GSGF>>REPORT

SMART_GRID_INTEROPERABILITY

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THE GLOBAL SMART GRID FEDERATION

The Global Smart Grid Federation (GSGF) is committed to creating smarter, cleaner electricity systems around the world. By linking the major public-private stakeholders and initiatives of participating countries, the federation will share best practices, identify barriers and solutions, foster innovation, and address key technical and policy issues. These and other activities help member organisations initiate changes to their country's electric systems to enhance security, increase flexibility, reduce emissions, and maintain affordability, reliability, and accessibility.

The Global Smart Grid Federation also works with the International Smart Grids Action Network (ISGAN) as well as with national and international government policymakers to address the broad challenges of deploying smarter grids. This nexus provides bidirectional communication and collaboration, which will advance smart grids around the world and facilitate consensus-building within the international community to address electricity system and climate change concerns.

EXECUTIVE SUMMARY

The whole energy value chain is undergoing a paradigm shift from a centrally focused, towards a more dynamic, distributed system, where the major challenges can be observed closest to the customer, in the local/distribution area. The vast amounts of distributed and renewable energy sources being integrated into the distribution grids is together with the empowering of customers/development and roll-out of smart metering, the smart Electric Vehicle charging infrastructure and the introduction of distributed energy storage, revolutionising the electricity systems and markets. The development of smart grids is key to reaching a sustainable, competitive and secure future energy economy. The active distribution grids will be augmented with data, information and communication systems in order to monitor, facilitate new services and coordinate energy flows. This creates great challenges for technologies, systems and organisations to operate and work together, with new roles and responsibilities, new business models, new services and products and new social interactions. To make this possible, a high level of system interoperability is needed, to ensure that new products and services can operate in a multi-vendor, multi-standards, local manufacturing and multi-operator environment.

Interoperability has a strong impact on markets, by reducing uncertainty and lock-in effects for consumers, utilities and vendors, reducing first-mover advantages, enabling the market to grow faster and generating more value for the consumer. Interoperability is mainly increased by developing standards and by imposing market regulation/defining and harmonising market models, roles and responsibilities for market players.

There is existing and on-going smart grid interoperability work in many parts of the world and there is a great need for further harmonisation. The basis for smart grid standards and interoperability is the international standard IEC 61850, but mapping exercises have identified at least 25 different definitions of interoperability and more than 530 different smart grid standards. In order to understand and apply the standards, there is a need to further define interoperability.

Standards for three areas – distribution grid management, network communication, and metering infrastructure – have been assessed, regarding current status of the work and the most obvious gaps needed to be managed. Upgradability is crucial, since smart grid development is a step-by-step process and there is a need to be prepared for changes in standards. Even when standards are followed there can be problems when e.g. communicating between components from different manufacturers, thus independent testing organisations for compliance to the standard are crucial.

Market regulation, market models, roles and responsibilities for market players, etc. differ greatly between markets globally. For many of the tasks that are crucial for smart grids, the roles, responsibilities and market regulation are unclear or even missing. There is a need to follow-up on the new roles and services critical for smart grid development, such as demand response, flexibility services, curtailment of distributed renewable energy resources how they are treated by market regulation and that both standards and market regulation are applied for the same smart grid item.

The development of smart grids and the enormously increasing use of information and communication technologies make data easier to access and increases system complexity, thus increases cyber and system security threats. In order to keep infrastructures secure, system architectures should be based on so called Security by Design. Interoperability can add to fundamental security, since well specified interfaces and functionalities will force developers to design their systems well, to which experts can be assigned and tests performed. There are existing basic procedures that should be undertaken in order to secure a system from cyber security issues, but there is a need for a specific advanced security framework for Interoperability.

There is a great need for further work on Interoperability, and this report is recommending a number of specific tasks that should be undertaken, for example by GSGF

- Arranging a workshop/webinars on smart grid interoperability
- Introducing a detailed follow-up study on interoperability and standards work in each country
- Introducing knowledge sharing among members and a follow-up study regarding market regulation, market design, roles and responsibilities
- Introducing knowledge sharing among members regarding cyber/system security and introduces a focused work on a security framework for Interoperability.

CONTENTS

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1 INTRODUCTION

The development of smart grids is key to reaching a sustainable, competitive and secure future energy economy. There is a pressing need to accelerate the development of low carbon technologies in order to address the global challenges of energy security, climate change and economic growth. The whole energy value chain is undergoing a paradigm shift from a centrally focused system towards a more dynamic, distributed system. The major challenges can be observed closest to the customer, in the local/distribution area where the grids will have to evolve from radial and passive towards actively managed meshed grids with distributed generation and active consumers. The vast amounts of distributed and renewable energy sources being integrated into the distribution grids are together with the empowering of customers/development and roll-out of smart metering, the smart Electric Vehicle charging infrastructure and the introduction of distributed energy storage, revolutionising the electricity systems and markets.

The active distribution grids will be augmented with data, information and communication systems in order to monitor, facilitate new services and coordinate energy flows throughout the network to match supply and demand more efficiently and realising more flexibility, needed to integrate the intermittent and sustainable distributed energy generation. These are smart grids, electricity networks that use digital and other advanced technologies to monitor and manage the transport of electricity, coordinating the actions, capabilities and needs of all generators, grid operators, end-users and electricity market stakeholders to operate all parts of the system as efficiently as possible.

This brings about great challenges for technologies, systems and organisations to operate and work together, with new roles and responsibilities, new business models, new services and products and new social interactions. To make this possible, a well identified and improved set of standards, capable of assuring a high level of system interoperability is needed, to ensure that new products and services can operate in a multi-vendor, multi-standards, local manufacturing and multi-operator environment. The distributed architecture of the future needs and the ability to share, aggregate, and execute actions based on data in the field on a near real time basis cannot happen without interoperability. Existing interfaces between systems, actors and organisations will have to change dramatically and new interfaces must emerge between existing and new systems, actors and organisations.

In many parts of the world there are already existing standards and on-going smart grid interoperability work. The Global Smart Grid Federation has introduced a working group on Interoperability and Standards in order to ensure that issues associated with reaching the right cohesion of the ecosystem of technologies, systems and organisations are identified and addressed. This first limited effort, addresses and assesses the interoperability work carried out throughout the world, highlighting good practices and where further work on interoperability is needed.

2 SCOPE AND OBJECTIVE

This introductory activity on interoperability aims to initiate a more strategic discussion on this important issue, by making the issue of interoperability available also outside the very technical and expert oriented standardisation community. The report addresses what interoperability is, why it is so important, and how it provides value. It maps on-going work and already existing frameworks on smart grid standards, highlighting the need for harmonisation, identifying areas where further work on standards and interoperability is needed, where standards are being/should be developed and where other measures are needed, highlighting also some best practices for smart grid interoperability.

The main target group for this work is the members of the board of the GSGF/decision makers in the smart grid community. The existing body of work on (smart grid) standards is very detailed, comprising of many hundreds of pages of text and often highly technical and very complicated. While only a smaller group of experts involved in the work normally understands it to its full extend, the well needed strategic discussions including top management and decision makers normally never take place. The general idea with the GSGF interoperability work is to make this more understandable and, therefore, accessible and opening up the possibility for a more strategic discussions among people not directly involved in the work, since interoperability cannot be resolved in the technical domain only.

Description of work

The document is:

- Describing and defining interoperability and its value, focusing on the customer side/distribution level rather than wholesale and transmission
- Short, limited to 15 pages of text and focused on a few important areas
- Mapping existing and on-going smart grid standards/interoperability activities globally, highlighting differences and needs for harmonisation
- Highlighting status, gaps and further work needed within important focus areas, such as Network communication/ Metering Infrastructure, Distribution Grid Management, Cyber Security and Market Design
- Identifying additional areas where further work on standards and interoperability is needed, where standards are being/ should be developed and where other measures are needed
- Highlighting important barriers and some best practices for smart grid interoperability.

3 DEFINITION OF INTEROPERABILITY

The general meaning of Interoperability is to ensure that new products and services can operate in a multi-vendor and multi-operator environment, defining a strong possibility to interact. The different steps from no interoperability at all to the highest grade of interchangeability are often described according to the International Electrotechnical Commission (IEC) TC65: Incompatibility ➔ Coexistence ➔ Interconnectability ➔ Interworkability ➔ **Interoperability** ➔ Interchangeability.

- **Incompatibility** – the inability of two or more devices to work together
- **Coexistence** – the ability of two or more devices, regardless of manufacturer, to operate independently of one another at the same communications network, or to operate together using some or all of the same communications protocols, without interfering with the functioning of other devices on the network.
- **Interconnectability** – the ability of two or more devices, regardless of manufacturer, to operate with one another using the same communication protocols, communication interface.
- **Interworkability** – the ability of two or more devices, regardless of manufacturer, to support transfer of device parameters between devices having the same communication interface and data types of the application data.
- **Interoperability** – the ability of two or more devices, regardless of manufacturer, to work together in one or more distributed applications. The application data, the semantic and application related functionality of each device is so defined that, should any device be replaced with a similar one of a different manufacture, all distributed applications involving the replaced device will continue to operate as before.
- **Interchangeability** – the ability of two or more devices, regardless of manufacturer, to work together in one or more distributed applications using the same communications protocol and interface, with the data and functionality of each device so defined that, if any device is replaced, any distributed applications involving the replaced device will continue to operate as before the replacement, including identical dynamic responses of the distributed applications.

Interoperability has a strong impact on markets, since it reduces uncertainty and lock-in effects for consumers, utilities and vendors, it reduces first-mover advantages, enables the market to grow faster and generates more value for the customer. Interoperability is mainly developed by:

- Developing standards,
- Imposing market regulation and defining and harmonising market models, roles and responsibilities for market players, etc.

What can be defined as a standard can also often be a part of the market regulation, thus there is a strong link between both and obvious risks of double steering.

Regarding standards, work on smart grid interoperability is on-going throughout the world, within for example the International Electrotechnical Commission (IEC), the European Committees for standardisation CEN/CENELEC/ETSI, the US National Institute of Standards and Technology (NIST), the Smart Grid Interoperability Panel (SGIP). The development of interoperability starts with the system requirements, defined by a domain/a use case (different organisations may have different methods/vocabularies), after which the possible options using already available standards for the different functions are assessed to see if there is an insufficiency and thus a need for standards to be upgraded.

The basis for smart grid standards and interoperability is the international standard IEC 61850, but there are different definitions of interoperability from different standardisation institutions, for example the IEC CIM (61968/61970), often used for common semantics. Further definitions, both in general terms (overall definition) and for a specific domain/use case, are needed and it is important to make the definition easy to understand and apply. The table provides some examples of interoperability definitions.

Standard	Definition
IEC 61850	Interoperability is the ability of two or more devices from the same, or different vendors, to exchange information and use that information for correct co-operation.
TR 50572	The ability of a system to exchange data with other systems of different types and/or from different manufacturers.
ESBII report V3.0 Part 1 def.pdf	Interoperability is: • The ability of a system to exchange data with other systems of different types and/or from different manufacturers. • The capability to communicate, execute programs, or transfer data among various functional units in a manner that requires the use to have little or no knowledge of the unique characteristics of those units.
IEC TC65/920/DC	Interoperability is the ability of two or more devices, regardless of manufacturer, to work together in one or more distributed applications. The application data, their semantic and application related functionality of each device is so defined that, should any device be replaced with a similar one of different manufacture, all distributed applications involving the replaced device will continue to operate as before. NOTE: Manufacturer-specific extensions in field devices or systems from different manufacturers may prevent interoperability.
NIST (http://www.nist.gov/smartgrid/nistandsmartgrid.cfm)	Interoperability—the ability of diverse systems and their components to work together—is vitally important to the performance of the smart grid at every level. It enables integration, effective cooperation, and two-way communication among the many interconnected elements of the electric power grid. To achieve effective interoperability, we must build a unifying framework of interfaces, protocols, and other consensus standards.

Regarding market regulation, and market models, roles and responsibilities for market players, etc., the regulator/governments on supranational, federal and local levels are in charge and thus there are many different regulatory schemes and models throughout the world. Regarding the market models/roles and responsibilities for market players, the models vary from totally regulated on the one hand and public on the other to private, deregulated and many different solutions in between. The different roles on the market – energy generation, transmission network/system operation to distribution network/system operation, possible independent system operation, energy storage, retail/supply and consumer, power exchange, and new market players as energy service companies, aggregators, etc. – are set up in different ways on different markets.

For many of the tasks that are crucial for smart grids development, the roles, responsibilities and the market regulation are unclear or missing on many markets.

4 ON-GOING WORK ON INTEROPERABILITY AND STANDARDS

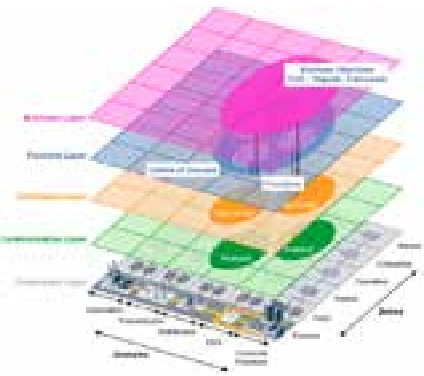
The strong development of smart grids, globally, is pushing the work on interoperability and standards.

The International Electrotechnical Commission (IEC)

The IEC has developed a Roadmap with recommendations and a set of international standards for smart grids, identifying over 100 relevant standards.

CEN/CENELEC-ETSI

The European Commission has issued a mandate (M/490) and requested the European Standards Organisations CEN, CENELEC and ETSI, to develop a framework and perform continuous standard enhancement and development in the field of smart grids, while maintaining consistency and promoting continuous innovation.



The CEN/CENELEC-ETSI work, presented in January 2013, includes a first set of standards, smart grid reference architecture, and definitions of sustainable processes and smart grid information security. The basis for the Smart Grid Architecture Model Framework and the different interoperability levels are shown in picture to the right.

The CEN/CENELEC-ETSI is following-up this work during 2013-2014, with further refinement of the methodology during 2013 and a complementary set of standards during 2014, including prioritisation of new gaps based on identified use cases. In December 2013, an intermediate report on interoperability – "Methodologies to achieve smart grid system interoperability through standardisation, system design and testing" – from the smart grid Coordination Group/Mandate M/490 was published.

Work is also ongoing within the CEN, CENELEC-ETSI on the standardisation of smart metering functionalities and communication (European Commission mandate M/441) and standardisation in the field of electric vehicles (European Commission mandate M/468).

National Institute of Standards and Technology

The US National Institute of Standards and Technology (NIST) is bringing together manufacturers, consumers, energy providers, and regulators to develop interoperable standards for smart grids as a result of Energy Independence and Security Act (EISA) of 2007. NIST has released multiple versions of a Framework and Roadmap for Smart Grid Interoperability Standards. The framework consists of seven domains, see picture below, each of which contains many applications and actors connected by associations, through interfaces.

Domain	Description
Customer	The end users of electricity. May also generate, store, and manage the use of energy. Traditionally, three customer types are discussed, each with its own sub-domain: home, commercial/building, and industrial.
Markets	The operators and participants in electricity markets.
Service Provider	The organizations providing services to electrical customers and to utilities.
Operations	The managers of the movement of electricity.
Bulk Generation	The generators of electricity in bulk quantities. May also store energy for later distribution.
Transmission	The carriers of bulk electricity over long distances. May also store and generate electricity.
Distribution	The distributors of electricity to and from customers. May also store and generate electricity.

In order to carry out its EISA-assigned responsibilities, NIST coordinated the establishment of the Smart Grid Interoperability Panel (SGIP). In 2012, the NIST Framework and Roadmap for Smart Grid Interoperability Standards, Release 2.0 was published, describing the 16 foundational standards for Smart Grids in the U.S.

The Smart Grid Interoperability Panel

The Smart Grid Interoperability Panel (SGIP) – a public/private partnership that defines requirements for essential communication protocols and other common specifications and coordinates development of these standards by collaborating organisations – was established in 2009 to support NIST in its fulfilment of its responsibilities pursuant to the EISA. SGIP's mission is to provide a framework for coordinating all Smart Grid stakeholders in an effort to accelerate standards harmonisation and advance the Interoperability of Smart Grid devices and systems. The SGIP fulfils this mission by facilitating standards development for Smart Grid interoperability, identifying necessary testing and certification requirements, overseeing the performance of these activities and continuing momentum, informing and educating smart grid industry stakeholders on interoperability, and conducting outreach to establish global interoperability alignment. Once SGIP developed a strategy and a structure, it transitioned in 2012 to SGIP 2.0, Inc., a member-funded organization that carried forth its predecessor's original mission.

IEEE smart grid standards

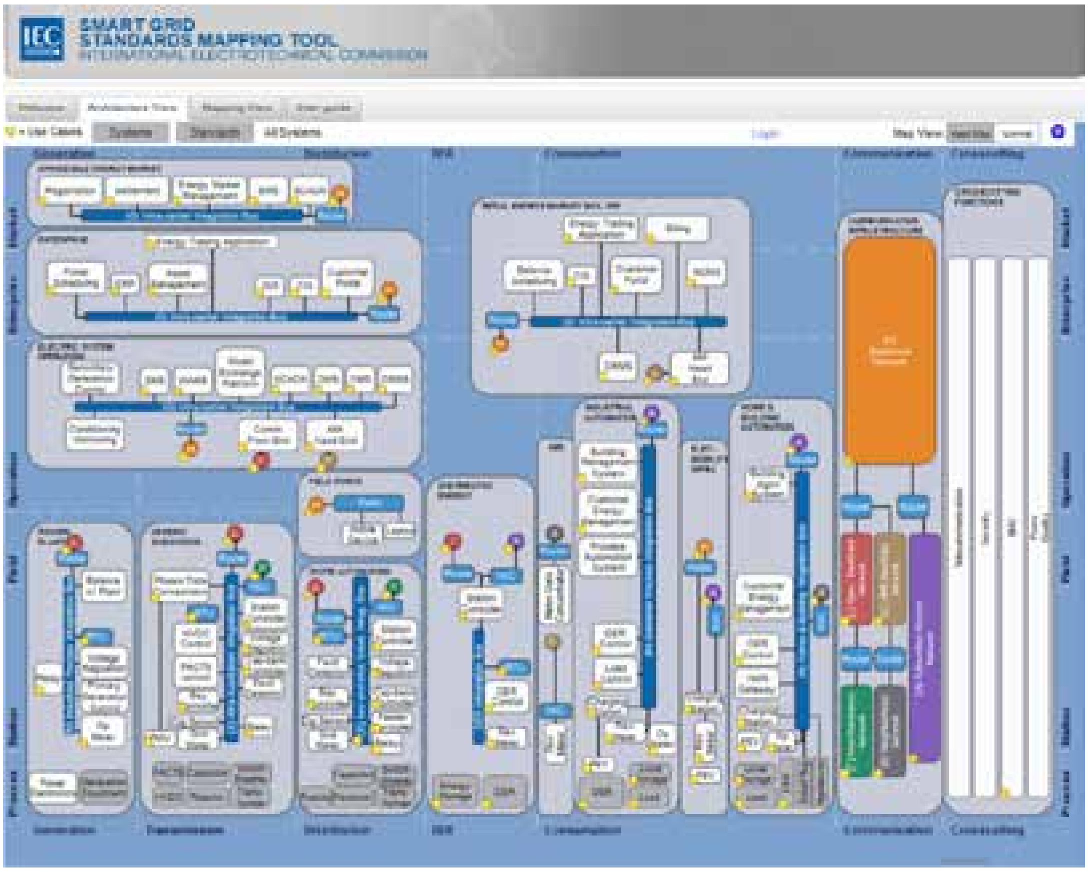
The Institute of Electrical and Electronics Engineers (IEEE) is collaborating with other global standards bodies to effectively facilitate standards coordination and to ensure the intensifying smart grid movement's success. IEEE has more than 100 existing standards and standards in development relevant to smart grid.

Mapping global interoperability and standards

The smart grid architecture is complex and requires a systematic approach to comprehend, explain, document and to use in practice. The complexity of smart grid architecture is further compounded by its dynamic nature and ever changing solution landscape. Currently, at the highest level of architecture, there are many technology/business clusters/use cases encompassing over 190 components interacting and interfacing together. Work on smart grid standards and interoperability is on-going throughout the world and more than 530 different smart grid standards have been identified.

Smart grid standards from all over the world have been gathered in existing and on-going work, in order to make it easier to understand and apply. Two examples are the IEC smart grid standards mapping tool and the matrix gathered within the on-going CEN/CENELEC-ETSI interoperability work:

- An intermediate CEN/CENELEC-ETSI interoperability report on "Methodologies to achieve smart grid system interoperability through standardisation, system design and testing" was published in December 2013, mapping more than 530 different standards important for the development of smart grids.
- The International Electrotechnical Commission (IEC) smart grid standards mapping tool, where at present 273 smart grid standards have been mapped, see picture below.



The value of participation in standards development and interoperability

Interoperability is crucial for the industry, but there is a great value also seen from the perspective of organisations/companies and the individual/the employee. E.g. as defined by SGIP 2.0, Inc.

Industry:	More efficient and effective deployment of technologies and best practices Accelerated realisation of benefits, including cyber security Improved regulatory treatment for investment recovery
Organisations:	Ensuring influence in shaping smart grid standards and policy Providing an influential voice in discussions and debates Enhanced commercial opportunities worldwide
Employees:	Growing your network and increasing your knowledge base Personally influencing potential game-changing issues and decisions Staying competitive, informed and well connected.

5 INTEROPERABILITY ASSESSMENT

The deployment and implementation of smart grids is and will be an incremental step-by-step process, strongly characterised by different main objectives and starting points in different countries and regions around the world. Since this is a process in development, there is a great need to also take into account interoperability with legacy products. To be prepared for changes to standards, systems and devices need to be extensible and upgradeable. This is important not only in terms of how standards are written, but also with regard to how much room (code space, RAM, etc.) to grow in deployed devices.

Standards are mostly relevant for and mostly initiated by vendors/manufacturers, while interoperability (e.g. between components from different vendors) is mostly relevant for and mostly initiated by the users. By developing a (standardised) methodology for reaching interoperability this must be recognised by all parties involved in the process from system design to full system operation.

Interoperability can be assessed in many different areas, for example: peak load management, SCADA systems, geographic information system (GIS), asset management, network operation, system security requirement, metering, billing, etc. In order to assess the present situation and the way forward, the status of interoperability is highlighted in a couple of the very important areas; distribution grid management, network communication, metering infrastructure, cyber security, market design, regulatory frameworks, and from the strict view of the manufacturer.

5.1 Distribution grid management/network communication/Metering Infrastructure

Standardisation is crucial for economic growth, eliminating barriers and encouraging innovation, enhancing productivity and shaping market structures. There is a great need for standards within different areas to ensure real interoperability, providing market penetration and customer convenience.

Due to major differences in network topology and technologies e.g. transformers, there is a huge variety of physical media for communication (e.g. PLC, wireless mesh, cellular, etc.). The main carrier in Europe is PLC, accounting for around 80% of the communication, but also the internet protocol (IP) for "internetworking" is used, which allows applications to only worry about the IP layer and not the underlying physical medium (not taking into account cyber security challenges). IP standards are becoming more and more adopted and have been proven in other industries, particularly for internetworking and cyber security.

For example regarding Advanced Metering Infrastructure (AMI) and other applications and services, the amount and types of data may flood into data storage, generating unprecedented data volume, speed and complexity. Thus, it is necessary to look at new technologies capable of high-volume data management and advanced analytics designed. Considering the volume and complexity of real-time system data, its value cannot be fully exploited by existing statistical/data analysis techniques. Big data analytics, which can efficiently retrieve useful information from a huge amount of data with minimum human intervention, can be a useful tool for benefitting from real-time system data. This direction can form new work for interoperability, i.e. smart grid big data management and analysis.

Regarding market design, although there are varying degrees of unbundling in energy markets globally, the European case makes overcoming the split-incentive problem evident. With competition also on the retail market combined with unbundling between on the one hand generation and supply of energy and on the other transmission (ownership unbundling) and distribution (functional and legal unbundling), make the situation for the European distribution system operator – the key player for the smart grid development – different from other parts of the world.

There is a need for standards in the areas of network management, integration of new usage to the grid and regarding markets and customers. These are the important areas and the related standards.

Area	Standard
Network Management • Electromagnetic compatibility and power quality • Advanced network operation and control (fault identification and self-healing, advanced network automation, Volt/Var/Watt control) • Smart metering and power line communication	IEC 61000 series, IEC 61968/61970/62325 (CIM), IEC 61850 series, IEC 60870 series, IEC 62689 series, IEC 62351 series, IEC 60255 series, ANSI C12 series, IEEE 1901 series
Integration of new usage to the grid • Distributed generation • Electric vehicles • New usage (storage, heat pumps, etc.)	EN 50438, IEC 61850 series, TS 50549-1 & 2, ISO/IEC 15118, IEC 62786, IEC 61851, IEEE 1547, SAE J2836, SAE J2847, SAE J2931, SEP 2.0
Markets and customers • Enabling the DSO to act as market facilitator/grid optimiser • Developing demand response and demand side management • Aggregating distributed energy resources and e-mobility • Balancing the power grid	IEC 61968/61970/62325 (CIM) IEC 62056 (DLM/COSEM), IEC 61850 series, SEP 2.0, Open ADR, etc.

Analyses of on-going work and gaps

Work is on-going, but there are still considerable gaps regarding standards related to smart grids. As of June 2013, these are the important areas with the relevant status highlighted:

Description of work	Status
Feeder and advance distribution automation Ensure increased automation of medium voltage networks.	* *Further work needed*
Connecting DER to the grid Guidance when connecting distributed energy resources to the grid. See also WG of GSGF on this matter	*Work on-going in the right direction. Coordination needed with EU regulation on network codes! In the US, work has been accomplished in IEEE 1547*[1].
Reviewing of existing EMC standards Further work on electromagnetic interference between electrical equipment/systems.	*
Communication between control centre and substation Creating WAN technology guidelines for IEC 61850.	*Work on-going in the right direction.*
Harmonised glossary, semantics and modelling Aligning glossaries and data modelling between control centres and field applications.	*
Harmonisation between IEC 62056 series (DLMS/COSEM) data model and IEC 61850/CIM The exchange of metering data and tariff information is fundamental to the implementation of smart grids.	*Work on-going in the right direction.*
Smart grid communication standards relying on the Internet based standard Web Services & harmonisation with CIM and IEC 61850	*Work on-going in the right direction.*
Extended field data modelling standard (part of IEC 61850) to support demand response, DER, VPP and home/building/industry automation	*
From Smart metering to smart grid, and e-mobility Ensuring harmonisation with existing metering models and other relevant standardisation initiatives related to smart grids.	*
Harmonise activities on data transport technologies Extending the frequency range and define supported protocols.	*
Develop cyber security around IEC 62351 Information processing systems are exposed to an increasing number of threats and vulnerabilities.	*Work on-going in the right direction.*
Smart metering data to building system interface	*Work on-going in the right direction.*
Electrical installation allowing DER installation New safety and protection issues.	*Work on-going in the right direction.*
Review EMC and Power Quality levels Reviewing EMC and power quality levels and measurement methods.	*Work on-going in the right direction.*
Consider distorting current emissions from DER equipment Standardise how to give a limitation to the distorting current emission by DER equipment.	*

[1]The focus of the IEEE P1547a - Amendment 1 WG is limited to establishing updates to voltage regulation, response to area electric power systems abnormal conditions of voltage and frequency, and considering if other changes to IEEE Std 1547 are absolutely necessary in response to the updates that are established under preceding topics of the amendment.

The development of smart grid standardisation is very time consuming, and apart from the difficulty to find consensus on standards between different markets and players, an important obstacle is the lack of experts to involve in the work due to the many are as in need of standardisation. It is of great importance to clearly prioritise the standards to focus on.

5.2 Interoperability from the view of the manufacturer

The development, building and realising of technologies in the energy sector is a global market. Large firms are active all over the world in this field, providing solutions, components and installations. No individual manufacturer can create a smart grid system by himself. There are always sub-contractors and a diverse set of different manufacturers needed to provide a smart grid. In the large majority of cases, the ordering client will need to find a wide variety of different manufacturers delivering components for smart grids. In order to integrate components, systems and technologies, there are several challenges:

- Protocols defined between the different components, systems, technologies and actors communicate together in order to ensure that the new smart grid solutions interoperate. The supplier's implementation of a protocol should be tested by an independent testing organisation for compliance with the standard. Interoperability of the supplier's technical components with other supplier's components for the same protocol can only be tested and verified by participating in an industry "plug fest", where components from different suppliers are interconnected and communicate with each other.
- Defined format in which the data can be sent and received between the interacting components, technologies and systems.
- Most of the technologies, products and services are being ordered locally, so there are a huge and wide variety of different standards for a specific and local solution. This hinders the access to information on these solutions (locally) and prevents economies of scale (e.g. differing standards from ANSI and IEC on metering).
- Manufacturers of smart grid technologies face difficulties finding testing facilities which are approved by (local) utilities.

Testing is a key step to guarantee that different components from different vendors can be used together blanco to build a system; compliance tests guarantee compliance to the specific standard, and even more important, conformance tests guarantee that the total system is working well and according to specifications.

5.3 Market Design

An important cornerstone of interoperability is the design of the market and the roles and responsibilities of the market players. The introduction of competition and market integration has changed the way we look at the energy value chain. The very strong development of the distributed renewable energy sources has resulted in a paradigm shift. The market design, regulatory frameworks and the different roles in the market differ greatly between the markets globally. This is also strengthened by the different starting points and time schedules for deregulation, privatisation, market integration, and development in different regions, countries and companies. Before even starting to address harmonisation, there is a great need for a clear setup of the market, roles and responsibilities in order to lay down a good basis for (cost) efficient development and added values for consumer and society. One example is the differences between the energy markets in the U.S. and the EU, and thus the impact on efficient smart grids development and deployment, with (as in the EU) and without retail market competition and unbundling between generation/retail/supply and distribution. While business cases for smart grid technology and tools can be quite straight forward in most U.S. markets, the regulator needs to be involved in almost every business case involving smart grid development in the EU markets, given the strong smart grid focus on the distribution system operator and the retail market competition and unbundling.

So far the energy systems/markets have been mostly defined by technology push, but in order to reap the full benefits of the market and smart grid development, policy and decision makers will also have to focus on how to accelerate market pull – how to set up the electricity (energy) (retail) markets in order to engage also customers and how to regulate the distribution system operators to incentivise investments in smart solutions beyond only the traditional approach of investment in firm capacity. The paradigm shift we will see when smart grid technologies are being implemented onto the primary infrastructure of electricity transmission and distribution will not only affect the technological aspects of the system, it will have a profound impact on the entire value chain, from generation and transmission, to distribution, supply/retail and consumption. The implementation of smart grid technologies will have to be combined with a top down approach with clearer definitions on market design, roles and responsibilities across the value chain. This will increase interoperability and decrease uncertainty for investors and market players, benefitting customer and society.

Several aspects will have to be addressed in the process of defining the future value chain, such as the extreme need for flexibility/flexibility services at local level, the real empowerment also of smaller consumers, with smart meters and demand response, other new grid users such as energy storage utilities, and new market players like aggregators and energy service companies.

Demand Response

The energy systems across the world are set to undergo a profound transformation in the coming decades. The large-scale integration of intermittent renewable sources of energy coupled with the development of the smart grids will necessitate the utilisation of demand side resources (DR) – by establishing a market where the end-customer and the grid-operators can act as intelligent partners. This will create benefits for the system, the market and of course for the consumer. Increased efficiency of asset utilisation, supporting greater penetration of renewables on the grid, easing capacity issues on distribution networks to facilitate further uptake of distributed generation on congested local networks, reducing the required generator margin and costs of calling on traditional reserve - including the associated environmental benefits. DR creates a reliable, repeatable and clean source of flexibility. One example from the U.S. highlights that 29.5 GW of demand side resources are under control and available to market participants, lowering the number of peaking plants and increasing efficiency. Canada, Australia, South Korea and Japan also have significant levels of participation. Reduced bills and avoided/ postpone investments (referring to U.S. market, where companies and homeowners already are benefitting from DR, mostly linked to the balancing and capacity markets). This could be developed even more and be made available in other countries.

Establishing appropriate framework conditions in the form of regulation and market structures enable the end-customer to participate effectively in the electricity market is essential for achieving the future low-carbon energy system.

Aggregators

Aggregators, or sometimes called energy service companies, are acting as intermediaries between their clients (energy customers or generators) and the value chain in the energy sector. Unlike the retailing of energy, they provide "energy services", using data from automated metering infrastructures and converting this into information on a customised basis. As with the roles and responsibilities of the previous mentioned market actors within the energy value chain, the regulatory framework often prevents these roles from being exercised. At the same time, it is important to know that the introduction of these new intermediaries is creating further need for flexibility, since these activities, evolving in the context of the internal energy market, are not taking grid constraints into account and can lead to local grid congestion and imbalances between supply and demand.

Energy storage

The already mentioned profound changes in the energy system will lead to the need to increase the flexibility throughout the system. As the generation of renewable energy resources is intermittent, generation is becoming less predictable. Several IEA roadmaps have identified energy storage technologies as being instrumental in facilitating the management of increasing amounts of wind, solar PV, and concentrating solar power (CSP) technologies. Storage allows for the temporal decoupling of energy supply and demand, in essence providing valuable flexibility to system operators. In Europe the Grid+ project has performed mapping and analyses of European storage projects of existing and on-going large as well as distributed energy storage projects. These technologies are often overlooked in energy policies and limited by unsuitable regulatory and market conditions that prevent them from receiving appropriate compensation for services provided. See also other GSGF WG report!

Active network management – flexibility services

Characteristics for the network areas are varying considerably: different voltage levels, network topologies, differences in network operation, the level of penetration of distributed energy resources (DER), geographic distribution of the resources, different generation and demand characteristics, etc. Starting from regions which face a substantial penetration of DER and many small-scale "prosumers", DSOs have to resolve network congestion and voltage challenges increasingly, both in the planning and the operational phase. The need for flexibility is increasing and the DSOs have to operate more complex systems requiring additional market facilitation services as well as procurement of flexibility services; reserve capacity, curtailment of RES, DR, and possible energy storage to manage the core task of maintaining secure energy supply and quality of service.

This activity of procuring flexibility services does not fit within most of the existing regulatory frameworks across the globe. Linked to this is the need to clearly define the different roles and responsibilities the market, between the regulated and non-regulated entities as well as between TSOs and DSOs.

5.4 Regulatory frameworks

The market regulation, market models, roles and responsibilities for market players, etc. is different in different markets. The regulator or the government on supranational, federal or local levels are responsible and thus there are many different regulatory schemes and models throughout the world. Different markets have different degrees of unbundling between the competition and regulated business. The energy and climate objectives and the deregulation and integration of energy markets are together with the development of smart grids, causing changes to the division between private and public activities and the different roles of the market players.

A key beneficiary of smart grids is the private sector introducing and selling new technology, products and services to utilities and customers. In order to implement smart grid technologies, huge investments are needed. The European Commission calculation that €1 trillion of investments are needed over a ten year period, of which €400 billion in the electricity and gas distribution networks. In order to make it possible to reach these investments needed, the possibility for DSOs to invest in smart solutions also beyond firm capacity/copper should be introduced in the regulating frameworks. Since there is a great need to test new solutions in large scale demonstrations, also investing in research, development and demonstration should be taken into account.

For many of the tasks that are crucial for smart grids and the functioning of the retail market, such as demand response, flexibility services, curtailment of distributed renewable energy resources the roles, responsibilities and the market regulation are unclear or missing.

5.5 Cyber/system security

The application and use of information and communication technologies in smart grids is increasing enormously, resulting in new threats having to be met, easier access to data (via the internet) and greater complexity (no one can have the total overview any longer). Disturbances to, or even destruction of electricity grids would have a serious impact on economic and societal functions. In order to keep the infrastructures resilient we have to invest in/build our systems using secure and resilient architectures.

With respect to cyber security, there are two different approaches to interoperability. A proprietary, one-vendor system is generally more consistently designed and offers less attack surface. By opening up interfaces and making specifications publically available, the system becomes transparent and open, and the interfaces may be available for attackers (a good negative example here is the PC architecture – opening up computers to general purpose machines with third party applications has created an enormous drive for the technology, while at the same time increasing cyber security issues). Finally, getting more parties involved in a system increases complexity and makes it harder to keep the overview. Numerous systems have shown to be vulnerable because every participant has assumed security is being taken care of by others.

At the same time, if well designed, interoperability adds to fundamental security. Having well specified interfaces and functionality forces developers to design their systems well, and allows to assign experts to develop and test the systems. A good positive example is encryption algorithms, where the (interoperable) standardised AES algorithm has withstood massive reviews and testing without any issues, while proprietary solutions routinely fail. In addition, interoperable systems create an ecosystem where components are replaceable and (ideally) available from several vendors. While this does increase the probability that an individual component has vulnerabilities, it similarly decreases the reach of an attacker, and allows replacing components that are insecure. Furthermore, interoperability require interfaces to be designed for upgradability, allowing the overall system to continuously evolve to higher security levels in a natural way.

For interoperability to best play out its advantages, it is necessary to design the system well from an early start on – "security by design". This requires a well-defined overall security architecture, clear responsibilities, documented trust models and assumptions, and ideally an assurance scheme that monitors the quality of the implementations. On a more technical level, it requires security experts to be involved in the system specification and implementation, and assisting manufacturers with the appropriate tools. Most importantly however, it requires vision and determination of business leaders to incorporate interoperability in their business plans and drive interoperability into organisation, processes and products.

Two basic elements should be undertaken in order to secure a system from cyber security issue digital protection impact assessment and best practices.

Data Protection Impact Assessment

When building a smart grid it should always undergo a structured review disclosing potential risks. This procedure is normally known as a Data Protection Impact Assessment (DPIA) and is linked with a number of important benefits:

- Understanding the major risks at an early stage.
- Preventing costly adjustments in processes or system redesign by mitigating privacy and data protection risks
- Reducing the impact of law enforcement and oversight involvement
- Improving the quality of personal data, service and operation processes, decision-making regarding data protection, the feasibility of a project
- Raising privacy awareness within the organisation
- Strengthening confidence of customers, employees or citizens in the way which personal data are processed and how final customer privacy is respected.

It should be noted that the end-consumer only benefits from the actions that are taken after a DPIA is implemented, not from the assessment itself. It is of essence that the DPIA is an integral part of risk management and/or has a structural place in all projects, programs or processes and as such needs to be performed at an early stage, during the design of new applications or systems (security by design). Relevant internal and external stakeholders should be actively involved in the assessment and it should be future oriented to support the identification of privacy risks before the usages of new applications or implementation of new programs. The DPIA is not – and shouldn't be – used as a static document but has to be adjusted during a project (especially when privacy risks are changing).

Best Practices

The reviewing of the Best Practices in the field of cyber security on smart grids is a continuing process, due to the nature of science, technology and privacy levels considered as being protectable. This means that best practices need to be periodically reviewed and, if necessary, updated accordingly. The precise process as well as detailed steps to be performed, amendments to be made, etc., should be continuously monitored within a so-called BPRD (Best Practices Review Document). A BPRD is a document drawn up for defined activities describing, for instance, the installation, operation, and maintenance of smart metering systems. Therefore, by definition, a BPRD is a descriptive document and it does not prescribe the use of specific techniques or technologies. To serve its main aim and ensure its user-friendliness, the content of the BPRD should be limited to the relevant information.

The best way to search for Best Practices is to start by defining the requirements the smart grid should fulfil and describe them in detail. Below an example regarding "smart meter readings to the customer": *Definition: (a) Provide meter reading to consumers, store and manage their data and provide in a neutral, non-discriminatory way for data to the commercial market* *players (with the customer's consent) so they can offer services and products to the customers. (b) This can be done in a closed system, including the meters (at the customer's premises) and the data hub (with the DSO). The "real time" data is delivered to the customer (exclusively) via the meter (or via another channel), (only download of data). The market players can retrieve data from the data hub (only upload). All interfaces and protocols are standardised.*

6 CONCLUSIONS

Smart grid development brings huge investment needs and introduces huge amounts of data, information and communication systems for monitoring, automation, the facilitation of new services, etc. This brings about great challenges for technologies, systems and organisations to operate and work together, with new roles and responsibilities, new business models, new services and products and new social interactions. To make this possible, a high level of interoperability is needed. Existing interfaces between systems, actors and organisations have to change dramatically and new interfaces to emerge.

Interoperability has a strong impact on markets, since it reduces uncertainty and lock-in effects for customer, utilities and vendors, it reduces first-mover advantages, enables the market to grow faster and generates more value for the customer. Interoperability is mainly developed by developing standards and by imposing market regulation/defining and harmonising market models, roles and responsibilities for market players.

Standards

There are existing and on-going smart grid standards and interoperability work in many parts of the world but there is a great need for further harmonisation. Even if the cooperation between standardisation organisations is increasing, there is much room for improvement:

- The basis for smart grid standards and interoperability is the international standard IEC 61850, but in order to understand and apply it, there is a need to further define interoperability, both in general terms and for a specific domain/use case – 25 different definitions have been found
- Mapping exercises, have identified more than 530 different smart grid standards
- Standards for three areas – distribution grid management, network communication, and metering infrastructure – have been assessed, along with the current status of the work and the most obvious gaps needed to be managed – standardisation is very time consuming, one important obstacle being the lack of experts to involve in the work
- Smart grid development is on-going around the world as a step-by-step process, and so there is a great need to be prepared for changes to standards, so called upgradability is crucial
- Even when standards are followed there can be problems when e.g. communicating between components from different manufacturers, thus independent testing organisations for compliance to the standard is crucial.

Market regulation, roles and responsibilities

Market regulation, market models, roles and responsibilities for market players, etc. differ greatly between markets globally. For many of the tasks crucial for smart grids (and the functioning of the retail market), the roles, responsibilities and market regulation are unclear or missing. There is a need to follow-up on the new roles and services critical for smart grid development, such as demand response, flexibility services, curtailment of distributed renewable energy resources, and the way they are treated by market regulation. In many areas, either standards or market regulation can be applied for the same smart grid item.

Cyber/system security

The development of smart grids and thus the enormously increasing use of information and communication technologies makes data easier to access and increases system complexity, and therefore also cyber and system security threats. In order to keep the infrastructures secure, systems need to be designed based on secure and resilient architectures (so called Security by Design). Interoperability can add to fundamental security, having well specified interfaces and functionalities. It forces developers to design their systems well, to which experts can be assigned and tests performed. There are so far two basic procedures that should be undertaken in order to secure a system from cyber security issues – Digital Protection Impact Assessment and Best Practices. But it is only in the beginning developments here – an advanced security framework is needed for Interoperability.

Recommended further work

There is a great need for further work on Interoperability, and this report is recommending a number of specific tasks that should be undertaken.

- In order to use the knowledge and ideas gathered, *it is recommended that the GSGF arranges a workshop/webinars on smart grid interoperability.*
- Interoperability varies considerably between different GSGF member countries and the representative organs such as IEC, CEN-CENELEC-ETSI, NIST and SGIP. *It is recommended that the GSGF introduces a follow-up detailed study, to follow up interoperability and standards work in each country.*
- Market regulation, market design, roles and responsibilities vary between the different GSGF countries. For many of the tasks that are crucial for smart grids, the roles, responsibilities and the market regulation are unclear or missing. *It is recommended that the GSGF introduces knowledge sharing among its members on this and a follow-up study to go more in detail.*
- Cyber/system security is of great importance for all GSGF members. *It is recommended that the GSGF introduces knowledge sharing regarding cyber/system security between its members and introduces a focused work on a security framework for Interoperability.*

Other further work of interest

- There is a need to perform a detailed study of the works by standardisation organisations like IEC, CEN/CENELEC-ETSI, NIST, SGIP, IEEE, etc. There is a need for more qualified experts and considerable time.
- It would also be of interest to analyse so called Killer Applications (applications that are so necessary that they prove core value) in order to achieve the goal for smart grids, such as energy storage, DR, DER curtailment, etc.

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