Smart Grid Architecture Model Standardization and the Applicability of Domain Language Specific Modeling Tools

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***Abstract*—In order to satisfy the increasing demand for electricity and to meet this demand with renewable energies, the present electrical grid has to adapt. The EU has already initiated measures to standardize and support a European Smart Grid development to facilitate communication amongst experts of different domains. Hence, this requires a mutual harmonization of terminologies as well as tools to strengthen its bearing. This paper compares the DISCERN toolbox and the SGAM toolbox. Both address the issue of a standardized modeling solutions in the domain of Smart Grids. For both toolboxes the availability, requirements, and ease of use are examined and validated based on practical use case examples. Finally, the applicability for smart grid model driven development is discussed, open development issues indicated and suggestions for further improvements provided.**

I. Introduction

As first European countries, Netherlands and Norway are about to regulate automotive cars sales, to restrict them to zero-emission vehicles by the year 2025. Other nations are about to follow the very same path, e.g. Germany with plans of executing a ban on selling petrol- and diesel-powered vehicles. These are merely examples, but electric cars are powerful components in a future electric grid that preferably should be charged by renewable energies, covering the supply and demands of a considerably growing number of distributed charging stations, photovoltaic (PV) power plants, and wind parks. Hence, the electrical grid has to adapt to the volatile nature of renewable energies, to new stakeholders connecting communicating components, and to the decentralization of the infrastructure. The EU has proactively initiated measures with the EU Mandate M/490 [11] to standardize and support the European Smart Grid development.

The electrical distribution grid of the future is not solely used by *Transmission System Operators* (TSOs) and *Distribution System Operators* (DSOs) to provide power plant generated energy at the trunk to supply consumers at the branched lines but sometimes turning the current system on its head, having distributed power plant owners (prosumers) feeding into central hydro storage power plants, using the excess energy. The future system will depend on a smart energy distribution among producers and consumers as part of a changing, evolving infrastructure of *Distributed Energy Resources* (DER). The authority and the responsibilities of an *actor* (such as DSO and DER) differs within the nations of the EU [1], making document based models hard and inefficient to maintain. Furthermore, to achieve an interdisciplinary understanding of various business divisions and authorities on a higher abstraction level, the use of *architecture models* is an enabling model driven approach [3]. This paper provides a brief but necessary overview of the *Smart Grid Architecture Model* (SGAM) [4] which serves as an architecture framework for Smart Grid Applications and takes a deeper look into two existing model driven approaches. In Section III the provided tools of the DISCERN [2] approach, followed by the SGAM toolbox [3] is examined and tested, based on practical use cases, as suggested by respective manuals or online resources. In Section IV the paper contributes comparative test results during exploratory tool-use and in Section V a discussion of to the applicability of the tools mentioned above. Lastly, open development issues and an outlook is provided in Section VI.

II. State of the Art

This section summarizes the SGAM necessary for the following state of the art modeling tools.

A. The Smart Grid Architecture Model - SGAM

As a product of the standardization process in the EU Mandate M/490, the Smart Grid Coordination Group concluded with the Smart Grid Architecture Model (SGAM), having especially interoperability in mind. This process in SGAM was approached with five so-called *Interoperability layers*. These layers are displayed in Figure 1. The *Business Layer* maps the regulation and economic structures (business actors), the *Function Layer* describes functions and services, the *Information Layer*, describes information objects within data models, transferred with specified tools inside protocols described in the *Communication Layer*, marking a physical

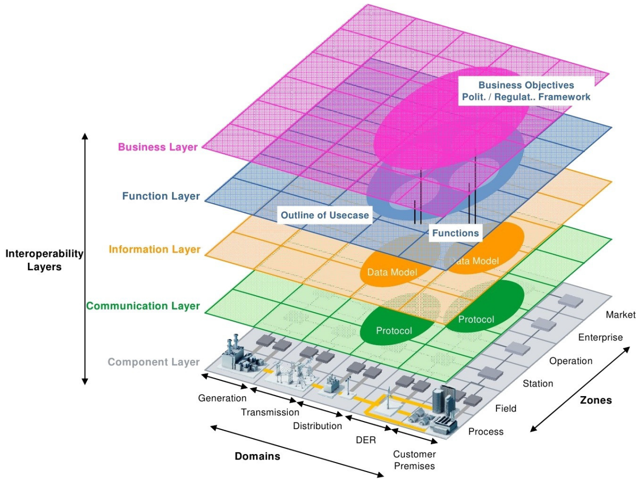

Fig. 1. Visualization of Smart Grid Architecture Model (SGAM) structure by CEN-CENELEC-ETSI [4]

endpoint, mapped and described in the *Component Layer*, covering everything from information and communication technology equipment to the power system itself [3].

There are two more dimensions covered by the SGAM as described in [4]. One axis describes the different *Domains*, which includes:

- **Generation** – large scale power plants, ranging from nuclear to renewable hydro power.
- **Transmission** – transporting the generated energy over great distances.
- **Distribution** – distributing the transported energy to and from resources.
- **Distributed Energy Resources** (DER) – energy resources can be producing, storing or consuming energy.
- **Customer Premises** – customers ranging from industry to companies to private households.

The other axis, *Zones*, correspond to the hierarchical levels of power system management: **Process**, ranging from generators to cables, sensors, and transformations in the form of heat, electricity, water; **Field**, covers any type of device, that collects, monitors, controls or protects the electrical power system; **Station**, is the location where e.g. data is aggregated by SCADA systems or used for substation automation; **Operation**, controlling the operation of the power systems; **Enterprise**, the company level; and **Market**, space for all kinds of different companies interactions in retail markets, energy trading, day-ahead pricing to name a few.

B. The DISCERN Project

In the EU Mandate M/490 a use case methodology is provided, offering a template that can be modified and extended. Hence, the replicability of results with a common understanding of terminologies is one of DISCERNs project goals (cf. [2]). Within DISCERN, the focus lies on use case management, which has been modified from the original SGAM use case mapping, in order to include information about *Key Performance Indicators* (KPI) for every use case. Upon an agreement of mutual definitions on KPIs, the indicator values can be compared and evaluated as well as undergo architectural analysis among different model approaches. Regardless, the same terms have to be used by all contributors. Under the hood of DISCERN, several major European DSOs worked together and developed the approach. A final evaluation of weak spots for improvement needing more work can be found in (cf. [2]).

Furthermore, the authors "have developed a consistent and coherent DISCERN-wide semantic model for SGAM-based architecture description, including guidelines for consistent use of use cases and SGAM, and a specialized DISCERN toolbox for the SGAM visualization"[2].

Trefke et al. state in their work [2] that the techniques used in DISCERN settled for the utilization of familiar tools for the users and adjusted them to the designated application. Therefore, users with no experience in in-depth modeling now can use office applications like Microsoft Visio for sharing smart grid domain specific high-level information whereas users with knowledge in the modeling process can use UML with specific profiles for sharing detailed architectural models (cf. [2]). One of the final results of the DISCERN project is the *Use Case Management Repository* (UCMR) which implements the IEC PAS 62559-2 template. The mentioned UCMR bowser tool SGAM visualization is rendered 3-D and can be seen with an exemplary data set in Figure 8.

C. The SGAM Toolbox

According to the description provided in [6], the introduced SGAM Toolbox has the goal to assist *Model Driven Engineering* (MDE) for cyber-physical smart grid systems or applications. Moreover, as they state, the concepts of *Model Driven Architecture* have to be introduced in the engineering process of such systems. As mentioned in Section 2, also during the MDE-workflow a shared understanding (e.g. use of symbols, processes) is necessary. Hence, the authors introduced a *Domain Specific Language* (DSL) that reflects the five SGAM *Interoperability Layers*. The reflection is depicted in Figure 2.

The architecture framework of the SGAM toolbox provides an overview of contributing elements as well as their relation to each other across the SGAM layers. The colored layers are corresponding to the SGAM *Interoperability Layers* of Figure 1. The lines connecting the different elements within and across layers describe different kinds of relations. The DSL results from applying the given relations and elements within the three SGAM dimensions. There are three major tasks involved for a user to create a complete picture of a new business idea with the help of the DSL:

1) **Business Analysis**,
2) **Functional Analysis**, and
3) **Architecture Development**.

In [3] this process is described in detail, including examples for a better understanding. The toolbox itself is currently

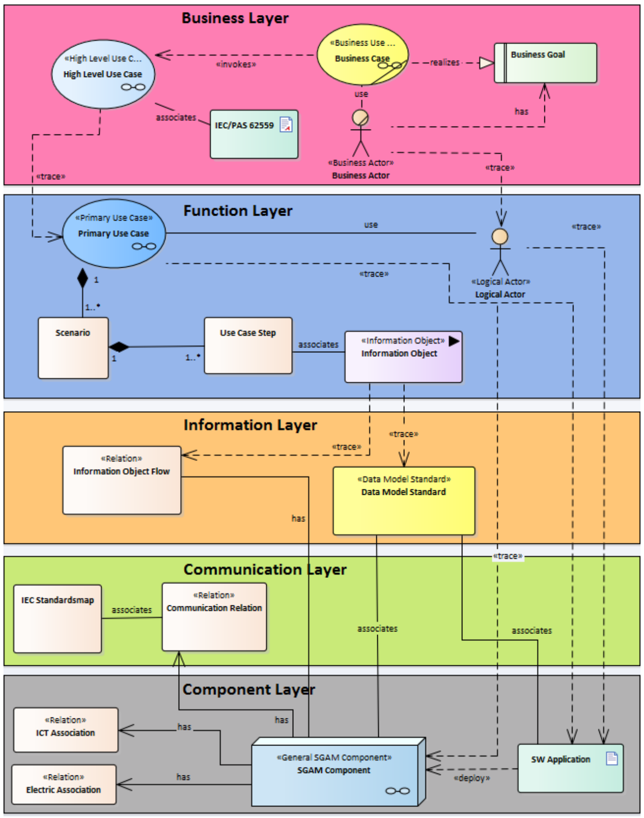

Fig. 2. Own representation of SGAM Toolbox architecture framework based on [3]

available as an extension [9] for the *Enterprise Architect* modeling software from Sparx Systems.

III. Applicability of Model Driven Smart Grid Application Tools

The previously described tools and definitions offer to provide an impression about the complexity and therefore the need for standardization. Both approaches agree on the use of SGAM, bringing useful applications to the smart grid domain. The investigated tools differ in their usage goals, as well their software. This makes a point by point comparison difficult, which is why this paper describes the findings on the applicability of the tools described without a strict testbook or guided scheme between them.

A. Using DISCERN Application Tools

The following results are produced with the help of the provided materials on the official project website, especially with the usage of files provided at [10].

Firstly, we explore the UCMR browser tool. After the login, a divided browser page appears, with the left side being a browser with the items *Use Cases*, *Actors*, *Functions*, *Requirements*, *Transactions* and *Open Submits* that are placed within an *Personal Space* folder. The right side is reactive to the item chosen on the left side. On a folder, it is possible to change the name or description and create new items of the category of the folder (e.g., in the folder *Use Cases*, one of the options is named “Create Use Case”). Within *Use Cases*, *Scenarios* can be created, that can be divided into *Steps* with a detailed description, of what should happen in a certain matter. Figure 3 shows a snapshot of an actual advice when the user performs a wrong action. In this picture, an *Actor* would have been drag-and-dropped into a *Function*-field, which is an incorrect operation and prohibited with the warning. The lower part of Figure 3 shows a warning for the user, that another user edits the current item. This warning prevents loss of information or versioning issues on the collaborative platform. Due to the fact, that this test has been conducted by one user and one UCMR account, therefore this claim in [5] cannot be proved or disapproved.

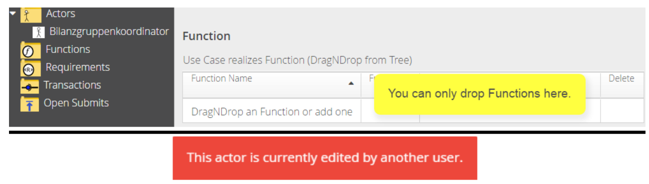

Fig. 3. Upper part: Advice for user making a not allowed operation. Lower part: Warning for collaborative work with locked items. [5]

To create a proper SGAM model, a Microsoft Visio Template is available from the DISCERN project page [12]. The archive file contains several different shape items for each layer, as well as a file for the SGAM model itself. The modeling is done throughout six layers, whereas the *Information Layer* is split for a view on the canonical data model and the view on business context. Layers can and should be synchronized, in order to keep the elements at the correct places on the grid of their *Domains* and *Zones* which is arranged as depicted in Figure 1. An example of the icon layout, the provided options and the indication of which layer is currently under editing, is given in Figure 4. The option *Shape Data Content* is crucial for creating metadata, essential for the textual based *SGAM XML Export* function.

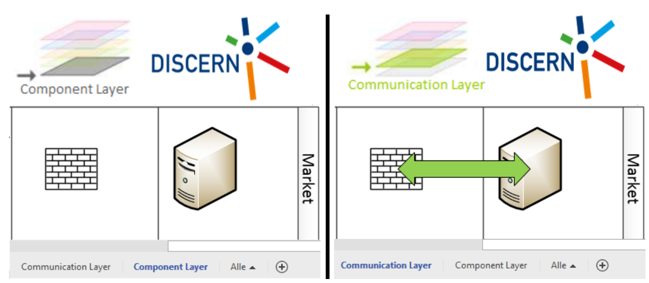

Fig. 4. Snapshot of Microsoft Visio 2016: SGAM levels and customized functions

Among the delivered tools of the DISCERN project, three libraries are provided. They contain detailed descriptions about *Actors*, *Functions* as well as *Requirements*. With the help of these libraries, the UCMR browser tool can be populated for having a common use and definition of involved participants in the SGAM model. In Table I an hierarchy example of the

Actor library is provided. The table contains five entries of the 68-entry library, with a further description on the actor itself. The parent column displays the hierarchy level as mentioned before. The *Smart Meter* is an *Actor* of greater detail than the *Meter*. The chain of hierarchy can be traced up to the *Device*, which can be seen as an *Logical Actor*, leading to the first item in the library, the *Actor*. Furthermore, in the *Source* column the origin of the *Actor* definitions is given. As it comes to the *Actors*, many of them origin from (sub-) projects of DISCERN, as others are defined for example in the *IEC 61850* standard.

B. *Using SGAM Toolbox*

As mentioned previously, the *SGAM Toolbox* is freely available as an extension to the Sparx System "Enterprise Architect" on the developer's website [9]. The current version V0.6 has been tested successfully with the Enterprise Architect Versions 12.1 and 13.0. The authors provided an extensive documentation with 39-pages as well as guided videos with more than 2.5 hours of content available on YouTube links [14].

Furthermore, an example file is given and also templates for the so-called *Risk Assessment*, which is exemplarily shown in Figure 5.

Due to illustrative purposes, the snapshot in Figure 5 is fitted. The red boxes indicate the *Risk Assessment calculation*, that contain six values: The *Hackers Motivation*, *Asset Reachability*, *Propagation of Secrets*, *SGIS Security Level*, *Direct Operational Effects* and the resulting *Calculated Risk*. The *Calculated Risk* is computed with a formula suggested in the documentation of the *SGAM Toolbox*. This suggestion may develop over time and experience. It is introduced with the purpose of making all investigated risk comparable and setting priorities for the affected systems and develop countermeasures.

For each risk, the user is able to place patterns into the *SGAM Toolbox* diagram, that can be generated for certain types of elements. Figure 6 shows the generated pattern for a *System Security Pattern* that has been associated with one component. These patterns can be populated further with information and objects. The provided patterns are still under development and will contain more details, *Policies* (blue rectangle), *Technical Measures* (green), *Detection and Forensic* (light-red), *Containment* (yellow) in the future.

The navigation is done via the project browser in Enterprise Architect. A grid pane similar to the one of the Visio template of *DISCERN* with *Zones* and *Domains* can be displayed. However, no context information creation depends on the placement of the elements on the grid. This context information has still to be done manually by the user. There are more possibilities in the toolbox to make errors due to the UML-modeling nature of the program, which requires background knowledge on this technique.

Additionally, the *SGAM Toolbox* offers the possibility to create sequence and activity diagrams, which deal with the schedule of interactions between *(Logical) Actors* in certain processes, that are necessary for a valuable *Use Case* description. These can be generated with the help of textual scenario descriptions, whereas the name of involved *(Logical) Actors* are used for creating the structure of the diagrams.

In the following section, the results will be discussed and compared with each other.

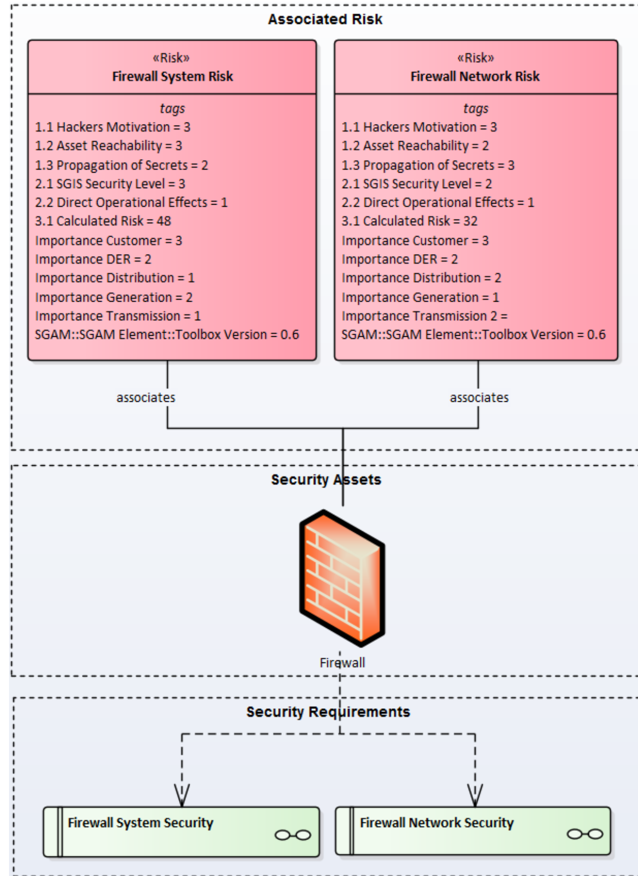

Fig. 5. Screenshot from the *SGAM Toolbox* of risk calculation and their relation to components.

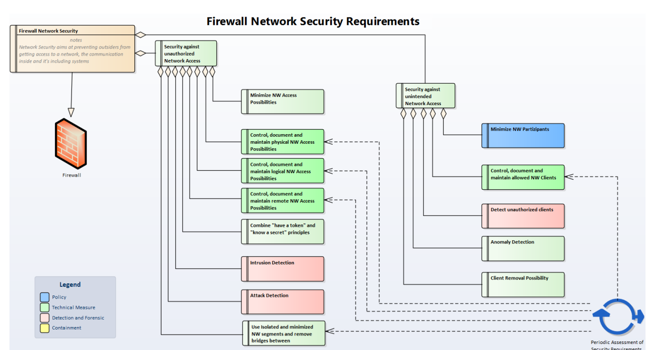

Fig. 6. Snapshot (SGAM Toolbox) of semi-automatical security pattern for a specific risk.

TABLE I
FORMATTED EXCERPT FROM THE DISCERN ACTOR LIBRARY AVAILABLE FROM [7].

Actor	Description	Parent	Source
Actor	Generic Actor		DISCERN
Logical Actor	Technical Entity that takes part in the execution of an Use Case. A Logical Actor can be mapped to a physical component.	Actor	INTEGRA
Device	Hardware-based device which physically implements a technical function	Logical Actor	DISCERN
Meter	Instrument intended to measure electrical energy by integrating power with respect to time	Device	DISCERN
Smart Meter	The Smart Meter is a combination of the following meter-related functions from the Smart Metering reference architecture: Metrology functions including the conventional meter display (register or index) that are under legal metrological control. When under metrological control, these functions shall meet the essential requirements of the MID; One or more additional functions not covered by the MID. These may also make use of the display; Meter communication functions	Meter	SGCG

IV. COMPARISON OF EXPLORATORY USAGE

Theoretically, the XML-export results described in Section III-A of the DISCERN tools should be able to be imported into the UCMR browser tool. For this reason, a user account of a specific project UCMR for the RASSA project [15] has been used for investigation on the applicability of the DISCERN browser tool.

Exploring the possibilities described in the UCMR manual [5], errors can be encountered while using the browser tool as it is shown in Figure 7. In the upper part of the line, a pictured description based on the instructions from the UCMR manual [5] is shown. The error occured with Google Chrome (version 54.0.2840.99 m) as well with Mozilla Firefox (version 50.0) with an installed and enabled version of Java (Build 1.8.0_65-b17). On other systems, the error was not reproducible. The lower part of Figure 7 shows an occurred error during the try of moving (or merging) an *Actor* failed due to an "java.lang.NoSuchMethodError".

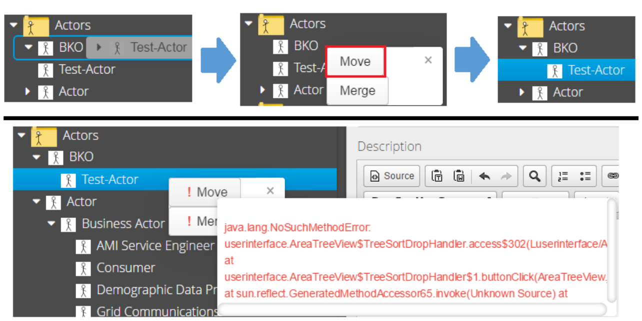

Fig. 7. Upper part: Visual description on how to move or merge actors.[5]. Lower part: Snapshot of occurred error in browser.

Secondly, the Microsoft Visio tool is incomplete in the *SGAM XML Export* for all the available elements in the provided tool template. During the process of modeling a complete SGAM example by the *Visio Template User Guide* [13] in Microsoft Visio 2016, after placing an element *Communication Protocol (Area)* into the *Communication Layer*, the *SGAM XML Export* produces an error message. Nevertheless, without this element, a functional looking model can be imported to the UCMR browser tool. The result of this test trial with a view on all five *Interoperability Layers* is presented in Figure 8.

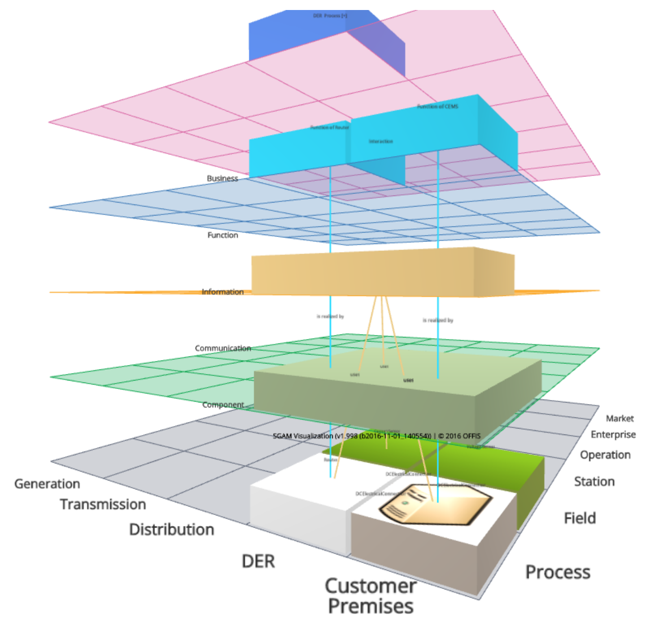

Fig. 8. Snapshot of prototypical SGAM model import in UCMR browser tool.

V. DISCUSSION

A request for the access to the DISCERN UCMR hosted by OFFIS [8] is not available without a personal request via email. To improve the handling speed of new requests for access to the UCMR in order to reduce pending days, an automatic access, either via email registration or a publicly available playground for new users would be beneficial to spread the use of the UCMR tool. Another area of improvement was located when testing the export functionality. The populated (and probably correctly used) *Use Cases* were not exportable via XML, because the option stayed grayed-out. A tooltip to achieve the XML export (e.g. on what information is missing or wrong) would be helpful.

Another issue is the "corrupted" *DISCERN Use Case Template* file, that has been described in Section III-A. Without a working (XML-) export function, the document only provides an impression of the standardized layout without the users content. This issue is reinforced by the fact, that within the template document, no field is editable and users are restricted to collaboration on *Use Cases* at the online platform (if access is possible).

Concerning the Microsoft Visio template, it can be said that it is not tremendously difficult to handle for new users. Necessary steps for modeling are described in the accompanying handbook. Error messages or helpful comments during the modeling process or after executing actions violating the model could be improved with more guidance or FAQ-examples. For example, if an element was dragged on the wrong *Interoperability Layer*, a message is displayed, mentioning the correct layer, but the element remains on the field. This is a potential source for errors, since a wrongly placed element can still be XML-exported (in some cases; e.g., when a *Business Layer* element was placed in the *Function Layer*, but is not exportable when the element is put into the *Component Layer*).

Users of the *SGAM Toolbox* should be able to integrate their security patterns in the future since different needs or company-internal policies could occur during the realization of a project.

With the export result of the DISCERN Visio template, it was not possible to import the exemplary SGAM XML file into the SGAM toolbox on any level. However, the promise of the ability to import an IEC 62559-2 standard compliant file, as Use-Case description, as described in [3] cannot be verified due to the fact, that the XML-export function in the DISCERN UCMR browser tool was not selectable during the test process and needs to be revisited.

VI. Outlook

The Austrian reference architecture development efforts are based on the described SGAM Toolbox. The mentioned issues are minor to the expected improvements of using a model driven approach across the smart grid domains instead of a model or document based approach used so far. The provided domain specific language is being extended and refined to the Austrian needs, but modelled and interlinked in accordance with national and international standards (SGAM, ENTSO-E, NIST-LRM, Austrias Domain Model of Smart Grids). Additional reactive and active security requirements will be added to the importance values, to extend the possible risk calculation, as can be seen already in Figure 5. The resulting models can be used as a blueprint for smart grid applications, even though managing and modelling these properly for risk analysis applications is still an open issue.

Finally, it is to say, that the *DISCERN* approach as well as the *SGAM Toolbox* provide both valuable tools for enhancing smart grid development efforts. The *SGAM Toolbox* provides more possibilities within one tool at the expense of high complexity, leading to a steep learning curve at the beginning. *DISCERN*'s outcome is a more partitioned approach, so that different user groups can work separately on smaller encapsulated fields.

Acknowledgment

Findings presented are from project *Architecture* as part of the Initiative *Reference Architecture for Secure Smart Grids Austria*, which was commissioned by the Austrian Climate and Energy Fund and supported by the Austrian Research Promotion Agency (FFG project number 848811) as part of the 1st Call *Energieforschungsprogramm* in the main area *Intelligente Netze*.

References

[1] A. Berger, M. Meisel, L. Langer, M. Litzlbauer and M. Uslar, RASSA-Stakeholderprozess, Technical Report for Bundesministerium für Verkehr, Innovation und Technologie; Report-Nr. 12, 2015; 79 p.

[2] J. Trefke, S. Rohjans, M. Uslar, S. Lehnhoff, L. Nordström and A. Saleem, "Smart Grid Architecture Model use case management in a large European Smart Grid project", in: *IEEE PES ISGT Europe 2013*, IEEE, pages 1-5, 2013.

[3] C. Neureiter, M. Uslar, D. Engel and G. Lastro, "A standards-based approach for domain specific modelling of smart grid system architectures", in: *11th System of Systems Engineering Conference (SoSE)*, IEEE, pages 1-6, 2016.

[4] Smart Grid Coordination Group: "Smart Grid Reference Architecture", Technical Report, CEN-CENELEC-ETSI, (Nov. 2012), available [ONLINE]: http://www.cencenelec.eu/standards/Sectors/SustainableEnergy/SmartGrids/Pages/default.aspx (accessed: 1/19 17)

[5] OFFIS, "DISCERN Use Case Management Repository User Guide", Version from 4/22 2016 Retrieved from: http://www.discern.eu/datas/DISCERN_Use_Case_Management_Repository_-_User_Guide.pdf

[6] C. Dänekas, S. Rohjans, J. Trefke, M. Uslar, D. Engel, C. Neureiter "Durchgängige Werkzeugunterstützung für das EU Mandat M/490: Vom Anwendungsfall bis zur Visualisierung" in Proceedings of: *VDE-Kongress 2014 - Smart Cities Intelligente Lösungen für das Leben in der Zukunft*

[7] OFFIS, DISCERN Actor Library Retrieved on 11/9 2016 from: http://www.discern.eu/datas/DISCERN_Libraries.zip

[8] OFFIS, UCMR, available [ONLINE] http://ucmr.offis.de (accessed: 11/9 17)

[9] Salzburg University of Applied Sciences, SGAM-Toolbox Setup (Extention for *Enterprise Architect* from Sparx Systems), available [ONLINE] http://www.en-trust.at/wp-content/uploads/SGAMToolbox.Setup_.zip (accessed: 1/19 17)

[10] innogy, DISCERN Use Case & SGAM Tools, available [ONLINE] http://www.discern.eu/project_output/tools.html (accessed: 1/19 17)

[11] European Commission, EU Mandate M/490, available [ONLINE http://www.smartgrids.eu/sites/default/files/private/2011_03_01_mandate_m490_en[1].pdf accessed: 1/19 17)

[12] innogy, DISCERN SGAM Visio template, available [ONLINE] http://www.discern.eu/datas/DISCERN_SGAM_Visio_Template.zip (accessed: 1/19 17)

[13] innogy, DISCERN SGAM Visio guide, available [ONLINE] http://discern.eu/datas/DISCERN_SGAM_Visio_Template_-_User_Guide.pdf (accessed: 1/19 17)

[14] Christian Neureither, Video: Presentation of System Analysis, available on YouTube [ONLINE] http://youtu.be/sekpJRysa74 (accessed: 1/19 17)

[15] SMARTGRIDS Austria, Reference Architecture for Secure Smart Grids Austria, available [ONLINE] http://www.smartgrids.at/plattform-aktivitaeten/rassa-initiative.html (accessed 1/19 17)