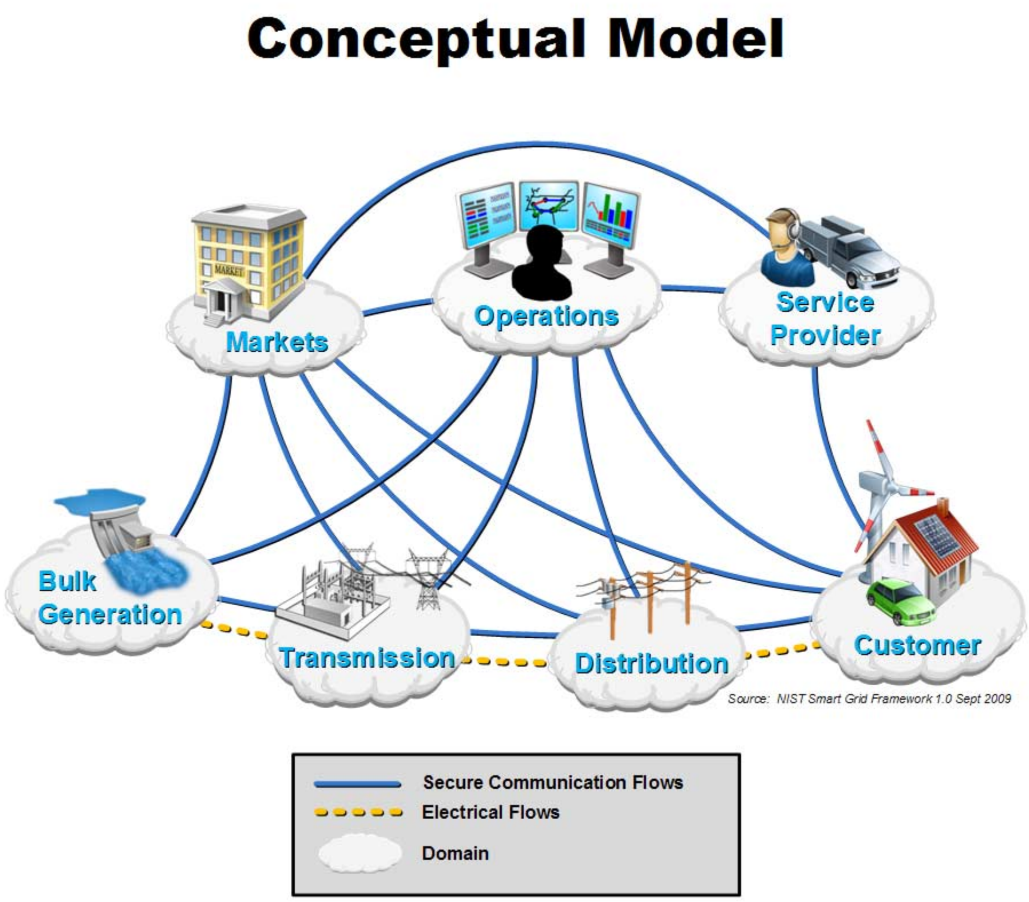
- *better facilitate the connection and operation of generators of all sizes and technologies;*
- *allow consumers to play a part in optimizing the operation of the system;*

- *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 must 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.

3.3 Smart Grid landscape

Smart Grid is the combination of subsets of the following elements into an integrated solution meeting the business objectives of the major players, i.e. a Smart Grid solution needs to be tailored to the users' needs (see Figure 2).



Source: NIST Smart Grid Framework 1.0 Sept 2009

Figure 2 – Conceptual model

The Smart Grid consists of the following:

- **Customer / Prosumer**
    - **Smart Consumption** will enable demand response and lies at the interface between distribution management and building automation.

- **Local Production** is currently not a large component, however it is proposed as a future driver of Smart Grid requirements.
- **Smart Homes** are houses which are equipped with a home automation system that automate and enhance 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.

- **Bulk Generation**
  - **Smart Generation** will include the increased use of power electronics in order to control harmonics, fault ride-through and fluctuating generation from renewables as well as the required increased flexibility of conventional Fossil Power Plants due to the increased fluctuation of feed from the renewables.
- **Power Grid (Transmission and Distribution)**
  - **Substation Automation & Protection** is the backbone for a secure transmission grid operation. During recent years serial bus communication has been introduced (IEC 61850). Security is based on protection schemes.
  - **Power Quality and Power Monitoring Systems** act in a very similar way to Quality Management Systems in companies. They are independent from Operation, Control and Management Systems and supervise all activities and assets/electrical equipments in a corresponding grid. Therefore such systems can be used as “early warning systems” and are a must to analyze faults and to find out the corresponding reasons.
  - 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. phasor measurements, visualization of the grid status, dynamic network stability analysis).
  - In contrast to traditional protection devices, which protect the primary equipment (e.g. transformers) from fatal fault currents, the **Decision Support Systems and System Integrity Protection Schemes** protect the power systems from instabilities and black-outs. System Integrity Protection Schemes will enhance the target of protection devices, to protect the primary equipment (e.g. transformers) from fatal fault currents in such a way that uncontrollable chain reactions, initiated by protective actions, are avoided by limited load shedding actions.
  - **Power Electronics** is among the “actuators” in the power grid. Systems like HVDC and FACTS enable actual control of the power flow and can help to increase transport capacity without increasing short circuit power.
  - **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.
  - **Distribution Automation and Protection:** Whereas automated operation and remote control is state of the art for the transmission grid, mass deployment of Distribution Automation is only recently becoming more frequent, leading to “Smart Gears”. Countries like the United States of America, where overhead

lines are frequently used, benefit most. Advanced distribution automation concepts promote automatic self configuration features, reducing outage times to a minimum ("self-healing grids"). Another step further is the use of distributed energy resources to create self-contained cells ("MicroGrids"). MicroGrids can help to assure energy supply in distribution grids even when the transmission grid has a blackout.

  - The **Distribution Management System (DMS)** is the counterpart to the EMS and is therefore the control center for the distribution grid. In countries where outages are a frequent problem, the Outage Management System (OMS) is an important component of the DMS. Other important components are fault location and interfaces to Geographic Information Systems.
  - **Smart Meter** is a generic term for electronic meters with a communication link. "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.

- **Communication**
  - **Communication** as a whole is the backbone of Smart Grid. Only by exchanging information on a syntactic and semantic level can the benefits of Smart Grid be achieved.
  - **Security** of a critical infrastructure has always been an issue. However Smart Grid solutions will see an enormous increase in the exchange of data both for observability but also for controllability. Therefore security of this data exchange and the physical components behind it will have an increased impact.

4 IEC Smart Grid Standardization Roadmap

4.1 Description of Work

The following Clause is intended to describe the procedure taken to identify existing IEC standards and gaps, which will need new standardization activities. First of all a top-down approach is taken. As described in the preceding Clause, the descriptions of the major applications of Smart Grids are based on the Smart Grid drivers. The use cases of the applications will indicate the requirements posed by such applications and use cases. These requirements in turn will help to analyze the tasks and necessities for standardization.

An even more detailed procedure is described as requirements building blocks:

1. Capturing and describing all the functional and system management requirements of electric energy operations
   - Organize operations into domains (e.g. market operations)
   - Identify all functions (e.g. distribution automation, generation dispatch) that are/will be/could be used for operations
   - Describe each function very briefly
   - Identify key interfaces between entities for each function
   - Determine all system management requirements (data management, security, etc.) for supporting each function
2. Evaluate and rate the impact of each functional and system management requirement on the design of an architecture
3. Identify and briefly assess those functions which could have significant impact on architectural designs

This document does not focus on an elaborate function and domain analysis. This is done elsewhere. However the major findings are presented in short form. A prerequisite for determination of existing standards and standards gaps are the requirements posed by the individual functions. These are described briefly in this Clause.

Whether the requirements are met by already existing standards or by yet to be developed standards will be analyzed. Finally each Subclause will end with recommendations concerning the IEC. These recommendations may address different levels of the organization of the IEC, from the top management councils like the SMB/SB1, to the more technical work in TCs, SCs and the respective working groups.

Most of the Clause consists of a summary of applications and requirements for a future power grid with Smart Grid capabilities. First of all general requirements are investigated.

One major common requirement for most of the Smart Grid applications and use cases is a higher level of interoperability of an increased number of intelligent devices, solutions and organizations. The classical definition of interoperability is:

"The ability of two or more systems or components to exchange information and to use the information that has been exchanged."

Therefore, interoperability includes operability and controllability of an ever more complex power grid. One main precondition for a smarter grid is intelligent devices, which are required to generate and provide the necessary information. Interoperability has different aspects which will be present in most of the applications listed below. Syntactic interoperability is the ability of two or more systems to communicate and exchange data. This is mainly done through standardized data formats and protocols and therefore is a typical domain for standardization. Much of the work of the IEC and other SDOs is concentrated on this form of interoperability. Syntactic interoperability is the precondition of a higher level of interoperability. The next step is the ability of two or more systems to automatically interpret the exchanged data. This is called semantic interoperability. To achieve this, one must accept a common information exchange reference model. This again is a major domain of standardization.

Following the remarks of the previous paragraph, communication in the above described aspects is a general requirement for all Smart Grid aspects. The increased exchange and automatic interpretation of information across all major domains of a future power net is therefore investigated in detail.

Another common requirement is security. Security is protection against danger, loss and criminal actions. Security must include provisions for actions which are intended to prevent harm. Since power grids are considered as critical infrastructures there are already many regulations and requirements through government agencies. However through the advent of Smart Grid, information exchange and the controllability of this critical infrastructure will increase significantly. Therefore Smart Grid requires a new level of cyber security, especially for these aspects.

After these general requirements the following Clauses will concentrate on 12 specific applications and requirements. These cover the main areas of Smart Grid.

Any other requirements will be analyzed later in this document. These are mainly requirements which are necessary to implement Smart Grid. However these are not specific to Smart Grid and the changes provided by Smart Grid. One example is EMC requirements, which must be fulfilled by Smart Grid solutions, but which are of course also valid for other systems.

Organization of the individual subsystems: Each Clause describing the subsystems will follow the same structure:

- Description
- Requirements
- Existing Standards
- Gaps
- Recommendations

First of all a short description of the applications, and if necessary some of its use cases, will be given. This is followed by the necessary requirements to cover such applications. Then – if they already exist – a number of possible candidate standards published by the IEC will be given. The remaining gaps are described and the need for new standards and the modification of existing standards are outlined. Each Subclause will end with a recommendation for the IEC.

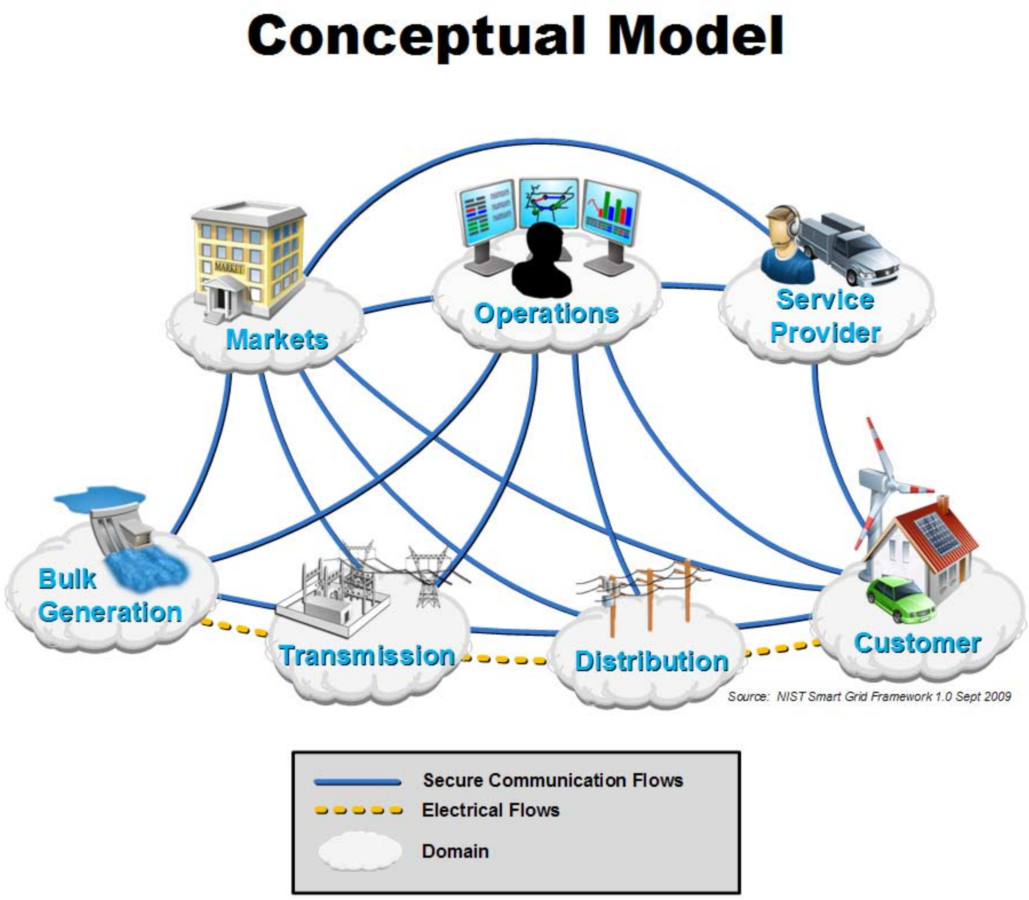
4.2 General

4.2.1 Communication

4.2.1.1 Description

A secure, reliable and economic power supply is closely linked to a fast, efficient and dependable communications infrastructure. The planning and implementation of communications networks requires the same care as the installation of the power supply systems themselves. In a smart grid context this means the efficient integration of all components and stakeholders for a common concept. For this purpose syntactic and semantic interoperability is the challenge to be met.

In order to identify the interfaces of the involved components and stakeholders, Figure 3 describes the basic systems and their interconnection in the power utility domain.



Source: NIST Smart Grid Framework 1.0 Sept 2009

Figure 3 – Conceptual model

From a communication point of view, each system plays the role of either supplier or consumer of information, or more typically both. In addition to this intersystem communication, these systems consist of subsystems with specific internal communications.

The following paragraphs introduce the basic system including subsystems and describe the motivations for communication.

System: Bulk Generation

Generation includes all plants for bulk energy conversion into electrical power, ranging, for example, from nuclear, hydro or fossil power plants to large solar and wind farms. The plants are usually connected directly to the transmission system and provide intelligent applications such as Power System Stabilizer (PSS) functionalities.

Bulk Generation	
Subsystem Communication	
Process Automation	In power plants process automation is applied to control and supervise the energy conversion process and provide the interface to the corresponding EMS/DMS Systems and planning systems, e.g. for generation and load schedules
Substation Automation	The scope of substation automation and protection is to

	protect and control the electric process and its equipment. Therefore protection and control devices exchange information about the status of the electric process. In case of abnormal conditions, an appropriate reaction is taken
Intersystem Communication	
Operation	Information is exchanged for energy scheduling and revision planning
Markets	For scheduling and trading purposes, information about the availability of power (transfer power, operating reserve) is transmitted to the market domain

System: Transmission

The transmission system of a power grid consists of electric power lines and substations in order to transmit electrical energy from generation to consumption over longer distances. For remote and local control and supervision of the transmission system, substations are equipped with substation automation systems.

Transmission	
Subsystem Communication	
Substation Automation	See Clause Substation Automation
Intersystem Communication	
Operation	The transmission system is typically remotely controlled and supervised by a transmission system operator. Therefore information is exchanged between substations and a central EMS application. This also includes the transmission of metering information and equipment condition information for asset management applications

System: Distribution

The scope of distribution systems is the local distribution of electric power to consumers. Traditionally the power is delivered by the transmission system. Due to the trend of local generation by DER, power will be increasingly fed directly into the distribution system. In addition, the automation is extended to small transformer substations (MV to LV) in order to reduce fault clearing times by a faster fault identification.

Distribution	
Subsystem Communication	
Substation Automation	See Clause Substation Automation
Distribution Automation	See Clause Distribution Automation
DER	See Clause DER
Intersystem Communication	
Operation	The distribution system is typically remotely controlled and supervised by a distribution system operator. Therefore information is exchanged between substations and a central DMS-application. Besides the transmission of metering information and equipment condition information for asset management applications, DER plants may coordinate control within a virtual power plant concept
Service	Support functions for operation (e.g. forecasting for renewable generation)
Prosumers	Metering, demand response and DER management require a coordinated information exchange with distribution management

System: Operation

The operation system includes the network control centres for energy management (EMS) and distribution management systems (DMS). Also see Clause “Blackout Prevention” for EMS, section “DMS”

Operation	
Subsystem Communication	
Substation Automation	See Clause Substation Automation
Distribution Automation	See Clause Distribution Automation
DER	See Clause DER
Intersystem Communication	
Bulk Generation	See Intersystem Communication Bulk Generation
Transmission	See Intersystem Communication Transmission
Distribution	See Intersystem Communication Distribution
Markets	For scheduling and trading purposes, information about the availability of power (transfer power, operating reserve) or order information is transmitted to or from the market system
Service	Support functions for operation (e.g. forecasting for renewable generation)
Prosumers	Metering, demand-site management and DER management require a coordinated information exchange between DMS and prosumer

System: Markets

In the electricity market system, electrical energy is purchased and sold as a commodity. The price of electrical energy is set by supply and demand.

In future systems market and price information will be distributed to a larger extent and to participants in the system which do not today receive price and market information. Information must be distributed online and within a far shorter time period than today. Pricing information at the consumer site may be available on an hourly or even shorter basis. The relevant standards are not within the scope of the IEC.

Markets	
Subsystem Communication	
Intra-Markets	See Clause Markets
Intersystem Communication	
Operation	For scheduling and trading purposes, information about the availability of power (transfer power, operating reserve) or order information is transmitted to or from the operation system
Bulk Generation	For scheduling and trading purposes, information about the availability of power (transfer power, operating reserve) is transmitted from the bulk generation system
Service	Support functions for markets (e.g. forecasting for renewable generation)
Prosumer	For scheduling and trading purposes information about the availability of power or order information is transmitted to or from the markets system

System: Service

The service system offers potential for a wide range of new service developments. New business models may emerge due to the opportunities of the future Smart Grid. Therefore the service system will have and depend on various interfaces to other systems.

Service	
Subsystem Communication	
The new service application shall follow a standardized way of software development in order to seamlessly fit into an overall system. The relevant standards are not within the scope of the IEC	
Intersystem Communication	
Operation	Support functions for operation (e.g. forecasting for renewable generation)
Market	Support functions for markets (e.g. forecasting for renewable generation)
Prosumers	Customer services (Installation, Maintenance, Billing, Home & Building Management) are quite conceivable

System: Prosumer
Description

Prosumer	
Subsystem Communication	
See Clause HBES/BACS	
Process Automation	In many industries (e.g. chemical, manufacturing) process automation is applied to control and supervise not only the manufacturing process but also the energy consumption or generation
Intersystem Communication	
Service	Support functions for operation (e.g. forecasting for renewable generation)
Operation	See Clause AMI, DER
Markets	For scheduling and trading purposes information about the availability of power or order information is transmitted to or from the markets system
Distribution	Typically the distribution system infrastructure is used for the communication to DMS

4.2.1.2 Requirements

From the viewpoint of Smart Grid, highly interoperable communication between all components is the major goal of smart grid communication. This means that the communication shall be based on a common semantic (data model), common syntax (protocol) and a common network concept. Therefore a convergence and a harmonization of subsystem communication shall be pursued.

General requirements are that the communication concept shall be future-proof. That means that it shall be open for future extensions regarding application fields as well as communication technologies.

The concept shall be open regarding an efficient integration of state-of-the-art components, but also open for integration of legacy communication components.

As an essential part of a critical infrastructure, the communication concept shall be deterministic, transparent and fully comprehensible at any time.

Real-time applications require system-wide time synchronization with high accuracy. In case of important and critical applications, the communication concept shall provide a high quality of service. Therefore enhanced redundancy concepts are essential.

4.2.1.3 Existing Standards

Interoperability standards

The IEC 62357 Reference Architecture (see Figure 4) addresses the communication requirements of the application in the power utility domain. Its scope is the convergence of data models, services and protocols for efficient and future-proof system integration for all applications. This framework comprises communication standards including semantic data models, services and protocols for the abovementioned intersystem and subsystem communications.

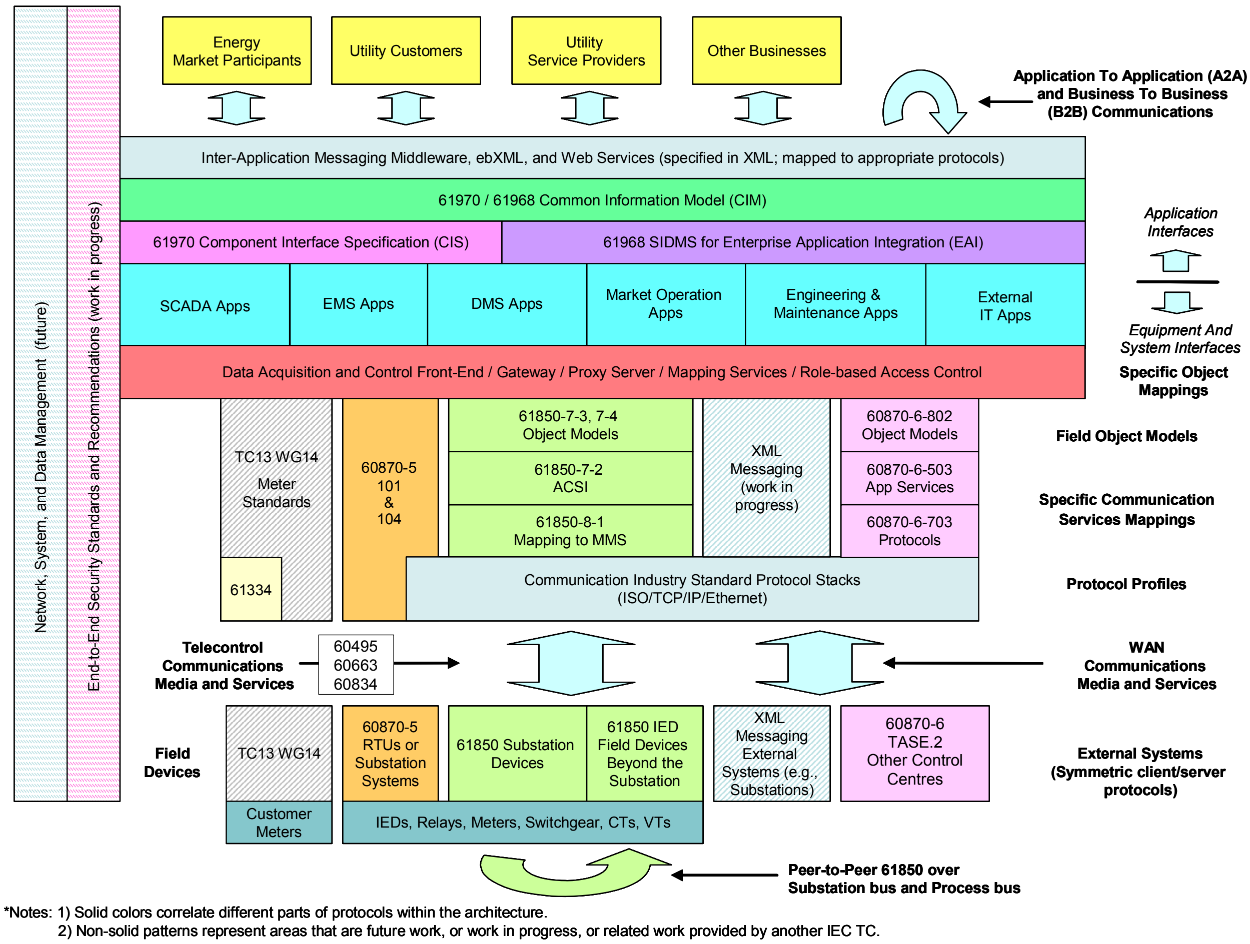


Figure 4 – Current TC 57 reference architecture

i) Service-oriented architecture (see Figure 5)

A modern network control system provides a service-oriented architecture with standardized process, interface and communication specifications based on standards IEC 61968 and IEC 61970. These form the basis for integrating the network control system in the enterprise service environment of the power supply company.

The services of a control system comprise:

- Data services with which, for example, the databases of the core applications can be accessed, e.g. readout of the operational equipment affected by a fault incident in the power supply system
- Functional logic services, e.g. for starting a computing program for calculating the load flow in the power supply system
- Business logic services that coordinate the business logic for specific energy management work processes of the participating systems, e.g. fault management in the network control system within the customer information system at the power supply company.

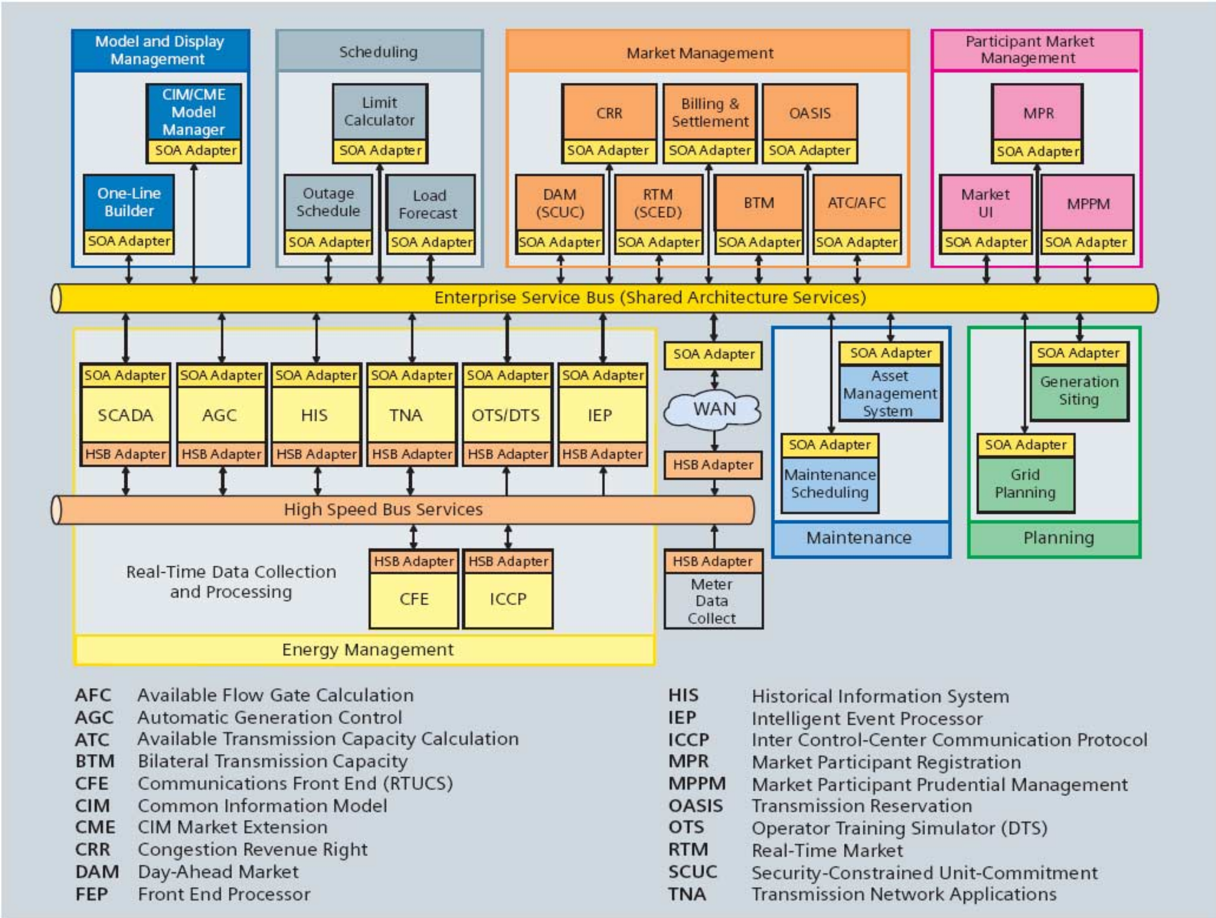


Figure 5 – Service-oriented architecture

Flexible integration of further applications (like data concentrators for PMUs) must be ensured.

ii) Data Model

In order to survive in the deregulated energy market, power supply companies today face the urgent task of optimizing their core processes. This is the only way that they can survive in this competitive environment. The vital step here is to combine the large number of autonomous IT systems into a homogeneous IT landscape. However, conventional network control systems can only be integrated with considerable effort because they do not use uniform data standards. Network control systems with a standardized data format for source data based on the standardized Common Information Model (CIM), in accordance with IEC 61970, offer the best basis for IT integration.

The CIM defines a common language and data modeling with the object of simplifying the exchange of information between the participating systems and applications via direct interfaces. The CIM was adopted by IEC TC 57 and fast-tracked for international standardization. The standardized CIM data model offers a very large number of advantages for power suppliers and manufacturers:

- Simple data exchange for companies that are near each other
- Standardized CIM data remains stable, and data model expansions are simple to implement

- As a result, simpler, faster and less risky upgrading of energy management systems and also, if necessary, migration to systems of other manufacturers
- The CIM application program interface creates an open application interface. The aim is to use this to interconnect the application packages of all kinds of different suppliers using “Plug and Play” to create an EMS.

The CIM forms the basis for the definition of important standard interfaces to other IT systems. The working group in IEC TC 57 plays a leading role in the further development and international standardization of IEC 61970 and the CIM. Working group WG14 (IEC 61968 Standards) in the TC 57 is responsible for standardization of interfaces between systems, especially for the power distribution area. Standardization in the outstation area is defined in IEC 61850.

With the extension of document IEC 61850 for communication to the control centre, there are overlaps in the object model between IEC 61970 and IEC 61850.

The CIM data model describes the electrical network, the connected electrical components, the additional elements and the data needed for network operation as well as the relations between these elements. The Unified Modeling Language (UML), a standardized, object-oriented method that is supported by various software tools, is used as the descriptive language. CIM is used primarily to define a common language for exchanging information via direct interfaces or an integration bus and for accessing data from various sources.

The CIM model is subdivided into packages such as basic elements, topology, generation, load model, measurement values and protection. The sole purpose of these packages is to make the model more transparent. Relations between classes may extend beyond the boundaries of packages.

iii) Protocols

Communication technology has continued to develop rapidly over the past few years and the TCP/IP protocol has also become the established network protocol standard in the power supply sector. The modern communication standards as part of the IEC 62357 reference architecture (e.g. IEC 61850) are based on TCP/IP and provide full technological benefits for the user.

IEC 61850 “Communication networks and systems in substations”

Since being published in 2004, the IEC 61850 communication standard has gained more and more relevance in the field of substation automation. It provides an effective response to the needs of the open, deregulated energy market, which requires both reliable networks and extremely flexible technology – flexible enough to adapt to the substation challenges of the next twenty years. IEC 61850 has not only taken over the drive of the communication technology of the office networking sector, but it has also adopted the best possible protocols and configurations for high functionality and reliable data transmission. Industrial Ethernet, which has been hardened for substation purposes and provides a speed of 100 Mbit/s, offers enough bandwidth to ensure reliable information exchange between IEDs (Intelligent Electronic Devices), as well as reliable communication from an IED to a substation controller. The definition of an effective process bus offers a standardized way to digitally connect conventional as well as intelligent CTs and VTs to relays. More than just a protocol, IEC 61850 also provides benefits in the areas of engineering and maintenance, especially with respect to combining devices from different vendors.

Key features of IEC 61850

As in an actual project, the standard includes parts describing the requirements needed in substation communication, as well as parts describing the specification itself. The specification is structured as follows:

- An object-oriented and application-specific data model focused on substation automation.
- This model includes object types representing nearly all existing equipment and functions in a substation – circuit breakers, protection functions, current and voltage transformers, waveform recordings, and many more.
- Communication services providing multiple methods for information exchange. These services cover reporting and logging of events, control of switches and functions, polling of data model information.
- Peer-to-peer communication for fast data exchange between the feeder level devices (protection devices and bay controller) is supported with GOOSE (Generic Object Oriented Substation Event).
- Support of sampled value exchange.
- File transfer for disturbance recordings.
- Communication services to connect primary equipment such as instrument transducers to relays.
- Decoupling of data model and communication services from specific communication technologies.
- This technology independence guarantees long-term stability for the data model and opens up the possibility to switch over to successor communication technologies. Today, the standard uses Industrial Ethernet with the following significant features:
    - 100 Mbit/s bandwidth
    - Non-blocking switching technology
    - Priority tagging for important messages
    - Time synchronization of 1 ms
- A common formal description code, which allows a standardized representation of a system's data model and its links to communication services.
- This code, called SCL (Substation Configuration Description Language), covers all communication aspects according to IEC 61850. Based on XML, this code is an ideal electronic interchange format for configuration data.
- A standardized conformance test that ensures interoperability between devices. Devices must pass multiple test cases: positive tests for correctly responding to stimulation telegrams, plus several negative tests for ignoring incorrect information.
- IEC 61850 offers a complete set of specifications covering all communication issues inside a substation.

IEC 60870-5, *Telecontrol equipment and systems – Part 5 – Transmission protocols*

This standard provides a series standard for the use of information transmission in the power utility domain. Since its publication in 1994 the standard is well established worldwide in gas, water and especially electric power telecontrol applications. Therefore today a huge installed base exists.

There are three parts for telecontrol communication:

- IEC 60870-5-101, *Telecontrol equipment and systems – Part 5-101: Transmission protocols – Companion standard for basic telecontrol tasks*
- IEC 60870-5-103, *Telecontrol equipment and systems – Part 5-103: Transmission protocols – Companion standard for the informative interface of protection equipment*
- IEC 60870-5-104, *Telecontrol equipment and systems – Part 5-104: Transmission protocols – Network access for IEC 60870-5-101 using standard transport profiles*

The parts IEC 60870-5-101 and 104 are predominantly used for the information exchange from substations to control centres but also within substations. The application fields range from primary substations (high and medium voltage level) down to secondary substations (medium to low voltage level). Because of their generic design and their pure signal oriented communication focus they can also be applied in non-electric domains. Consequently their use for communication with gas transmission and distribution substations and in water supply facilities is popular.

IEC 60870-5-104 addresses the requirement to overcome the performance limitations of serial end-to-end communication by introducing Ethernet and TCP/IP for IEC 60870-5. This allows higher transmission rates and the use of bus systems.

IEC 60870-5-103 focuses on electric protection relays. In comparison to IEC 60870-5-101 and 104 the generic data objects are clearly defined as application specific objects to represent information of protection functions. This standard is predominantly used for communication of protection relays within substations.

Due to the widespread application of IEC 60870-5, changing the current power systems to smart grids naturally poses the requirement to adopt this existing telecontrol infrastructure in order to shape smart grid functionality.

The following paragraphs show which IEC standards cover the intersystem and subsystem communication of the basic systems. In addition it is indicated which interoperability level is provided by the individual standards.

System: Bulk Generation

Bulk Generation		
Subsystem Communication		
Substation Automation	IEC 61850, *Communication networks and systems in substations*	1), 2), 3)
	IEC 60870-5-101, *Telecontrol equipment and systems – Part 5-101: Transmission protocols – Companion standard for basic telecontrol tasks*	1), 2)
	IEC 60870-5-103, *Telecontrol equipment and systems – Part 5-103: Transmission protocols – Companion standard for the informative interface of protection equipment*	1), 2), 3)
	IEC 60870-5-104, *Telecontrol equipment and systems – Part 5-104: Transmission protocols – Network access for IEC 60870-5-101 using standard transport profiles*	1), 2)
	IEC 60255-24, *Electrical relays - Part 24: Common format for transient data exchange (COMTRADE) for power systems*	2), 3)
	IEC 61400-25, *Wind turbines - Part 25: Communications for monitoring and control of wind power plants*	1), 2), 3)
Process Automation	IEC 61158, Ind*ustrial communication networks – Fieldbus specifications*, IEC 61784-1, *Industrial communication networks – Profiles*	1), 2)
Intersystem Communication		
Operation	IEC 61850, *Communication networks and systems in substations*	1), 2), 3)
	IEC 60870-5-101, *Telecontrol equipment and systems – Part 5-101: Transmission protocols – Companion standard for basic telecontrol tasks*	1), 2)
	IEC 60870-5-104, *Telecontrol equipment and systems – Part 5-104: Transmission protocols – Network access for IEC 60870-5-101 using standard transport profiles*	1), 2)
Markets	See Clause Markets	

1) Network Interoperability, 2) Syntactic Interoperability, 3) Semantic Interoperability

System: Transmission

Transmission		
Subsystem Communication		
Substation Automation	IEC 61850, *Communication networks and systems in substations*	1), 2), 3)
	IEC 60870-5-101, *Telecontrol equipment and systems – Part 5-101: Transmission protocols – Companion standard for basic telecontrol tasks*	1), 2)
	IEC 60870-5-103, *Telecontrol equipment and systems – Part 5-103: Transmission protocols – Companion standard for the informative interface of protection equipment*	1), 2), 3)
	IEC 60870-5-104, *Telecontrol equipment and systems – Part 5-104: Transmission protocols – Network access for IEC 60870-5-101 using standard transport profiles*	1), 2)
	IEC 60255-24, *Electrical relays - Part 24: Common format for transient data exchange (COMTRADE) for power systems*	2), 3)
	IEC 60834, *Teleprotection equipment of power systems – Performance and testing*	1)
	IEC 60495, *Single sideband power-line carrier terminals*	1)
Intersystem Communication		
Operation	IEC 61850 *Communication networks and systems in substations*	1), 2), 3)
	IEC 60870-5-101 *Telecontrol equipment and systems – Part 5-101: Transmission protocols – Companion standard for basic telecontrol task*	1), 2)
	IEC 60870-5-104 *Telecontrol equipment and systems – Part 5-104: Transmission protocols – Network access for IEC 60870-5-101 using standard transport profiles*	1), 2)
	IEC 60255-24 *Electrical relays - Part 24: Common format for transient data exchange (COMTRADE) for power systems*	2), 3)
Distribution	IEC 61850 *Communication networks and systems in substations*	1), 2), 3)

1) Network Interoperability, 2) Syntactic Interoperability, 3) Semantic Interoperability

System: Distribution

Distribution		
Subsystem Communication		
Substation Automation, Distribution Automation, DER	IEC 61850, *Communication networks and systems in substations*	1), 2), 3)
	IEC 60870-5-101, *Telecontrol equipment and systems – Part 5-101: Transmission protocols – Companion standard for basic telecontrol tasks*	1), 2)
	IEC 60870-5-103, *Telecontrol equipment and systems – Part 5-103: Transmission protocols – Companion standard for the informative interface of protection equipment*	1), 2), 3)
	IEC 60870-5-104, *Telecontrol equipment and systems – Part 5-104: Transmission protocols – Network access for IEC 60870-5-101 using standard transport profiles*	1), 2)
	IEC 61400-25, *Wind turbines – Part 25: Communications for monitoring and control of wind power plants*	1), 2), 3)
	IEC 60255-24, *Electrical relays – Part 24: Common format for transient data exchange (COMTRADE) for power systems*	2), 3)
Intersystem Communication		
Operation	IEC 61850, *Communication networks and systems in substations*	1), 2), 3)
	IEC 60870-5-101, *Telecontrol equipment and systems – Part 5-101: Transmission protocols – Companion standard for basic telecontrol tasks*	1), 2)

	IEC 60870-5-104, *Telecontrol equipment and systems – Part 5-104: Transmission protocols – Network access for IEC 60870-5-101 using standard transport profiles*	1), 2)
	IEC 60255-24, *Electrical relays - Part 24: Common format for transient data exchange (COMTRADE) for power systems*	2), 3)
	IEC 61400-25, *Wind turbines - Part 25: Communications for monitoring and control of wind power plants*	1), 2), 3)
Service	Open, not an IEC issue	
Prosumers	IEC 61850-7-420, *Communication networks and systems for power utility automation – Part 7-420: Basic communication structure - Distributed energy resources logical nodes*	1), 2), 3)
	IEC 61850, *Communication networks and systems in substations*	1), 2), 3)
	IEC 62056, *Electricity metering – Data exchange for meter reading, tariff and load control"*	1), 2)
	IEC 61334-4-41, *Distribution automation using distribution line carrier systems – Part 4: Data communication protocols – Section 41: Application protocols – "Distribution line message specification* (DLMS)	3)
	IEC 61334, *Distribution automation using distribution line carrier systems*	1)

1) Network Interoperability, 2) Syntactic Interoperability, 3) Semantic Interoperability

System: Operation

Operation		
Subsystem Communication		
EMS DMS	IEC 61968, *Application integration at electric utilities – System interfaces for distribution management*	2), 3)
	IEC 61970, *Energy Management system application program interface (EMS-API)*	2), 3)
	IEC 60870-6-503, *Telecontrol equipment and systems – Part 6-503: Transmission protocols - Telecontrol protocols compatible with ISO standards and ITU-T recommendations – Tase 2* (ICCP)	1), 2)
Intersystem Communication		
Transmission Distribution Bulk Generation	IEC 61850, *Communication networks and systems in substations*	1), 2), 3)
	IEC 60870-5-101, *Telecontrol equipment and systems – Part 5-101: Transmission protocols – Companion standard for basic telecontrol tasks*	1), 2)
	IEC 60870-5-104, *Telecontrol equipment and systems – Part 5-104: Transmission protocols – Network access for IEC 60870-5-101 using standard transport profiles*	1), 2)
	IEC 60255-24, *Electrical relays - Part 24: Common format for transient data exchange (COMTRADE) for power systems*	2), 3)
	IEC 61400-25, *Wind turbines - Part 25: Communications for monitoring and control of wind power plants*	1), 2), 3)
Service	Open, not a IEC issue	
Prosumers	IEC 61850-7-420, *Communication networks and systems for power utility automation – Part 7-420: - Basic communication structure - Distributed energy resources logical nodes*	1), 2), 3)
	IEC 61850, *Communication Networks and Systems in Substations*	1), 2), 3)
	IEC 62056, *Electricity metering – Data exchange for meter reading, tariff and load control*	1), 2)
	IEC 61334-4-41, *Distribution automation using distribution line carrier systems – Part 4: Data communication protocols –Section 41: Application protocols – Distribution line message specification* (DLMS)	3)
	IEC 61334, *Distribution automation using distribution line carrier systems*	1)

Markets	De facto standards, predominantly defined by regulation authorities or user associations	

1) Network Interoperability, 2) Syntactic Interoperability, 3) Semantic Interoperability

System: Markets

Profiles for market communications are predominantly driven by local regulation or local user associations. Therefore a large number of regional specific communication standards exist.

IEC 62325 does not standardize market communication. It applies the ebXML standard of UN/CEFACT to the energy market and the required market information. The goal is to provide a standard alternative to the proprietary information standards used otherwise - EDIFACT, X12, etc. and to provide an open, technology-independent framework.

IEC 61970-302 Ed. 1.0, *Energy management system application program interface (EMS-API) - Part 302: Common information model (CIM) financial, energy scheduling and reservations*[1]

A large variety of protocols and standards is used in this sector. However a concentration on using UML on the modeling side can be observed. Combined with the further advancement of the CIM of IEC 61970 and IEC 61968, a roadmap for implementing pricing models would be available.

Markets		
Subsystem Communication		
Intra-Markets	Proprietary data model and communication solutions, predominantly defined by regulation authorities or user associations	
Intersystem Communication		
Operation Bulk Generation Service Prosumers	IEC/TR 62325, *Framework for energy market communications*	1)
	De facto standards, predominantly defined by regulation authorities or user associations	

1) Syntactic Interoperability

System: Service

Service		
Subsystem Communication		
Intra-Service	The new service application shall follow a standardized way of software development in order to seamlessly fit in an overall system. The relevant standards are not within the scope of the IEC.	
Intersystem Communication		
Operation Markets Prosumers	The new service application shall follow a standardized way of software development in order to seamlessly fit in an overall system. The relevant standards are not within the scope of the IEC.	

System: Prosumers

Prosumers		
Subsystem Communication		
AMI, AMR	See Clause AMI, AMR	
Home Automation	See Clause Smart Home and Building Automation	
Building Automation	See Clause Smart Home and Building Automation	

[1] This document is at PWI (Potential new work item) stage and is not yet published.

Intersystem Communication		
Service	The new service application shall follow a standardized way of software development in order to seamlessly fit in an overall system. The relevant standards are not within the scope of the IEC.	
Operation Distribution	IEC 61850-7-420, *Communication networks and systems for power utility automation – Part 7-420: Basic communication structure - Distributed energy resources logical nodes*	1), 2), 3)
	IEC 61850, *Communication networks and systems in substations*	1), 2), 3)
	IEC 62056, *Electricity metering – Data exchange for meter reading, tariff and load control*	1), 2)
	IEC 61334-4-41, *Distribution automation using distribution line carrier systems – Part 4: Application protocols – Distribution line message specification* (DLMS)	3)
	IEC 61334 “Distribution automation using distribution line carrier systems”	1)
Markets	Local issue, driven by local regulation authorities or user associations. Not an IEC issue	

1) Network Interoperability, 2) Syntactic Interoperability, 3) Semantic Interoperability

4.2.1.4 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.

Currently no complete mapping exists between IEC 61850 and IEC 61970.

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.

The integration and migration of technology standard IP v6 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.

4.2.1.5 Recommendation

Recommendation G-C-1

Although the focus of CIM and Service Oriented Architecture (SOA) is on the electric energy domain, the CIM and SOA concept is open and flexible to being adapted to non-electric domains. In the Distribution System Operation the gas and water supply is also managed. For a common concept of multi-utility management an integration of non-electric extensions of CIM and SOA shall be considered.

Investigate multi-utility effects on the further development of IEC 61970 and IEC 61850.

Recommendation G-C-2

A seamless smart grid communication requires mappings between intersystem and subsystem communication. Investigate existing profiles for mapping between established core standards. Develop profiles in case of missing profiles.

Recommendation G-C-3

Users require future-proof communication standards in order to safeguard their investment in communication infrastructures. A future-proof communication standard is expected to be independent from communication technologies. Therefore the communication standards shall be open so that state-of-the-art communication technologies can be applied.

Recommendation G-C-4

For AMI communication different mappings on physical communication technologies are required. Include Wireless Transport protocols.

Recommendation G-C-5

In a Smart Grid concept technical and business processes along the energy chain grow together. CIM and SOA provide a common concept for the integration of technical and business processes. The underlying IEC 61970 SOA structure allows the flexible implementation of new applications.

Promote and inform other stakeholders about the capabilities, benefits and limits of the CIM and SOA structure of power automation.

Recommendation G-C-6

There is a lot of confusion among stakeholders about the application of IP-based communication to Smart Grid. There is a perception that the existing power automation framework of TC 57 standards (e.g. IEC 61850 and IEC 61970) is somewhat in contradiction with a widespread usage of IP-protocols and communication. However IEC 61850 and IEC 61970 clearly offer the possibilities to use IP and TCP/IP for non-time-critical Smart Grid applications. This misperception should be actively fought by the IEC, in order to avoid re-inventing the wheel.

Evangelize / inform stakeholders about the close connection of power automation standards to TCP/IP.

4.2.2 Security

4.2.2.1 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 must 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 subsequent 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.

4.2.2.2 Requirements

Based on the main objective, the mitigation of risks in order to achieve a stable and secure operation of the Smart Grid, Cyber Security requirements will be derived as a result of risk assessments and general architectural decisions. In order to achieve this in a comprehensive and granular manner, security objectives based on the classical security goals (confidentiality, integrity, availability, non-repudiation, and privacy) are a precondition.

Cyber Security requirements for the Smart Grid do already partly exist in the different domains and specific applications. New requirements will evolve as those applications move forward to address Cyber Security as an important driver. In addition, the characteristic of the Smart Grid as a network of many inter-connected networks and applications will produce new and more common system-spanning Cyber Security requirements.

The initial requirement management activities can be based on well-defined requirement analysis and risk management processes. As a technical precondition, a detailed architecture and description of the Smart Grid needs to be elaborated. This architecture should reflect the specific applications and underlying domains as well as their relationship and interaction. Based on the documented architecture of the Smart Grid, essential use cases relevant for Cyber Security can be developed. Both artefacts, the architecture and the essential use cases, are bases for the risk assessments that need to be conducted. The outcome of the risk assessment and risk management process will lead to a comprehensive security architecture which comprises all security controls.

In a final step, more granular Cyber Security requirements based on measurements and processes can be derived. It is important to consider the impact of existing systems and interfaces that are already part of the Smart Grid. This constraint will affect the process of the definition of Cyber Security requirements at any time.

Furthermore, change and growth are significant characteristics of the Smart Grid. This makes a continuous cycle of risk assessments and subsequent adjustments of implemented security controls necessary. Finally, the high increase in IT and telecommunication technologies and systems might create new requirements in the scope of power systems that already exist in these domains and which are covered by standards and recommendations. The broad utilization of wireless technologies is a perfect example to illustrate this.

4.2.2.3 Existing Standards

Cyber Security requirements already exist for specific applications and domains. They differ in granularity and scope, ranking from process oriented to technical standards. Some standards address the operator, while others contain very detailed implementation requirements.

The subsequent bullets list relevant documents:

- IEC 62351-1 to 6, *Power systems management and associated information exchange - Data and communications security* (Content: security for protocols, network and system management, role-based access control; NWIPs are in planning)
- NERC CIP-002 and CIP-003 to CIP-009 (Content: The North American Electric Reliability Corporation (NERC) has issued the *Critical Infrastructure Protection (CIP) Cyber Security Standards* to protect electrical systems. The CIP Cyber Security Standards are mandatory and enforceable across all users, owners and operators of the bulk-power system. CIP-002 specifies the means by which critical cyber assets are identified. CIP-003 through CIP-009 cover security management controls, personnel and training, electronic security perimeters, physical security of cyber assets, systems security management, incident handling and recovery planning.)
- IEEE 1686-2007, *IEEE Standard for Substation Intelligent Electronic Devices (IEDs) Cyber Security Capabilities*, Institute of Electrical and Electronics Engineers (Content: Specifies functionality of intelligent electronic devices in order to address critical infrastructure protection programmes)
- ISO/IEC 27001, *Information technology - Security techniques - Information security management systems - Requirements*
- ANSI/ISA-99, *Security for Industrial Automation and Control Systems* (Content: Covers the process for establishing an industrial automation and control systems security programme based on risk analysis, establishing awareness and countermeasures, and monitoring and Cyber Security management systems)
- NIST Special Publication 800-82 [Content: Guide to Industrial Control Systems (ICS) Security; Current status is draft]

4.2.2.4 Gaps

Missing standards and recommendations will be identified as a result of the risk assessment and the Cyber Security requirements which stem from that. There is a high probability that existing standards are not sufficient to cover the complex architecture and the manifold use cases of the Smart Grid. Not all protocols have a "security" extension. As an example, IEEE 1588 has no security mechanism at all while being crucial for protection applications.

In addition to domain- and application-specific standards, common and application-spanning aspects need to be addressed.

This is especially true for the requirements covering the aspects of end-to-end security. Furthermore, technical requirements will not be sufficient to address the complexity of the Smart Grid, especially towards growth and change. Operational aspects such as policies and training as well an ongoing cycle of risk assessments needs to be developed and introduced.

4.2.2.5 Recommendation

In order to capture the complexity of the Smart Grid, an Overall Security Architecture needs to be addressed by standardization efforts. It should contain the following aspects, either as integral parts or as references to separate standards.

Recommendation G-S-1

A specification of a dedicated set of security controls (e.g. perimeter security, access control) to protect the Smart Grid needs to be comprehensively developed. As an example, a specification of granular access controls for the discrete boundaries derived from compartmentalization needs to be determined.

Recommendation G-S-2

A compartmentalization of Smart Grid applications (domains) based on clear network segmentation and functional zones needs to be developed.

Recommendation G-S-3

A specification comprising identity establishment (based on trust levels) and identity management in the Smart Grid as a large network connecting a high number of entities and end points needs to be developed. It should cover the aspect of credential management (distribution, validation, revocation) as an essential part.

Recommendation G-S-4

Moreover, existing standards must be reviewed, adapted and enhanced to support general and ubiquitous security across wired and wireless connections.

Recommendation G-S-5

IEC 62443 should confirm the standards architecture and the implementation methods, harmonize the constitution of standards with ISA and other organizations, speed up the standardization process, and be compatible with the contents of the Smart Grid. The goal is to realize the unification and standardization of any industrial control systems.

Recommendation G-S-6

Security of the legacy components in the Smart Grid was not fully considered in the initial design, thus the security performance was poor and difficult to upgrade. Standardization of the physical protection and network protection should be enhanced for the legacy.

4.2.3 Planning for the Smart Grid

4.2.3.1 Description

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. Here the two types of standards are analyzed and some suggestions are put forward.

4.2.3.2 Requirements

To provide the favourable conditions for renewable power or connection of distributed generation is one of the goals of Smart Grid development.

The 'IEC Standard for connecting MicroGrids with electric power systems' may include the following contents:

1. Design standard of MicroGrid. This includes equipment, protection schemes, and information system inside MicroGrid, etc.
2. Standard for MicroGrid operating in island mode. This includes power management, voltage and frequency control, stability, protection, cold load pickup, monitoring and communication, power quality, installation and testing, etc.
3. Standard for connecting MicroGrids with grid:

   Grid connection mode and conditions. This includes access mode (single PCC or multiple PCC), isolation mode, interconnection transformer, grounding mode, prevention of electromagnetic interference, withstanding voltage and current surge capacity, etc. Connection methods have major effects on the planning and operating of transmission system. Some organizations have their own standards for connection of wind power but up to now there has been no international standard for this. There are some national or international standards for PV connection, but they concern only distributed connection of small PV system.

With the development of distributed generation, standards for interconnection of distribution generation and distribution network planning standards with distribution generation incorporated in them are needed. On the other hand, as an effective way to utilize distribution generation, MicroGrid will play an important role in the smart grid. Therefore, standards for MicroGrid interconnection with power networks or distribution system planning standards with MicroGrid incorporated are required.

4.2.3.3 Existing Standards

IEC 61727:2004, *Photovoltaic (PV) systems – Characteristics of the utility interface*. This is suitable for PV system smaller than 10 kVA, connected with LV distribution system.

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 IEEE 1547 Serial Standardsare currently the most widely accepted standards in the field of distributed resources interconnection and have been formally affirmed as one of the first batch of the USA Smart Grid construction standards. The IEEE 1547 series are outlined as follows:

IEEE 1547.1:2005, *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.

IEEE 1547.2:2008, *Application Guide for IEEE 1547 Standard for Interconnecting Distributed Resources with Electric Power Systems.* This provides a technical background on the standard.

IEEE 1547.3:2007, *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.

IEEE 1547.4: *Draft Guide for Design, Operation, and Integration of Distributed Resource Island Systems with Electric Power Systems* (draft). This is a guide for design, operation, and integration of conforming systems.

IEEE P1547.5: *Draft Technical Guidelines for Interconnection of Electric Power Sources Greater than 10MVA to the Power Transmission Grid* (draft). Designed for distributed sources larger than 10 MVA

IEEE P1547.6: *Draft Recommended Practice for Interconnecting Distributed Resources with Electric Power Systems Distribution Secondary Networks* (draft). This describes practices for secondary network interconnections.

4.2.3.4 Gaps

Although some corporations and organizations have enacted their own wind turbine connection code, there is no universal international standard. For example, in the Nordic Wind Turbine Connection Code, there are detailed performance requirements in relation to voltage and frequency, as shown in Figure 6. Is it necessary to give such detailed and strict standards? An IEC standard for wind turbine connections is needed to give the fundamental requirements.

Existing international standards for PV systems connection, such as IEC 61727, *Photovoltaic (PV) systems – Characteristics of the utility interface* and IEEE 929-2000, *Recommended practice for utility interface of photovoltaic (PV) systems*, are only suitable for PV system connection into the distribution network. They are focused on requirements concerning power quality, security and protection. There are no international standards for large-scale PV system connections into transmission systems.

In the IEEE 1547 series, IEEE 1547.4 is the only standard worldwide that deals with MicroGrid interconnection, and it is still currently a draft standard. It is suggested that an IEC standard dealing with MicroGrid interconnection should be drawn up.

(See Figure 6)

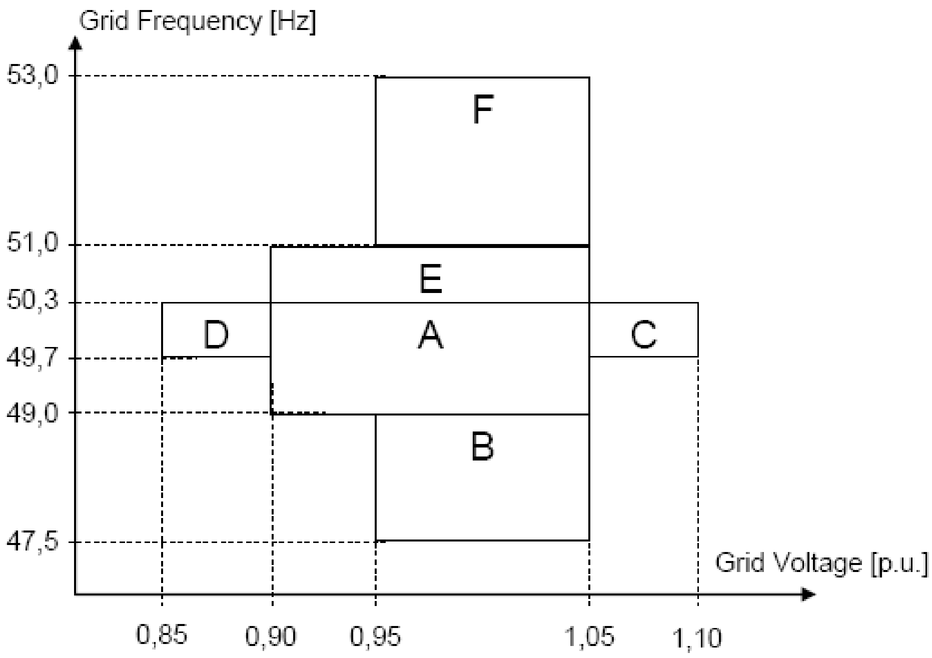


Figure 5 – Grid frequency and voltage

4.2.3.5 Recommendation

Recommendation S-PSG-1

The ‘IEC Standard for wind turbine connection' may include the basic requirements concerning active power control, reactive power control, reactive power capacity, dimensioning voltage and frequency and operating characteristics under grid disturbances.

Recommendation S-PSG-2

The ‘IEC Standard for PV station connection' may include the basic requirements concerning effects on power quality, active power control, reactive power control, dimensioning voltage and frequency and operating characteristics under grid disturbances.

Recommendation S-PSG-3

The development of an IEC standard for connecting microgrids with electrical Power Systems. This new standard should include the contents mentioned under requirements in Clause 4.2.3.2.

4.3 Specific Applications

The Smart Grid concept as described in the preceding Clause spans the whole energy chain from generation to consumption and alters the way power grids are operated, connecting the two domains.

4.3.1 Smart transmission systems, Transmission Level Applications

4.3.1.1 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).

The use cases 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 economical 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.

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 800kV and higher.

Flexible AC Transmission Systems (FACTS) have been evolving into a mature technology with high power ratings. This technology, proven in various applications, 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)

Additional benefits of voltage-source-converter based HVDC and FACTS:

- Damping of power oscillations (POD)
- Load-flow control
- Mitigation of SSR (sub synchronous resonances)
- Increase in system stability

4.3.1.2 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 must 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).

4.3.1.3 Existing Standards

Product standards

Product standardization of HVDC and FACTS is already quite mature and is dealt with in the TC/SC 8, SC 22F and TC 115.

Many product standards already exist for HVDC, e.g.:

IEC 60633, Ed. 2.0, *Terminology for high-voltage direct current (HVDC) transmission*

IEC/TR 60919 (series), *Performance of high-voltage direct current (HVDC) systems with line-commutated converters*

IEC 60700-1, Ed.1.2, *Thyristor valves for high voltage direct current (HVDC) power transmission - Part 1: Electrical testing*

IEC 61954, Ed.1.1, *Power electronics for electrical transmission and distribution systems - Testing of thyristor valves for static VAR compensators*

IEC 61803, Ed.1, *Determination of power losses in high-voltage direct current (HVDC) converter stations*

Interoperability standards

Relevant to Smart Grid issues is the question of how the equipment is connected to an overall system. Regarding this connection of HVDC/FACTS to the overall system, communication standards do exist. However, for the equipment itself, this is more a question of providing interfaces to the overall communication. These interfaces should be consistent with the following standards:

IEC 60870-5, *Telecontrol equipment and systems*

IEC 60870-5-101, *Telecontrol equipment and systems - Part 5-101: Transmission protocols - Companion standard for basic telecontrol tasks*

IEC 60870-5-103, *Telecontrol equipment and systems - Part 5-103: Transmission protocols - Companion standard for the informative interface of protection equipment*"

IEC 60870-5-104, *Telecontrol equipment and systems - Part 5-104: Transmission protocols - Network access for IEC 60870-5-101 using standard transport profiles*

IEC 61850 series, *Communication networks and systems in substations*

Mapping of IEC 61850 Common Data Classes on IEC 60870-5-104 (IEC 61850-80-1 TS)

IEC 61970-401, *Energy management system application program interface (EMS-API) – Part 401: Component interface specification (CIS) framework*

IEC 61970-404, *Energy management system application program interface (EMS-API) – Part 404: High Speed Data Access (HSDA)*

Power quality

IEC 61000, *Electromagnetic compatibility (EMC)*

IEC 60038 Ed. 7.0, *IEC standard voltages*

IEC/TR 62510, *Standardising the characteristics of electricity*

Other standards in use

DNP 3.0 and proprietary standards are in use for telecontrol purposes. However these standards are not suitable to meet the higher requirements regarding data exchange, bandwidth etc. to be integrated in a System Integrity Protection Scheme described in the following Subclause.

4.3.1.4 Gaps

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 HVDC and FACTS can be expected from the newly founded TC 115 (DC Systems). SG2 coordinates and supports the work of IEC TC 115 and SC 22F.

Interoperability standards

Large substations, especially at transmission level, can have serial links as defined in IEC 60870-5-101 (serial), although 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 (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 must be amended in order to fulfill 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.

4.3.1.5 Recommendation

Recommendation S-HF-1

TC 57 should investigate the following subjects: Object model must be verified and amended. Mapping of communication services to communication stack must be defined. Transfer of access rights needs to be discussed. Generally communication between switchgear and control centre is already possible with IEC 61850, since data exchange is based on TCP/IP.

TC 57 and SC 17C should continue their cooperation. This particularly concerns SC 17C WG 11 - Communication requirements of HV switchgear assemblies. The use of IEC 61850 should be promoted for this equipment.

4.3.2 Blackout Prevention / EMS

4.3.2.1 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 reestablished.

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 must be extended to phasor measurement provided by PMUs (Phasor Measurement Units).

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

Wide Area Measurement Systems

By its very definition, as applied to power system protection, wide-area measurement systems (Power Quality and Monitoring Systems) are a synergistic combination of relays, instrument transformers, control equipment, automation equipment, monitoring equipment, and communication employed to encompass extensive system elements, as opposed to the more traditional view of individual equipment or point-to-point protection. The increasing world-wide application of digital devices and high-speed wideband communication and Global Positioning Systems (GPSs), plus the growing acceptance of adaptive relay protection philosophy and practice, have dramatically altered the fundamental role of power-system protection.

System Integrity Protection Schemes

System Integrity Protection Schemes (SIPSs) are automated systems which protect the grid against system emergencies. These automatic measures minimize the potential and extent of wide outages that could result from more serious but less common or anticipated events. Due to the vast interconnected grid control area, it may not be possible to provide for the many possible contingencies or to address transmission path ratings and system availability without

SIPSs to complement grid reliability. SIPSs are an important class of countermeasures that can be applied due to their relatively low cost, shorter installation time, and the rarity of contingencies.

The different schemes are engineered and designed and, compared to installation of major equipment such as transmission lines or substation power facilities, are economically and technically more effective. Such schemes cover contingencies over an entire region that may include multiple grid control centres or several interconnected countries. They are also referred to as Remedial Action Schemes (RASs). These schemes are intended to address power system constraints or when constraints could occur as a result of increased transfer limits.

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&D grid, installing new generation and control systems (e.g. reactive power devices, Flexible AC Transmission Systems (FACTSs), High-Voltage DC (HVDC)) 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.

4.3.2.2 Requirements

Requirements to fulfill 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 must meet latency and real-time application requirements. Processing must be able to integrate data from field level up to EMS systems.

In order to control such a large system, equipment as described in paragraph 4.3.1.3 is necessary (FACTS, HVDC etc.). The relevant information about standardization is given there.

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.

4.3.2.3 Existing Standards

See Communication System: Operation

Product standards / New sensor devices

IEC 61869, Instrument transformers

future IEC 61869-7, Electronic voltage transformers

future IEC 61869-8, Electronic current transformers

future IEC 61869-9, Digital interface for instrument transformers

Interoperability standards (see Figure 6)

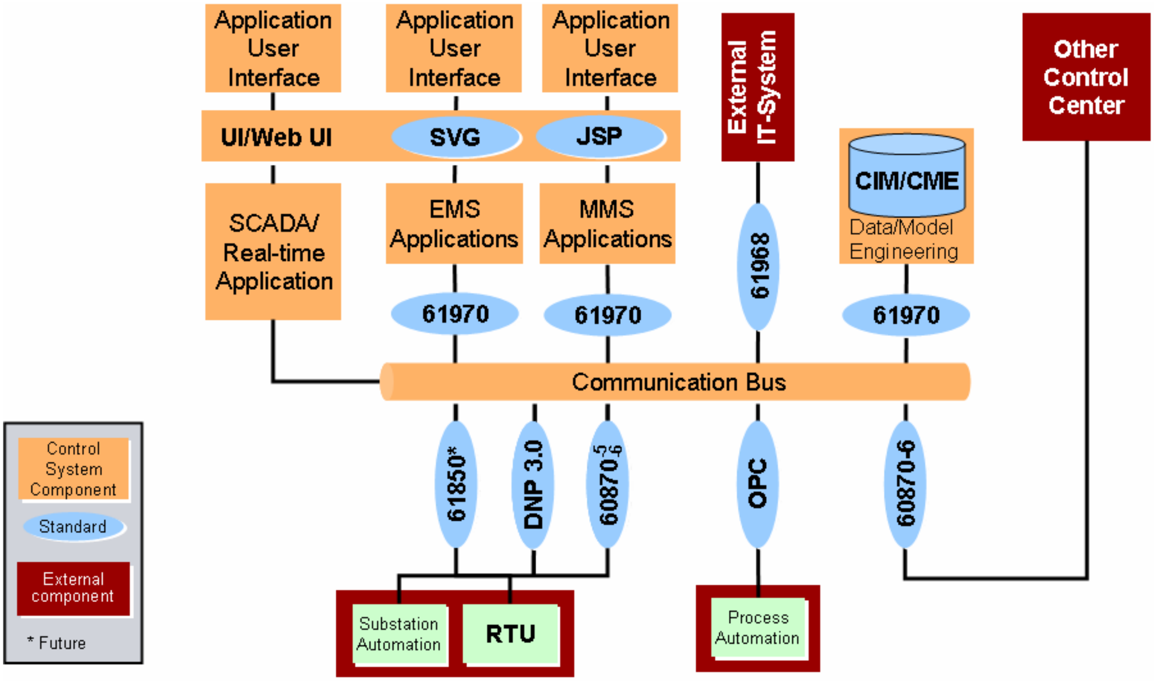


Figure 6 – Overview of advanced EMS architecture

IEC/TR 62357, *Power system control and associated communications – Reference architecture for object models, services and protocols*, describes the general interconnection between the various standards of TC 57

IEC 61850, *Communication networks and systems in substations*

IEC 61850 describes information models for the following functions:

- Protection
- Local control and supervision
- Remote control and supervision
- Current and Voltage transformer
- Transformer supervision
- Meter data
- Measuring Units
- Online-diagnosis
- Special communication requirements are fulfilled:
    - High data throughput
    - Short transmission time
    - Time Synchronization for events (accuracy 1 ms) and sample values (accuracy <25 μs, phasor/vector in 50/60 Hz net)
    - Usage of open communication standards (Ethernet, TCP/IP, XML)

IEC 61850 allows interoperability on the communication level. Functional interoperability is not within the scope of IEC 61850. This must be ensured by specifications of the functional requirements. Profiles should be developed for specific use cases.

IEC 61970, *Energy Management system application program interface (EMS-API)*, defines data exchange, semantic information, classes and services available for EMS applications. The Service Oriented Architecture (SOA) allows the flexible generation of applications around the EMS. The data description and data models are described in the subparts of IEC 61970.

IEC 61970-401*, Energy management system application program interface (EMS-API) – Part 401: Component interface specification (CIS) framework*

The CIS defines an interface which can be implemented by equipment and applications, if these components have the necessity to exchange data with other components. It is therefore applied to connect equipment to an Energy Management System. The CIS framework is superseded by the Generic Interface Definition (GID) and this does not apply to IEC 61968.

IEC 61970-402, *Energy management system application program interface (EMS-API) – Part 402: Common services.* This defines common services, which include

- Resource identification
- Resource description
- Classification

This may include functions such as Asset Management, Geographic Information Services, etc.

IEC 61970-453, *Energy management system application program interface (EMS-API) – Part 453: CIM based graphics exchange* defines graphic elements which can be exchanged between control centres and may serve the increasing need for visualization of complex situations.

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

Time Synchronization

IEC 61850, *Communication networks and systems in substations*

IEC 61850 specifies the following time synchronization requirements:

Time Synchronization for sequence of events (SNTP, accuracy 1 ms) and sample values (e.g. IEEE 1588, accuracy <= 1 *µ*s)

Security

IEC/TS 62351, *Power systems management and associated information exchange – Data and communications security*

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

IEC/TS 62351-5, *Power systems management and associated information exchange – Data and communications security – Part 5: Security for IEC 60870-5 and derivatives* (i.e. DNP 3.0)

IEC/TS 62351-6, *Power systems management and associated information exchange – Data and communications security – Part 6: Security for IEC 61850*

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*

IEC/TS 62351-8, *Power systems management and associated information exchange – Data and communications security – Role-based access control*

Other standards in use

IEEE C37.118, *IEEE Standard for Synchrophasors for Power Systems*

NERC CIP002-009, *Implementation Plan for Cyber Security Standards*

4.3.2.4 Gaps

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

Data models, classes and functionalities may be required for advanced state estimation, which includes phasor information. This must 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.

4.3.2.5 Recommendation

IEC 61850 is the only internationally recognized and used standard for the exchange of process data on the high-, medium- and increasingly also low-voltage level. It is ideally suited for the task of providing the necessary measurement data for advanced EMS systems.

The IEC 61970 CIM is a very good base and, due to its SOA structure, allows the inclusion of new application and data models. These however must be specified.

Recommendation S-BP-1

Currently a NWIP on a dual logo standard IEC/IEEE is at the voting stage. This will determine the future usage of PMUs in the IEC TC 57 reference architecture. The IEEE standard has no CIM- or 61850-based modelling behind it and no clear mapping approach for information to reach IEC based protocols or models. From an IEC perspective the use of IEEE C37.118 should be consistent with the overall IEC TC 57 architecture. Only under this precondition should a harmonization of IEC 61850 and IEEE C 37.118 PMU be performed.

Recommendation S-BP-2

There is a lot of confusion among stakeholders about the application of IP-based communication to Smart Grid. There is a perception that the existing power automation framework of EMS standards (e.g. IEC 61970) is somewhat in contradiction with a widespread usage of IP protocols and communication. Since IEC 61970 can be used for data exchange using a SOA structure, it allows the flexible implementation of new applications and clearly offers possibilities to use IP and TCP/IP at the transport layer. This misperception should be actively fought by the IEC, in order to avoid reinventing the wheel. Therefore the IEC should actively promote and inform stakeholders about the possibilities of the IEC 61970 series via means of whitepapers, workshops and active involvement with other organizations (e.g. NIST, UCAiug etc.).

Recommendation S-BP-3

A uniform platform standard which specifies services used by all types of energy management applications and dynamic object message protocols which take advantage of object-oriented technology and self-description technology.

Recommendation S-BP-4

IEC Standard for Synchrophasors for Power Systems.

Recommendation S-BP-5

IEC standard for Common Format and transmission protocol for Transient Data Exchange.

4.3.3 Advanced Distribution Management

4.3.3.1 Description

Over the past few decades, management of the Energy Distribution Network has been progressively supported by Information Technology (IT) systems to improve work-flow and optimize network operations and overall security. This has mainly resulted in the implementation of individual applications specific to each function and functional group of the utility.

Liberalization and deregulation, together with a globally stagnating economy, force 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.

DMS as key component for Distribution Management

A distribution management system covers all the functions needed to efficiently operate a power 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
– geospatial information systems (GIS)
– customer information
– asset 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 fact 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 power 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 analyzing 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-energy 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 Document 57/991/DC, *Roadmap for WG14: System interfaces for distribution management (SIDM)*.

4.3.3.2 Requirements

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

Connections to Home Area Networks (HAN) is important 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 utility systems, as well as enabling demand-response (DR) and energy efficiency programmes. 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.

Cyber security is a requirement as well as the incorporation of **pricing information**.

4.3.3.3 Existing Standards

See Communication System Operation.

Effective sharing and exchange of information between the systems of various departments is usually a tortuous process for utilities.

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.

The rapid advance of integration middleware technologies has created an urgent need for industry standards that establish the common semantics required for interoperability in specific industry domains.

In the electricity domain, TC 57 of the IEC is undertaking the development of such standards. Within this framework, Working Group 14 (WG 14) is to identify and establish requirements for standard interfaces of a Distribution Management Systems (DMS) based on an interface architecture. This will facilitate information exchange among systems supporting planning, construction, maintenance and operation of electricity distribution networks.

The standard interfaces will only cover areas within the focused domain of IEC-TC 57.

They 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.

Interoperability standards – Communication

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.

The IEC 61968 series of standards supports this integration by developing information exchange standards using the Common Information Model (CIM), normative message structures, additional normative parameters, and informative recommendations and examples.

There is a huge market demand for information exchange standards focused on the utility distribution enterprise, and WG 14 is in an ideal position to meet this demand since data and communications are within the scope of IEC TC 57. WG 14 needs to address the needs of all distribution utilities, including the 10 000 smaller DSOs needing only one or a few of the most common interfaces, as well as medium and larger utilities with Enterprise Application Infrastructure projects which can make more extensive use of the standards.

Applications are described for the coupling of two systems by defining XML-messages to be exchanged. The different parts of IEC 61968 include interfaces to grid operation, asset management, planning and optimizing grid operation, expansion and maintenance of the grid and metering (see Figure 8).

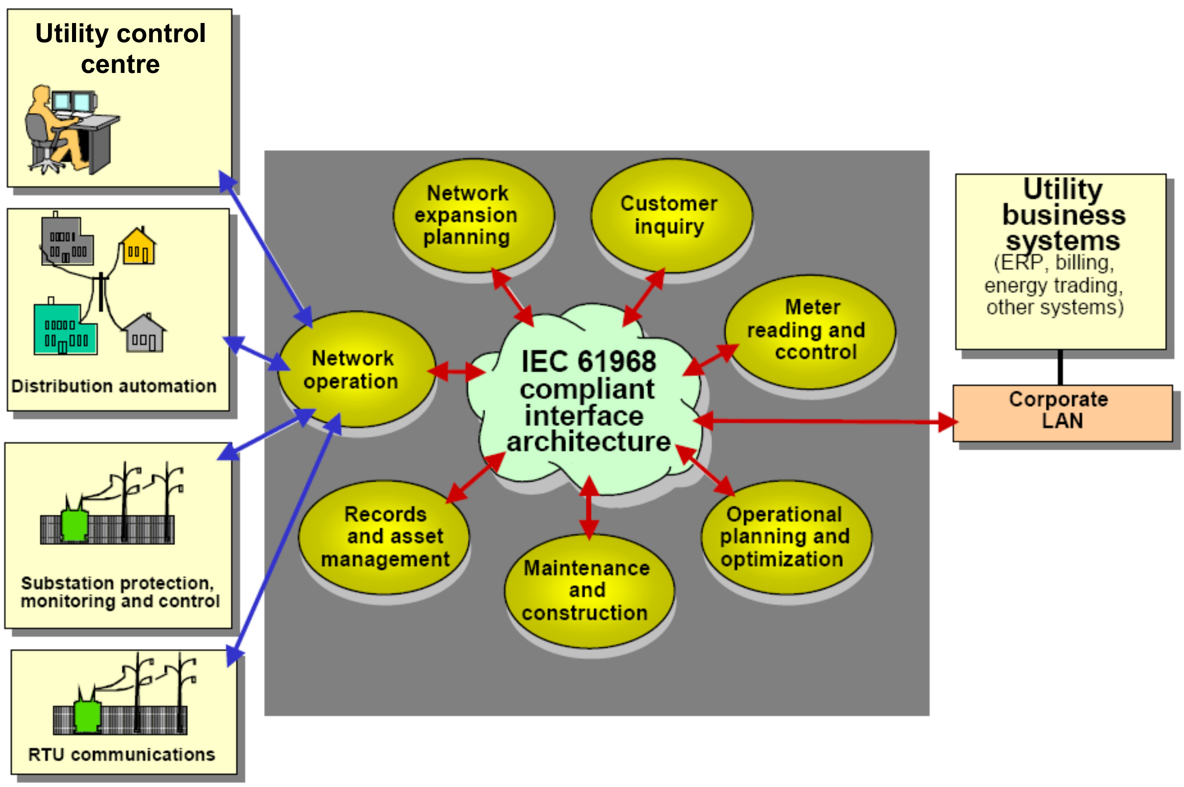


Figure 8 – IEC 61968 compliant interface architecture

Part	Scope
61968-1	Introduction
61968-1-1	Enterprise Service Bus (ESB) Profile
61968-1, Clause 2	XML naming and design rules

Part	Scope
61968-2	Glossary
61968-3	Interface for network operations
61968-4	Interfaces for records & Asset Management (AM)
61968-5	Operational Planning & Optimization (OP)
61968-6	Maintenance & Construction (MC)
61968-7	Network Extension Planning (NE)
61968-8	Interface standard for Customer Support (CS)
61968-9	Interfaces for Meter Reading and control (MR)
61968-11	Common Information Model (CIM) extensions for Distribution
61968-12	Use Cases
61968-13	CIM RDF Model Exchange Format for Distribution (CDPSM)
61968-14-1	Mapping between MultiSpeak 4.0 and IEC 61968, parts 3 through 9 and 13
61968-14-2	CIM profile for MultiSpeak 4.0, one profile for IEC 61968, parts 3 through 9 and 13

Other standards in use

Multispeak 4.0

The MultiSpeak® Initiative is a collaboration of the National Rural Electric Cooperative Association (NRECA), 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 WG 14 to effectively address the needs of smaller utilities on an international basis. As most utility and vendor involvement in WG 14 has been more oriented to large utilities with significant information technology needs and capabilities, this collaboration is invaluable.

4.3.3.4 Gaps

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

- Operational Planning & Optimization (OP) – Part 5
- Maintenance & 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 needs to be extended regarding modeling of DR command signals, different signals, e.g. for interruptible load, emergency DR and DR bidding are not in the standard

Further gaps are described in the IEC TC 57 WG 14 roadmap: Vision for the Next Generation of CIM and Related Standards.

The following diagramme depicts a vision for the next generation of CIM and its related standards.

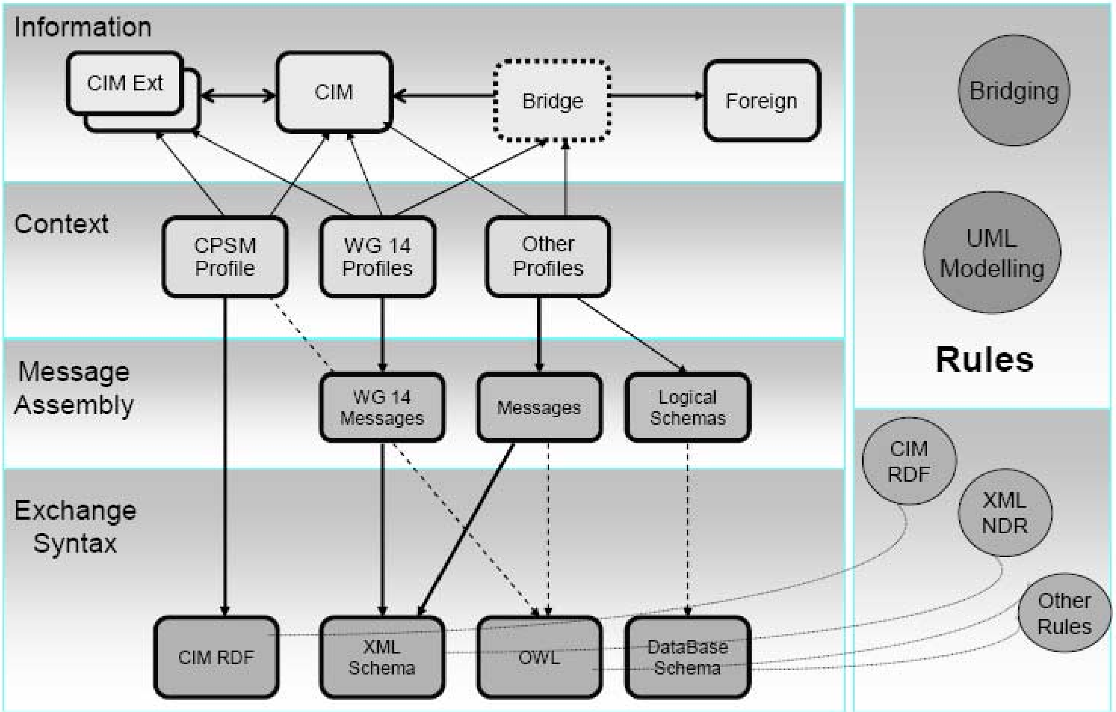


Figure 9 – Next-generation CIM

As shown in Figure 9, the future vision embraces some new concepts in a four layer architecture not currently incorporated into the CIM and related standards architecture:

1. Information Layer – This layer includes the CIM but provides for the reality that there are other sources of information as well as the CIM that need to be taken into consideration when creating CIM-based information exchanges or repositories. These different models/standards and ways of bridging them together comprise the Information layer.
2. Contextual Layer – This layer formally recognizes that only a subset of the models in the Information Layer is needed for any particular interface or message definition. The Profile standards defined in this layer:
   - define a subset of the models in the Information layer needed for a particular business purpose as well as constraining those model elements to address specific business needs, and
   - provide a way to incorporate model elements from the different information sources in the Information layer in addition to the CIM.
3. Message Assembly Layer – This layer defines the structure of a Message that carries the Profile Information and what kind of operation should be performed with message payload.
4. Implementation Layer – or Message Syntax layer – provides for specific implementations of the Profiles defined in the Contextual layer.

An important feature of this layered architecture is that for the first time there are clear boundaries defined between the information models in the Information Layer and the business context in the Contextual Layer. Without this distinction the current CIM has suffered from an “identity crisis” – trying to be an information model which also incorporates business context in a non-uniform way. The tension is created by trying to have the CIM be both general and generic enough to be used in any application while being as specific and constrained as possible to include descriptions more useful to an application in a specific business context. It is not possible to satisfy both objectives in an information model, although attempts have been made in some cases by incorporating poor modeling practices, such as having an attribute mean one thing if the context is A, but something else if the context is B, where the context is indicated by the value of a flag attribute.

Currently the market for OMS and (M)WFM is served by proprietary solutions.

4.3.3.5 Recommendation

Recommendation S-DMS-1

IEC TC 57 WG 14 already has put together a roadmap of further activities. Under Smart Grid aspects attention should be drawn to the points:

- Network Operations – Part 3
- Records & Asset Management (AM) – Part 4
- Operational Planning & Optimization (OP) – Part 5
- Network Extension Planning (NE) – Part 7

The IEC should be supportive of the roadmap results.

Recommendation S-DMS-2

To serve the smaller and medium utilities (similar objectives as, for example, the MultiSpeak® Initiative from NRECA), develop Normative Message Types that enable bulk and incremental transfers in the sense that the form of the message is clearly identified, standardized and hence testable.

IEC TC 57 WG 14 should evaluate a possible mapping from IEC 61968 to available industry standards like MultiSpeak 4.0.

Recommendation S-DMS-3

Promote CIM for distribution management. Define the scope through profiles using existing definitions as far as possible.

Recommendation S-DMS-4

Develop neutral hosted interoperability testing based on CIM profiles.

Recommendation S-DMS-5

Integrate DER profiling and device discovery in future IEC 61968 network extension models. Synchronize with IEC 61850-7-420.

Recommendation S-DMS-6

Incorporate AMI and HAN models to allow for Demand Response capabilities and interfaces to these domains. Financial incentives and direct intervention cannot by themselves guarantee a successful demand response. Modeling of load behaviour at end-user level seems to be necessary for implementing a successful DR.

4.3.4 Distribution Automation

4.3.4.1 Description

The power 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. 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 abovementioned 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 nowadays 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 110kV 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 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 for the Automation of Distribution feeders. In case of a disturbance on a distribution feeder, the number of the affected customers is low, and the amount of revenue loss is also low.

However the increasing integration of Decentralized Energy Resources (DERs), for example photovoltaic systems at low-voltage level and wind generators at medium-voltage level cause 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 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 microgrids, 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.

4.3.4.2 Existing Standards

Interoperability standards

IEC 60870-5, *Telecontrol equipment and systems*

IEC 60870-5-101, *Telecontrol equipment and systems - Part 5-101: Transmission protocols - Companion standard for basic telecontrol tasks*

IEC 60870-5-103, *Telecontrol equipment and systems - Part 5-103: Transmission protocols - Companion standard for the informative interface of protection equipment*

IEC 60870-5-104, *Telecontrol equipment and systems - Part 5-104: Transmission protocols - Network access for IEC 60870-5-101 using standard transport profiles*

IEC 61850-7-4, *Communication networks and systems for power utility automation - Part 7-4: Basic communication structure – Compatible logical node classes and data object classes*

IEC 61850-7-420, *Communication networks and systems for power utility automation – Part 7-420: Basic communication structure – Distributed energy resources logical nodes*

Time Synchronization

IEC 61850, *Communication networks and systems for power utility automation*

IEC 61850 fulfills the following time synchronization requirements

Time Synchronization for events (SNTP, accuracy 1 ms)

Security

IEC 62351, *Power systems management and associated information exchange – Data and communications security*

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

IEC 62351-5, *Power systems management and associated information exchange – Data and communications security – Part 5: Security for IEC 60870-5 and derivatives* (i.e. DNP 3.0)

IEC 62351-6, *Power systems management and associated information exchange – Data and communications security – Data and communications security – Part 6: Security for IEC 61850*

IEC 62351-7, *Power systems management and associated information exchange – Data and communications security – Data and communications security – Part 7: Network and system management (NSM) data object models*

IEC 62351-8, *Power systems management and associated information exchange – Data and communications security - Part 8: Role-based access control*

4.3.4.3 Gaps

The existing standards provide a good coverage of substation and feeder equipment of high- and medium-voltage power systems in their semantic data models. Low-voltage equipment so far is rarely considered in IEC 61850.

4.3.4.4 Recommendation

Recommendation S-DA-1

The use cases of the different distribution automation concepts need to be considered in the information data models. Therefore the IEC 61850-7-4 data models shall cover all distribution automation objects.

Recommendation S-DA-2

The IEEE has started activities in the field of distribution automation standardization. The IEC should seek cooperation (TC 8 - power system concepts, TC 57 - requirements for information exchange).

Recommendation S-DA-3

For the interconnection and integration of DER and on-line monitoring and controlling of the smart grid, IEC 61580-7-420 is advised in the integration of DER.

Add DER profile to the network models of IEC 61968 correspondingly

Recommendation S-DA-4

For the Integration of the DER and energy dispatching management of the smart grid, IEC 61970 should meet the requirement of distribution dispatching management system.

Speed up the development of the IEC 61970 standard for Active Distribution of the Energy Management System.

4.3.5 Smart Substation Automation – Process bus

4.3.5.1 Description

The possibility to build Substation Automations 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, 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 *station-bus application*, which lets IEDs communicate with each other and with a substation controller. An extension to this communication will be the so called process bus. This technology (see Figure 10) allows signals of a conventional or non-conventional instrument transformer to be sampled and digitally transmitted to one or several protection and measuring devices.

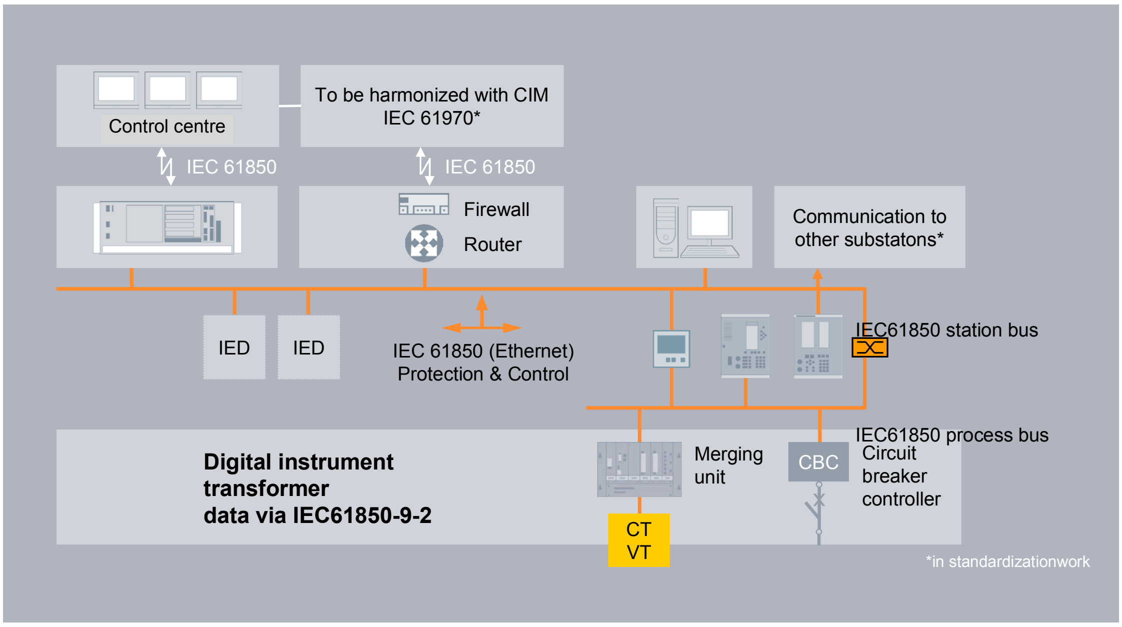


Figure 10 - Smart Substation Automation – Process bus

In the future, substation automation will be centered around such a digital signaling platform covering the needs of a whole substation e.g. a real time Ethernet bus. The optimized measuring transformer design (conventional as well as non-conventional) will open up solutions for the substation, bringing a lot of technical advantages for future changes in network conditions and functional requirements. Novel integrated multi-functional switchgear with integrated sensors and actuators, including monitoring and diagnostics functions, have been developed. Non-conventional instrument transformers for current and voltage without the heavy iron core, meaning for example no saturation, are available both for protection and for metering. Common are Rogowski coils for current and capacitive dividers for voltage measurement.

Any signal, once brought into the digital system, will be available to be rearranged in the bus communication structures without major hardware changes. The fixed built-in parameters of today may become easy-to-change setting values in the electronics of the future (e.g. rated current in metering systems).

Today such solutions are difficult to place during the normal specification and evaluation process. This new technology opens ways to decrease overall cost for the initial investment (e.g. integrated non conventional measuring sensors) and speed up project execution.

4.3.5.2 Requirements

Devices of different vendors must 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 must support different operation methods and must 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 *μ*s)
- 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 must 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 must meet extraordinarily high requirements for availability and reliability.

4.3.5.3 Existing Standards

Product standards

IEC 61869, *Instrument transformers*

Future IEC 61869-7, *Instrument transformers – Electronic Voltage Transformers*

Future IEC 61869-8, *Instrument transformers – Electronic Current Transformers*

Future IEC 61869-9, *Instrument transformers – Digital Interface for Instrument Transformers*

Interoperability standards – Communication

IEC 60255-24, *Electrical relays – Part 24: Common format for transient data exchange (COMTRADE) for power systems*

This part of IEC 60255 defines a format for files containing transient waveform and event data collected from power systems or power system models. This standard applies to files stored on physical media such as digital hard drives and diskettes. It is not a standard for transferring data files over communication networks. The format is intended to provide an easily interpretable format for use in exchanging data; as such, it does not make use of the economies available from data encoding and compression which proprietary formats depend upon for competitive advantage.

Multiple protocols 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.

Different Control centre connection protocols are available:

- IEC 60870-5-101
- IEC 60870-5-104
- DNP V3.00 (serial and “over IP”; non-IEC standard)

IED and substation connection

- IEC 61850
- IEC 60870-5-101
- IEC 60870-5-103
- IEC 60870-5-104
- DNP V3.00 (serial and “over IP”)
- PROFIBUS FMS
- PROFIBUS DP
- MODBUS (non-IEC standard)

IEC 61850

IEC 61850 is the communication standard for interconnecting the devices at the feeder and station control levels on the basis of Ethernet. IEC 61850 supports the direct exchange of data between IEDs, thus enabling switching interlocks across feeders independently of the station control unit, for example.

Since 2004, the Ethernet-based IEC 61850 protocol is the worldwide standard for protection and control systems used by power supply corporations. By means of this protocol, information can also be exchanged directly between feeder units so as to set up simple master less systems for feeder and system interlocking.

Figure 11 shows the interface model of substation automation:

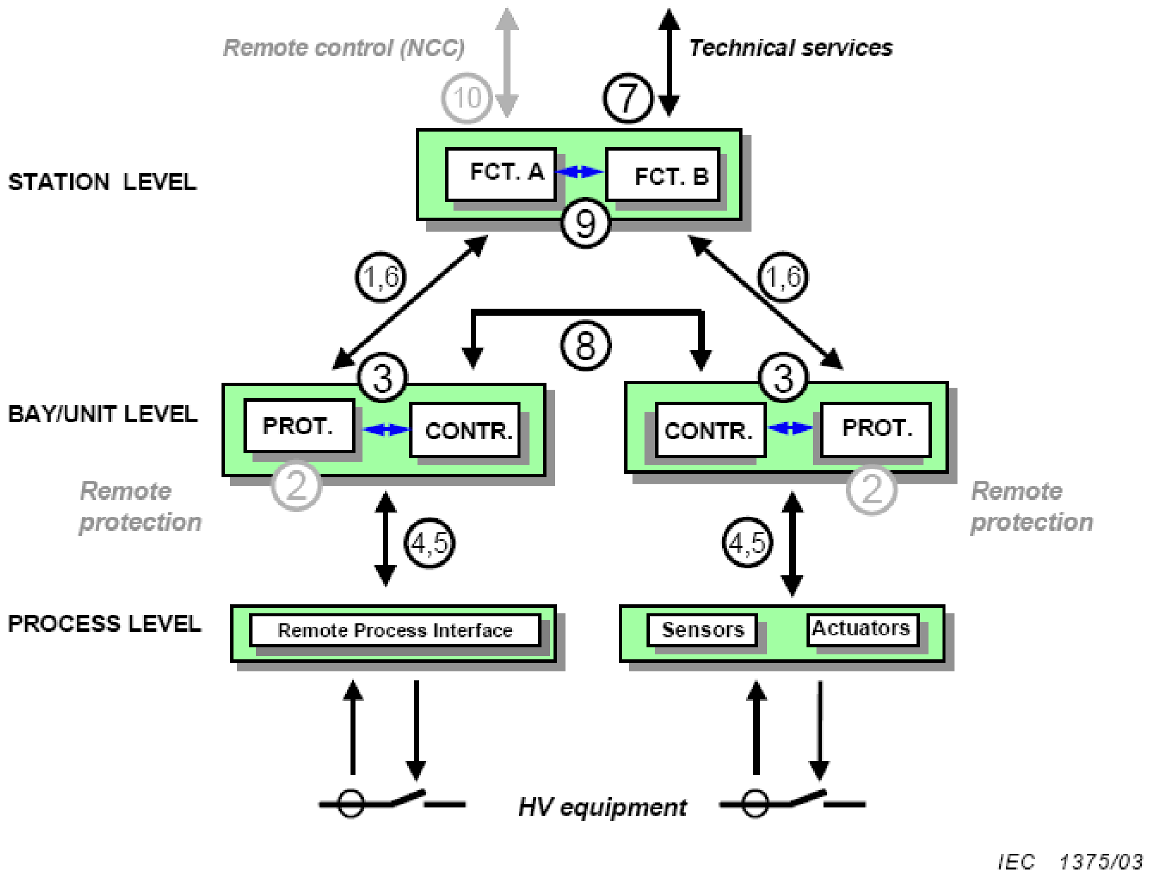


Figure 11 – Interface model of substation automation

The meanings of the interfaces are as follows:

IF1: protection-data exchange between bay and station level.

IF2: protection-data exchange between bay level and remote protection (IEC 60870-5-103).

IF3: data exchange within bay level.

IF4: CT and VT instantaneous data exchange (especially samples) between process and bay level.

IF5: control-data exchange between process and bay level.

IF6: control-data exchange between bay and station level.

IF7: data exchange between substation (level) and a remote engineer's workplace.

IF8: direct data exchange between the bays especially for fast functions such as interlocking.

IF9: data exchange within station level.

IF10: control-data exchange between substation (devices) and a remote control centre (IEC 60870-5-101/104).

The devices of a substation automation system may be physically installed on different functional levels (station, bay, and process).

Figure 12 shows the IEC Technical Committees that are responsible for standards related to devices; a close cooperation with these committees is considered to be mandatory. To guarantee a close cooperation, all the committees mentioned below have delegated specialists to the working groups responsible for the elaboration of the IEC 61850 series.

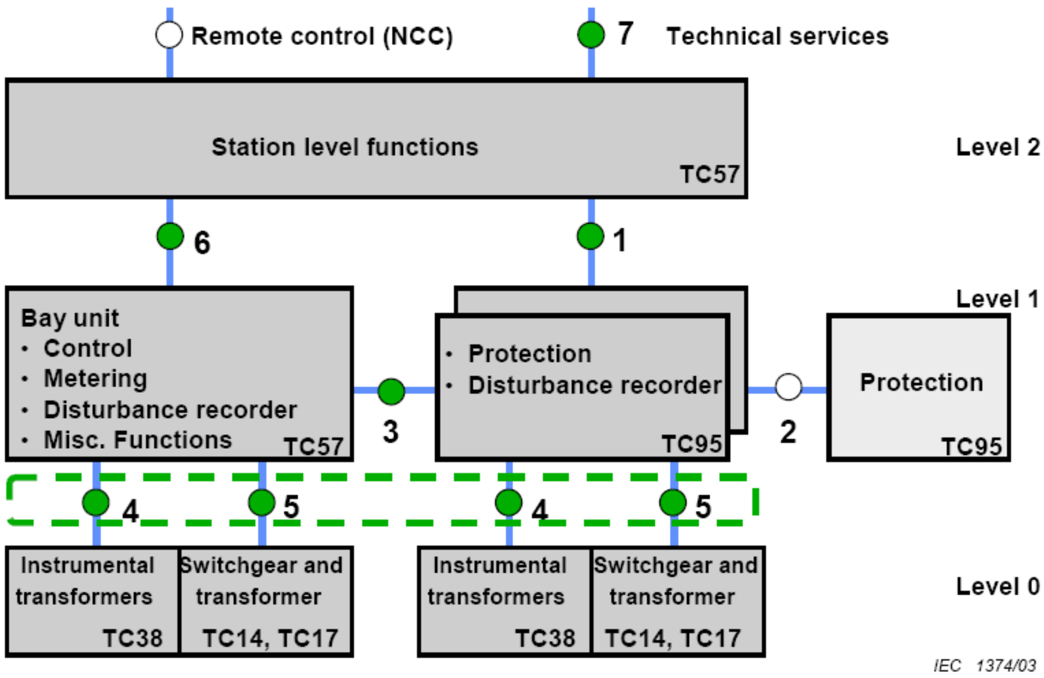


Figure 12 – Responsible IEC Technical Committees

IEC 60870-5-103:

Protection units, IEDs, bay control units, measured value recorders and transformer controllers from many manufacturers support the IEC 60870-5-103 protocol. IEC 60870-5-103 is an internationally standardized protocol for efficient communication between the protection relays and the central unit.

IEC 60870-5-101 (Master):

The IEC 60870-5-101 protocol is generally used to connect telecontrol units. “Balanced” and “unbalanced” traffic modes are supported. Automatic dialing is also supported for the connection of substations with this protocol.

IEC 60870-5-104 (Master):

Furthermore, connection of substations is also supported by the TCP/IP-based IEC 60870-5-104 protocol.

IEDs and substations can also be connected with DNP V3.00 (serial and “over IP”) and MODBUS.

The standard series IEC 61850 defines the following aspects:

- Standardized information (for circuit breakers, measuring unit, control etc.) with description (IEC 61850-7-4) which are based on standard data types (IEC 61850-7-3). Standardized services (IEC 61850-7-2)
- Standardized networks for data exchange, services which are communicated through standardized communication systems (IEC 61850-8-1, 61850-9-1 and 61850-9-2)
- Standardized configurations for the complete description of the unit. IEC 61850-6 offers a XML-based description language (Substation Configuration Language SCL)

The functions themselves (such as overvoltage protection) are not defined in IEC 61850. However the necessary logical nodes are defined. This procedure enables an open and flexible way to incorporate new functions and applications in substation automation through a standardized way of exchanging information and information models. Therefore, the standard has to consider the operational requirements, but the purpose of the standard is not to standardise (or limit in any way) the functions involved in substation operation or their allocation within the SAS. The application functions will be identified and described in order to define their communication requirements (for example, amount of data to be exchanged, exchange time constraints, etc.). The communication protocol standard, to the maximum possible extent, should make use of existing standards and commonly accepted communication principles.

Other standards in use

DNP V3.0
ModBUS

Time synchronization
IEEE 1588

4.3.5.4 Gaps

Currently IEC 61850 is mostly used for the so-called station-bus application, which lets IEDs (Intelligent Electronic Devices) communicate with each other and with a substation controller.

However, another of the key technologies in IEC 61850 is much less well-known and rarely used, despite its great potential: the process-bus application. This technology allows signals from a conventional or non-conventional instrument transformer to be sampled and digitally transmitted to one or several protection and measuring devices. The communications structure based on IEC 61850-9-2 in a substation can be considerably facilitated with additional protocols regarding seamless redundancy and highly precise time synchronization directly over Ethernet. However the introduction of devices for process-bus has been slow and practical experience is limited.

One of the biggest concerns using Ethernet for substation communications was the bandwidth of the communication system and whether this was sufficient for the transmission of the amount of data appearing in a substation communication system. Given the progress Industrial Ethernet has made in the last years, absolutely collision-free systems can be set up by the use of so-called Ethernet Switches.

Since data exchange is crucial for the substation automation system, a system for redundancy is required. The upcoming IEC 62439 standard, originally designed for factory-automation applications, defines a protocol based on the HyperRing redundancy system. Called the *Medium Redundancy Protocol* (MRP), it promises ring redundancy with the features mentioned above.

Being more flexible, the RSTP protocol is now also part of IEC 62439 and covers not only ring redundancy but also meshed system configurations. It is the most used redundancy protocol for station-bus applications today.

The IEC 62439 standard also describes a *Parallel Redundancy Protocol* (PRP). This protocol is based on a system with two interfaces in the IEDs and a completely separated, doubled Ethernet system — along with another type of redundancy especially made for Fieldbus systems.

Currently a new solution is specified in IEC 62439 called HSR High Availability Seamless Automation Ring. This specification provides ring redundancy with no telegram loss similar to

PRP in parallel configuration. However HSR can also cover parallel configurations with the same coding.

The RSTP, PRP and HSR will be described as optional redundancy protocols in IEC 61850 Ed. 2.0.

The requirements for the accuracy of a bus (subnet)-wide time synchronization depend on the application and differ between the station-bus and the process-bus. In the station-bus application, many event-driven messages and user-initiated controls are sent and time-stamped with an accuracy of 1 ms. An accuracy of 1 ms can be achieved in local networks without the need of special network components. For the station-bus application, this is standardized in part 8-1 of IEC 61850.

The process-bus application is more sophisticated. Samples of 1,4 up to about 16 kHz for a 60Hz system (i.e. 256 samples/cycle) shall be unambiguously identifiable especially when they come from different merging units. This is provided by resetting a sample counter every second with an accuracy of 1 µs. Since IEC 61850-9-2 does not standardize a time sync protocol, today the time synchronization is provided by an external 1 pps input to the merging unit. A much better solution will be synchronizing these devices directly over the Ethernet system. This can be provided by the IEEE 1588 protocol. However IEEE 1588 specifies a lot of different possibilities offering its adoption for the particular application. The use of substation application Synchrophasors for process-bus is currently specified in IEEE PSRC WG H7. Taking over these results in the IEC after evaluation is a proposed way to go.

Currently, there is a discussion about the necessary quality of service for process-bus solutions. Provision of low latency transmission of important signals is recommended; today priority tagging of GOOSE and Sampled Values is used. In future, other methodologies for QoS may be available in Ethernet technologies. The ongoing development of Ethernet must be periodically checked for its use in substations in order to provide optimal solutions for substation communication systems.

4.3.5.5 Recommendation

IEC 61850 is the only international standard for substation automation which is open for future application. Currently IEC 61850 is extended for use outside substations. Promote the use of IEC 61850 concept also in non-electric domains (e.g. gas and water supply).

Recommendation S-SA-1

Promote the use of IEC 61850; promote the IEC to act as governance for further developments.

Keep consistency and refrain from local deviation.

Recommendation S-SA-2

IEC 61850 is the international state-of-the-art technology in substations. Adding to this the specifications for sampled-values transmission provides the basis for an effective process-bus solution.

Watch upcoming Ethernet technologies and integrate them in existing protocols.

For example: Quality of service is an essential requirement, especially in the case of process-bus applications. Promote and coordinate efforts to extend IEC 61850 with IEC 62439 HSR.

Recommendation S-SA-3

Use time synchronization of IEEE 1588 PSRC Profile as general method for high accuracy time synchronization in IEC 61850 networks.

Recommendation S-SA-4

Evaluate the IEEE 1588 time sync mechanism not only in local networks but also in private utility WANs to achieve independence of the quality of GPS-antennas receivers or other third party time sources.

Recommendation S-SA-5

IEC 61850 allows an open and flexible design and operation of communication networks. Users require a guideline to design communication networks to meet their specific requirements. Therefore provide an Ethernet Substation guide (currently in work as TR 61850-90-4). Update this every 2 to 3 years.

Recommendation S-SA-6

The IEC should promote the fact that IEC 61850 not only provides a protocol for communication but is a whole new concept for naming and configuration substations and power grids.

4.3.6 Distributed Energy Resources

4.3.6.1 Description

In parallel with the liberalization of the energy markets, the decentralized generation of electrical power and heat and cold energy becomes more and more important. The generation of these types of energy near to the consumers offers economical 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 cooling energy as well as electricity. A successful operation of a virtual power plant requires the following technical equipment:

1. An energy management system that monitors, plans and optimizes the operation of the decentralized power units
2. A forecasting system for loads that is able to calculate very short-term forecasts (1 hour) and short-term forecasts (up to 7 days)
3. A forecasting system for the generation of renewable energy units. This forecast must be able to use weather forecasts in order to predict the generation of wind power plants and photovoltaics
4. An energy data management system which collects and keeps the data that is required for optimization and forecasts, e.g., profiles of generation and loads as well as contractual data for customer supply
5. 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 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 must be very precise because rough models could yield optimization results that cannot be realized by the power system. Because the virtual power plant must 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 modeled 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 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.

4.3.6.2 Requirements

An essential requirement for DER is first of all 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.

4.3.6.3 Existing Standards

Product standards- Solar voltaic

IEC 60904, *Photovoltaic devices*

IEC 61194, *Characteristic parameters of stand-alone photovoltaic (PV) systems*

IEC 61724, *Photovoltaic system performance monitoring - Guidelines for measurement, data exchange and analysis*

IEC 61730, *Photovoltaic (PV) module safety qualification*

IEC/TS 61836, *Solar photovoltaic energy systems – Terms, definitions and symbols*

IEC 62446, *Grid connected photovoltaic systems - Minimum requirements for system documentation, commissioning tests and inspection*

IEC/TS 62257, *Recommendations for small renewable energy and hybrid systems for rural electrification*

Etc.

Product standards- Wind power

See IEC 61400 series

IEC 61400-1, *Wind turbines - Part 1: Design requirements*

IEC 61400-2, *Wind turbines - Part 2: Design requirements for small wind turbines*

IEC 61400-3, *Wind turbines - Part 3: Design requirements for offshore wind turbines*

Product standards- Marine power

IEC 62600 series *Marine energy*

IEC 62600-1, *Terminology*

IEC 62600-100, *Marine energy – Wave, tidal and other water current converters – Part 100: The assessment of performance of wave energy converters in open sea*

IEC 62600-200, *Marine energy – Wave, tidal and other water current converters – Part 200: The assessment of performance of tidal energy converters*

Product standards- Fuel Cells

IEC/TS 62282 series, *Fuel cell technologies*

Interoperability standards – Communication

IEC 61400-25-1, *Wind turbines - Part 25-1: Communications for monitoring and control of wind power plants - Overall description of principles and models*

IEC 61400-25-2, *Wind turbines - Part 25-2: Communications for monitoring and control of wind power plants - Information models*

IEC 61400-25-3, *Wind turbines - Part 25-3: Communications for monitoring and control of wind power plants - Information exchange models*

IEC 61400-25-4, *Wind turbines - Part 25-4: Communications for monitoring and control of wind power plants - Mapping to communication profile*

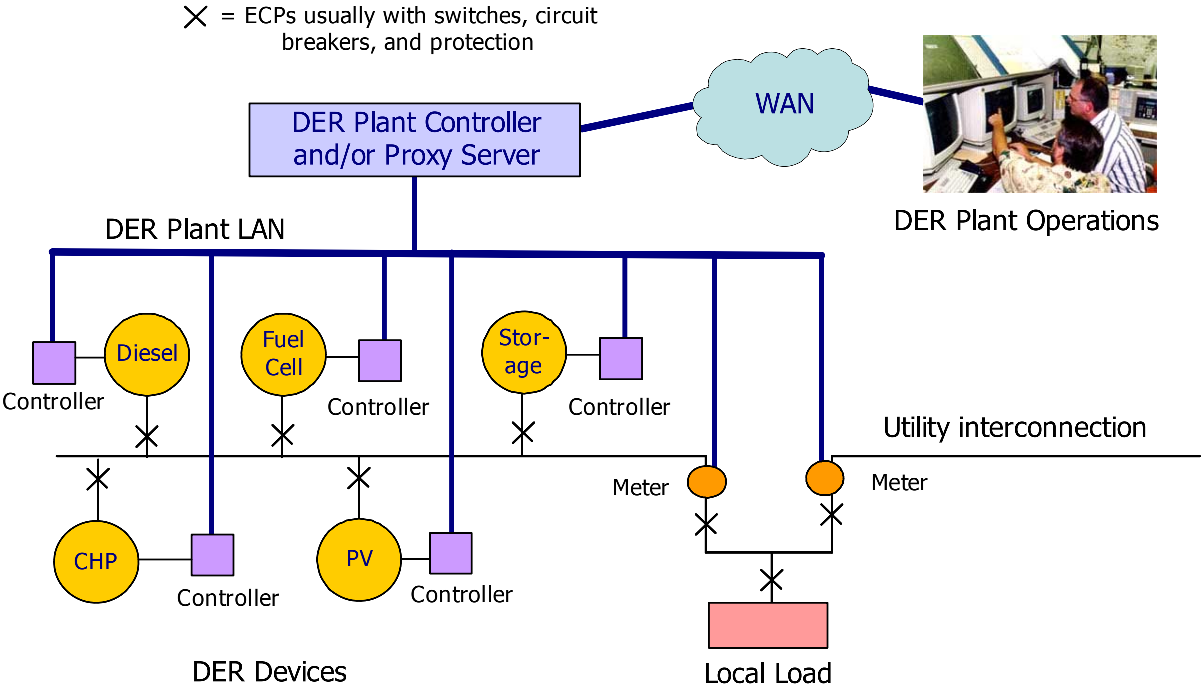
IEC 61400-25-5, *Wind turbines - Part 25-5: Communications for monitoring and control of wind power plants - Conformance testing*

IEC 61850-7-4, Communication networks and systems for power utility automation - Part 7-4: Basic communication structure - Compatible logical node classes and data object classes

IEC 61850-7-420 Ed.1, *Communication networks and systems for power utility automation – Part 7-420: Basic communication structure - Distributed energy resources logical nodes* (DER)

IEC 61850-7-420 offers a standard to describe the data exchange between DER equipment and any system which will supervise, control, maintain and general utilize and operate this DER equipment.

Figure 13 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 13 – Example of a communications configuration for a DER plant

In basic terms, 'communications' can be separated into four parts:

- information modeling (the types of data to be exchanged – nouns),
- services modeling (the read, write, or other actions to take on the data – verbs),
- communication protocols (mapping the noun and verb models to actual bits and bytes),
- telecommunication media (fibre optics, radio systems, wireless systems and other physical equipment).

IEC 61850-7-420 addresses only the IEC 61850 information modeling for DER. Other IEC 61850 documents address the services modeling (IEC 61850-7-2) and the mapping to communication protocols (IEC 61850-8-x). In addition, a systems configuration language (SCL) for DER (IEC 61850-6-x) would address the configuration of DER plants. Although IEC 61850-7-420 does not address CIM relationships for DER, it is fully compatible with the CIM concepts. IEC 61850-7-420 uses a high-level description of DERs with the help of logical nodes and devices.

A logical node (LN) is a predefined grouping of data objects that serve specific functions and can be used as 'bricks' to build the complete device. These LNs are described in IEC 61850-7-4.

A logical device (LD) is a device model composed of the relevant logical nodes for providing the information needed for a particular device (see Figure 14).

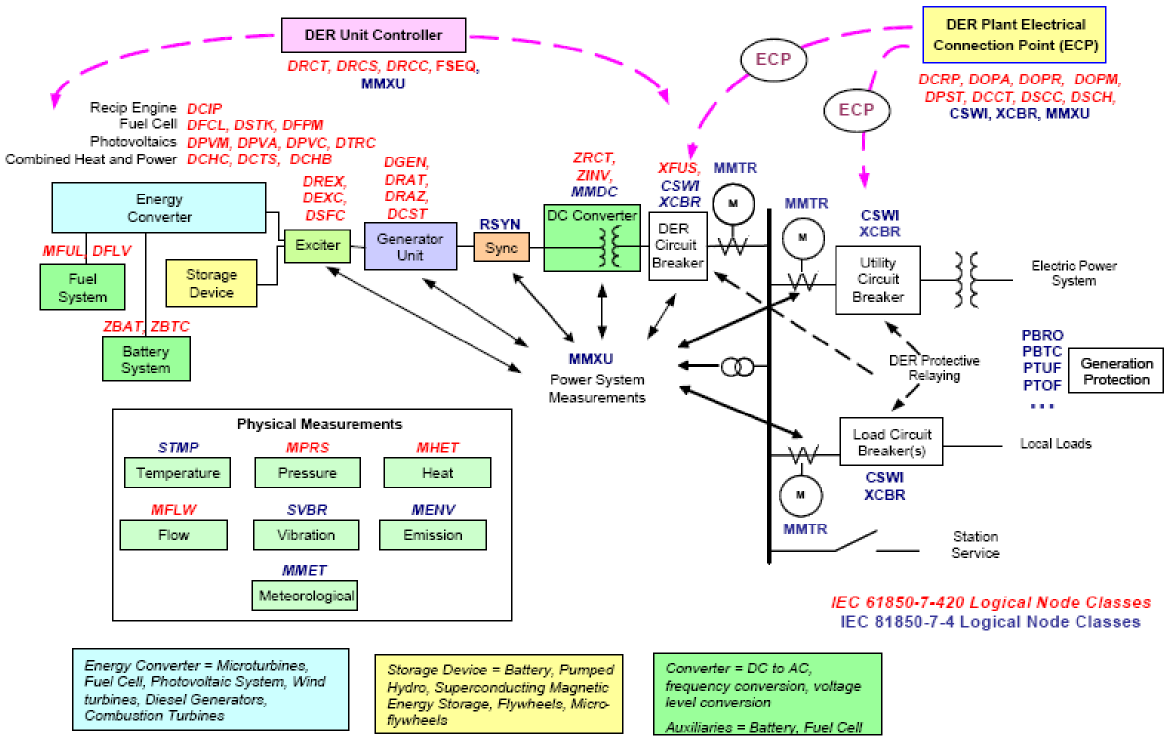


Figure 14 – Overview: Conceptual organization of DER logical devices and logical nodes

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, 7-410 (hydro power) and IEC 61400-25-2 (wind power).

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, microgrids, 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 15, 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 the IEEE 1547 'Standard for Interconnecting Distributed Resources with Electric Power Systems'.

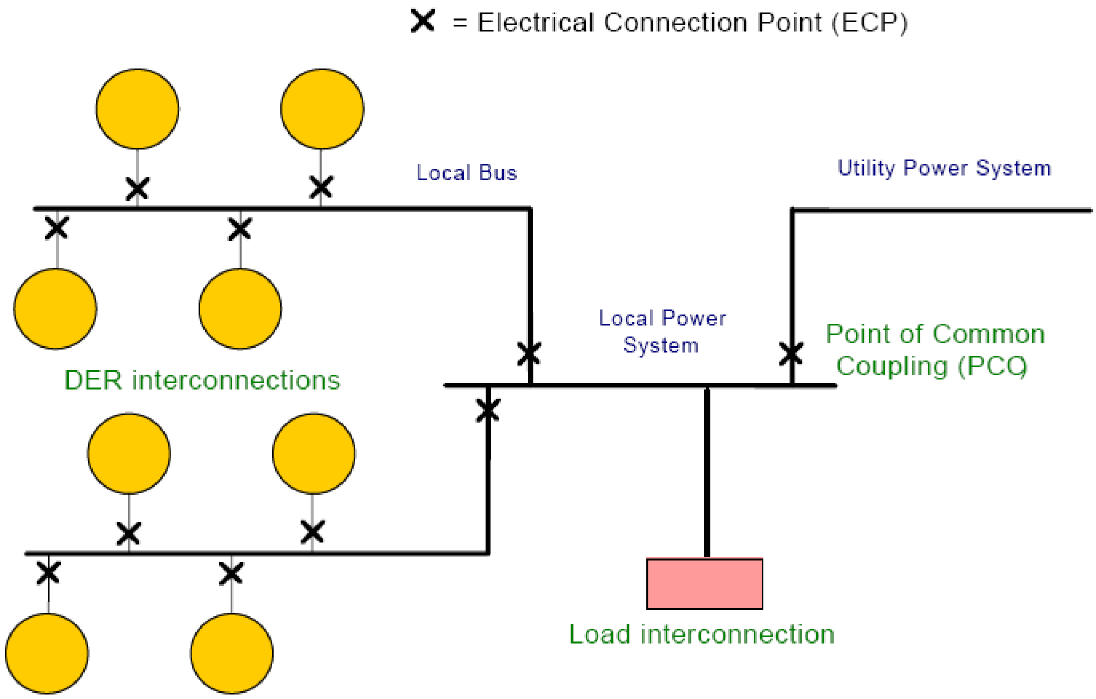


Figure 15 – Illustration of electrical connection points (ECP) in a DER plant

Generally IEC 61850-7-420 is a relatively new standard. However it is perfectly suited to the overall system architecture of TC 57 and the CIM.

Alternatively DER equipment can be directly connected and controlled via HEBS/BACS. The relevant standards and description are given in Subclause 4.3.9.

IEC 61850-7-410, *Communication networks and systems for power utility automation - Part 7-410: Hydroelectric power plants - Communication for monitoring and control*

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 61400-25, *Wind turbines Part 25: Communications for monitoring and control of wind power plants*

Besides the standardization of the communication for, supervision and control of the individual wind turbines, the standard series provides standards for communication between wind power plants (single or groups of) wind turbines and with overall system supervision and control. The wind power information model in IEC 614000-25 covers not only data of individual turbines but also functions for control of the total active and reactive power of groups of turbines. IEC 61400-25 integrates wind turbines in the overall power automation and extends the information and data models to the wind turbine area. All the syntactic and semantic patterns of IEC 61850 are presumed. Therefore it is a perfect match and extension of IEC 61850 in the wind power area. Part 3 specifies the abstract data models necessary to define Client-Server relations. The concrete description of the data formats and protocols are described in Part 4. Mappings are provided for the following communication solutions:

- Web services
- OPC-XML
- IEC 61850-8-1
- IEC 60870-5-101/104
- DNP3

IEC 61400-25 combined with IEC 61850 is the most promising and complete integration of renewable energies in the power grid. Since wind turbines are high-cost objects, the realization of standard-conform interfaces is not so price-sensitive as in other distributed energy resources. Therefore a widespread implementation of IEC 61400-25 can be expected.

IEC 61727, *Photovoltaic (PV) systems - Characteristics of the utility interface*

Technical connection standards

Specification of connection conditions is often subject to regulation. However IEC TC 8 PT 1 started work on the connection of distributed generation to distribution network.

EMC

IEC 61000-4-30, Electromagnetic compatibility (EMC) – Part 4-30: Testing and measurement techniques – Power quality measurement methods

Other standards in use

There are a number of national connection standards for distributed generation, e.g. ENA Engineering Recommendations G83/1, G59/1, G75/1 in the UK, FNN Anschlussregeln in Germany etc. In Europe there is a draft TS currently being prepared by WG3 of Cenelec TC8X, which specifies the generic requirements for connecting DG to the public distribution network.

In the US IEEE 1547, *Standard for Interconnecting Distributed Resources with Electric Power Systems*, is used. The Energy Policy Act of 2005 established IEEE 1547 as the national standard for the interconnection of distributed generation resources. Currently, there are six complementary standards designed to expand upon or clarify the initial standard, two of which are published, and the other four still in the draft phase.

IEEE 1547.1, published in 2005, further describes the testing of the interconnection in order to determine whether or not it conforms to standards.

IEEE 1547.2 provides a technical background on the standard.

IEEE 1547.3, published in 2007, details techniques for monitoring of distributed systems.

IEEE 1547.4 is a guide for the design, operation, and integration of conforming systems.

IEEE 1547.5 is designed for distributed sources larger than 10 MVA.

IEEE 1547.6 describes practices for secondary network interconnections.

4.3.6.4 Gaps

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

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

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

4.3.6.5 Recommendations

Promote the use of IEC 61850-7-420. This offers a method to describe the communication of DERs with the power system. It is consistent with the IEC 61850 framework (IEC 61400-25 should be used for wind power plants).

Recommendation S-DER-1

Promote the use of IEC 61850-7-420 for all DER equipment and expand the standard to all kinds of possible equipment. This should be done in a generic way, which enables the inclusion of all kinds of DER equipment without explicitly describing single DER equipment. The current standard is too detailed and therefore poses difficulties in achieving interoperability.

Recommendation S-DER-2

IEC 61850-7-420 should be open and generic enough to include other important local standards and requirements, which are subject to technical regulation. Seek close cooperation with relevant national and regional standards bodies on this topic (e.g. Cenelec and IEEE).

4.3.7 Advanced Metering for Billing and Network Management

4.3.7.1 Description

Advanced Metering Infrastructure (AMI) integrates smart grid infrastructure with smart metering. AMI refers to systems that measure, collect, analyze 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.

4.3.7.2 Smart Grid Infrastructure

4.3.7.2.1 Description

Distribution network operators must optimize existing network operation processes. AMI combines metering and management of distribution networks in one system. As a Smart Grid solution it acquires data and information on prosumers, special contract customers and the distribution network infrastructure and transmits them to a control centre. This allows distribution network operators to optimize essential key processes and offers new services and data to their customers, both on the supplier as well as the consumer/prosumer side. Providing monitoring information to distribution network operators AMI facilitates them to control energy supply to a steadily growing number of prosumers, and to ensure better power quality.

4.3.7.3 Requirements

Smart Grid Infrastructure takes a special position as it serves as an intersystem interface between the distribution network on the one side and smart metering, building automation, industry automation, e-mobility and distributed energy resources on the other. Together with smart metering it is also a key function of the Demand Response solution.

System requirements

Smart Grid Infrastructure must meet the following functions:

- Distribution network monitoring
- Power quality monitoring
- Fraud detection
- Load leveling
- Demand response functions
- New business models
- Record capacity utilization
- Minimization of down time
- Load/source-shedding
- Management & control of energy (re)sources
- Remote Switching procedures
- Customer information
- Asset Management

In addition the usual security and quality of the supply must be maintained.

Product requirements

AMI devices must fulfill certain requirements regarding accuracy, safety and reliability.

Security

Cyber security, especially privacy issues, are a major requirement. This will include local deviating regulation by authorities.

Communication requirements

Communication between different domains is an essential part of Smart Grid Infrastructure. Input and output of a smart grid device as an interface between different automation domains (power automation, business models, building automation etc.) must be specified. Data models and protocols capable of supporting the smart grid/meter functions in all domains must be developed.

4.3.7.4 Existing Standards

Product standards

IEC/TR 62051, *Electricity metering - Glossary of terms*

IEC 61968-9, *Application integration at electric utilities – System interfaces for distribution management – Part 9: Interfaces for meter reading and control*

Transport level – remote transmission

Each of the different methods has their pros and cons. No single method will be the method of choice under all circumstances:

PSTN Public Switched Telephone Network

IEC/TR 61334, *Distribution automation using distribution line carrier systems* (PLC)

GPRS General Packet Radio Service

GSM/CSD Circuit Switched Data

WIMAX Worldwide Interoperability for Microwave Access based on IEEE 802.11

Usage of IP

Primary communication within the building

In the connection to building automation a number of standards are in use, with a lot of regional differences:

ISO 16484-5, *Building automation and control systems - Part 5: data communication protocol*

ISO/IEC 14543-3, *Information technology - Home Electronic System (HES) architecture*

EN 13321 series, *Open data communication in building automation, controls and building management - Home and building electronic systems*

EN 50090 series, *Home and building electronic systems (HBES)*

EN 50428, *Switches for household and similar fixed electrical installations - Collateral standard - Switches and related accessories for use in home and building electronic systems (HBES)*

EN 50491 series, *General requirements for Home and Building Electronic Systems (HBES) and Building Automation and Control Systems (BACS)*

China: GB/Z 20965, *Information technology - Home Electronic System (HES) architecture*

USA: ANSI/ASHRAE 135, *BACnet - A Data Communication Protocol for Building Automation and Control Networks*

Security

Security on the power grid level is described in IEC 62351.

Pricing information

Price information must be available on all levels of the Energy Marketplace (EMS-DMS-Smart Metering).

For metering, the UN/EDIFACT (United Nations Electronic Data Interchange for Administration, commerce and Transport) standard is mainly used. UN/EDIFACT is an international standard for exchanging business data. EDIFACT specifies syntax rules.

Building on that, MSCONS (Metered Services Consumption Report Message) defines data sets for the exchange of meter billing information. EDIFACT/MSCONS is currently concentrated on automated meter reading. A wider concept with flexible tariffs will need the inclusion of pricing information through other channels.

IEC/TR 62325, *Framework for energy market communications*

IEC/TR 62325-501, *Framework for energy market communications - Part 501: General guidelines for use of ebXML*

IEC 62325 does not standardize market communication. It applies the ebXML standard of UN/CEFACT on the energy market and the required market information. The goal is to provide a standard alternative to the proprietary information standards used otherwise: EDIFACT, X12 etc. and to provide an open, technology-independent framework.

The variety of protocols and standards used is quite large in the sector. However a concentration on using UML on the modeling side can be observed. Combined with the further advancement of the CIM (Common Information Model) of IEC 61970 and IEC 61968, a roadmap for implementing pricing models would be available.

EMC

IEC 60870-2-1, *Telecontrol equipment and systems - Part 2: Operating conditions - Section 1: Power supply and electromagnetic compatibility*

IEC 61000-3-8, *Electromagnetic compatibility (EMC) - Part 3: Limits - Section 8: Signalling on low-voltage electrical installations - Emission levels, frequency bands and electromagnetic disturbance levels*

CISPR 22, *Information technology equipment - Radio disturbance characteristics - Limits and methods of measurement*

Limit values are important for several preferred transport methods.

A product standard for meters exists in Europe including EMC: EN 50470-1, *Electricity metering equipment (a.c.) - Part 1: General requirements, tests and test conditions - Metering equipment (class indexes A, B, and C)*

General

IEC 61000-4-30, *Electromagnetic compatibility (EMC) – Part 4-30: Testing and measurement techniques – Power quality measurement methods*

Other standards in use

EN 13757, *Communication systems for remote reading of meters. Physical and link layer* (M-Bus)

M-Bus (Metering Bus) is a European standard for meter data reading and defines a bus-system with serial communication. M-Bus has been extended to a wireless variant in the 900 MHz frequency band. Other transport media can also be addressed. However it is far from a “Plug and Play” capability. Being widespread in Europe, M-Bus is capable of automatic meter reading and communication between meters in a building complex. Revision of EN 13757 is currently in progress.

E-DIN 43863-4 IP, *IP Telemetric Protocol*

ANSI C 12.18

ANSI C12.18 is widespread in the US and is applied for automatic meter reading. ANSI C 12.18 specifies a local optical data exchange, C12.21 data exchange via modem and ANSI C12.22 specifies the data exchange to Communication networks.

ANSI C12.18-2006, *Protocol Specification for ANSI Type 2 Optical Port*

ANSI C12.19-1997, *Utility Industry End Device Data Tables*

ANSI C12.21-2006, *Protocol Specification for Telephone Modem Communication*

ANSI C12.22 (working draft), *Protocol Specification for Interfacing to Data Communications Networks*

AMI-SEC Advanced metering infrastructure (AMI) and Smart Grid end-to-end security

4.3.7.5 Gaps

The main problem in AMI is the existence of a number of parallel and even conflicting standards. Subsets of common semantics must be defined. The question of how to describe a common set of cross-cutting requirements within these standards to facilitate exchange of confidential and authentic information across standards must be solved.

Regarding the IEC standards alone, the current protocols and data exchange standards (DLMS/COSEM) are concentrated on meter data exchange with AMR units and do not fulfill all the requirements posed by Smart Grid. This includes functions such as power quality support, fraud detection and load/source-shedding.

These functions are a domain of the overall power automation, which is currently only loosely coupled to the meter domain.

In power automation a metering object description must be present. This should be consistent with the DLMS/COSEM standards. Currently that is not realized.

The different domains (Energy Market, Transmission and Distribution, Distributed Energy (Re)sources, Building, Industry, E-Mobility) need to define common interfaces. This is currently not supported by standards.

4.3.7.6 Recommendation

Recommendation S-AMI-1

TC 13 and TC 57 should work on the necessary expansions. A clear separation of work should be promoted: TC 13 (Electrical energy measurement, tariff- and load control) should be responsible for defining the meter functions, and TC 57 (Power systems management and associated information exchange) should be responsible for defining the communication functions for smart grid and smart meters.

Recommendation S-AMI-2

IEC 61850 should be expanded to include the DLMS/COSEM objects. This would require no extensions or changes in DLMS and would promote the coexistence of meter and smart grid application. The TC 57 framework needs to be expanded to include metering data in any case. Basing that on DLMS/COSEM would pose the advantage of implementing a standard object description instead of proprietary metering protocol.

Recommendation S-AMI-3

The different functions of automation, automated meter reading and communication systems must be brought together at the interface of the smart grid device (including meter and other AMI devices). A set of objects and profiles should be described and standardized in order to give guidelines for paths to interoperability of these domains. This task should be performed jointly by TC 8, TC 13 and TC 57. In order to enable an interface to building and home automation, a liaison to ISO TC 205 and ISO/IEC JTC 1 should be sought.

TC 57 has already developed a method to prove conformity to its standards through the means of UCA interoperability tests and conformance testing is available for DLMS/COSEM from DLMS UA. This would be a way to limit the often wide scope of standards to a set of interoperable functions, which can be supported by standards.

Recommendation S-AMI-4

A close cooperation with the "demand response" activities is needed. Here use cases must be defined in order to specify the scope and involvement of the different stakeholders. For example the contribution of smart appliances or building automation systems needs to be described in order to define their share in the overall systems.

4.3.7.7 Smart Metering

4.3.7.7.1 Description

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 & efficiency targets and to improve the operation of the free market.

Society as a whole may benefit through less 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 gaining 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.

4.3.7.7.2 Requirements

Smart metering systems must meet a complex set of requirements including:

- user friendliness;
- legal metrology;
- data security;
- privacy;
- openness and flexibility;
- cost effectiveness;
- interoperability;
- reliability.

User friendliness: Involvement of the energy end-user is the cornerstone of the success in realizing the benefits of smart metering. Therefore, smart metering systems shall provide accurate, relevant and timely information to the energy end-user.

Legal metrology: Among all the functions in the scope of smart grids, smart metering is the only one under metrological control. There are strict requirements set by legal metrology bodies concerning allowable errors, repeatability, durability, reliability, suitability and protection against corruption.

Data security: Smart grids and their sub-systems built on public infrastructures and open standards are highly vulnerable to security attacks and qualify as a critical infrastructure. Therefore adequate security policies, mechanisms and algorithms must be implemented. In the context of smart metering, tampering with meters, illegal access to or falsification of billing and fiscal data and / or credit / debit data, illegal changes of configuration, illegal connection / disconnection of supply, denial of access can be mentioned.

Privacy: While any and all information collected from the meters may be useful, protection of the privacy of the energy end-users must be respected to the utmost and this should be considered as a top priority. If customers believe that their privacy is endangered, this may cause smart metering to fail.

Openness and flexibility: While most basic functional requirements may remain unaltered for a long time, some new requirements may emerge, and communication technologies will continue evolving rapidly. Therefore, smart metering systems must be based on standards providing an open system and protocol architecture to accommodate new requirements and new communication technologies.

Cost effectiveness: The business case equation depends heavily on the cost of purchasing, installing and operating smart metering systems. Therefore, cost effectiveness shall be considered in terms of product costs, installation costs and operation costs. To keep product costs low, avoiding over-specification, use of standard components, economies of scale and multi-sourcing can be mentioned. Installation costs can be minimized by plug-and-play features. To minimize operation costs, low power consumption, efficient data organization and transport, remote diagnostics and upgrades and high reliability are important.

Interoperability: Data provided by smart metering systems will be used across the entire smart grid by all stakeholders. For this reason, they must be presented in such a form that can be used across the whole system, or can be easily translated / mapped at system boundaries. Smart metering systems must also work together with other systems of the smart grid, the most closely related systems being local generation systems and home automation systems.

Reliability: Reliability is one of the key factors in operating costs, given that the cost of installation and metering site visits is of the same order of magnitude as purchasing new equipment. Unreliable equipment may invalidate any business case.

4.3.7.7.3 Existing Standards

Standards for electricity metering, tariff-and load control are under the responsibility of IEC TC 13.

Product standards (TC 13 / WG 11)

IEC 62052 parts 11, 21 and 31 (in draft), *Electricity metering equipment (AC) - General requirements, tests and test conditions* specify mechanical, climatic, electrical, EMC and safety requirements and test methods for meters, tariff- and load control

NOTE Part -11, covering electromechanical meters is not relevant for smart metering.

IEC 62053 parts 11, 21, 22, 23, 24, 31, 52 and 61, *Electricity metering equipment (a.c.) - Particular requirements* specify type test requirements and test methods for a.c. meters for active / reactive / apparent energy, including power supply and pulse interface requirements

IEC 62054 parts 11 and 21, *Electricity metering (a.c.) - Tariff and load control* specify type test requirements and test methods for tariff and load control equipment (times switches and ripple control receivers). These functions are often integrated to meters.

IEC 62058 parts 11, 21, and 31, *Electricity metering equipment (AC) - Acceptance inspection* specify requirements for acceptance inspection, an important tool of quality assurance in the purchasing process.

Payment systems standard (WG 15)

The IEC 62055 series *Electricity metering - Payment systems* specifies a framework for standardization, including functions, processes, data elements, system entities and interfaces, type testing of payment interfaces and a physical and application layer protocol for one way and two way token carrier systems. Recently, work has been started on multi-part installations, which may be highly relevant for smart metering. Its approach may be useful for the specification of smart metering systems.

Reliability standards (WG 13)

The IEC 62059 series *Electricity metering equipment – Dependability* specifies reliability prediction and assessment methods.

Standards for data exchange (WG 14)

The IEC 62056 series *Electricity metering - Data exchange for meter reading, tariff and load control* specifies meter data exchange, including data models, messaging methods and communication media specific protocols.

These standards are based on proven, international, general purpose communication standards such as the OSI model, ASN.1 abstract syntax, HDLC, internet RFCs, NIST and FIPS, as far as possible. Some of these standards are based on the IEC 61334 series, *Distribution automation using distribution line carrier systems.*

Although the scope of these standards is limited to electricity metering, their principles and solutions can also be used for metering utilities other than electricity. For this reason they have been adopted by CEN TC 294 and from the basis of the EN 13757-1 standard *Communication system for meters and remote reading of meters - Part 1: Data exchange.*

The DLMS/COSEM suite

The DLMS/COSEM suite includes data model, messaging and communication protocol standards for data exchange over local ports, PSTN, GSM, GPRS, Internet and, more recently, narrow band PLC.

DLMS/COSEM is supported by the DLMS User Association through a D-Type liaison with IEC TC 13 WG 14. The DLMS UA has a global membership of 150. It provides maintenance, registration, conformance certification and user support services.

Data model and data identification

These are the most important standards, as they allow the modeling of any metering application independently of the utility (energy) type, messaging method and communication media. They are of key importance in achieving interoperability: the same data can be accessed the same way from any meter, using DLMS services specified in IEC 62056-53.

IEC 62056-61, *Electricity metering - Data exchange for meter reading, tariff and load control - Part 61: Object identification system (OBIS)* provides an unambiguous data identification system for all kinds of data, including abstract data elements and energy (utility) type-related data elements. The OBIS codes are used to identify COSEM interface objects and data on the meter display and they can be used across the system up to the bill. The identifiers for non-electricity metering are specified in EN 13757-1 based on the principles of IEC 62056.

IEC 62056-62, *Electricity metering - Data exchange for meter reading, tariff and load control - Part 62: Interface classes* specifies the COSEM interface classes for modeling the various functions of the meter. The required functionality of the meter is built by instantiating the necessary kind and number of COSEM interface objects. Although the COSEM interface classes are currently metering domain oriented, they can easily be extended to cover other applications.

These standards have been considerably extended recently by the DLMS UA for smart metering, including data security, load limitation, connect / disconnect, firmware update, data exchange with devices using M-BUS (EN 13757 parts 2 to 5) and S-FSK PLC. The results are available for international standardization.

Messaging

IEC 62056-53, *Electricity metering - Data exchange for meter reading, tariff and load control - Part 53: COSEM application layer* specifies how to build application associations between peer applications, and the DLMS messaging services to access data modeled by the COSEM objects. The DLMS services are common for all interface classes and independent from the lower, media-dependent layers.

The messaging services are based on IEC 61334-41, *Distribution automation using distribution line carrier systems - Part 4: Data communication protocols - Section 41: Application protocols - Distribution line message specification*, established by TC 57. The amendments are upwards compatible, and render the standard more simple and efficient.

The COSEM Application layer is the top layer of any DLMS/COSEM protocol stacks.

Protocol stack for PSTN / GSM

IEC 62056-42, *Electricity metering - Data exchange for meter reading, tariff and load control - Part 42: Physical layer services and procedures for connection-oriented asynchronous data exchange*

IEC 62056-46, *Electricity metering - Data exchange for meter reading, tariff and load control - Part 46: Data link layer using HDLC protocol*

Protocol stack for Internet / GPRS

IEC 62056-47, *Electricity metering - Data exchange for meter reading, tariff and load control - Part 47: COSEM transport layers for IPv4 networks*, connects the COSEM application layer and the Internet UDP-TCP protocols through wrapper.

Narrow-band PLC (specified by the DLMS UA, available for international standardization)

This protocol stack is based on the following standards from IEC TC 57:

IEC 61334-4-32, *Distribution automation using distribution line carrier systems - Part 4: Data communication protocols - Section 32: Data link layer - Logical link control (LLC).* Alternatively, the HDLC based LLC layer can be used (IEC 62056-46).

IEC 61334-4-511, *Distribution automation using distribution line carrier systems - Part 4-511: Data communication protocols - Systems management - CIASE protocol.* Recently, this standard has been extended by the DLMS UA to facilitate plug-and play installation.

IEC 61334-4-512, *Distribution automation using distribution line carrier systems - Part 4-512: Data communication protocols - System management using profile 61334-5-1 - Management Information Base (MIB).* The MIB variables have been mapped to DLMS/COSEM by the DLMS UA.

IEC 61334-5-1, *Distribution automation using distribution line carrier systems - Part 5-1: Lower layer profiles - The spread frequency shift keying (S-FSK) profile.* This standard specifies the Phy and MAC layers.

Standards for local data exchange

IEC 62056-21, *Electricity metering - Data exchange for meter reading, tariff and load control - Part 21: Direct local data exchange* (earlier: IEC 61107). This standard specifies data exchange through local optical and electrical ports. A new mode has been added to switch to DLMS/COSEM.

IEC 62056-31 *Electricity metering - Data exchange for meter reading, tariff and load control - Part 31: Use of local area networks on twisted pair with carrier signaling.* This standard is currently being amended to extend its use with DLMS/COSEM.

Other standards, based on IEC 61334-4-41 DLMS:

These were the first standards for meter data exchange based on DLMS. They are used in some countries.

IEC/TS 62056-41, *Electricity metering - Data exchange for meter reading, tariff and load control - Part 41: Data exchange using wide area networks: Public switched telephone network (PSTN) with LINK+ protocol*

IEC/TS 62056-51, *Electricity metering - Data exchange for meter reading, tariff and load control - Part 51: Application layer protocols*

IEC/TS 62056-52, *Electricity metering - Data exchange for meter reading, tariff and load control - Part 52: Communication protocols management distribution line message specification (DLMS) server*

4.3.7.7.4 Gaps

The Scope of IEC TC 13 currently covers a.c. metering, and mainly industrial, commercial and residential applications, generally “fixed locations”. This may need to be extended to cover d.c. metering and metering for mobility, including trains and pluggable hybrid electrical vehicles (PEHVs), in cooperation with the relevant IEC TCs. The extensions should cover all aspects: metrology, safety, reliability payment and data exchange.

Although the standards from WG 11 cover bi-directional metering, this standard may need to be revisited to make sure that all aspects of local generation and its control are adequately covered. The safety standards shall cover the remote connection / disconnection of supply.

As explained above, the IEC 62056 DLMS/COSEM suite has been recently extended by the DLMS UA, in liaison with IEC TC WG 14, for smart metering. These additions have to be brought in line with the IEC standards; this work has been initiated.

As a result of ongoing requirement analysis within the European M/441 standardization mandate, the OPEN meter project and other similar efforts, new requirements may be identified: Some of these are already known:

- (pre)payment metering;
- customer information;
- pricing information;
- control of distributed generation;
- link to home automation.

Modeling of these functions has to be added to the COSEM model and the OBIS identification system, again in cooperation with relevant TCs.

Concerning communication media, new communication profiles found to be useful for smart metering have to be covered, including PLC and wireless.

To maximize throughput and to minimize communication costs, further optimizing of the protocols may be necessary. These include data compression algorithms, push operation, the possibility to include a series of read and write requests on a single list of requests and specifying fully self-contained information.

Concerning data security, DLMS/COSEM already covers role-based access and access security. This has been recently extended by transport security, providing authenticated encryption using symmetric key algorithms (AES-GCM-128). These are available for international standardization and may need to be extended by further mechanisms.

DLMS/COSEM currently specifies the data transport between meters and metering centres, either directly or using concentrators (useful in the case of PLC and LP wireless). Although these methods can also be used between the concentrator and the metering centre, other, more powerful, internet based technologies may be considered here (e.g. XML, web services).

DLMS/COSEM specifies the messages between the metering centre and the meter, but it does not specify how the data shall be stored in the metering centre and how it should be passed on to other utility and market systems. To define this, we propose that IEC TC 13 works together with TC 57 (IEC 61698 series).

Interfaces to in-house systems and home automation systems should also be specified.

4.3.7.7.5 Recommendations

Recommendation S-SM-1

Revisit the type test standards to ensure that requirements of smart metering systems are fully covered:

- distributed generation;
- connection / disconnection of supply, including safety;
- customer information;
- e-mobility metering: metering on board of trains and PEHVs.

This may involve the extension of the scope of TC 13 and liaisons with the relevant TCs.

Recommendation SSM-2

Extend the COSEM object model and the DLMS-based protocol architecture to accommodate new requirements and new communication technologies (work has already been started by the DLMS UA), with a view to multi-energy metering, in cooperation with relevant ISO / CEN TCs. Incorporate IPv6.

Recommendation SSM-3

Specify how the OBIS data identification system can be used across the whole smart metering system and beyond to all stakeholders, from 'meter to bill'.

Recommendation S-SM-4

PLC (or DLC) communication has become the major communication technology supporting smart metering applications. The existing IEC 61334 PLC standards must be maintained and extended considering the latest developments in smart metering as reflected by the IEC 62056 standards series.

Recommendation S-SM-5

Optimize protocol stack to maximize throughput (all media) and minimize costs (public media).

Recommendation S-SM-6

Make sure that the security mechanisms, including customer privacy, are adequate and coherent across the whole system.

Recommendation S-SM-7:

Internationally standardize conformance testing for DLMS/COSEM specified by the DLMS User Association.

Smart Metering – Smart Grid

PLC communication is often used in the LV distribution networks to support smart metering applications. Typically the PLC network is managed by a concentrator located in the MV/LV transformer station. With the introduction of Smart Grid this concentrator may act as a RTU for the MV/LV substation automation. In this case it will be necessary to interface IEC 61850 (substation automation) with IEC 62056 (metering, tariffs and load mgt). This will require a close cooperation between TC 57 and TC 13.

Another obvious interface between smart metering and the smart grid processes is located at central station level. Interfaces based on IEC 61968-9 may be considered for that purpose; harmonization with other international standards like ZigBee should be anticipated.

4.3.8 Demand Response / Load Management

4.3.8.1 Description

Demand Response or Load Management is a feature which is closely connected to DER (Clause 4.3.6), AMI (Clause 4.3.7) and HBES/BACS (Clause 4.3.9). 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 plan and adjustable power generation with fossil and nuclear fuel, renewable power generation is only in parts plan- and adjustable (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 charging period, generally 15 to 60 minutes.
- Near real-time power management: this means energy needs to be balanced at all times.

The latter poses significantly higher requirements to 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, e.g. 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 programmes 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 must 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 behavior 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.

As with virtual power plants, buildings can then be summarized in an electrical energy sense and control the energy supply in a way which satisfies all load demands and at the same time act as part of the overall energy system. Decentralized energy resources can be embedded in such a system.

In such a system there is a planning phase and real-time operation control. In the planning phase, the energy consumption or generation is predicted for e.g. the next day and energy transfer is optimized to the condition of the overall energy market. From this the optimal offering to the overall energy market can be derived.

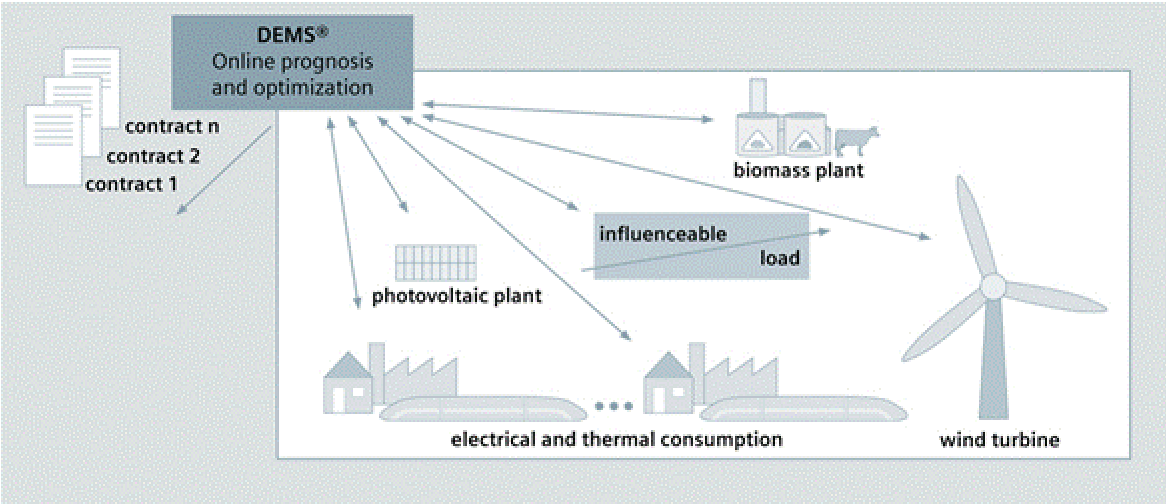


Figure 16 – Control principles of a virtual power plant

A superior power grid control level (see Figure 16) can use the power offered by the virtual power plant to optimize power balance in the overall system. Such a hierarchically organized system can integrate demand response in existing grid structures without the need to reorganize existing power installations. Virtual power plants offer the solution of integrating building and home automation in the power grid.

Core elements of a Demand Response application will be the distribution management system, smart metering systems and building automation.

4.3.8.2 Requirements

The main requirement for Demand Response is the active involvement of the consumer, which must 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 manageable loads, sources and storage which 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 must be available across all levels.

Connecting conditions must 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.

4.3.8.3 Existing Standards

Power grid

IEC 61968, *Application integration at electric utilities - System interfaces for distribution management*

IEC 61850-7-420, *Communication networks and systems for power utility automation - Part 7-420: Basic communication structure - Distributed energy resources logical nodes*

Building

ISO 16484 series, *Building automation and control systems (BACS)*

ISO/IEC 14543-3, *Information technology -- Home Electronic System (HES) architecture*

EN 13321 series, *Open data communication in building automation, controls and building management - Home and building electronic systems*

EN 50090 series, *Home and building electronic systems (HBES)*

EN 50428, *Switches for household and similar fixed electrical installations - Collateral standard - Switches and related accessories for use in home and building electronic systems (HBES)*

EN 50491 series, *General requirements for Home and Building Electronic Systems (HBES) and Building Automation and Control Systems (BACS)*

China: GB/Z 20965, *Information technology -- Home Electronic System (HES) architecture*

USA: ANSI/ASHRAE 135, *BACnet - A Data Communication Protocol for Building Automation and Control Networks*

4.3.8.4 Gaps

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

4.3.8.5 Recommendation

Recommendation S-DR-1

The Distributed Energy Management System (DEMS) and the Building Automation System (HBES/BACS) must be brought together at the domain interface. A set of profiles should be described and standardized in order to give guidelines for paths to the interoperability of these two domains. This task should be performed jointly in liaison with IEC TC 13, TC 57, ISO TC 205 and ISO/IEC JTC 1.

4.3.9 Smart Home and Building Automation

4.3.9.1 Description

Smart Home and Building Automation include Home Automation (HBES) and Building Automation and Control Systems (BACS). 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, 3.30).

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 respect to Smart Grid the buildings become an active element within the power net 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 co-generation plants, as well as storages such as heating or cooling reservoirs. Therefore resources (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 communicate with DEMS via AMI. HBES/BACS needs information from AMI and delivers information to AMI as follows:

AMI → 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)

HBES/BACS→AMI:

- Actual switchable loads and resources
- Actual feed-in power value
- Forecast value
- Etc. (list not complete)

4.3.9.2 Requirements

System requirements

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 must 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.

DEMS will require energy consumption and production forecast information from HBES/BACS as well as actual potential switchable loads and feed-in power values.

Communication requirements

The AMI is the gateway between DEMS and HBES/BACS and must therefore transform the data flow between the two systems on a syntactic level.

4.3.9.3 Existing Standards

ISO 16484 series, *Building automation and control systems (BACS)*

ISO/IEC 14543-3, *Information technology -- Home Electronic System (HES) architecture*

EN 13321 series, *Open data communication in building automation, controls and building management - Home and building electronic systems*

EN 13757 series, *Communication system for meters and remote reading of meters*

EN 50090 series, *Home and building electronic systems (HBES)*

EN 50428, *Switches for household and similar fixed electrical installations - Collateral standard - Switches and related accessories for use in home and building electronic systems (HBES)*

EN 50491 series, *General requirements for Home and Building Electronic Systems (HBES) and Building Automation and Control Systems (BACS)*

China: GB/Z 20965, *Information technology -- Home Electronic System (HES) architecture*

USA: ANSI/ASHRAE 135, *BACnet - A Data Communication Protocol for Building Automation and Control Networks*

4.3.9.4 Gaps

Definition of the required interface(s) and communication protocol(s) between AMI and HBES/BACS.

Definition of profiles (common semantic/data model/interworking standard) between AMI and HBES/BACS.

4.3.9.5 Recommendation

Recommendation S-HBES/BACS-1

A close cooperation with the “demand response” activities is needed. Here use cases must be defined in order to specify the scope and involvement of the different stakeholders. For example the contribution of HBES/BACS needs to be described in order to define their share in the overall systems (refer to S-AMI-4).

Recommendation S-HBES/BACS-2

Based on the use cases in accordance with S-HBES/BACS-1 a set of profiles should be described and standardized in order to give guidelines for paths to interoperability of DEMS and HBES/BACS. This task should be performed jointly in a liaison with ISO/IEC JTC 1/SC 25 - Interconnection of information technology equipment and ISO TC 205 (refer to S-DR-1).

4.3.10 Electric Storage

4.3.10.1 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 must 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.

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 DEMS has an indirect influence on these storages by using the HBES/BACS network/communication.

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

- serving as a spinning reserve
- serving as a manageable load
- power system stabilization
- load leveling
- load shedding
- reactive power support

Energy storage is a major element of Smart Grid.

4.3.10.2 Requirements

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.

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 must be available to make full use of the potential benefit of Energy Storage.

Communication must 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.

4.3.10.3 Existing Standards

General standards for distributed energy storage (PHEV) are described in the next Clause.

Interoperability standards

IEC 61850-7-410 describes the connection of pumped hydro power plants to the overall power automation. IEC 61850-7-410, *Communication networks and systems for power utility automation - Part 7-410: Hydroelectric power plants - Communication for monitoring and control,* is perfectly fitted to the overall system architecture of TC 57 and the CIM. 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 is more specialized. However since hydro power is normally a much bigger facility than DER equipment, the requirements for the implementation of IEC 61850-7-410 can be more easily fulfilled and a widespread application of IEC 61850-7-410 can be assumed.

For building automation and control systems see Subclause 4.3.9.

4.3.10.4 Gaps

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

Profiles must be developed to decide on the amount and kind of data that need to be exchanged. These data must 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.

4.3.10.5 Recommendation

Recommendation S-ES-1

TC 57 should develop an equivalent standard for connection of large and distributed storage equipment. The result should be a generic description of the necessary data models, in order to accommodate the different requirements and possibilities of large and distributed energy storage.

Recommendation S-ES-2

Review of work plans for TC 21 (Secondary cells and batteries), TC 35 (Primary cells and batteries) and TC 40 (Capacitors and resistors for electronic equipment) to include the respective equipment into grid electrical storage.

TC 21 and TC 35 should develop verification, testing and classification standards in order to harmonize and develop key parameters and methods for battery utilization in power systems (e.g. charging history, remaining power capacity and necessary parameters for power system connection).

4.3.11 E-mobility

4.3.11.1 Description

E-Mobility is one option for a Smart Grid in 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 today existing plug) 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 leveling
- load shedding
- individual mobility (not relevant for Smart Grid)
- energy conservation (increased efficiency compared to combustion engines)

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

4.3.11.2 Requirements

Product requirements

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

Safety requirements must be fulfilled in an overall perspective. In particular, application and design concepts for the use of batteries must confirm 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 must be standardized.

EMC requirements must 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.

Communication requirements

Bidirectional communication is not a necessary requirement for E-Mobility. For the use case of simple home charging no major changes are required. However such a scenario would not be a Smart Grid application. Inclusion in the Smart Grid is only possible through an information exchange between power automation and electrical vehicle. This requires protocols, data models and a semantic understanding of information models.

4.3.11.3 Existing Standards

Product and Safety Standards

IEC 61982-1, *Secondary batteries for the propulsion of electric road vehicles - Part 1: Test parameters*

IEC 61982-2, *Secondary batteries for the propulsion of electric road vehicles - Part 2: Dynamic discharge performance test and dynamic endurance test*

IEC 61982-3, *Secondary batteries for the propulsion of electric road vehicles - Part 3: Performance and life testing (traffic compatible, urban use vehicles)*

IEC 61982, (work in progress)

IEC 61982-4, *Secondary batteries for the propulsion of electric road vehicles - Performance testing for lithium-ion cells and batteries*

IEC 61982-5, *Secondary batteries for the propulsion of electric road vehicles - Safety testing for lithium-ion cells and batteries*

IEC 62576, *Electric double-layer capacitors for use in hybrid electrical vehicles - Test methods for electrical characteristics*

IEC/NWIP 62619, *Secondary cells and batteries containing alkaline or other non-acid electrolytes - Safety requirements for large format secondary lithium cells and batteries for stationary and motive applications*

The LV installation shall be according the requirements of the IEC 60364 series of TC 64, *Low-voltage electrical installations*.

The following standards are seen to be important for Smart Grid:

IEC 60364-5-53, *Electrical installations of buildings - Part 5-53: Selection and erection of electrical equipment - Isolation, switching and control*

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*

IEC 60364-7-712, *Electrical installations of buildings – Part 7-712: Requirements for special installations or locations – Solar photovoltaic (PV) power supply systems*

IEC 60364-7-722, *Electrical installations of buildings - Part 7-722: Requirements for special installations or locations - Supply of Electrical Vehicle*

IEC/ NP 60364-7-760, *Electrical installations of buildings – Part 7-760: Electrical vehicle*

Interoperability standards - Physical interconnection

IEC 60309 Ed. 4.1, *Plugs, socket-outlets and couplers for industrial purposes*

IEC 60309-1 Ed 4.1, *Part 1: General requirements*

IEC 60309-2 Ed 4.1, *Part 2: Dimensional interchangeability requirements for pin and contact-tube accessories*

IEC 62196 Ed, 1.0, *Plugs, socket-outlets, vehicle couplers and vehicle inlets – Conductive charging of electric vehicles*

IEC 62196-1, *Part 1: Charging of electric vehicles up to 250 A a.c. and 400 A d.c.*

Work in progress:

IEC 62196-2, *Part 2: Dimensional interchangeability requirements for a.c. pin and contact-tube accessories*

IEC 61851, *Electric vehicle conductive charging system*

IEC 61851-1*, Part 1: General requirements*

IEC 61851-21, *Part 21: Electric vehicle requirements for conductive connection to an a.c./d.c. supply*

IEC 61851-22, *Part 22: AC electric vehicle charging station*

IEC 61851-23, *Part 23: D.C. Electric vehicle charging station*

IEC 61980-1, *Electric equipment for the supply of energy to electric road vehicles using an inductive coupling – Part 1: General requirements*

Interoperability standards - Communication

IEC 61850, *Communication networks and systems in substations*

IEC 61968, *Application integration at electric utilities - System interfaces for distribution management*

In order to achieve the advantages of E-mobility in the Smart Grid environment, a connection must be possible between the individual charging management of the vehicle with the automation on distribution level. This must include 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 61850/61968) is therefore absolutely necessary.

IEC 61851-31, *Electric vehicle conductive charging system – Part 31: Data interface for recharging of electric road vehicles supplied from the a.c. mains*

IEC 61851-32, *Electric vehicle conductive charging system – Part 32: Data interface for the recharging of electric road vehicles supplied from an external d.c. charger*

ISO/IEC 15118, *Road vehicles – Communication protocol between vehicle and grid* (TC 22/ SC 3 JWG V2G C1) work in progress

ISO/IEC 15118-1, *Part 1: Definitions and use-case*

ISO/IEC 15118-2, *Part 2: Sequence diagrams and communication layers*

ISO/IEC 15118-3, *Part 3: Physical communication layers*

Several communication media are being evaluated, which include (in no particular order)

- Home Plug Green Phy ITU G.hn
- G3/Prime
- HDPLC
- IEC 61334 PLC on Earth Lon works

For communication standards for HBES / BACS see Subclause 4.3.9.

Market information

The focus of the market information is Smart Metering (referred to in Subclause 4.3.7). Price information must be available on all levels of the Energy Marketplace (EMS-DMS-Smart Metering-Vehicle).

IEC/TR 62325, *Framework for energy market communications*

IEC/TR 62325-501, *Framework for energy market communications - Part 501: General guidelines for use of ebXML*

IEC 62325 does not standardize market communication. It applies the ebXML standard of UN/CEFACT on the energy market and the required market information. The goal is to provide a standard alternative to the proprietary information standards used otherwise: EDIFACT, X12, etc. and to provide an open, technology-independent framework.

The variety of protocols and standards used is quite large in the sector. However a concentration on using UML on the modeling side can be observed. Combined with the further advancement of the CIM (Common Information Model) of IEC 61970 and IEC 61968, a roadmap for implementing pricing models would be available.

Other standards in use

ISO/CD 12405, Road vehicles -- Electrically propelled road vehicles -- Test specification for Lithium-Ion traction battery systems -- Part 1: High power applications

ISO 6469 -1, *Electrically propelled road vehicles - Safety specifications - Part 1: On-board electrical energy storage system (RESS)*

ISO 6469-2, *Electrically propelled road vehicles - Safety specifications - Part 2: Vehicle operational safety means and protection against failures*

ISO 6469-3, *Electric road vehicles - Safety specifications - Part 3: Protection of persons against electric hazards*

USA - SAE Hybrid vehicle task force J1771 Definition of charging connector

USA - SAE Hybrid Taskforce J2836 Communication between vehicle and grid

4.3.11.4 Gaps

- Determination of data model, protocol etc. in ISO/IEC TC22/SC3 JWG V2G C1 (ISO/IEC 15118-1,-2 and -3).
- Matching of these data models with information models of TC 57.
- Inclusion and harmonization with IEC 61850 and IEC 61968 and relevant standards of other SDOs, if any
- Finalize IEC 61851 series for preferred plug and socket option (1/3-phase, 400V, 63A) within IEC 62192-2

4.3.11.5 Recommendation

From the Smart Grid viewpoint an electrical vehicle is an integral part of an overall energy system. Standardization and communication must therefore be adapted to the overall requirements of the power grid.

Recommendation S-EV-1

The IEC should take a bigger part in the standardization of an electrical vehicle as a whole. Responsibilities should be readjusted between the ISO and the IEC in the light of this new development.

Recommendation S-EV-2

Standardization should focus on an integration of e-mobility in the automation of the energy system. Data models, protocols and semantic interoperability should follow the approved framework of power utility and building automation.

Therefore close coordination between TC 57, TC 69 and ISO TC 22/SC3 JWG V2G C1 is essential.

Recommendation S-EV-3

Amend, include and harmonize pricing models based on XML in IEC 61970, IEC 61968 and the standardization work of ISO TC 22 SC3 JWG V2G C1.

4.3.12 Condition Monitoring

4.3.12.1 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. Additionally great efforts are being made to extend average life cycles and minimize 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.

Condition Monitoring 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 e.g. through the line impedance phase shift and the HotSpot 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.

4.3.12.2 Requirements

Measuring and testing procedures must be available for all components.

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

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

4.3.12.3 Existing Standards

Product standards

There is extensive standardization activity for transformers, circuit breakers and switchgear, which also includes procedures for monitoring and measuring the state of the equipment. This includes the activities of TC 14 (Transformers, e.g. IEC 60076, *Power Transformers*, and guideline papers), SC 17A (High voltage switchgear and controlgear, e.g. IEC 62271-1x series) and SC 17C (High voltage switchgear and controlgear assemblies, e.g. IEC 62271-2x series)

Overhead lines – TC 11 (Overhead Lines, e.g. IEC 61897)

Communication standards

Condition Monitoring makes use of standard communication like IEC 61850 for connection to the overall SCADA system. Furthermore IEC 61970 (EMS) and IEC 61968 (DMS, especially IEC 61968-4, *Application integration at electric utilities - System interfaces for distribution management - Part 4: Interfaces for records and asset management*) apply.

4.3.12.4 Gaps

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

4.3.12.5 Recommendations

Recommendation S-CM-1

General technical requirement for on-line diagnosis of smart transmission and transformation equipment.

Recommendation S-CM-2

Standard and guide for fault diagnosis and prediction model of smart transmission and transformation equipment.

Recommendation S-CM-3

Technical specification for power system real time dynamic monitoring (control) system.

Recommendation S-CM-4

Reliability assessment of smart transmission and transformation equipment

4.3.13 Renewable Energy Generation

4.3.13.1 Description

In considering the energy crisis and sustainable development, renewable energy generation is becoming more and more important. 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. Smart Grid will play an important role in ensuring power supply security and sustainable development.

According to different kinds of energy, studies of renewable 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.)
- Marine Power

Nowadays large-scale solar photovoltaic generation plants the size of 10 GW are under construction, so as to build(?) large-scale wind power fields. These plants in such a large size will bring on 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 SmartGrid 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.

4.3.13.2 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.

Technical standards for manufacturing, testing, maintenance and management of devices for renewable energy generation should be studied and developed.

4.3.13.3 Existing Standards

Product Standards – Wind Power

IEC 61400 series (Parts 1, 2, 3, 11, 12-1, 12, 14, 21, 22, 23, 24 and 25), *Wind turbines*

ISO 81400-4, *Wind turbines - Part 4: Design and specification of gearboxes*

Product standards- Solar voltaic

IEC-60904 series, *Photovoltaic devices*

IEC 60904-1, *Photovoltaic devices - Part 1: Measurement of photovoltaic current-voltage characteristics*

IEC 60904-2, *Photovoltaic devices - Part 2: Requirements for reference solar devices*

IEC 60904-3, Photovoltaic devices - *Part 3: Measurement principles for terrestrial photovoltaic (PV) solar devices with reference spectral irradiance data*

IEC 60904-4, *Photovoltaic devices - Part 4: Reference solar devices - Procedures for establishing calibration traceability*

IEC 60904-5, *Photovoltaic devices - Part 5: Determination of the equivalent cell temperature (ECT) of photovoltaic (PV) devices by the open-circuit voltage method*

IEC 60904-6, *Photovoltaic devices - Part 6: Requirements for reference solar modules*

IEC 60904-7, *Photovoltaic devices - Part 7: Computation of the spectral mismatch correction for measurements of photovoltaic devices*

IEC 60904-8, *Photovoltaic devices - Part 8: Measurement of spectral response of a photovoltaic (PV) device*

IEC 60904-9, *Photovoltaic devices - Part 9: Solar simulator performance requirements*

IEC 60904-10, *Photovoltaic devices - Part 10: Methods of linearity measurement*

IEC 61194, *Characteristic parameters of stand-alone photovoltaic (PV) systems*

IEC 61724, *Photovoltaic system performance monitoring - Guidelines for measurement, data exchange and analysis*

IEC 61730 series, *Photovoltaic (PV) module safety qualification*

IEC 61730-1, *Photovoltaic (PV) module safety qualification- Part 1: Requirements for construction*

IEC 61730-2, *Photovoltaic (PV) module safety qualification - Part 2: Requirements for testing*

IEC/TS 61836, *Solar photovoltaic energy systems - Terms, definitions and symbols*

IEC 62446, *Grid connected photovoltaic systems - Minimum requirements for system documentation, commissioning tests and inspection*

IEC/TS 62257, *Recommendations for small renewable energy and hybrid systems for rural electrification*

IEC 61727, *Photovoltaic (PV) systems - Characteristics of the utility interface*

Product standards- Fuel Cells

IEC 62282 series, *Fuel cell technologies*

IEC 62282-1, *Fuel cell technologies - Part 1: Terminology*

IEC 62282-2, *Fuel cell technologies - Part 2: Fuel cell modules*

IEC 62282-3-1, *Fuel cell technologies - Part 3-1: Stationary fuel cell power systems - Safety*

IEC 62282-3-2, *Fuel cell technologies - Part 3-2: Stationary fuel cell power systems - Performance test methods*

IEC 62282-3-3, *Fuel cell technologies - Part 3-3: Stationary fuel cell power systems - Installation*

IEC 62282-5-1, *Fuel cell technologies - Part 5-1: Portable fuel cell power systems - Safety*

IEC 62282-6-200, *Fuel cell technologies - Part 6-200: Micro fuel cell power systems - Performance test methods*

IEC 62282-6-300, *Fuel cell technologies - Part 6-300: Micro fuel cell power systems - Fuel cartridge interchangeability*

Product standards- Pumped Storage

IEC 60193, *Hydraulic turbines, storage pumps and pump-turbines - Model acceptance tests*

IEC 60041, *Field acceptance tests to determine the hydraulic performance of hydraulic turbines, storage pumps and pump-turbines*

Product standards- Distributed Generation

IEC 62257 series, *Recommendations for small renewable energy and hybrid systems for rural electrification*

IEC 62257-1, *Recommendations for small renewable energy and hybrid systems for rural electrification - Part 1: General introduction to rural electrification*

IEC 62257-2, *Recommendations for small renewable energy and hybrid systems for rural electrification - Part 2: From requirements to a range of electrification systems*

IEC 62257-3, *Recommendations for small renewable energy and hybrid systems for rural electrification - Part 3: Project development and management*

IEC 62257-4, *Recommendations for small renewable energy and hybrid systems for rural electrification - Part 4: System selection and design*

IEC 62257-5, *Recommendations for small renewable energy and hybrid systems for rural electrification - Part 5: Protection against electrical hazards*

IEC 62257-6, *Recommendations for small renewable energy and hybrid systems for rural electrification - Part 6: Acceptance, operation, maintenance and replacement*

IEC 62257-7, *Recommendations for small renewable energy and hybrid systems for rural electrification - Part 7: Generators*

IEC 62257-7-3, *Recommendations for small renewable energy and hybrid systems for rural electrification - Part 7-3: Generator set - Selection of generator sets for rural electrification systems*

IEC 62257-8-1, *Recommendations for small renewable energy and hybrid systems for rural electrification - Part 8-1: Selection of batteries and battery management systems for stand-alone electrification systems - Specific case of automotive flooded lead-acid batteries available in developing countries*

IEC 62257-9-1, *Recommendations for small renewable energy and hybrid systems for rural electrification - Part 9-1: Micropower systems*

IEC 62257-9-2, *Recommendations for small renewable energy and hybrid systems for rural electrification - Part 9-2: Microgrids*

IEC 62257-9-3, *Recommendations for small renewable energy and hybrid systems for rural electrification - Part 9-3: Integrated system - User interface*

IEC 62257-9-4, *Recommendations for small renewable energy and hybrid systems for rural electrification - Part 9-4: Integrated system - User installation*

IEC 62257-9-5, *Recommendations for small renewable energy and hybrid systems for rural electrification - Part 9-5: Integrated system - Selection of portable PV lanterns for rural electrification projects*

IEC 62257-9-6, *Recommendations for small renewable energy and hybrid systems for rural electrification - Part 9-6: Integrated system - Selection of Photovoltaic Individual Electrification Systems (PV-IES)*

IEEE 1547, *Standard for Interconnecting Distributed Resources with Electric Power Systems*

IEEE 1547.3, *Guide for Monitoring, Information Exchange, and Control of Distributed Resources Interconnected with Electric Power Systems*

MAIN Guide NO. 3B, *Procedure for The Uniform Rating And Reporting Of Non-Conventional Resource Capability*

Product standards - Nuclear Generation

NERC Standard NUC-001-1, *Nuclear Plant Interface Coordination*

Product Standards – Conventional Power

IEC standards

IEC 60308, *Hydraulic turbines - Testing of control systems*

IEC 61850-7-410, *Communication networks and systems for power utility automation – Part 7-410: Hydroelectric power plants – Communication for monitoring and control*

4.3.13.4 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; PV system low voltage ride through capability testing standard; and PV power generation prediction standard.

4.3.13.5 Recommendations

Recommendation S-REG-1

Currently the IEC 61400 standard series does not include a wind turbine/wind farm low voltage ride through capability testing standard. This standard needs to be established in order to meet the requirements of low voltage ride through capability testing of grid-connected wind farms. The standard should be the necessary added core standard.

Recommendation S-REG-2

Currently the IEC standard series does not include a wind power generation prediction standard. This standard needs to be established in order to meet the requirements of wind power generation prediction of grid-connected wind farms. The standard should be the necessary added core standard.

Recommendation S-REG-3

Currently the IEC standard series does not include a testing methodology and regulation for PV systems connecting to power grids. This standard needs to be established in order to meet the requirements of testing methodology and regulation for PV systems connecting to power grids. The standard should be the necessary added core standard.

Recommendation S-REG-4

Currently the IEC standard series does not include a PV system low voltage ride through capability testing standard. This standard needs to be established in order to meet the requirements of low voltage ride through capability testing of grid-connected PV systems. The standard should be the necessary added core standard.

Recommendation S-REG-5

Currently the IEC standard series does not include a PV power generation prediction standard. This standard needs to be established in order to meet the requirements of PV power generation prediction of grid-connected PV systems. The standard should be the necessary added core standard.

4.4 Other General Requirements

4.4.1 EMC

Electromagnetic Compatibility is a prerequisite for all applications and products and is therefore not limited and not unique to SmartGrid. The design and operation of a SmartGrid shall conform to the requirements set out in the EMC compatibility standards 61000-2-2 (LV) and 61000-2-12 (MV).

For a number of applications (e.g. Electric Vehicle or PLC in the metering domain) compliance with EMC will be a major issue. This will then include the IEC 61000 series and CISPR 11 and 22 especially. When designing a SmartGrid that utilises equipment in the frequency range 9kHz to 400Ghz, the user shall comply with the emission requirements of CISPR 22 or CISPR 32 (to be published).

In terms of equipment immunity, IT equipment used within a SmartGrid shall comply with the requirements of CISPR 24 or CISPR 35 (to be published).

Emission limits can be found in IEC 61000-6-3 (Residential & light-industrial) and 61000-6-4 (Industrial).

If no product standard comprising of EMC part(s) exists, the requirements of the generic EMC standards apply according to its application:

IEC 61000-6-1, *Electromagnetic compatibility (EMC) – Generic standards – Immunity for residential, commercial and light-industrial environments*

IEC 61000-6-2, *Electromagnetic compatibility (EMC)* – Generic standards – Immunity for industrial environments

IEC 61000-6-3, *Electromagnetic compatibility (EMC) – Generic Standards – Emission standard for residential, commercial and light-industrial environments*

IEC 61000-6-4, *Electromagnetic compatibility (EMC) – Generic Standards – Emission standard for industrial environments*

IEC 61000-6-5, *Electromagnetic compatibility (EMC) – Generic standards - Immunity for power station and substation environments*

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

Gaps

Recent EMC standardization shows some gap of specifications

- for immunity in the frequency range from 2 kHz to 150 kHz in general and
- for emissions except for power line communications (IEC 61000-3-8 and IEC 61334-3-1)
- for electrical equipment connected to electricity distribution networks. This relates in particular to electromagnetic interferences (EMI) caused by voltage components, originating from network disturbances, especially in differential mode (between wires), with the following characteristics:
  - discontinuous
  - duration of some hundred ms

Following the thorough change in use of the electricity supply network by modern electronic equipment having taken place during the last decades and, therefore, the increasing occurrence of voltage components above the frequency range of harmonics, up to 150 kHz, this development also urges the consideration of this frequency range for ensuring EMC.

Therefore, a growing **need for consideration of voltage components in the frequency range below 150 kHz appears, in particular when specifying immunity requirements** for electrical equipment which might be disturbed by such short, discontinuous voltage components voltage components in this frequency range.

It appears to be advisable to urge SC 77A, as well as those Product Committees defining EMC requirements in their product standards, to review the existing standards concerning appropriate completion for covering the abovementioned gaps in EMC standardization.

Recommendation S-EMC-1

SC 77A and Product Committees to review existing standards concerning an appropriate modification for closing gaps in also ensuring EMC in the frequency range from 2 kHz to 150 kHz.

Furthermore the following actions of the standardisation communities are suggested to support EMC including Power Quality for Smart Grid:

Recommendation S-EMC-2

Standardise electromagnetic compatibility levels for disturbances in terms of Voltage Quality for all standard voltage levels of public electrical power networks. This means extending the

IEC 61000-2-series to coverage of voltage levels from 230 V up to the highest transmission voltages of public national electrical networks.

Recommendation S-EMC-3

Standardise how to define planning levels, i.e. limits of electromagnetic disturbances in terms of Voltage Quality at sites in electrical networks, based on compatibility levels.

Recommendation S-EMC-4

Standardise how to apportion available immunity of electrical networks in order to meet planning levels, i.e. explain how to fairly allocate the ability of networks to absorb distorting current emissions among present and possibly forthcoming connected equipment at sites in networks. Connected equipment may well be other network(s). The work is recommended to originate from documents IEC TR 61000-3-6, IEC TR 61000-3-7 and IEC TR 61000-3-13.

4.4.2 LV Installation

The LV installation shall be according the requirements of the IEC 60364 series of TC 64 (Electrical installations and protection against electric shock).

In particular, the following standards are seen to be very important for Smart Grid LV-installations:

IEC 60364-4-41, *Low-voltage electrical installations – Part 4-41: Protection for safety – Protection against electric shock*

IEC 60364-5-53, *Electrical installations of buildings - Part 5-53: Selection and erection of electrical equipment - Isolation, switching and control*

HD 60364-5-55, *Electrical installations of buildings -- Part 5-55: Selection and erection of electrical equipment - Other equipment - Clause 551: Low-voltage generating sets*

IEC 60364-7-712, *Electrical installations of buildings – Part 7-712: Requirements for special installations or locations – Solar photovoltaic (PV) power supply systems*

IEC 60364-7-722, *Electrical installations of buildings – Part 7-722: Requirements for special installations or locations - Supply of Electrical Vehicle*

IEC/NP 60364-7-760, *Electrical installations of buildings – Part 7-760: Electrical vehicle*

Verification

The LV installation shall be tested according to IEC 60364-6, *Low-voltage electrical installations – Part 6: Verification*, 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 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.

4.4.3 Object Identification, Product Classification, Properties and Documentation

Identification of objects, classification of objects and properties associated with the objects are essential working areas, influencing the full scope of business activities, from procurement, engineering, maintenance, service and phasing out of operation.

The above issues are key requisites for implementation of advanced electronic engineering processes.

From a Smart Grid perspective the most important features are:

- the identification of the objects (from HV breaker to counting equipment in a household) within the grid considered; this requires the use of a common identification system for the objects including all grids participating in the smart grid;
- a classification of the objects used in the grid;
- If the relevant object is clearly identified, the technical data associated with the object need to be computer-interpretable.

These items are absolute prerequisites, for example, for any asset management applications, which must be able to include different vendor equipment. For this equipment the same technical properties must be made available by the supplier of the products.

Another issue is documentation. In order to support consistency and common understanding, general guidelines and electronic product descriptions must be present.

Existing Standards

Identification of objects:

IEC 81346-1, *Industrial systems, installations and equipment and industrial products - Structuring principles and reference designations - Part 1: Basic rules*

IEC 62507-1, *Requirements for identification systems enabling unambiguous information interchange – Part 1: Principles and methods – Proposed as horizontal standard* (under preparation by TC3)

IEC 61666, *Industrial systems, installations and equipment and industrial products - Identification of terminals within a system*

IEC 61175, *Industrial systems, installations and equipment and industrial products – Designation of signals*

Classification of objects:

IEC 81346-2, *Industrial systems, installations and equipment and industrial products - Structuring principles and reference designations - Part 2: Classification of objects and codes for classes*

NOTE For the objects managed within the smart grid no further classification activities as in IEC 81346-2 is required.

Electronic product description activities:

IEC 61360-1, *Standard data elements types with associated classification scheme for electric items - Part 1: Definitions - Principles and methods*

IEC 61360-2, *Standard data element types with associated classification scheme for electric components - Part 2: EXPRESS dictionary schema*

ISO 13584, *Industrial automation systems and integration - Parts library* (PLIB). PLIB is developed and maintained by the ISO technical committee TC 184 (Technical Industrial automation systems and integration), sub-committee SC 4 (Industrial data).

NOTE ISO 13583 and IEC 61360-2 are identical.

IEC 61360-4, *Standard data element types with associated classification scheme for electric components - Part 4: IEC reference collection of standard data element types and component classes*

IEC 61360-5, *Standard data element types with associated classification scheme for electric components - Part 5: Extensions to the EXPRESS dictionary schema*

IEC PAS 62569-1, *Generic specification of information on products - Part 1: Principles and methods*

IEC PAS 62569-2, *Generic specification of information on products - Part 2 - Structure of specifications* (under preparation in IEC TC 3)

Gaps

The work on the CIM (Common Information Model) and other specific work such as IEC 61850-7-420 (DER) already specifies technical properties of objects used in the data models. Currently these models are not aligned to the principles of IEC 61360.

Recommendations

Recommendation S-PPC-1

For future activities, the above standards for identification and classification should be applied as they are already widely used in grid systems by power suppliers. The principles defined by IEC 61360 and IEC PAS 62569 should be used when defining properties associated with objects/products in the work of IEC TC 57.

A close cooperation of IEC TC 3 and IEC TC 57 should be established. This would, inter alia, promote the extension of existing (technical) properties in the existing data models of IEC 61850/61968 and 61970 to other applications and would open the path to new applications. In addition, IEC 62491, *Industrial systems, installations and equipment and industrial products – Labeling of cables and cores*; and

IEC 62023, *Structuring of technical information and documentation*.

4.4.4 Use Cases

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 standardization.

Smart Grid requires such an analytic approach in order to identify gaps and necessities for standardization. This document does not describe these use cases in a detailed manner. This must still be done for the respective standardization work.

TC 8 has proposed the following subjects:

- Generic Use cases for Advanced Metering projects
- Generic Consumer Use cases projects
- Generic Use cases for Advanced Distribution Automation projects
- Generic Transmission Synchro-Phasor Use Case

Recommendation S-UC-1

Use cases must be specified with the experts involved and the respective TCs, e.g. “Generic Use cases for Advanced Distribution Automation projects” can only be developed in close cooperation with TC 57 WG 14; “Generic Transmission Synchro-Phasor Use Case” should be assigned to TC 57 WG 13.

Recommendation S-UC-2

TC 8 should take the position of coordinator. It must include a systems perspective and avoid conflicts between the individual use case definitions. Typical areas for work would be “Generic Consumer/Prosumer Use cases”.

Recommendation S-UC-3

The IEC must keep close contact and observe the major market developments in the different use case areas. A close connection must be ensured in order to optimally align future standardization work. This could be part of the task of IEC SMB SG 3.

5 General Recommendations

Recommendation G-1

There is no single unified concept of what a "Smart Grid" is. Smart Grids can have multiple shapes. Furthermore legacy systems must be incorporated. Therefore existing mature domain communication systems should be used. The IEC should further standardize necessary interfaces and product requirements and must avoid standardizing applications and business models.

Recommendation G-2

The IEC should promote its excellent work on Smart Grid standardization. In particular the potential of IEC/TR 62357 should be promoted. IEC should take the chance to inform stakeholders about the possible applications of the TC 57 framework through white papers, promotions and workshops.

Recommendation G-3

Technical connection criteria are subject to standards, regulations and various local specifications. A harmonization of these criteria seems to be out of the scope of IEC standardization. General requirements can be specified, but the IEC should refrain from detailed standardization of these issues.

Recommendation G-4

The IEC should seek close cooperation with stakeholders in the domain "markets". A lot of proprietary work is done in that field. The IEC should seek close cooperation with organizations such as UN/CEFACT and UN/EDIFACT as well as other important regulation authorities and trade associations. An investigation of the most promising market data systems must be performed. This input is vital for an extension of the Smart Grid with market information.

Recommendation G-5

Close cooperation with NIST SmartGrid Interoperability roadmap activities. The IEC should define a contact within NIST (e.g. through the NIST coordinator G Arnold). IEC SG 3 to act as partner to NIST. A preferred partnership should be considered. The IEC as the international electrotechnical standardization organization should be supportive of the excellent work already done by NIST and the participants of the NIST roadmap effort. The IEC should actively offer support in the identified prioritized action fields where the IEC is involved and offer consultation in some areas, whereas NIST focuses on local or regional standards (e.g. AMI, DER).

IEC SG 3 should take the first steps at its next meeting in Washington, which will be held at NIST.

Recommendation G-6

Traditional information technologies in power grids and domains of production-control are inseparable; however, with the progress of technology and innovation of management, a new issue is that production control will now be integrated with the enterprise management. To solve this problem, it is necessary to build an integrative model which could cover both, rather than the original CIM model, which is limited to production control.

6 Appendix

6.1 Appendix – Core Standards

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.

Core Standard	Topic
IEC 62357	Reference Architecture – SOA Energy Management Systems; Distribution Management Systems
IEC 61970/61968	CIM (Common Information Model) EMS; DMS; DA; SA; DER; AMI; DR; E-Storage
IEC 61850	Substation Automation EMS; DMS; DA; SA; DER;AMI
IEC 61968	Distribution Management
IEC 61970	Energy Management
IEC 62351	Security
IEC 62056	Data exchange for meter reading, tariff and load control
IEC 61508	Functional safety of electrical/electronic/programmable electronic safety-related systems

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

Standard	Topic
IEC 60870-5	Telecontrol EMS; DMS; DA; SA
IEC 60870-6	TASE2 Inter Control Center Communication EMS; DMS
IEC/TR 61334	“DLMS” Distribution Line Message Specification AMI
IEC 61400-25	Wind Power Communication EMS; DMS; DER
IEC 61850-7-410	Hydro Energy Communication EMS; DMS; DA; SA; DER
IEC 61850-7-420	Distributed Energy Communication DMS; DA; SA; DER
IEC 61851	EV-Communication Smart Home; Emobility
IEC 62051-54/58-59	Metering Standards DMS; DER; AMI; DR; Smart Home; E-Storage; Emobility
IEC 62056	COSEM DMS; DER; AMI; DR; Smart Home; E-Storage; Emobility

6.2 Appendix - Overview of IEC Standards

Bottom-up analysis: In Figure 17, standardization issues will be derived from a collection of standards and comments given by IEC TCs on the request to comment on their involvement in Smart Grid standards.

	HVDC/FACTS	Blackout Prevention / EMS	DMS	Distribution Automation	Substation Automation	DER	AMI	DR	Smart Home	Electric Storage	Electromobility	Relevance for Smart Grid
SOA – IEC 62357		x	x									Core
CIM – IEC 61970-301		x	x	x	x	x	x	x		x		Core
ISO/IEC 14543									x			Low
ISO/IEC 27001									x			Low
IEC 60255			x	x	x							Low
IEC 60364						x			x			Medium
IEC 60495							x		x			Low
IEC 60633	x											Low
IEC 60834		x	x		x							Low
IEC 60870-5		x	x	x	x							High
IEC 60870-6		x	x									High
IEC 60904						x		x	x			Medium
IEC/TR 61000						x	x		x	x	x	Low
IEC/TS 61085												
IEC 61140									x		x	Medium
IEC/TR 61158 / 61784					x							Medium
IEC/TR 61334							x					High
IEC 61400		x	x			x						High
IEC 61508												
IEC 61850		x	x	x	x	x	x			x	x	Core
IEC 61850-7-410		x	x	x	x	x						High
IEC 61850-7-420			x	x	x	x						High
IEC 61851									x		x	High
IEC 61869				x	x							Medium
IEC 61954	x											Low
IEC 61968			x			x	x	x				Core
IEC 61970		x	x		x							Core
IEC 61982											x	Low
IEC 62051-54 / 58-59			x			x	x	x	x	x	x	High
IEC 62056			x			x	x	x	x	x	x	High
	HVDC/FACTS	Blackout Prevention / EMS	DMS	Distribution Automation	Substation Automation	DER	AMI	DR	Smart Home	Electric Storage	Electromobility	Relevance for Smart Grid
IEC 62282						x						Low
IEC/TR 62325												Medium
IEC 62351		x	x	x	x	x	x	x		x	x	Core
IEC/TR 62357		x	x	x	x	x	x	x		x	x	Core
IEC 62439												
IEC 62443												Low
IEC CDV 62576											x	Low
IEC 62600						x						Low

Figure 17 – Overview of IEC standards

6.2.1 SOA – IEC 62357

Smart Grid Relevance: **Core**

Relevant Application: EMS, DMS

In order to survive in the deregulated energy market, power supply companies today face the urgent task of optimizing their core processes. This is the only way that they can survive in this competitive environment. The requirements in the energy market have undergone permanent change. Modern network control systems are optimized to meet these requirements. The high degree of scalability with regard to hardware configuration and software functionality allows flexible matching to changing requirements over the entire life cycle of the system and beyond. The aim is to make the system architecture modular and component-based so that a flexible configuration and IT integration can be implemented in a cost-efficient manner. The crucial step here is to combine the large number of autonomous IT systems into one homogeneous IT landscape. However, conventional network control systems can only be integrated with considerable effort.

Open systems through the use of standards

A modern network control system provides the basis for integration of an energy management system in the existing system landscape of the power supply company through the use of standards and de facto standards.

- IEC 61970 – Common Information Model (CIM) – defines the standard for data models in electrical networks. It supports the import and export of formats such as XDF, RDF and SVG, which are based on the XML standard
- Client/server configuration based on standard LANs and protocols (TCP/IP)
- Open interfaces (OBCD, OLE, OPC, etc.)
- Internationally standardized transmission protocols (IEC 60870-5, IEC 60870- 6)

Service-oriented architecture

A modern network control system provides a service-oriented architecture (see Figure 18) with standardized process, interface and communication specifications based on standards IEC 61968 and IEC 61970. They form the basis for integrating the network control system in the enterprise service environment of the power supply company.

The services of a control system comprise:

- Data services with which, for example, the databases of the core applications can be accessed, e.g. readout of the operational equipment affected by a fault incident in the power supply system
- Functional logic services, e.g., for starting a computing program for calculating the load flow in the power supply system
- Business logic services that coordinate the business logic for specific energy management work processes of the participating systems, e.g. fault management in the network control system within the customer information system at the power supply company.

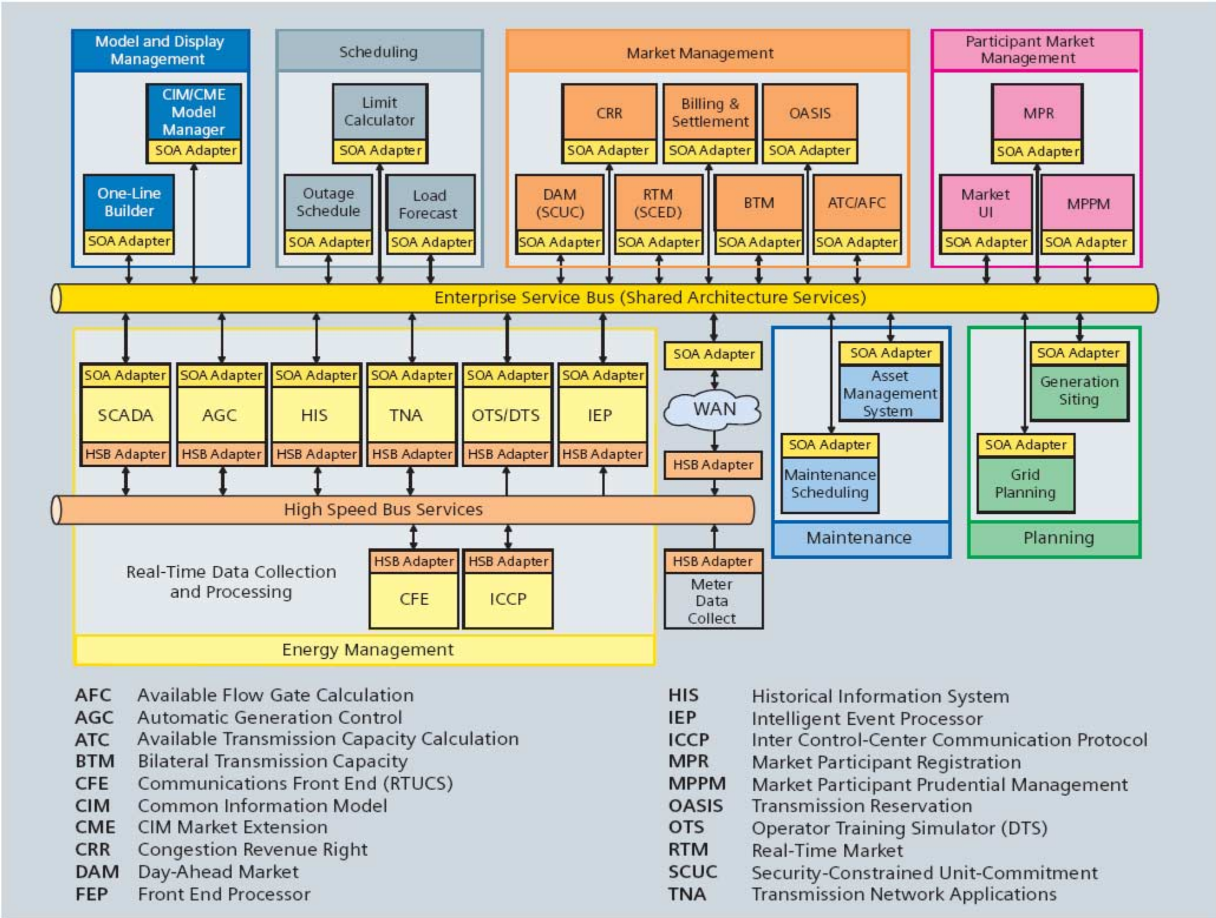


Figure 18 – Service-oriented architecture

6.2.2 Common Information Model (CIM) – IEC 61970

Smart Grid Relevance: **Core**

Relevant Application: EMS, DMS, DA, SA, DER, AMI, DR, Storage

In order to survive in the deregulated energy market, power supply companies today face the urgent task of optimizing their core processes. This is the only way that they can survive in this competitive environment. The vital step here is to combine the large number of autonomous IT systems into a homogeneous IT landscape. However, conventional network control systems can only be integrated with considerable effort because they do not use uniform data standards. Network control systems with a standardized data format for source data based on the standardized data model Common Information Model (CIM), in accordance with IEC 61970, offer the best basis for IT integration.

CIM – key to interoperability and openness

The CIM defines a common language and data modeling with the object of simplifying the exchange of information between the participating systems and applications via direct interfaces. The CIM was adopted by IEC TC 57 and fast-tracked for international standardization. In the United States, the CIM is already stipulated by the North American Reliability Council (NERC) for the exchange of data between electricity supply companies. The standardized CIM data model offers a very large number of advantages for power suppliers and manufacturers:

- Simple data exchange for companies that are near each other;

- Standardized CIM data remains stable, and data model expansions are simple to implement;
- As a result, simpler, faster and less risky upgrading of energy management systems, and if necessary, also migration to systems of other manufacturers;
- The CIM application program interface creates an open application interface. The aim is to use this to interconnect the application packages of all kinds of different suppliers per "Plug and Play" to create an EMS.

The CIM forms the basis for the definition of important standard interfaces to other IT systems. The working group in IEC TC 57 plays a leading role in the further development and international standardization of IEC 61970 and the Common Information Model. Working group WG 14 (IEC 61968 standards) in the TC 57 is responsible for standardization of interfaces between systems, especially for the power distribution area. Standardization in the outstation area is defined in IEC 61850.

With the extension of document 61850 for communication to the control centre, there are overlaps in the object model between 61970 and 61850.

CIM data model and packages

The CIM data model describes the electrical network, the connected electrical components, the additional elements and the data needed for network operation as well as the relations between these elements. The Unified Modeling Language (UML), a standardized, object-oriented method that is supported by various software tools, is used as the descriptive language. The CIM is used primarily to define a common language for exchanging information via direct interfaces or an integration bus and for accessing data from various sources.

The CIM is subdivided into packages such as basic elements, topology, generation, load model, measurement values and protection. The sole purpose of these packages is to make the model more transparent. Relations between classes may extend beyond the boundaries of packages.

6.2.3 Information Technology – HES – ISO/IEC 14543

Smart Grid Relevance: Low

Relevant Application: Smart Home

ISO/IEC 14543-2-1, *Information technology - Home electronic system (HES) architecture - Part 2-1: Introduction and device modularity*

ISO/IEC 14543-3-1, *Information technology - Home electronic system (HES) architecture - Part 3-1: Communication layers - Application layer for network based control of HES Class 1*

ISO/IEC 14543-3-2, *Information technology - Home electronic system (HES) architecture - Part 3-2: Communication layers - Transport, network and general parts of data link layer for network based control of HES Class 1*

ISO/IEC 14543-3-3, *Information technology - Home electronic system (HES) architecture - Part 3-3: User process for network based control of HES Class 1*

ISO/IEC 14543-3-4, *Information technology - Home electronic system (HES) architecture - Part 3-4: System management - Management procedures for network based control of HES Class 1*

ISO/IEC 14543-3-5, *Information technology - Home electronic system (HES) architecture - Part 3-5: Media and media dependent layers - Powerline for network based control of HES Class 1*

ISO/IEC 14543-3-6, *Information technology - Home electronic system (HES) architecture - Part 3-6: Media and media dependent layers - Twisted pair for network based control of HES Class 1*

ISO/IEC 14543-3-7, *Information technology - Home electronic system (HES) architecture - Part 3-7: Media and media dependent layers - Radio frequency for network based control of HES Class 1*

ISO/IEC/TS 14543-4, *Information technology - Home electronic system (HES) architecture - Part 4: Home and building automation in a mixed-use building*

ISO/IEC 14543-4-1, *Information technology - Home electronic system (HES) architecture - Part 4-1: Communication layers - Application layer for network enhanced control devices of HES Class 1*

ISO/IEC 14543-4-2, *Information technology - Home electronic system (HES) architecture - Part 4-2: Communication layers - Transport, network and general parts of data link layer for network enhanced control devices of HES Class 1*

6.2.4 Information technology – Security – ISO/IEC 27001

Smart Grid Relevance: Low

Relevant Application: Smart Home

ISO/IEC 27001, *Information technology - Security techniques - Information security management systems – Requirements*

6.2.5 Electrical Relays – IEC 60255

Smart Grid Relevance: Low

Relevant Application: DMS, DA, SA

IEC 60255-24, *Electrical relays - Part 24: Common format for transient data exchange (COMTRADE) for power systems*

6.2.6 Electrical installations of buildings – IEC 60364

Smart Grid Relevance: Medium

Relevant Application: DER, Smart Home

IEC 60364-4-41, *Low-voltage electrical installations - Part 4-41: Protection for safety - Protection against electric shock*

IEC 60364-5-51, *Electrical installations of buildings - Part 5-51: Selection and erection of electrical equipment - Common rules*

IEC 60364-5-53, *Electrical installations of buildings - Part 5-53: Selection and erection of electrical equipment - Isolation, switching and control*

IEC 60364-5-54, *Electrical installations of buildings - Part 5-54: Selection and erection of electrical equipment - Earthing arrangements, protective conductors and protective bonding conductors*

IEC 60364-5-55, *Electrical installations of buildings - Part 5-55: Selection and erection of electrical equipment - Other equipment*

6.2.7 Power-line – IEC 60495

Smart Grid Relevance: Low

Relevant Application: AMI, Smart Home

IEC 60495, *Single sideband power-line carrier terminals*

6.2.8 HVDC – IEC 60633 et al

Smart Grid Relevance: Low

Relevant Application: HVDC/FACTS

IEC 60633, *Terminology for high-voltage direct current (HVDC) transmission*

IEC/TR 60919-1, *Performance of high-voltage direct current (HVDC) systems with line-commutated converters - Part 1: Steady-state conditions*

IEC 61803, *Determination of power losses in high-voltage direct current (HVDC) converter stations*

6.2.9 Teleprotection equipment of power systems – IEC 60834-1

Smart Grid Relevance: Low

Relevant Application: EMS, DMS, SA

IEC 60834-1, *Teleprotection equipment of power systems - Performance and testing - Part 1: Command systems*

6.2.10 Telecontrol – IEC 60870-5

Smart Grid Relevance: **High**

Relevant Application: EMS, DMS, DA, SA

IEC 60870-5 provides a communication profile for sending basic telecontrol messages between two systems, which uses permanent directly connected data circuits between the systems. The IEC Technical Committee 57 (Working Group 03) have developed a protocol standard for Telecontrol, Teleprotection, and associated telecommunications for electric power systems. The result of this work is IEC 60870-5, *Telecontrol equipment and systems*.

Five documents specify the base IEC 60870-5:

- IEC 60870-5-1, *Transmission frame formats*
- IEC 60870-5-2, *Link transmission procedures*
- IEC 60870-5-3, *General structure of application data*
- IEC 60870-5-4, *Definition and coding of application information elements*
- IEC 60870-5-5, *Basic application functions*

IEC TC 57 has also generated companion standards:

- IEC 60870-5-101, *Transmission Protocols, companion standard for basic telecontrol tasks*
- IEC 60870-5-102*, Companion standard for the transmission of integrated totals in electric power systems* (this standard is not widely used)
- IEC 60870-5-103, *Transmission protocols, Companion standard for the informative interface of protection equipment*
- IEC 60870-5-104, *Transmission Protocols, Network access for IEC 60870-5-101 using standard transport profiles*

6.2.11 TASE2 – IEC 60870-6

Smart Grid Relevance: **High**

Relevant Application: EMS, DMS

Inter Control Centre Communications.

6.2.12 Solar voltaic – IEC 60904 et al

Smart Grid Relevance: Medium

Relevant Application: DER, DR, Smart Home

IEC 60904, *Photovoltaic devices*

IEC 61194, *Characteristic parameters of stand-alone photovoltaic (PV) systems*

IEC 61724, *Photovoltaic system performance monitoring - Guidelines for measurement, data exchange and analysis*

IEC 61727, *Photovoltaic (PV) systems - Characteristics of the utility interface*

IEC 61730, *Photovoltaic (PV) module safety qualification*

IEC/TS 61836, *Solar photovoltaic energy systems – Terms, definitions and symbols*

IEC/TS 62257, *Recommendations for small renewable energy and hybrid systems for rural electrification*

6.2.13 Electromagnetic compatibility (EMC) – IEC/TR 61000

Smart Grid Relevance: Low

Relevant Application: DER, AMI, Smart Home, Storage, EV

IEC 61000-2-2 and 61000-2-12, EMC general

IEC 61000-3-15, EMC - Limits

IEC 61000-3-2, 61000-3-12, 61000-3-3 and 61000-3-11, EMC emission standards for equipment

IEC 61000-3-6, 61000-3-7 and 61000-3-13, EMC emission standards for installations

IEC 61000-4 series, in particular standards 61000-4-11, 61000-4-27 and 61000-4-34, EMC immunity standards

6.2.14 General considerations for telecommunication services for electric power systems – IEC/TS 61085

Smart Grid Relevance: Medium

Relevant Application: Communication

6.2.15 LV-protection against electric shock – IEC 61140

Smart Grid Relevance: Medium

Relevant Application: Smart Home, EV

IEC 61140, *Protection against electric shock - Common aspects for installation and equipment*

6.2.16 DLMS" Distribution Line Message Specification – IEC/TR 61334

Smart Grid Relevance: **High**

Relevant Application: AMI

IEC/TR 61344-1-1, *Distribution automation using distribution line carrier systems - Part 1: General considerations - Section 1: Distribution automation system architecture*

IEC/TR 61334-1-2, *Distribution automation using distribution line carrier systems - Part 1-2: General considerations - Guide for specification*

IEC/TR 61334-1-4, *Distribution automation using distribution line carrier systems - Part 1: General considerations - Section 4: Identification of data transmission parameters concerning medium and low-voltage distribution mains*

IEC 61334-3-1, *Distribution automation using distribution line carrier systems - Part 3-1: Mains signaling requirements - Frequency bands and output levels*

IEC 61334-3-21, *Distribution automation using distribution line carrier systems - Part 3: Mains signaling requirements - Section 21: MV phase-to-phase isolated capacitive coupling device*

IEC 61334-3-22, *Distribution automation using distribution line carrier systems - Part 3-22: Mains signaling requirements - MV phase-to-earth and screen-to-earth intrusive coupling devices*

IEC 61334-4-1, *Distribution automation using distribution line carrier systems - Part 4: Data communication protocols - Section 1: Reference model of the communication system*

IEC 61334-4-32, *Distribution automation using distribution line carrier systems - Part 4: Data communication protocols - Section 32: Data link layer - Logical link control (LLC)*

IEC 61334-4-33, *Distribution automation using distribution line carrier systems - Part 4-33: Data communication protocols - Data link layer - Connection oriented protocol*

DLMS

IEC 61334-4-41, *Distribution automation using distribution line carrier systems - Part 4: Data communication protocols - Section 41: Application protocols - Distribution line message specification*

IEC 61334-4-42, *Distribution automation using distribution line carrier systems - Part 4: Data communication protocols - Section 42: Application protocols - Application layer*

IEC 61334-4-61, *Distribution automation using distribution line carrier systems - Part 4-61: Data communication protocols - Network layer - Connectionless protocol*

IEC 61334-4-511, *Distribution automation using distribution line carrier systems - Part 4-511: Data communication protocols - Systems management - CIASE protocol*

IEC 61334-4-512, *Distribution automation using distribution line carrier systems - Part 4-512: Data communication protocols - System management using profile 61334-5-1 - Management Information Base (MIB)*

IEC 61334-5-1, *Distribution automation using distribution line carrier systems - Part 5-1: Lower layer profiles - The spread frequency shift keying (S-FSK) profile*

IEC/TS 61334-5-2, *Distribution automation using distribution line carrier systems - Part 5-2: Lower layer profiles - Frequency shift keying (FSK) profile*

IEC/TS 61334-5-3, *Distribution automation using distribution line carrier systems - Part 5-3: Lower-layer profiles - Spread spectrum adaptive wideband (SS-AW) profile*

IEC/TS 61334-5-4, *Distribution automation using distribution line carrier systems - Part 5-4: Lower layer profiles - Multi-carrier modulation (MCM) profile*

IEC/TS 61334-5-5, *Distribution automation using distribution line carrier systems - Part 5-5: Lower layer profiles - Spread spectrum - fast frequency hopping (SS-FFH) profile*

IEC 61334-6, *Distribution automation using distribution line carrier systems - Part 6: A-XDR encoding rule*

Defines a set of encoding rules that may be used to derive the specification of a transfer syntax for values of types defined in the DLMS core standard using the ASN.1 notation.

6.2.17 Wind Turbines – IEC 61400

Smart Grid Relevance: **High**

Relevant Application: EMS, DMS, DER

IEC 61400-1, *Wind turbines - Part 1: Design requirements*

IEC 61400-2, *Wind turbines - Part 2: Design requirements for small wind turbines*

IEC 61400-3, *Wind turbines - Part 3: Design requirements for offshore wind turbines*

IEC 61400-11, *Wind turbine generator systems - Part 11: Acoustic noise measurement techniques*

IEC 61400-12-1, *Wind turbines - Part 12-1: Power performance measurements of electricity producing wind turbines*

IEC/TS 61400-13, *Wind turbine generator systems - Part 13: Measurement of mechanical loads*

IEC/TS 61400-14, *Wind turbines - Part 14: Declaration of apparent sound power level and tonality values*

IEC 61400-21, *Wind turbines - Part 21: Measurement and assessment of power quality characteristics of grid connected wind turbines*

IEC/TS 61400-23, *Wind turbine generator systems - Part 23: Full-scale structural testing of rotor blades*

IEC/TR 61400-24, *Wind turbine generator systems - Part 24: Lightning protection*

IEC 61400-25-1, *Wind turbines - Part 25-1: Communications for monitoring and control of wind power plants - Overall description of principles and models*

IEC 61400-25-2, *Wind turbines - Part 25-2: Communications for monitoring and control of wind power plants - Information models*

IEC 61400-25-3, *Wind turbines - Part 25-3: Communications for monitoring and control of wind power plants - Information exchange models*

IEC 61400-25-4, *Wind turbines - Part 25-4: Communications for monitoring and control of wind power plants - Mapping to communication profile*

IEC 61400-25-5, *Wind turbines - Part 25-5: Communications for monitoring and control of wind power plants - Conformance testing*

IEC WT 01, *IEC System for Conformity Testing and Certification of Wind Turbines - Rules and procedures*

ISO 81400-4, *Wind turbines - Part 4: Design and specification of gearboxes*

IEC 61508, *Functional safety of electrical/electronic/programmable electronic safety-related systems*

6.2.18 Substation Automation – IEC 61850

Smart Grid Relevance: **Core**

Relevant Application: EMS, DMS, DA, SA, DER, AMI, Storage, EV

Since its publication in 2004, the IEC 61850 communication standard has gained more and more relevance in the field of substation automation. It provides an effective response to the needs of the open, deregulated energy market, which requires both reliable networks and extremely flexible technology – flexible enough to adapt to the substation challenges of the next twenty years. IEC 61850 has not only taken over the drive of the communication technology of the office networking sector, but it has also adopted the best possible protocols and configurations for high functionality and reliable data transmission. Industrial Ethernet, which has been hardened for substation purposes and provides a speed of 100 Mbit/s, offers enough bandwidth to ensure reliable information exchange between IEDs (Intelligent Electronic Devices), as well as reliable communication from an IED to a substation controller. The definition of an effective process bus offers a standardized way to digitally connect conventional as well as intelligent CTs and VTs to relays. More than just a protocol, IEC 61850 also provides benefits in the areas of engineering and maintenance, especially with respect to combining devices from different vendors.

Key features of IEC 61850

As in an actual project, the standard includes parts describing the requirements needed in substation communication, as well as parts describing the specification itself. The specification is structured as follows:

- An object-oriented and application-specific data model focused on substation automation.
- This model includes object types representing nearly all existing equipment and functions in a substation – circuit breakers, protection functions, current and voltage transformers, waveform recordings, and many more.
- Communication services providing multiple methods for information exchange. These services cover reporting and logging of events, control of switches and functions and polling of data model information.
- Peer-to-peer communication for fast data exchange between the feeder level devices (protection devices and bay controller) is supported with GOOSE (Generic Object Oriented Substation Event).
- Support of sampled value exchange.
- File transfer for disturbance recordings.
- Communication services to connect primary equipment such as instrument transducers to relays.
- Decoupling of data model and communication services from specific communication technologies.
- This technology independence guarantees long-term stability for the data model and opens up the possibility to switch over to successor communication technologies. Today, the standard uses Industrial Ethernet with the following significant features:
    - 100 Mbit/s bandwidth
    - Non-blocking switching technology
    - Priority tagging for important messages
    - Time synchronization
- A common formal description code, which allows a standardized representation of a system's data model and its links to communication services.
- This code, called SCL (Substation Configuration Description Language), covers all communication aspects according to IEC 61850. Based on XML, this code is an ideal electronic interchange format for configuration data.
- A standardized conformance test which ensures interoperability between devices. Devices must pass multiple test cases: positive tests for correctly responding to stimulation telegrams, plus several negative tests for ignoring incorrect information.
- IEC 61850 offers a complete set of specifications covering all communication issues inside a substation.

IEC 61850 consists of the following parts detailed in separate IEC 61850 standard documents:

- IEC61850-1: *Introduction and overview*
- IEC61850-2: *Glossary*
- IEC61850-3: *General requirements*

- IEC61850-4: *System and project management*
- IEC61850-5: *Communication requirements for functions and device models*
- IEC61850-6: *Configuration description language for communication in electrical substations related to IEDs*
- IEC61850-7: *Basic communication structure for substation and feeder equipment*
    - IEC61850-7-1: *Principles and models*
    - IEC61850-7-2: *Abstract communication service interface (ACSI)*
    - IEC61850-7-3: *Common Data Classes*
    - IEC61850-7-4: *Compatible logical node classes and data classes*
- IEC61850-8: *Specific communication service mapping (SCSM)*
    - IEC61850-8-1: *Mappings to MMS (ISO/IEC9506-1 and ISO/IEC 9506-2)*
- IEC61850-9: *Specific communication service mapping (SCSM)*
    - IEC61850-9-1: *Sampled values over serial unidirectional multidrop point to point link*
    - IEC61850-9-2: *Sampled values over ISO/IEC 8802-3*
- IEC61850-10: *Conformance testing*

6.2.19 Hydro Power – IEC 61850-7-410

Smart Grid Relevance: **High**

Relevant Application: EMS, DMS, DA, SA, DER

IEC 61850-7-410, *Communication networks and systems for power utility automation - Part 7-410: Hydroelectric power plants - Communication for monitoring and control*.

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.

6.2.20 DER – IEC 61850-7-420

Smart Grid Relevance: Low

Relevant Application: DMS, DA, SA, DER

IEC 61850-7-420 Ed.1, *Communication networks and systems in substations – Part 7-420: Communications systems for distributed energy resources* (DER) *logical nodes.*

IEC 61850-7-420 offers a standard to describe the data exchange between DER equipment and any system which will supervise, control, maintain and generally utilize and operate this DER equipment.

6.2.21 Electrical vehicle charging – IEC 61851 et al

Smart Grid Relevance: **High**

Relevant Application: Smart Home, EV

IEC 60309-1 Ed. 4.1, *Plugs, socket-outlets and couplers for industrial purposes*

IEC 61851, *Electric vehicles conductive charging system*

IEC 61851-1, *Electric vehicles conductive charging system - Part 1: General requirements*

IEC 61851-21, *Electric vehicles conductive charging system - Part 21: Electric vehicle requirements for conductive connection to an a.c./d.c. supply*

IEC 61851-22, *Electric vehicles conductive charging system -Part 22: AC electric vehicle charging station*

IEC 61851-23, *Electric vehicles conductive charging system -Part 23: D.C. Electric vehicle charging station*[2]

IEC 61980-1, *Electric equipment for the supply of energy to electric road vehicles using an inductive coupling - Part 1: General requirements*[2]

6.2.22 Instrument transformers – IEC 61869

Smart Grid Relevance: Medium

Relevant Application: DA, SA

IEC 61869-1, *Instrument transformers - Part 1: General requirements*

IEC 61869-2, *Instrument transformers - Part 2: Specific requirements for current transformers*

IEC 61869-3, *Instrument transformers - Part 3: Specific requirements for inductive voltage transformers*

IEC 61869-4, *Instrument transformers - Part 4: Specific requirement for combined transformers*

IEC 61869-5, *Instrument Transformers - Part 5: Specific requirements for Capacitive Voltage Transformers*

future IEC 61869-7, *Electronic Voltage Transformers*

future IEC 61869-8, *Electronic Current Transformers*

future IEC 61869-9, *Digital Interface for Instrument Transformers*

6.2.23 Power electronics for electrical transmission and distribution systems – IEC 61954

Smart Grid Relevance: Low

Relevant Application: HVDC/FACTS

IEC 61954, *Power electronics for electrical transmission and distribution systems - Testing of thyristor valves for static VAR compensators*

6.2.24 Distribution Management – IEC 61968

Smart Grid Relevance: **Core**

Relevant Application: DMS, DER, AMI, DR

IEC 61968-1, *Application integration at electric utilities - System interfaces for distribution management - Part 1: Interface architecture and general requirements*

IEC/TS 61968-2, *Application integration at electric utilities - System interfaces for distribution management - Part 2: Glossary*

IEC 61968-3, *Application integration at electric utilities - System interfaces for distribution management - Part 3: Interface for network operations*

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2 This document is at PWI (Potential new work item) stage and is not yet published.

IEC 61968-4, *Application integration at electric utilities - System interfaces for distribution management - Part 4: Interfaces for records and asset management*

IEC 61968-9, *Application integration at electric utilities - System interfaces for distribution management - Part 9: Interfaces for meter reading and control*

IEC 61968-13, *Application integration at electric utilities - System interfaces for distribution management - Part 13: CIM RDF Model exchange format for distribution*

IEC 61968: work in progress:

IEC 61968-11 Ed. 1.0 E (CCDV), *Application integration at electric utilities - System interfaces for distribution management - Part 11: Common information model (CIM) extensions for distribution*

IEC 61968-8 Ed. 1.0 E (ANW), *Application integration at electric utilities - System interfaces for distribution management - Part 8: Interface Standard For Customer Support*

6.2.25 Energy management system application program interface (EMS-API) – IEC 61970

Smart Grid Relevance: **Core**

Relevant Application: EMS, DMS, SA

See 6.2.2 Common Information Model – IEC 61970.

6.2.26 Secondary batteries for the propulsion of electric road vehicles – IEC 61982

Smart Grid Relevance: Low

Relevant Application: EV

IEC 61982-1, *Secondary batteries for the propulsion of electric road vehicles - Part 1: Test parameters*

IEC 61982-2, *Secondary batteries for the propulsion of electric road vehicles - Part 2: Dynamic discharge performance test and dynamic endurance test*

IEC 61982-3, *Secondary batteries for the propulsion of electric road vehicles - Part 3: Performance and life testing (traffic compatible, urban use vehicles)*

IEC 61982-4, *Secondary batteries for the propulsion of electric road vehicles - Performance testing for lithium-ion cells and batteries*

IEC 61982-5, *Secondary batteries for the propulsion of electric road vehicles - Safety testing for lithium-ion cells and batteries*

6.2.27 Metering – IEC 62051-54 and IEC 62058-59

Smart Grid Relevance: **High**

Relevant Application: DMS, DER, AMI, DR, Smart Home, Storage, EV

IEC/TR 62051, *Electricity metering - Glossary of terms*

IEC/TR 62051-1, *Electricity metering - Data exchange for meter reading, tariff and load control - Glossary of terms - Part 1: Terms related to data exchange with metering equipment using DLMS/COSEM*

IEC 62052-11, *Electricity metering equipment (AC) - General requirements, tests and test conditions - Part 11: Metering equipment*

IEC 62052-21, *Electricity metering equipment (a.c.) - General requirements, tests and test conditions - Part 21: Tariff and load control equipment*

IEC 62052-31, *Electricity metering equipment (AC) - General requirements, tests and test conditions - Part 31: Safety requirements*[3]

IEC 62053-11, *Electricity metering equipment (a.c.) - Particular requirements - Part 11: Electromechanical meters for active energy (classes 0,5, 1 and 2)*

IEC 62053-21, *Electricity metering equipment (a.c.) - Particular requirements - Part 21: Static meters for active energy (classes 1 and 2)*

IEC 62053-22, *Electricity metering equipment (a.c.) - Particular Requirements - Part 22: Static meters for active energy (classes 0,2 S and 0,5 S)*

IEC 62053-23, *Electricity metering equipment (a.c.) - Particular requirements - Part 23: Static meters for reactive energy (classes 2 and 3)*

IEC 62053-31, *Electricity metering equipment (a.c.) - Particular requirements - Part 31: Pulse output devices for electromechanical and electronic meters (two wires only)*

IEC 62053-52, *Electricity metering equipment (AC) - Particular requirements - Part 52: Symbols*

IEC 62053-61, *Electricity metering equipment (a.c.) - Particular requirements - Part 61: Power consumption and voltage requirements*

IEC 62054-11, *Electricity metering (a.c.) - Tariff and load control - Part 11: Particular requirements for electronic ripple control receivers*

IEC 62054-21, *Electricity metering (a.c.) - Tariff and load control - Part 21: Particular requirements for time switches*

IEC 62058-11, *Electricity metering equipment (AC) - Acceptance inspection - Part 11: General acceptance inspection methods*

IEC 62058-21, *Electricity metering equipment (AC) - Acceptance inspection - Part 21: Particular requirements for electromechanical meters for active energy (classes 0,5, 1 and 2)*

IEC 62058-31, *Electricity metering equipment (AC) - Acceptance inspection - Part 31: Particular requirements for static meters for active energy (classes 0,2 S, 0,5 S, 1 and 2)*

IEC/TR 62059-11, *Electricity metering equipment - Dependability - Part 11: General concepts*

IEC/TR 62059-21, *Electricity metering equipment - Dependability - Part 21: Collection of meter dependability data from the field*

IEC 62059-31-1, *Electricity metering equipment - Dependability - Part 31-1: Accelerated reliability testing - Elevated temperature and humidity*

IEC 62059-41, *Electricity metering equipment - Dependability - Part 41: Reliability prediction*

6.2.28 COSEM – IEC 62056

Smart Grid Relevance: **High**

Relevant Application: DMS, DER, AMI, DR, Smart Home, Storage, EV

IEC 62056-21, *Electricity metering – Data exchange for meter reading, tariff and load control – Part 21: Direct local data exchange*

IEC 62056-31, *Electricity metering – Data exchange for meter reading, tariff and load control – Part 31: Using local area networks on twisted pair with carrier signalling*

IEC 62056-42, *Electricity metering – Data exchange for meter reading, tariff and load control – Part 42: Physical layer services and procedures for connection-oriented asynchronous data exchange*

IEC 62056-46, *Electricity metering – Data exchange for meter reading, tariff and load control – Part 46: Data link layer using HDLC protocol*

[3] This document is at ANW (Approved New Work) stage and is not yet published.

IEC 62056-47, *Electricity metering - Data exchange for meter reading, tariff and load control – Part 47: COSEM transport layers for IPv4 networks*

IEC 62056-53, *Electricity metering – Data exchange for meter reading, tariff and load control – Part 53: COSEM Application layer*

IEC 62056-61, *Electricity metering – Data exchange for meter reading, tariff and load control – Part 61: OBIS Object identification system*. For G, H, W, meters OBIS codes are specified in EN 13757-1 (CEN TC 294); interface objects are common.

IEC 62056-62, *Electricity metering – Data exchange for meter reading, tariff and load control – Part 62: Interface classes*

IEC 62056-62 / 6-61 - IEC 62056-53 Use of GPRS/GSM networks

IEC 62056-62 / 6-61 - Application layer: IEC 62056-53 "Use of IP networks"

IEC 62056-62 / 6-61 - Application layer: IEC 62056-53 "Use of PSTN networks"

IEC 62056-62 / 6-61 - Application layer: IEC 62056-53 "Use of local communication networks"

6.2.29 Fuel cell standards – IEC 62282

Smart Grid Relevance: Low

Relevant Application: DER

IEC/TS 62282-1, *Fuel cell technologies - Part 1: Terminology*

IEC 62282-2, *Fuel cell technologies - Part 2: Fuel cell modules*

IEC 62282-2, Amendment 1, *Fuel cell technologies - Part 2: Fuel cell modules*

IEC 62282-3-1, *Fuel cell technologies - Part 3-1: Stationary fuel cell power systems - Safety*

IEC 62282-3-2, *Fuel cell technologies - Part 3-2: Stationary fuel cell power systems - Performance test methods*

IEC 62282-3-3, *Fuel cell technologies - Part 3-3: Stationary fuel cell power systems - Installation*

IEC 62282-5-1, *Fuel cell technologies - Part 5-1: Portable fuel cell power systems - Safety*

IEC 62282-6-200, *Fuel cell technologies - Part 6-200: Micro fuel cell power systems - Performance test methods*

IEC 62282-6-300, *Fuel cell technologies - Part 6-300: Micro fuel cell power systems - Fuel cartridge interchangeability*

IEC/PAS 62282-6-100, *Fuel cell technologies - Part 6-1: Micro fuel cell power systems – Safety*

6.2.30 Framework for energy market communications – IEC/TR 62325

Smart Grid Relevance: Medium

Relevant Application:

IEC/TR 62325-101, *Framework for energy market communications - Part 101: General guidelines*

IEC/TR 62325-102, *Framework for energy market communications - Part 102: Energy market model example*

IEC/TR 62325-501, *Framework for energy market communications - Part 501: General guidelines for use of ebXML*

IEC/TS 62325-502, *Framework for energy market communications - Part 502: Profile of ebXML*

6.2.31 Security – IEC 62351

Smart Grid Relevance: **Core**

Relevant Application: EMS, DMS, DA, SA, DER, AMI, DR, Smart Home, Storage, EV

IEC 62351, *Power systems management and associated information exchange – Data and Communications Security*

IEC 62351-1, *Power systems management and associated information exchange – Data and Communications Security – Part 1: Communication network and system security – Introduction to security issues*

IEC 62351-2, *Power systems management and associated information exchange – Data and Communications Security – Part 2: Glossary of terms*

IEC 62351-3, *Power systems management and associated information exchange – Data and Communications Security – Part 3: Profiles including TCP/IP*

IEC 62351-4, *Power systems management and associated information exchange – Data and Communications Security – Part 4: Profiles including MMS*

IEC 62351-5, *Power systems management and associated information exchange – Data and Communications Security – Part 5: Security for IEC 60870-5 and derivatives* (i.e. DNP 3.0)

IEC 62351-6, *Power systems management and associated information exchange – Data and Communications Security – Part 6: Security for IEC 61850*

IEC 62351-7, *Power systems management and associated information exchange – Data and Communications Security – Part 7: Network and system management (NSM) data object models*

IEC 62351-8, *Power systems management and associated information exchange – Data and Communications Security – Part 8: Role-based access control*[4]

6.2.32 IEC TR 62357

Smart Grid Relevance: **Core**

Relevant Application: EMS, DMS, DA, SA, DER, AMI, DR, Smart Home, Storage, EV

IEC TR 62357, *Power system control and associated communications – Reference architecture for object models, services and protocols*

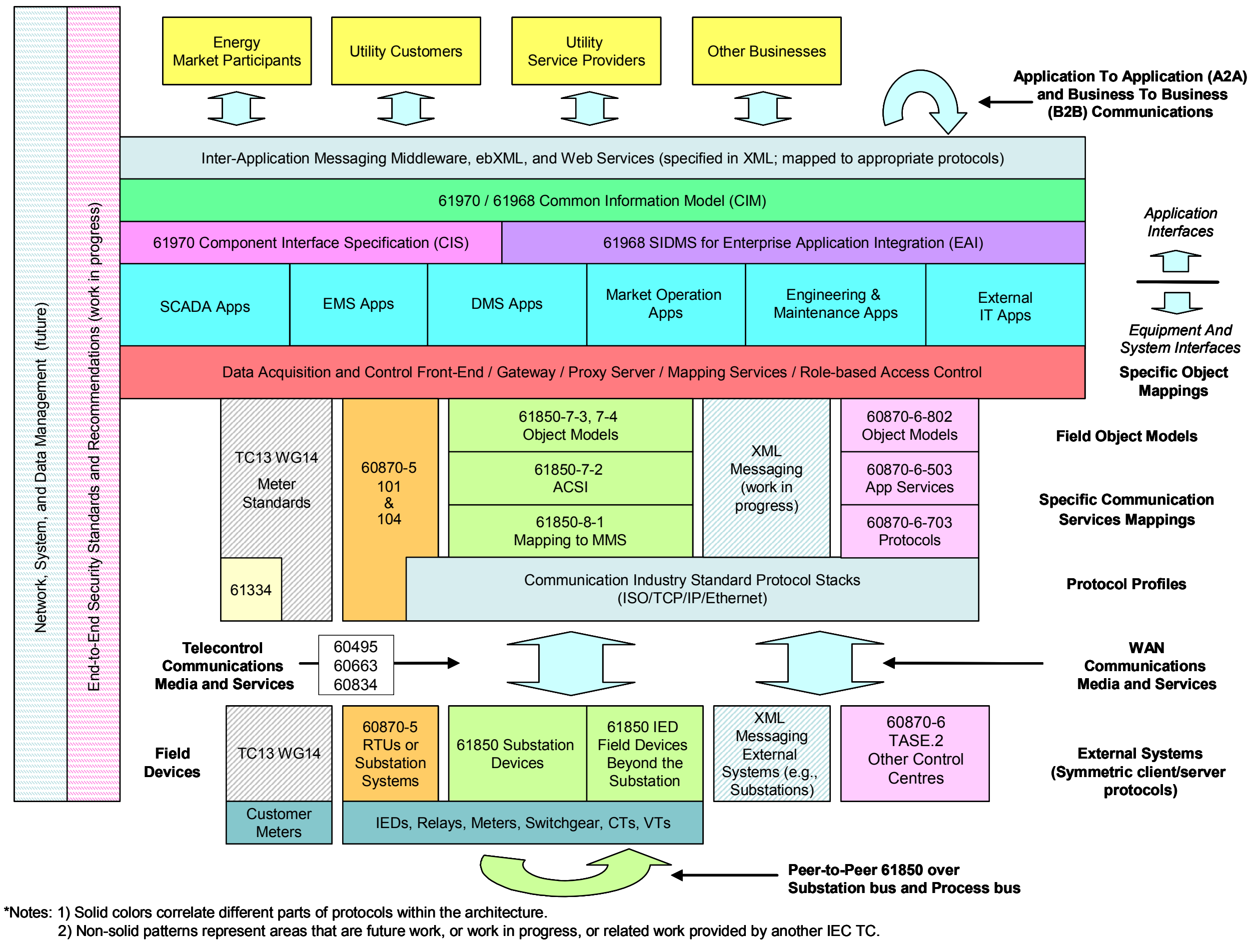
IEC TC 57 develops standards for electric power system control and associated telecommunications in the areas of generation, transmission and distribution real-time operations and planning. The primary purpose of this Technical Report is to provide a reference architecture to show how the various standardisation activities within TC 57 relate to each other and how they individually and collectively contribute to meeting the objectives of TC 57. A second objective is to develop a strategy to combine and harmonize the work of these various activities to help facilitate a single, comprehensive plan for deployment of these standards in product development and system implementations.

The need for this framework is motivated by at least two major factors:

- There are multiple independent standard initiatives that need to be coordinated and harmonized to minimize the need for data transformation to exchange data between systems using these various standards.
- There is a need to have a comprehensive vision of how to deploy these standards for actual system implementation and integration efforts.

[4] This document is at ACDV (Draft approved for Committee Draft with Vote) stage and is not yet published.

There are several different initiatives within TC 57, each dealing with a selected part of the real-time operations and planning. Each has a specific objective and may have sufficient breadth of scope to provide the bulk of the relevant standards needed for product vendors to develop products based on those standards.



*Notes: 1) Solid colors correlate different parts of protocols within the architecture.
2) Non-solid patterns represent areas that are future work, or work in progress, or related work provided by another IEC TC.

Figure 19 – Current TC 57 reference architecture

IEC TR 62357 describes the reference architecture of the TC 57 standard series and describes the interdependencies between the different standards (see Figures 19 and 20).

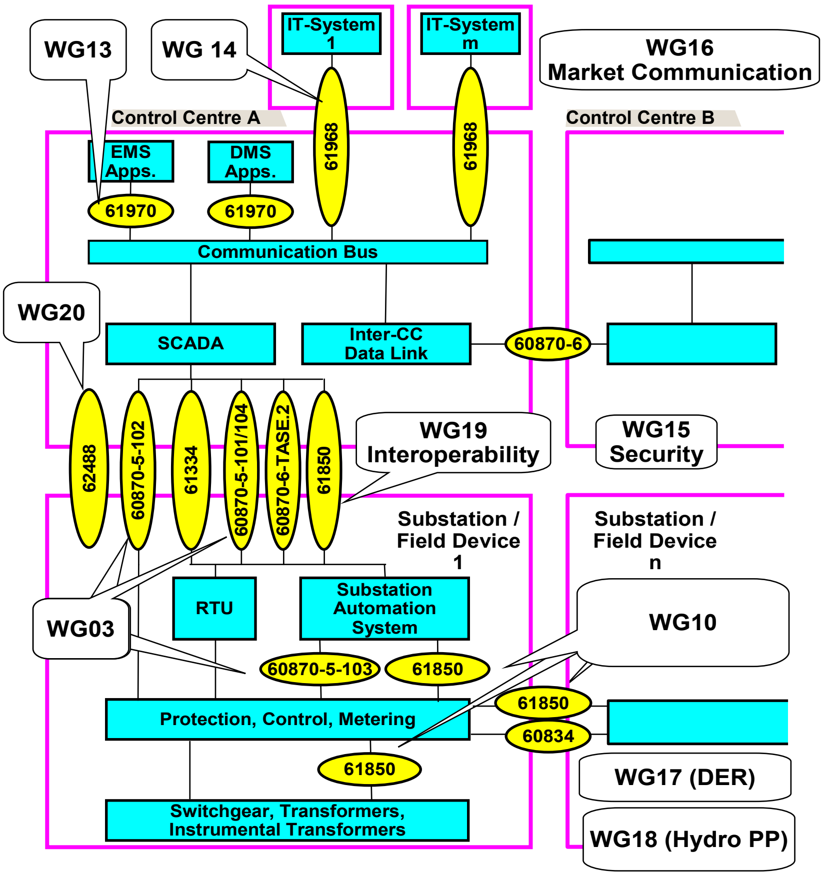


Figure 20 – IEC TC 57 – Overview of standards

6.2.33 High availability automation networks – IEC 62439

Smart Grid Relevance: High

Relevant Application: Various

IEC 62439 is applicable to high-availability automation networks based on the ISO/IEC 8802-3 (Ethernet) technology. It specifies:

- a classification scheme for network characteristics;
- a methodology for estimating network availability;
- a set of communication protocols which realize high availability automation networks via the use of redundancy and which can be used in a variety of applications.

6.2.34 Security of Control Systems – IEC 62443

Smart Grid Relevance: High

6.2.35 Electric Double-Layer Capacitors for Use in Hybrid Electric Vehicles – IEC 62576

Smart Grid Relevance: Low

Relevant Application: EV

IEC 62576, *Electric double-layer capacitors for use in hybrid electric vehicles - Test methods for electrical characteristics*

6.2.36 Marine Power – IEC 62600 series

Smart Grid Relevance: Low

Relevant Application: DER

IEC 62600-1, *Terminology*

IEC 62600-100, *Marine energy – Wave, tidal and other water current converters – Part 100: The assessment of performance of wave energy converters in open sea*

IEC 62600-200, *Marine energy – Wave, tidal and other water current converters – Part 200: The assessment of performance of tidal energy converters*

6.2.37 Functional safety of electrical/electronic/programmable electronic safety-related systems – IEC 61508

Smart Grid Relevance: Low

Relevant Application: DER

6.3 Appendix - Technical Committee / Subcommittee Involvement

Involved TC/SCs are TC 3, **TC 8, TC 13**, TC 21, SC 22F, SC 23F, TC 38, **TC 57, TC 64**, TC 65, TC 69, TC 77, TC 82, TC 88, TC 95, TC 105, and CISPR. The main TC/SCs are marked bold.

TC 3

IEC 81346, *Industrial systems, installations and equipment and industrial products - Structuring principles and reference designations*

IEC 61360, *Standard data elements types with associated classification scheme for electric items*

IEC 61666, *Industrial systems, installations and equipment and industrial products - Identification of terminals within a system*

IEC PAS 62569, *Generic specification of information on products*

TC 8

IEC 60038, *IEC standard voltages*

IEC/TR 62510, *Standardising the characteristics of electricity*

IEC/PAS 62559, *IntelliGrid Methodology for Developing Requirements for Energy Systems*

TC 13

IEC 62051, *Electricity metering - Data exchange for meter reading, tariff and load control - Glossary of terms*

IEC 62052, *Electricity metering equipment (AC) - General requirements, tests and test conditions*

IEC 62053, *Electricity metering equipment (a.c.) - Particular requirements*

IEC 62054, Electricity metering (a.c.) - Tariff and load control

IEC 62056, *Electricity metering - Data exchange for meter reading, tariff and load control*

IEC 62056-21 *Electricity metering - Data exchange for meter reading, tariff and load control - Part 21: Direct local data exchange*

IEC 62056-53, *Electricity metering - Data exchange for meter reading, tariff and load control - Part 53: COSEM application layer*

IEC 62056-61, *Electricity metering - Data exchange for meter reading, tariff and load control - Part 61: Object identification system (OBIS)*

IEC 62056-62, *Electricity metering - Data exchange for meter reading, tariff and load control - Part 62: Interface classes*

IEC 62058-31: *Electricity metering equipment (AC) - Acceptance inspection – Part 31: Particular requirements for static meters for active energy (classes 0,2 S, 0,5 S, 1 and 2)*

IEC 62059, *Electricity metering equipment - Dependability*

TC 21

IEC 61982-1, *Secondary batteries for the propulsion of electric road vehicles - Part 1: Test parameters*

IEC 61982-2, *Secondary batteries for the propulsion of electric road vehicles - Part 2: Dynamic discharge performance test and dynamic endurance test*

IEC 61982-3, *Secondary batteries for the propulsion of electric road vehicles - Part 3: Performance and life testing (traffic compatible, urban use vehicles)*

IEC/NWIP 62619, *Secondary cells and batteries containing alkaline or other non-acid electrolytes - Safety requirements for large format secondary lithium cells and batteries for stationary and motive applications*[5]

IEC 62485-2, *Safety requirements for secondary batteries and battery installations - Part 2: Stationary batteries*

IEC 62485-3, *Safety requirements for secondary batteries and battery installations - Part 3: Traction batteries*

SC 22F

iEC 60633, *Terminology for high-voltage direct current (HVDC) transmission*

IEC 60700-1, *Thyristor valves for high voltage direct current (HVDC) power transmission - Part 1: Electrical testing* (This document and its separate amendments continue to be valid together with the consolidated version)

IEC 60919, *Performance of high-voltage direct current (HVDC) systems with line-commutated converters*

IEC 61803, *Determination of power losses in high-voltage direct current (HVDC) converter stations*

IEC 61954, *Power electronics for electrical transmission and distribution systems - Testing of thyristor valves for static VAR compensators* (This document and its separate amendments continue to be valid together with the consolidated version)

TC 23 Electrical accessories

Electrical accessories for household and similar purposes, the word similar including locations such as offices, commercial and industrial premises, hospitals, public building, etc.

[5] This document is at PWI (Potential new work item) stage and is not yet published.

These accessories:

- are intended for fixed installation, or for use in or with appliances and other electrical or electronic equipment, and may include electronic components;
- are normally installed by instructed or skilled persons and are normally used by ordinary persons;
- include, in particular:
    - conduit systems
    - cable trunking systems
    - cable ducting systems
    - cable support systems
    - switches
    - HBES switches
    - plugs and socket-outlets
    - cable reels
    - adaptors
    - circuit breakers for over current protection
    - devices protecting against electric shock
    - contactors- connecting devices
    - enclosures for accessories
    - appliance couplers
    - cord sets

TC 32 Fuses

Specifications of all types of fuses, with the object of determining:

1. the characteristics which are essential in specifying the conditions for installation and operation of the fuses.
2. the requirements to be met by the fuses and the tests designed to ascertain their compliance with such requirements as well as the procedures to be followed for these tests;
3. markings.

To prepare for these fuses international standards for standard value of :

1. characteristics : rated voltages, currents and breaking capacities;
2. dimensions in connection with the fixing and interchangeability of high-voltage and low-voltage fuses.

TC 38

IEC 61869, *Instrument transformers*

future IEC 61869-7*, Instrument transformers – Part 7: Electronic Voltage Transformers*

future IEC 61869-8, *Instrument transformers – Part 8: Electronic Current Transformers*

future IEC 61869-9, *Instrument transformers – Part 9: Digital Interface for Instrument Transformers*

TC 57

IEC 60495, *Single sideband power-line carrier terminals*

IEC 60834, *Teleprotection equipment of power systems - Performance and testing*

IEC 60870-5-101, *Telecontrol equipment and systems - Part 5-101: Transmission protocols; Companion standard for basic telecontrol tasks*

IEC 60870-5-103, *Telecontrol equipment and systems - Part 5-103: Transmission protocols - Companion standard for the informative interface of protection equipment*

IEC 60870-5-104, *Telecontrol equipment and systems - Part 5-104: Transmission protocols - Network access for IEC 60870-5-101 using standard transport profiles*

IEC 60870-6-1, *Telecontrol equipment and systems - Part 6: Telecontrol protocols compatible with ISO standards and ITU-T recommendations - Section 1: Application context and organization of standards*

IEC 61085, *General considerations for telecommunication services for electric power systems*

IEC 61334, *Distribution automation using distribution line carrier systems*

IEC 61850, *Communication networks and systems in substations*

IEC 61850-6-x, *Communication networks and systems for power utility automation - Part 6: Configuration description language for communication in electrical substations related to IEDs*

IEC 61850-7-2, *Communication networks and systems in substations - Part 7-2: Basic communication structure for substation and feeder equipment; Abstract communication service interface (ACSI)*

IEC 61850-7-4, *Communication networks and systems in substations - Part 7-4: Basic communication structure – Compatible logical node classes and data classes*

IEC 61850-7-410, *Communication networks and systems for power utility automation - Part 7-410: Hydroelectric power plants - Communication for monitoring and control*

IEC 61850-7-420, *Communication networks and systems for power utility automation - Part 7-420: Basic communication structure - Distributed energy resources logical nodes*

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

IEC/TS 62351-5, *Power systems management and associated information exchange – Data and communication security - Part 5: Security for IEC 60870 and derivatives*

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TC 64

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TC 65

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TC 69

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TC 77

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TC 82

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TC 88

IEC 61400-1, *Wind turbines - Part 1: Design requirements*

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IEC 61400-25-1, *Wind turbines - Part 25-1: Communications for monitoring and control of wind power plants - Overall description of principles and models*

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IEC 61400-25-4, *Wind turbines - Part 25-4: Communications for monitoring and control of wind power plants - Mapping to communication profile*

IEC 61400-25-5, *Wind turbines - Part 25-5: Communications for monitoring and control of wind power plants - Conformance testing*

IEC/CDV 61400-25-6, *Wind turbines - Part 25-6: Communications for monitoring and control of wind power plants - Logical node classes and data classes for condition monitoring*

IEC 61400-3, *Wind turbines - Part 3: Design requirements for offshore wind turbines*

TC 95

IEC 60255-24, *Electrical relays - Part 24: Common format for transient data exchange (COMTRADE) for power systems*

TC 105

IEC 62282, *Fuel cell technologies*

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6 This document is at 3CD (3rd Committee Draft) stage and is not yet published.

CISPR

CISPR 11, *Industrial, scientific and medical equipment - Radio-frequency disturbance characteristics – Limits and methods of measurement*

CISPR 22, *Information technology equipment - Radio disturbance characteristics – Limits and methods of measurement*

CISPR 24 for immunity of ITE in SmartGrid control and appliances

CISPR 16 (various parts which include basic RF measurement methods and test instrumentation specifications), may be referenced from other product standards

CISPR 12/25 for vehicles

6.4 Appendix - Abbreviation

AMI	Advanced Metering Infrastructure
AMR	Advanced Meter Reading
ANSI	American National Standards Institute
API	Application Programming Interface
BACS	Building Automation and Control Systems
BMS	Battery Management System
CC	Control Centre
CHP	Combined Heat and Power
CIM	Common Information Model
CIP	Critical Infrastructure Protection
CIS	Component Interface Specification
COMTRADE	Common Format for Transient Data Exchange
COSEM	Companion Specification for Energy Metering
CT	Current Transformer
DA	Distribution Automation
DEMS	Distributed Energy Management System
DER	Distributed Energy Resources
DLMS	Distribution Line Message Specification
DMS	Distribution Management System
DNP	Distributed Network Protocol
DoE	Department of Energy (USA)
DR	Demand Response
DSO	Distribution System Operator
ECP	Electrical Connection Point
EMC	Electromagnetic Compatibility
EMS	Energy Management System (tech.)
ERP	Enterprise Resource Planning
EV	Electric Vehicle
FACTS	Flexible Alternating Current Transmission System
FSC	Fixed Series Compensation
GID	Generic Interface Definition
GIS	Geographic Information System
GOOSE	Generic Object Oriented Substation Event
GPS	Global Positioning System
HAN	Home Area Network
HBES	Home and Building Electronic System
HES	Home Electronic System

HSR	High Availability Seamless Automation Ring
HVAC	Heating, Ventilating and Air Conditioning
HVDC	High Voltage Direct Current
ICCP	Inter Control Center Communication Protocol
IEC	International Electrotechnical Commision
IED	Intelligent Electronic Device
IEEE	Institute of Electrical and Electronics Engineers
IP	Internet Protocol
ISA	International Society of Automation
ISO	International Organization for Standardization
IT	Information Technology
JTC	Joint Technical Committee (ISO/IEC)
LD	Logical Device
LN	Logical Node
LV	Low Voltage
MDM	Meter Data Management
MRP	Medium Redundancy Protocol
MV	Medium Voltage
MWFM	Mobile Workforce Management
NERC	North American Electric Reliability Corporation (USA)
NIST	National Institute of Standards and Technology (USA)
NSM	Network and System Management
OMS	Outage Management System
PCC	Point of Common Coupling
PHEV	Plug-in Hybrid Electric Vehicle
PMU	Phasor Measurement Unit
POD	Damping of Power Oszillations
PPC	Product Properties and Classification
PRP	Parallel Redundancy Protocol
PV	Photovoltaic
RAS	Remedial action Scheme
RTU	Remote Terminal Unit
SA	Substation Automation
SB	Sector Board (IEC)
SC	Sub Committee (IEC)
SCADA	Supervisory Control and Data Acquisition
SCL	System Configuration Language
SDO	Standardization Developing Organization
SG	Strategic Group (IEC)
SIDM	System Interfaces for Distribution Management
SIPS	System Integrity Protection Scheme
SMB	Standardization Management Board
SNTP	Simple Network Time Protocol
SOA	Service Oriented Architecture
SSR	Sub Synchronous Resonances
STATCOM	Static Synchronous Compensator
SVC	Static Var Compensator
TASE	Telecontrol Application Service Element
TC	Technical Committee (IEC)

TCP	Transmission Control Protocol
TCSC/TPSC	Thyristor Controlled/Protected Series Compensation
TNA	Transmission Network Application
UML	Unified Modeling Language
V2G	Vehicle to Grid
VT	Voltage Transformer
WFM	Workforce Management
XML	Extensible Markup Language

6.5 Appendix – Literature

[1] "Report to NIST on the Smart Grid Interoperability Standards Roadmap", EPRI, Jun 17, 2009

[2] "Untersuchung des Normungsumfeldes zum BMWi-Förderschwerpunkt "e-Energy – IKT –basiertes Energiesystem der Zukunft"", Studie für das BMWi, OFFIS, Schwarz Consult, MPC, 2009

[3] European Technology Platform SmartGrids
Strategic Deployment Document for Europe's Electricity Networks of the Future
September 2008; (http://www.smartgrids.eu)

Graphics

Smart Grid Conceptual Model diagrams, sometimes known as the "cloud" diagrams, found in this document, the Smart Grid Roadmap and the NIST Smart Grid Framework make use of a library of licensed commercial icons.

Source: NIST Smart Grid Framework 1.0 Sept 2009