Applying the Smart Grid Architecture Model SGAM to the EV Domain

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Abstract

Within this contribution, we will introduce the so called Smart Grid Architecture Model (SGAM) which has been developed in the European Commissions' M/490 mandate. After having proved successful in dozens of projects and especially standardization, the SGAM can be considered as state of the art to document smart grid architectures on a high level. However, as electric mobility is a part of the overall Smart Grid, a better fit to this domain can be achieved with tailoring the SGAM to an Electric Mobility Architecture Model (EMAM). This paper outlines the transfer process, an overview on standards to be applied and a final recommendation how to use the EMAM in context with existing SGAM processes.

1. Introduction to Smart Grid Standardization

A future smart grid is a complex system-of-a-systems or often also called a cyber-physical system. One particular important aspect in such grids is the growing need for using ICT for communication between the various components involved in the processes. Particular goals to be achieved by the smart grid may be related to aspects like the optimization and coordination of the various elements and their operation in the transmission as well as distribution grid. For instance for aspects of critical infrastructure protection, the level needed for the different protection scenarios of the components involved is rather ambitious and elevated. Also, the importance of the aspect of (system) availability and uptime for the electric power distribution system is undeniably high.

Additionally, the dependability of the infrastructure as well as of its basic components is the focus of system and interface design at design-time, even before actual deployment. At design time, interoperability and interchangeability have to be taken into account to ensure a meaningful analysis of the technical and non-technical requirements. To achieve this goal, one particular way is to standardize technical solutions at both international and national level.

To fulfil the interoperability requirements in a holistic architecture and to enable a smarter, ICT-controlled transmission and distribution grid, the system openness as well as the necessary amount of data exchange between participating parties and components inside a smart grid ecosystem has to rely on an agreed set of concepts. This basically leads to standardization of data models, interfaces, processes and communication protocols. Without standardization (e.g. in terms of data models and interfaces), overall costs for integrating (distribution automation) components as well as applications would increase due to the large number of new interfaces and processes involved. After the first standardization initiatives were raised by both IEC and NIST, the very idea that standards do answer most questions became apparent. But non-interoperable standards can still occur. So the NIST framework and roadmap for interoperability as well as the European initiatives derived from the M/490 Smart Grid mandate focus on properly using, expanding and adopting so called IEC core standards as well as various related ones.

The objective of the M/490 [1], [2] mandate has been to develop and/or update a set of consistent standards within a common European perspective as well as integrating a variety of digital compu-

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ting and communication technologies and electrical architectures, their associated processes, and, finally, services. Business models are out of scope for standardization but have been included in the foundational work of the mandate. The consistent set of standards shall achieve interoperability and, thus, will enable and facilitate the implementation of the different high level Smart Grid services and functionalities in Europe as defined by the Smart Grid Task Force. This set should be as well flexible enough to accommodate future developments. Building, Industry, Appliances, and Home Automation are out of the scope of the M/490 mandate; however, their interfaces with the Smart Grid and related services have to be treated under this mandate.

This initiative was a huge leap forward in Smart Grid standardization for Europe as, first time after the Joint-Working-Group Smart Grids report, communication (ETSI), electrical engineering (IEC) and automation (ISO) worked alongside a common storyline covering the integration of their best-practices using shared technologies and ICT. In addition, a link to the Northern American's National Institute of Standards and Technology (NIST) initiatives was built with the Smart Grid Advisory Committee (SGAC) groups and regular discussions and round-tables about architectures, roles, actors, domains, and use cases. One of the main items developed was the so called Smart Grid Architecture Model SGAM [3] enabling a holistic architecture definition.

The remainder of the paper is organized as follows: based on the Smart Grid Architecture Model overview in Section 2, Section 3 will outline the need for a transfer of the general design principles for new use cases like the Smart City Infrastructure Architecture Model suggested by the German Standardization roadmap for Smart Cities as well as problems occurring when design principles are violated. For the German funding schema "IKT für Elektromobilität II", we propose a possible solution for a better architectural modelling of the aspects of electric vehicles and their connection to the smart grid in Section 4. Section 5 concludes the paper with an outlook on future work and preliminary results.

2. SGAM – Smart Grid Architecture Model

In the context of the European Commission's standardization mandate M/490 a holistic viewpoint of an overall Smart Grid infrastructure named Smart Grid Architecture Model (SGAM) has been developed. This work is based on existing approaches and subsumes the different perspectives and methodologies of the Smart Grid concepts. The SGAM comprises five so called core viewpoint layers, which address particular concerns in terms of interoperability, also addressing business aspects which are usually out of scope of standardization. These layers are named Business, Function, Information, Communication, and Component. They were adopted from the Gridwise Alliance Architecture Council (GWAC) stack and its context-setting framework (CSF). Therefore, the eight layers of the GWAC stack can be mapped onto the five distinctive layers of the SGAM for backward compatibility of US approaches like the NIST Conceptual Model or the context setting framework for the Gridwise Alliance.

The Business Layer provides a Business viewpoint focusing on strategic and tactical goals, business processes and business services as well as regulatory aspects. For standardization purposes, this layer could be considered out of scope. The Function Layer includes IT-oriented, technology independent descriptions of general Smart Grid use cases, their functions and used technical services. The Information Layer makes for information about data and information models to support the exchange of business objects and data models of the Function Layer to enable interface interoperability. The Communication Layer presents protocols and procedures for the data exchange between components based on the Information Layer. The Component Layer provides a physical and technical view on Smart Grids components. Besides power-system related infrastructure and equipment, ICT-infrastructure and -systems are also considered as possible items.

Each of the layers mentioned above consists of five domains which subdivided in six zones. Domains are constituted according to organizational cohesion to allow for simpler identification of organizational boundaries to identify inter-organizational interfaces. The domains are in particular made up from the supply chain in the energy sector in their order from generation to use. Accordingly they are named Generation, Transmission, Distribution, DER, and Customer Premises.

The zones are defined according to zones of automation, i.e. from enterprise-level automation down to the process level. This is essential to distinguish between different types of technologies and standards used. The zones are named Market, Enterprise, Station, Operation, Field, and Process.

An overall graphical representation of the SGAM (SGAM cube) can be found in Figure 1.

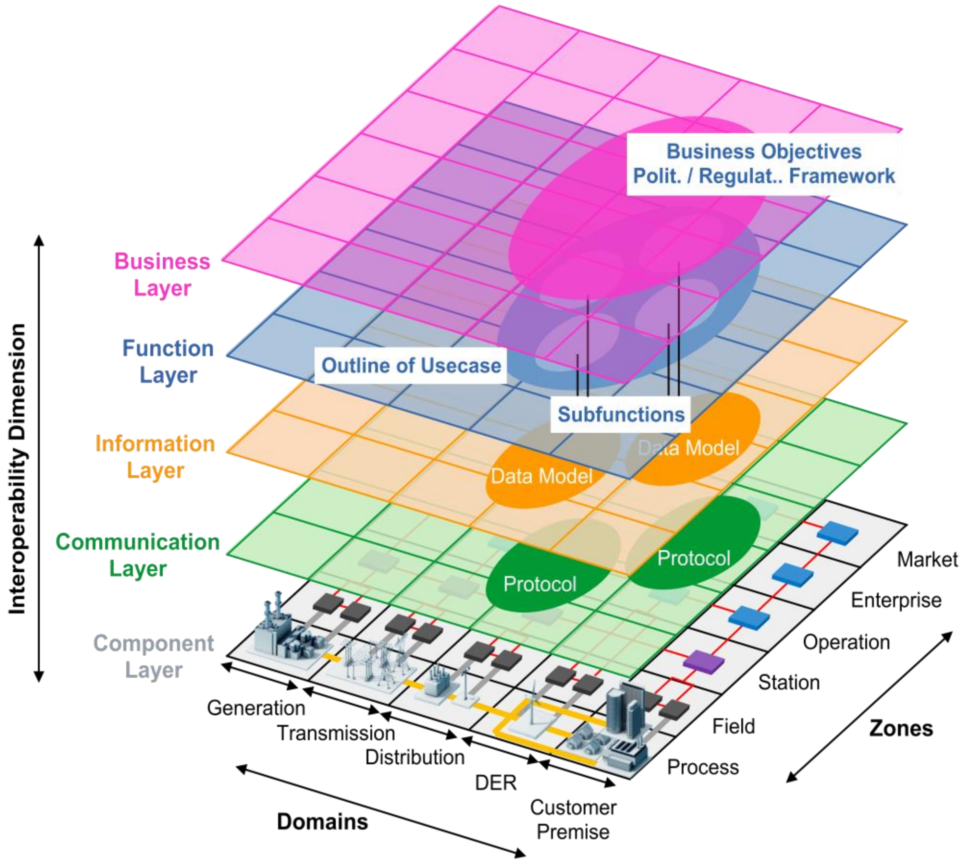

Figure 1: The Smart Grid Architecture Model as developed in the EU mandate M/490 for Smart Grids

3. Design principles and extended models

The SGAM provides a tool for the static analysis of systems, their interdependencies as well as their context in the electricity value chain and the utilities' organizational dimension and structure [5]. Yet, no formal model has been defined to properly assess the semantics of the graphical elements to be painted on the SGAM canvas, however some recommendations from the enterprise architecture context exist in the mandate work and other early approaches exist [4]. Prerequisites for filling out the SGAM model by standardized use case and user story descriptions have been evaluated and put in the very context of the SGAM meta-model [6], [7].

The SGAM can be used to create a description of static architecture states, i.e. of a current infrastructure, the possible data flows, the status of a future architecture envisioned, standards to be applied in the individual layer, domains and zones and documenting overlap between standards. It has been solely developed with the focus given in [5]. One of the key aspects is the visualisation of complex system-of-systems from a holistic perspective to show heterogeneous stakeholders, if they have to interact, and with whom.

Additionally, services [8] can be made more transparent to show which devices at field level finally contribute in which way to the overall business function and result. Creating an SGAM model always leads to one system being exact at one place and layer. Communicating about SGAM models has proven to be a useful solution in several EU FP 7 projects and national roadmaps [9]. Due to its success, different initiatives have tried to re-use both the use case process and the system documentation process suggested by the SGAM. Tools like the SGAM toolbox [7], implemented in Sparx Enterprise Architect as a UML profile have proven to be useful to start a holistic requirements engineering [10] process and trying to re-use model-driven architecture engineering principles.

Two of the most prominent adaptions are the Smart City Infrastructure Architecture Model (SCIAM) [11] and the DKE Smart Home Architecture Model (SHAM); the SCIAM can be seen in Figure 2.

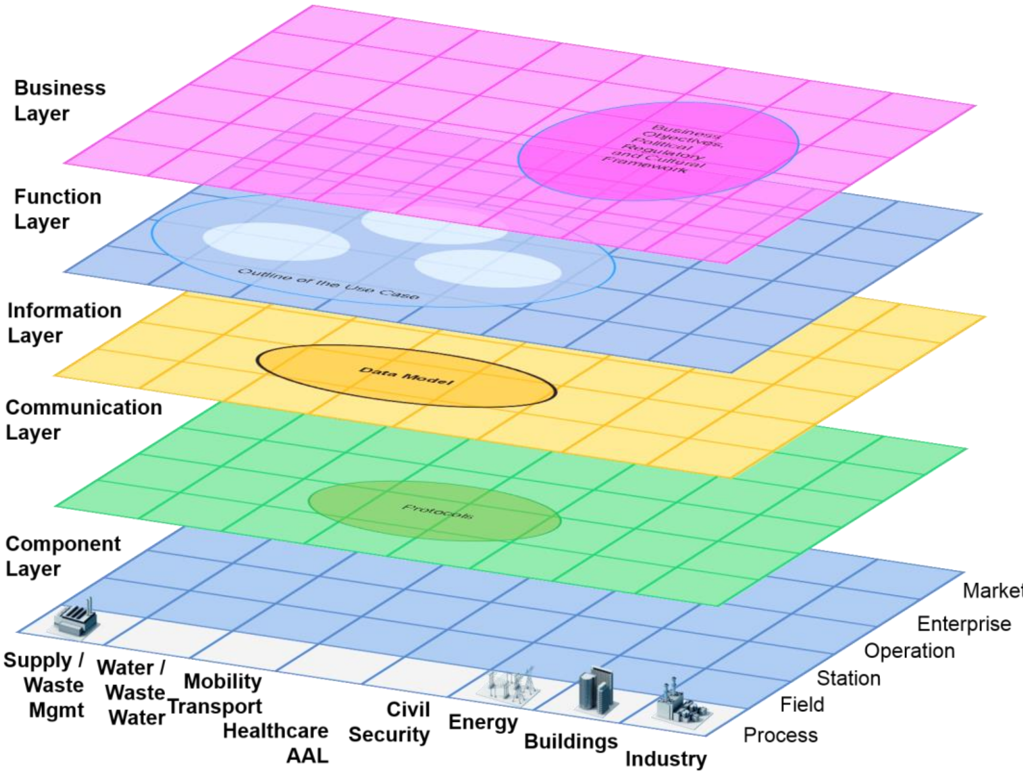

Figure 2: The Smart City Architecture Model (SCIAM) based on the SGAM (adopted from [11])

However, in the SCIAM there is a violation of the general SGAM principle in terms of the value chain for the domains. The domains are in no particular, logical order, leading to the fact that systems which are used on a plane for, e.g., energy as well as AAL (e.g., Smart meter Home Gateway) have to be put into the graphical representation twice due to the fact, that domain Civil Security them in terms of the graphical representation. Similar problems exist for the SHAM with its zones; therefore, one main aspect of re-using SGAM modelling visualisations is the aspect of insisting on ordered items for both domains and zones. The proposed EMAM will adhere to the principles depicted.

4. A focus on EV – the Electric Mobility Architecture Model

Recent work has been done to transfer the overall SGAM concept to deal with vehicles and charging infrastructure, thus making all analyses functions and modelling for the SGAM-like standards assignment, technical migration paths, risk assessment to technical components, and reliability calculation also available for this part of the smart grid domain. Previous work has been done by [12], proposing the re-use of SGAM with no emphasized focus on the design principles and use cases for SGAM communication. A meaningful morphological analysis on EV integration into the grid is provided in [13] to outline scenarios for EV to derive an information systems architecture. Later work of the authors [14] proposes to adapt the SGAM for EV purposes shortening the zonal dimension by field and process, renaming it scope and distinguish in the domain character between moving infrastructure and immobile infrastructure. Still, the SGAM is considered a good base.

We suggest changing the SGAM as little as possible to make for highest compatibility with the existing methods, meta-models and tooling and changing only limited aspects of the domain value chain. The aspect for immobile assets and mobile assets is taken into account, but it has to be kept in mind that SGAM has no dimension of time, so all aspects shall be treated static. This and the aforementioned aspects lead to the following proposal for the EMAM in a first edition.

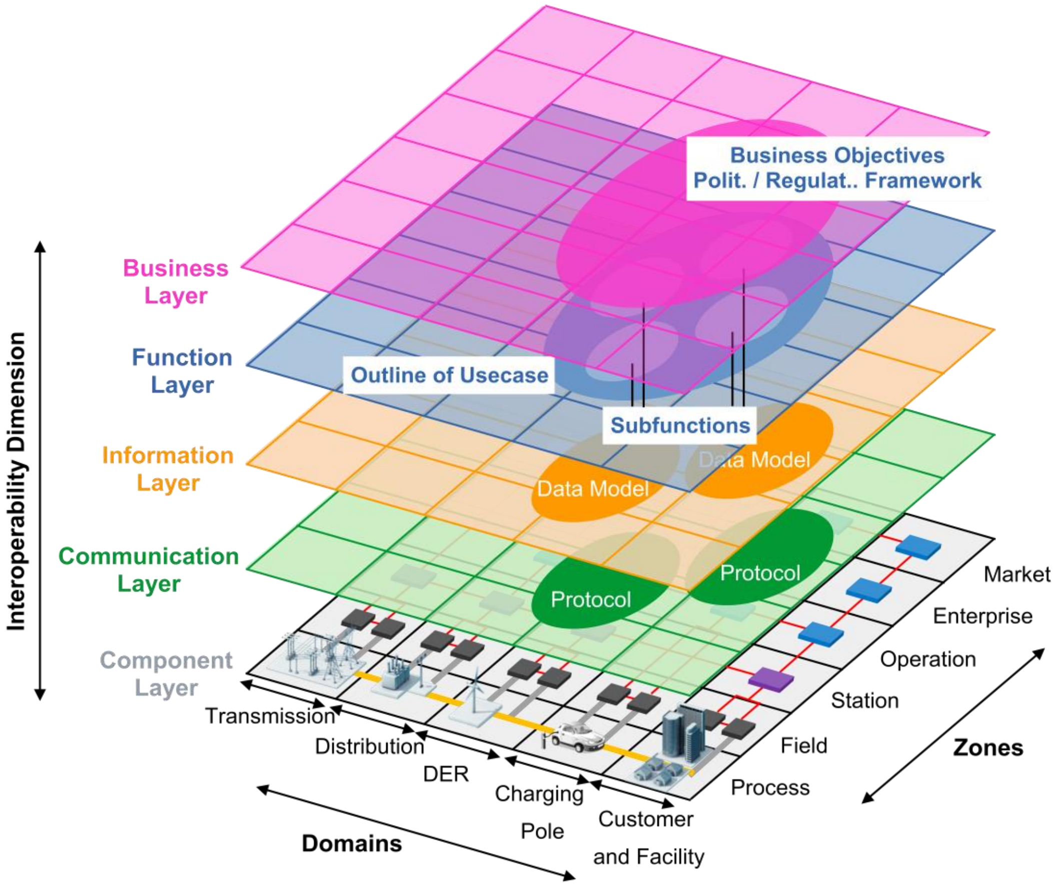

Figure 3: Proposal for an Electro Mobility Architecture Model (EMAM) adhering to SGAM principles

5. Conclusion and outlook

This contribution presented the SGAM presented as a standardized, accepted way to describe smart grid architectures in the form of models and a visualization in the SGAM cube. Additionally, extensions based on the SGAM were presented and design and use principles discussed. Based on previous work, we proposed to adhere to those principles creating a so called Electric Mobility Architecture Model which has been discussed beforehand.

The EMAM is still work in progress and future work will elaborate formal models supporting the definition of EMAM architectures and analyses based on that foundation. Furthermore the EMAM will in future be checked for modelling all the scenarios described in [15], [16] and [17] in the context of the IKT-EM II program and the M/490 mandate.

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