Conceptual assessment of smart meters compatibility levels

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***Abstract*— In the context of emerging technologies and increased consumer awareness, device interoperability and portability is becoming one of the most important features in today's market. A study based on the level of interoperability as defined in the SGAM for commercially available smart meters is conducted in this paper. The findings focus on available information for the communication layer of smart meters and propose a set of interoperability levels based on communication performances and dynamic behaviour.**

***Keywords*: smart meters, interoperability, reference architecture**

I. Introduction

The emergence of cutting-edge technologies shaping the future communities influences the development of cross-domain services while impacting the technology deployment in some fields based on previous end-user experience/perception. Everyday life provides a multitude of good examples of technologies becoming mainstream features based on their adaptive capacity. Devices based on USB protocol may be the best example of ubiquitous presence based on its large applicability, versatility and continuous development. Service level approach leads us to digital cellular networks promoting access to interactive environments and a seamless experience based on number portability. All these existing and promised interaction shapes the need for walking through different domain technologies without constraints.

Energy supply - as key part of today's society - progresses towards a shared approach in providing interactions with the end users. An important step is the large-scale deployment of smart meters [1] that allow bidirectional and real time exchange of information.

As the consumer has access to detail it becomes aware of the available options to use electrical energy efficiently and maybe maximize the benefits taking advantage of the liberalized energy markets. To access this opportunity, technology providers, face the necessity of developing devices that meet a series of requirements [1] including standardization and interoperability.

The capacity of multiple devices from vendors to use and exchange data efficiently is defined as interoperability [2].

Because the set of standards is a path towards seamless interoperability [3], standardization is required between all layers of interoperability within Smart Grids – communication, information, function and business.

The objective of the study presented in this paper is to assess Smart Metering infrastructure interoperability. A technological approach was used based on specific standards and protocols for interfacing objects within the system and following the levels proposed in SGAM [3].

The paper is organized in sections as follows Section II deals with the Smart Grid Architecture Model while Section III describes the proposed interoperability levels for smart meters.

II. Smart Grid Architecture Model

The European Commission ordered standard organizations to develop a reference architecture facilitating the creation of rules for design and analysis of Smart grid solutions. The Smart Grid Architecture Model (SGAM) is a representation of Smart Grid solutions and is popular among Smart Grid stakeholder (utilities and research institutes) [3]. SGAM has been developed as part of the reference architecture framework specified in EU Mandate M/490 [4]. SGAM defines a four-layer architectural approach alongside with concepts and a mapping tool for use cases (Figure 1).

In all smart grid topics beyond interoperability aspects, interchange-ability is the new goal of technical and commercial arrangements to maintain the fictional integrity when switching suppliers or replacing devices. Beyond interoperability, interchange-ability implies the same functional behaviour on devices communication interfaces for relevant communication protocol(s) [5]. Thus, interchange-ability deals with several additional conditions concerning the functional behaviour of devices at their communication interfaces. To achieve Smart Grid interoperability requires the use of standards in data acquisition, data exchange, data storage, data model and data behaviour (profiles). One of the reference models which address interoperability based on the architectural approach in Smart Grids is SGAM [3]. Applying these architectural principles and concepts the set of standards to be considered for each layer as follows:

- Business layer - architectural design compliant with the business model;
- Function layer - data behaviour;
- Information layer - data storage, data model;
- Communication layer - data acquisition, data exchange, data access;
- Component layer - devices, components.

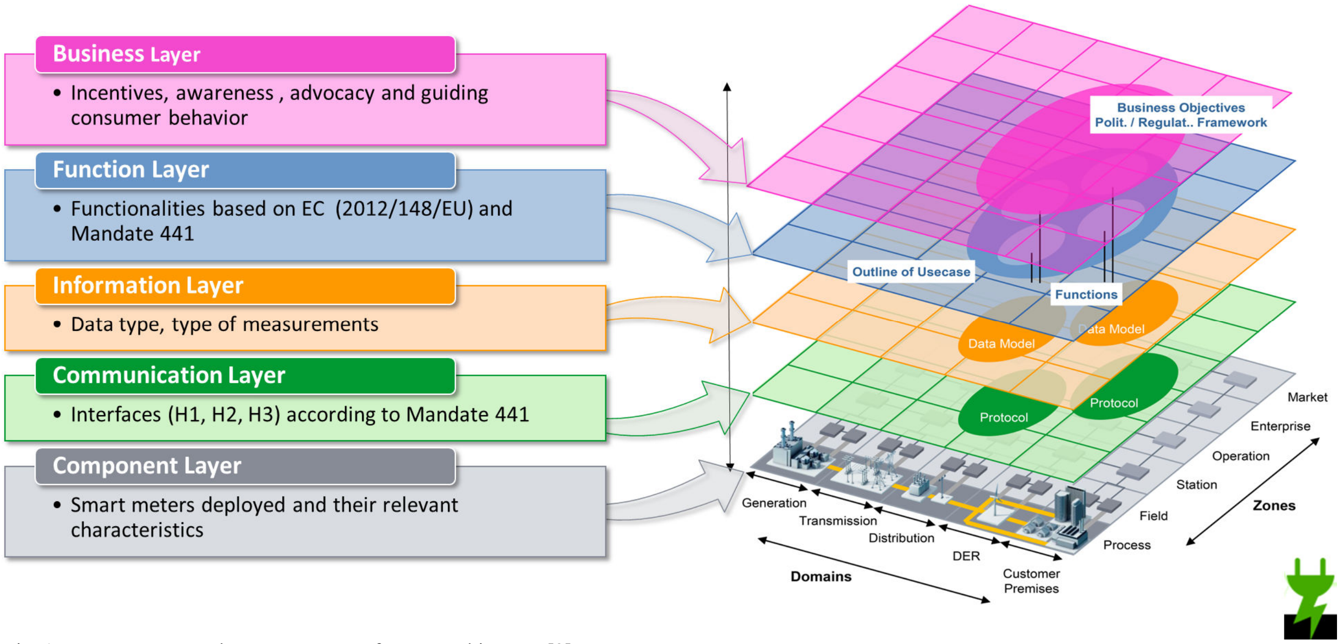

Fig. 1. SGAM Framework – Component reference architecture [3]

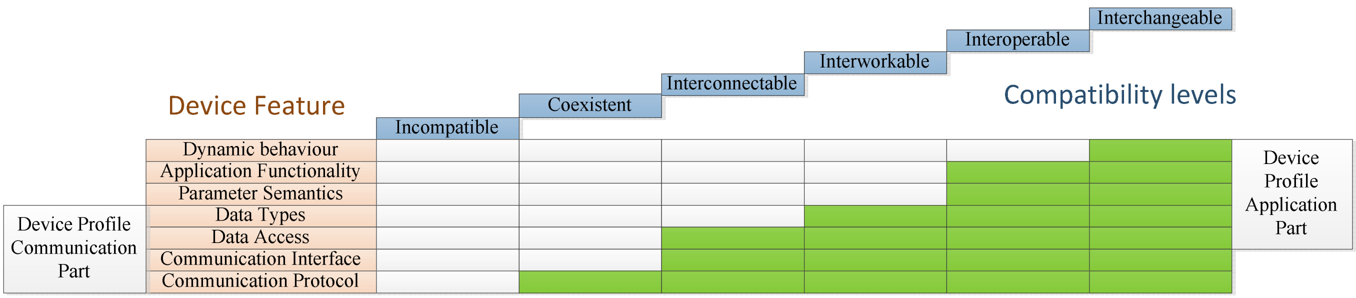

Fig.2 Levels of compatibility according to TC65/920/DC [8]

For smart metering solutions, the study focussed on the communication layer and information layer of interoperability, addressing, for example, data formats for energy usage information and data exchange protocols to facilitate automated data transfer.

Communication interoperability uses standards and protocols for data acquisition and data exchange. Most of the analysed smart meters are compliant with the standards required for interoperability at communications layer.

Achieving interoperability requires more than compliance with EU communication standards. In [6] two additional interoperability degrees are proposed:

- 1st degree interoperability addressing communication;
- 2nd degree interoperability addressing application part;

This framework has three axes. The power system equipment and energy conversion axis cover generation, transmission, distribution, distributed energy resources and customer premises. This axis is physically connected through electrical power systems to the second axis. The information management zones which is the corresponding axis to the power system equipment and energy conversion one, includes process, field, station, operation, enterprise and market. The information management zones are a conceptual representation of the groups of actors in Smart Grids. The plan created by the domains and the zones represents the level of power system management interactions.

A. Component layer

System actors, applications, power system equipment, protection and remote-control devices, network infrastructure and any kind of computers as part of smart grid and their physical distribution are part of the component layer [3]. Electronic meters can transfer readings remotely and the function is called Automated Meter Reading (AMR). The evolution of AMR is Advanced Metering Infrastructure (AMI) which supports bidirectional communication and can implement the management of consumption creating user awareness. The AMI is also known as the Smart Metering System (SMS) [7].

In 2002 the International Electrotechnical Commission (IEC) provided a device profile guideline (IEC TC 65/290/DC) [8] in which smart meters are included. In this guideline, six compatibility levels are considering the device application and communication features.

Most of the global providers of smart meters have backgrounds in electronics and are members of the Interoperable Device Interface Specifications (IDIS) [9].

The compatibility levels are defined as:

Incompatibility *- two devices can't work together in the same framework.*

Coexistence *- two devices from the same or different manufacturers can operate independently in the communication network, or together without interfering with other devices' functionality.*

Interconnect-ability *- two devices from the same or different manufacturers can operate together using the same communication protocols and communication interface.*

Interwork-ability *- two devices from the same or different manufacturers can transfer device parameters using the same data types and communication interface.*

Interoperability *- two devices from the same or different manufacturers can operate with one another in distributed applications using the same standards. Interoperability doesn't address dynamic behaviour if the replacement of the device keeps the integrity of the application data, semantics and functionality.*

Interchange-ability *- two interoperable devices that also have the same dynamic behaviour.*

IEC TC 65/290/DC [8] discriminates between device profile application and device profile communication features. The following features are considered when studying compatibility levels.

Open Smart Grid Protocol (OSGP) was created to complement EN 14908 [10] for utilities deploying multi-application smart grid infrastructures and can be applied for different smart grid devices [11].

B. Information layer (data type and measurements)

Data used and exchanged by components for functions and services represent the information layer [3] including information objects and canonical data models representing the common semantics for functions and services enabling interoperable operations.

Regarding Smart Metering solutions, the actual study was led mainly on communication layer and information layer of interoperability, addressing for instance usual data formats (e.g. XML) for energy usage information and data exchange protocols to facilitate automated data transfer (e.g. PLC).

European Smart Grids Task Force EG1 – Standards and Interoperability [12] distinguishes between human-friendly and machine friendly formats. The first category includes formats like CSV, XLS, PDF while the last one refers to XML, JSON, CSV formats.

Device Language Message Specification (DLMS) integrated in IEC 62056 is dedicated to direct information access from meters.

Companion Specification for Energy Metering (COSEM) is based on Object Identification System (OBIS) codes compatible with DLMS including interface classes for storage, access control, time and scheduling and communication.

In DLMS/COSEM communication the data collection system requests data from servers (meters). Servers and clients can support one or more communication profiles (protocol stacks independent of layers) to exchange information over different media without constrains.

To provide a common model for the components in power systems in a common Energy Management System Application Programming Interface (API), Electric Power Research Institute defined Common Information Model (CIM) [13] - as part of the IEC TC57 WG13.

Similarly, the data model is not dependent of a specific language and can define classes (e.g. inheritance, association aggregation), parameters and relationships between them [14].

Electric power grid components can be described using CIM. In the same time, SCADA is modelled for simulation and inter-control centre communication purposes. CIM facilitates integration by defining semantics to enable applications or systems to access and exchange information independent of intern representation of data [15].

C. Function layer (functionalities)

Functions, services and their relationships are described from an architectural viewpoint in the function layer. As defined in [3], functions, actors and physical implementations are represented independent from one another in applications, systems and components.

Within Mandate M/441 [16], CEN, CENELEC and ETSI produced a European standard for communications: the technical report CEN-CLC-ETSI TR 50572:2011 “Functional reference architecture for communications in smart metering systems”. Functions, services and their relationships are described from an architectural viewpoint in the function layer. As defined in [3], functions, actors and physical implementations are represented independent from one another in applications, systems and components. In 2012, European Commission, through Recommendation of 9 March 2012 (2012/148/EU) [1] provided guidance to Member States on preparations for smart metering roll-out. The document is organized in four thematic sections, focusing on aspects regarding the customer, the metering operator, energy supply from a commercial perspective and distributed energy generation while maintaining the security and data protection.

More in detail, the third section of Recommendation provides guidance on measures to be taken to ensure appropriate interoperability and the use of proper standards for smart metering systems currently being developed under Mandates M/441 [16] and M/490 [4]. To this purpose, the documents list a set of (common minimum functional) requirements for smart metering systems including.

D. Business layer (Consumer benefits)

The information exchange related to smart grids represented from a business perspective is detailed in the business layer. Regulatory and market structures and policies, business models and portfolios can also be mapped using SGAM together with business capabilities and processes helping executives in deploying business models and use cases as well as policy makers in defining new market models [3]. Modernization of energy infrastructure (smart grid) is part of the way of life technology is offering to us.

Installation of smart meters puts an end to estimation billing providing a real perspective on electricity consumption in "real-time" (most of the deployed smart meters offer reading at 15 minutes interval). Precise consumption measurements, real-time meter data access and anti-fraud detection allow utilities to avoid unnecessary technical losses.

- Engagement of end-users: As the consumer has access to detailed own consumption data and to price rates, it becomes aware of the available options to use electrical energy efficiently and maybe to reduce the cost of own invoice. Providing the user with data that create direct connection between own consumption and billing may encourage behavioural change and increase energy efficiency. End-consumers with access to usage data can actively participate in conservation activities. This leads to greater environmental awareness and improves utilities` customer service. Smart meters equipped with demand response features provide consumer with the possibility to save energy during peak demand events;
- Policy design for specific consumers: System monitoring, timely collection of data and understanding consumer patterns makes demand forecasting an easy and transparent step in energy management processes;
- Sustainability: State-of-the-art technologies enable reliable and efficient delivery of electrical energy;
- Consumer behaviour: Forecasting based on consumer behaviour. Accurate and constant data availability leads to environmentally friendly consumer behaviour.

III. Smart Meters Interoperability Levels

The European Smart Grids Task Force initiated since 2015 discussions regarding functionalities, standards and interfaces of the smart meter infrastructures. The investigation is carried out based on a survey among the 17 Member States and concentrates on three aspects: functionalities, interfaces and communication standards [17].

Similarly, in this paper a survey of commercially available meters is made and following the review of the datasheets and main features of each device they are classified in compatibility levels. Extending the scope of the interoperability layers proposed by SGAM we have applied this to interoperability issues related to smart meters. According to a strict layer definition smart meters are only relevant to the Component layer of SGAM. But, taking a broader view, within a Smart grid, all the layers of interoperability are affected by meters. This is the only device sending data to the utility/DSO in an Advanced Metering Infrastructure (AMI) or in a customer system.

Figure 3 presents a conceptual approach to assessing smart meters. Thus, from bottom to top, the main features of smart meters depict the level of compatibility, top layer representing the highest degree of compatibility (assuming also compliance with all the features beneath).

The findings are based on information provided by smart meter producers from their product data sheets and the information gathered from different EU countries. Thus, the results detailed below can be considered as the starting point for further investigations.

To decide upon a compatibility level, the following parameters of the identified smart meters were considered: (1) Dynamic behaviour; (2) Semantic interoperability; (3) Number of tariffs; (4) Import/export formats; (5) Remote ON/OFF; Demand response; (6) Demand interval report; (7) Communication protocols.

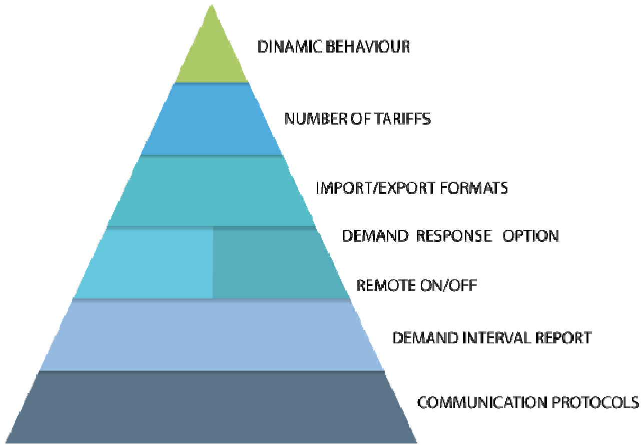

Fig. 3. Conceptual assessment of identified smart meters [18]

For most commercial smart meters consistent information is available for communication and standard protocols. This is why, in this study, smart meters are classified in a matrix considering their compatibility with associated communication and protocols. Based on this information provided by smart meter producers in their products data sheet and the information gathered by partners and on the levels of compatibility as defined in TC65/920/DC [8] and applying the conceptual assessment presented in Figure 3, the smart meters may be grouped in three major categories:

Level 1 – Interchangeable: This is based on the fact that PRIME PLC, G3 PLC and CX1 use DLMS/COSEM and thus achieving semantic interoperability.

Level 2 – Interoperable: Due to lack of info considering type of data and data access separating between interworkable and interoperable was not possible. Thus, all smart meters that are not interchangeable were downgraded to interworkable.

Level 3 - Interworkable and interconnectable: In this category are included the meters able to transmit data using wireless communication (e.g. GSM, RF etc) and the ones only able to transmit information by wired communication (e.g. PLC, PSTN etc)

It is worth mentioning that the **Coexistent** level is not applicable in the present assessment as all the devices considered have similar typologies and functionalities; they are all smart meters.

Considering the second layer of the pyramid presented in Figure 3, all the studied meters can be considered interoperable since they all have available the standard 15 min reporting rate. If it is necessary, when demand interval is lower, the information can be aggregated.

For the 3rd layer (demand response), there is not enough public information as there is no large-scale demand response service implemented by DSO in EU-28.

For the layer 4 (import/export data) and 6 (dynamic behaviour), there is not enough information to draw a conclusion. This is mainly due to this type of information being usually use case specific and not necessary for most applications (billing, typical curves).

Most of the listed meters have varying tariff procedures ranging from 2 tariffs (day/night) to complex or comprehensive structures with multiple parameters (working days, week-end, holidays, seasons etc.) and the limitations are more based on the specifications of the countries in which the meters were deployed than the technology itself.

The technical solutions proposed and implemented across EU-28 comply with most of the functionalities described in EC Recommendation 2012/148/EU [1].

IV. Conclusions

Given the migration towards de-regulated markets, switching electricity suppliers is likely to become increasingly important to consumers. As a consequence, the technology readiness level of smart meter devices and application services become one of the aspects to be immediately considered when taking large scale deployment decisions.

The maturity level of smart meter solutions can be assessed based on the compatibility level of the devices/components. Availability of latest communication standards and protocols, canonical data models, semantics and formats and a clearly defined dynamic behaviour facilitates interchange-ability. The interchange-ability of smart meters supports scalability and long term sustainability of the deployed smart metering solution as part of Smart Grid.

This study challenges only a part of the smart meter devices commercially available in Europe and opens new perspectives on the reliability of reported figures, compliance and consumer benefits availability. Similar initiatives [19] tackle the practical aspects of testing interoperability levels.

Clearly defining the interoperability levels offers an improved image of the smart metering landscape and provides valuable insights to technology developers in the effort to design next generation devices that aim at ease of interaction and user mobility.

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