Introduction to the „SGAM Toolbox“

Author: Christian Neureiter (christian.neureiter@en-trust.at)

Version: 0.4
Date: 2014-04-27

Table of Contents

1. Introduction

The document at hands describes the ideas and the usage of the *SGAM-Toolbox* for developing Smart Grid systems in reference to the *Smart Grid Architecture Model (SGAM)* as introduced by the *Smart Grid Coordination Group (SGCG) in 2012* [1].
It focuses on the SGAM-Toolbox and its' application and does not describe the underlying methods or technologies like Systems-Engineering, UML-based modeling or the handling of the involved modeling tool (*Enterprise Architect* from *Sparx Systems*[1]).

If you have any feedback according the toolbox or need further help please feel free to contact us and send a mail to *christian@en-trust.at*.

Please take note of the available Video-Tutorials that demonstrate in detail how to utilize the SGAM Toolbox for architecting Smart Grid Systems. Simply follow the links on www.en-trust.at or search for "SGAM Toolbox" on YouTube.

[1] www.sparxsystems.com

2. The Smart Grid Architecture Model (SGAM)

The *Smart Grid Architecture Model (SGAM)* was introduced by the *Smart Grid Coordination Group* in 2012 [1].
The SGAM focuses on a structured description of a distributed Smart Grid System in order to identify standardization gaps. However, the proposed architecture model appears to be very useful for architecting smart grid systems. Hence, the SGAM Toolbox was developed in order to ease the modeling of Smart Grid Systems in reference to the SGAM.
The architecture model helps to analyze Smart Grid systems and interactions by mapping them to a three dimensional cube that is depicted in listing

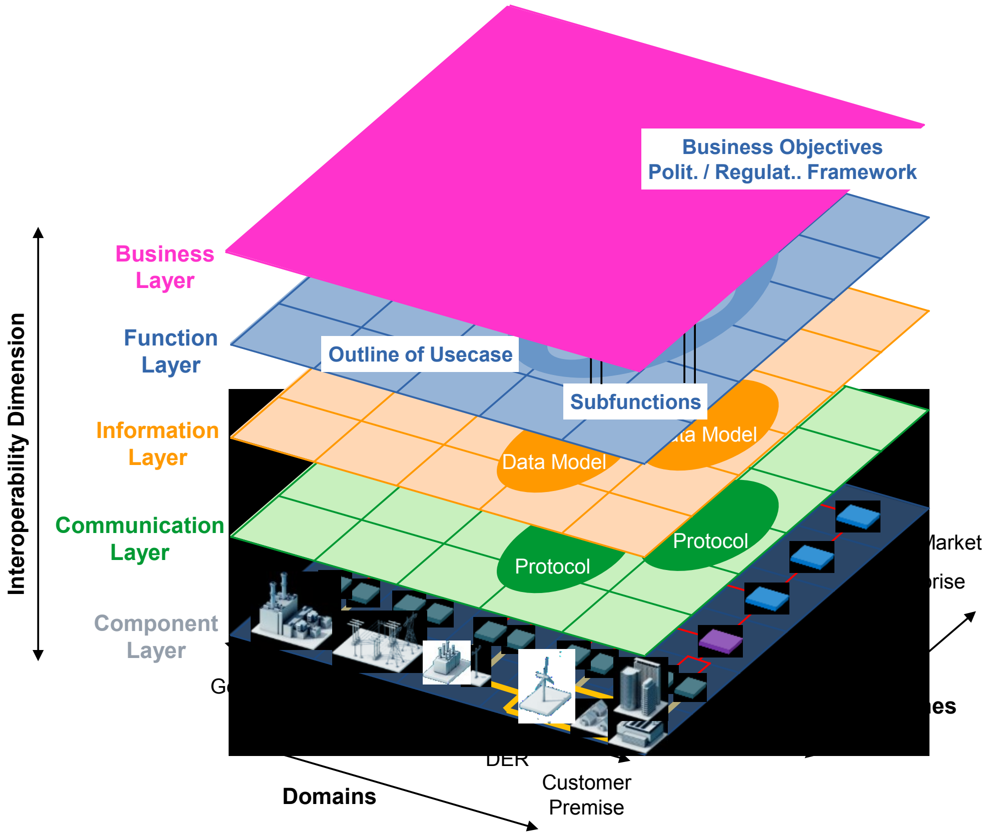


Figure 1 - The Smart Grid Architecture Model (SGAM) [1]

The following subsections that comprise explanations for the single SGAM elements are taken from section "*7.2 – SGAM Framework Elements"* of the original, public available Smart Grid Coordination Group Document [1].

2.1. The Interoperability Layer

In order to allow a clear presentation and simple handling of the architecture model, the interoperability categories are aggregated into five abstract interoperability layers.

Business Layer: The business layer represents the business view on the information exchange related to smart grids. SGAM can be used to map regulatory and economic (market) structures and policies, business models, business portfolios (products & services) of market parties involved. Also business capabilities and business processes can be represented in this layer. In this way it supports business executives in decision making related to (new) business models and specific business projects (business case) as well as regulators in defining new market models.

Function Layer: The function layer describes functions and services including their relationships from an architectural viewpoint. The functions are represented independent from actors and physical implementations in applications, systems and components. The functions are derived by extracting the use case functionality which is independent from actors.

Information Layer: *The information layer describes the information that is being used and exchanged between functions, services and components. It contains information objects and the underlying canonical data models. These information objects and canonical data models represent the common semantics for functions and services in order to allow an interoperable information exchange via communication means.*

Communication Layer: *The emphasis of the communication layer is to describe protocols and mechanisms for the interoperable exchange of information between components in the context of the underlying use case, function or service and related information objects or data models.*

Component Layer: *The emphasis of the component layer is the physical distribution of all participating components in the smart grid context. This includes system actors, applications, power system equipment (typically located at process and field level), protection and tele-control devices, network infrastructure (wired / wireless communication connections, routers, switches, servers) and any kind of computers.*

2.2. The Smart Grid Plane

Every layer itself is depicted by the utilization of the Smart Grid Plane, which is defined as follows:

In general power system management distinguishes between electrical process and information management viewpoints. These viewpoints can be partitioned into the physical domains of the electrical energy conversion chain and the hierarchical zones (or levels) for the management of the electrical process (refer to [IEC62357-2011, IEC 62264-2003]). Applying this concept to the smart grid conceptual model introduced in section 6.3 allows the

foundation of the Smart Grid Plane (see Figure 7.). This smart grid plane enables the representation on which levels (hierarchical zones) of power system management interactions between domains take place.
According to this concept those domains, which are physically related to the electrical grid (Bulk Generation, Transmission, Distribution, DER, Customer Premises) are arranged according to the electrical energy conversion chain. The conceptual domains Operations and Market are part of the information management and represent specific hierarchical zones. The conceptual domain Service Provider represents a group of actors which has universal role in the context of smart grid. This means that a Service Provider can be located at any segment of the smart grid plane according to the role he has in a specific case.

2.3. Domains

The Smart Grid Plane covers the complete electrical energy conversion chain, as described in Table 1 - SGAM Domains.

Domain	Description
Bulk Generation	Representing generation of electrical energy in bulk quantities, such as by fossil, nuclear and hydro power plants, off-shore wind farms, large scale solar power plant (i.e. PV, CSP)– typically connected to the transmission system
Transmission	Representing the infrastructure and organization which transports electricity over long distances
Distribution	Representing the infrastructure and organization which distributes electricity to customers
DER	Representing distributed electrical resources directly connected to the public distribution grid, applying small-scale power generation technologies (typically in the range of 3 kW to 10.000 kW). These distributed electrical resources may be directly controlled by DSO
Customer Premises	Hosting both - end users of electricity, also producers of electricity. The premises include industrial, commercial and home facilities (e.g. chemical plants, airports, harbors, shopping centers, homes). Also generation in form of e.g. photovoltaic generation, electric vehicles storage, batteries, micro turbines… are hosted

Table 1 - SGAM Domains

2.4. Zones

The SGAM zones represent the hierarchical levels of power system management [IEC62357-2011]. These zones reflect a hierarchical model which considers the concept of aggregation and functional separation in power system management. The basic idea of this hierarchical model is laid down in the Purdue Reference Model for computer-integrated manufacturing which was adopted by IEC 62264-1 standard for ―enterprise-control system integration‖ [IEC 62264-2003]. This model was also applied to power system management. This is described in IEC 62357 ―Reference architecture for object models services‖ [IEC 62357-2003, IEC 62357-1-2012].
The concept of aggregation considers multiple aspects in power system management:

- Data aggregation – data from the field zone is usually aggregated or concentrated in the station zone in order to reduce the amount of data to be communicated and processed in the operation zone

- Spatial aggregation – from distinct location to wider area (e.g. HV/MV power system equipment is usually arranged in bays, several bays form a substation; multiple DER form a plant station, DER meters in customer premises are aggregated by concentrators for a neighborhood)

In addition to aggregation the partitioning in zones follows the concept of functional separation. Different functions are assigned to specific zones. The reason for this assignment is typically the specific nature of functions, but also considering user philosophies. Real-time functions are typically in the field and station zone (metering, protection, phasor-measurement, automation…). Functions which cover an area, multiple substations or plants, city districts are usually located in operation zone (e.g. wide area monitoring, generation scheduling, load management, balancing, area power system supervision and control, meter data management…).
The SGAM zones are described in Table 2 - SGAM Zones

Zone	Description
Process	Including the physical, chemical or spatial transformations of energy (electricity, solar, heat, water, wind …) and the physical equipment directly involved. (E.g. generators, transformers, circuit breakers, overhead lines, cables, electrical loads any kind of sensors and actuators which are part or directly connected to the process,…).
Field	Including equipment to protect, control and monitor the process of the power system, e.g. protection relays, bay controller, any kind of intelligent electronic devices which acquire and use process data from the power system.
Station	Representing the areal aggregation level for field level, e.g. for data concentration, functional aggregation, substation automation, local SCADA systems, plant supervision…
Operation	Hosting power system control operation in the respective domain, e.g. distribution management systems (DMS), energy management systems (EMS) in generation and transmission systems, microgrid management systems, virtual power plant management systems (aggregating several DER), electric vehicle (EV) fleet charging management systems.
Enterprise	Includes commercial and organizational processes, services and infrastructures for enterprises (utilities, service providers, energy traders …), e.g. asset management, logistics, work force management, staff training, customer relation management, billing and procurement…
Market	Reflecting the market operations possible along the energy conversion chain, e.g. energy trading, mass market, retail market.

Table 2 - SGAM Zones

3. SGAM Toolbox Architecture

The SGAM Toolbox mainly consists of three components:

1. SGAM MDG Technology
2. SGAM Model Templates
3. SGAM Reference Data

The definition of the elements that can be used to model a SGAM related project is done by the use of MDG Technology. The SGAM MDG Technology holds these definitions.
To ease the work with the Toolbox some Model Templates have been created. They are based on the above mentioned definitions and can be accessed via the New Model Wizard.
The SGAM Reference Data holds some Information concerning the representation of defined elements and some definitions for a Model-Import or -Export.

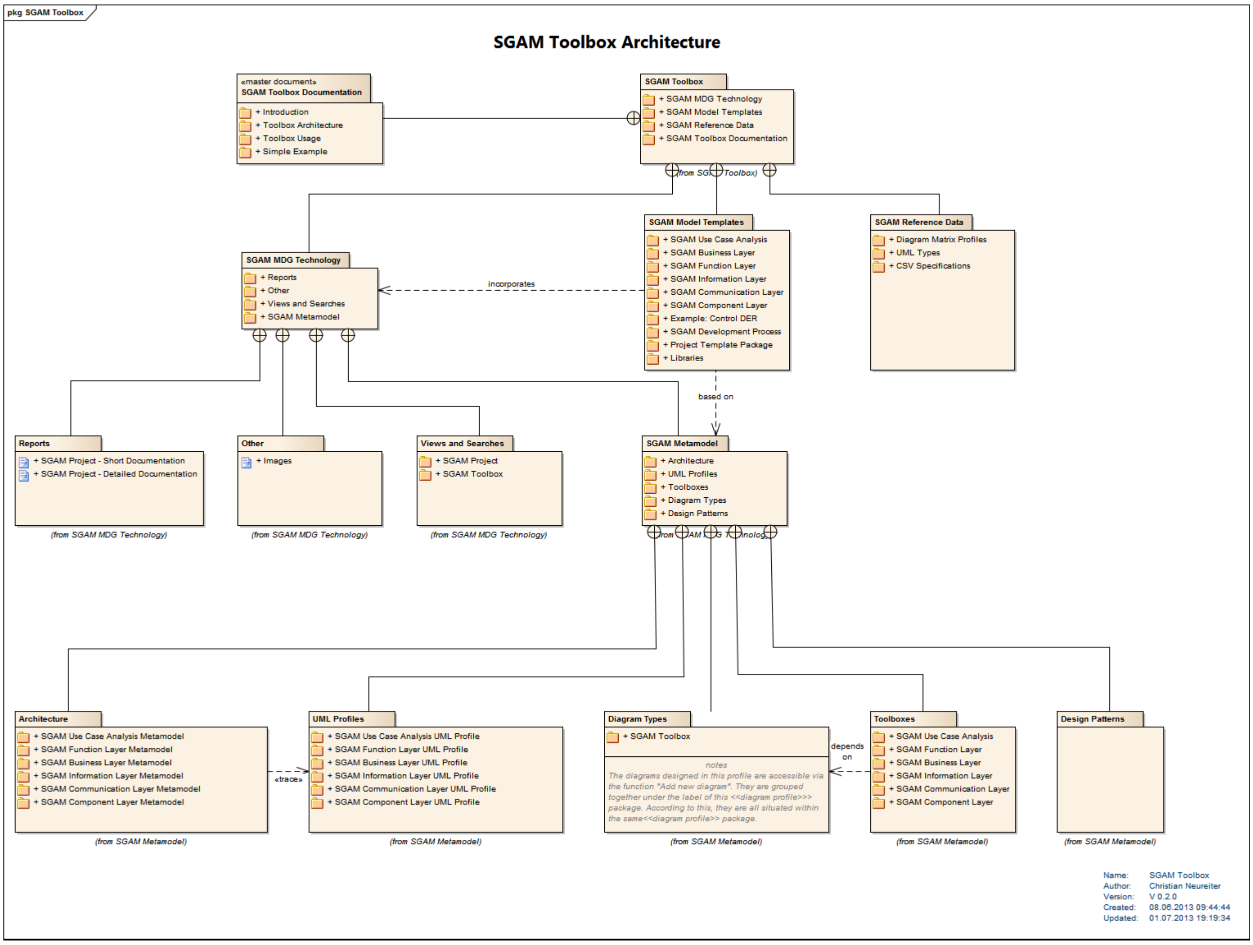

pkg SGAM Toolbox
SGAM Toolbox Architecture
«master document»
SGAM Toolbox Documentation
+ Introduction
+ Toolbox Architecture
+ Toolbox Usage
+ Simple Example
SGAM Toolbox
+ SGAM MDG Technology
+ SGAM Model Templates
+ SGAM Reference Data
+ SGAM Toolbox Documentation
(from SGAM Toolbox)
SGAM MDG Technology
+ Reports
+ Other
+ Views and Searches
+ SGAM Metamodel
incorporates
SGAM Model Templates
+ SGAM Use Case Analysis
+ SGAM Business Layer
+ SGAM Function Layer
+ SGAM Information Layer
+ SGAM Communication Layer
+ SGAM Component Layer
+ Example: Control DER
+ SGAM Development Process
+ Project Template Package
+ Libraries
SGAM Reference Data
+ Diagram Matrix Profiles
+ UML Types
+ CSV Specifications
based on
Reports
+ SGAM Project - Short Documentation
+ SGAM Project - Detailed Documentation
(from SGAM MDG Technology)
Other
+ Images
(from SGAM MDG Technology)
Views and Searches
+ SGAM Project
+ SGAM Toolbox
(from SGAM MDG Technology)
SGAM Metamodel
+ Architecture
+ UML Profiles
+ Toolboxes
+ Diagram Types
+ Design Patterns
(from SGAM MDG Technology)
Architecture
+ SGAM Use Case Analysis Metamodel
+ SGAM Function Layer Metamodel
+ SGAM Business Layer Metamodel
+ SGAM Information Layer Metamodel
+ SGAM Communication Layer Metamodel
+ SGAM Component Layer Metamodel
(from SGAM Metamodel)
«trace»
UML Profiles
+ SGAM Use Case Analysis UML Profile
+ SGAM Function Layer UML Profile
+ SGAM Business Layer UML Profile
+ SGAM Information Layer UML Profile
+ SGAM Communication Layer UML Profile
+ SGAM Component Layer UML Profile
(from SGAM Metamodel)
Diagram Types
+ SGAM Toolbox
notes
The diagrams designed in this profile are accessible via the function "Add new diagram". They are grouped together under the label of this <<diagram profile>>> package. According to this, they are all situated within the same<<diagram profile>> package.
(from SGAM Metamodel)
depends on
Toolboxes
+ SGAM Use Case Analysis
+ SGAM Function Layer
+ SGAM Business Layer
+ SGAM Information Layer
+ SGAM Communication Layer
+ SGAM Component Layer
(from SGAM Metamodel)
Design Patterns
(from SGAM Metamodel)
Name: SGAM Toolbox
Author: Christian Neureiter
Version: V 0.2.0
Created: 08.06.2013 09:44:44
Updated: 01.07.2013 19:19:34

Figure 2 - The SGAM Toolbox Architecture

The most important element of the SGAM Toolbox is the SGAM Metamodel, which is derived from the SGAM and delivers the available elements and their relations.
Figure 3 - The SGAM Metamodel depicts the SGAM Metamodel as rough overview without mentioning the individual attributes (implemented as Tagged Values).

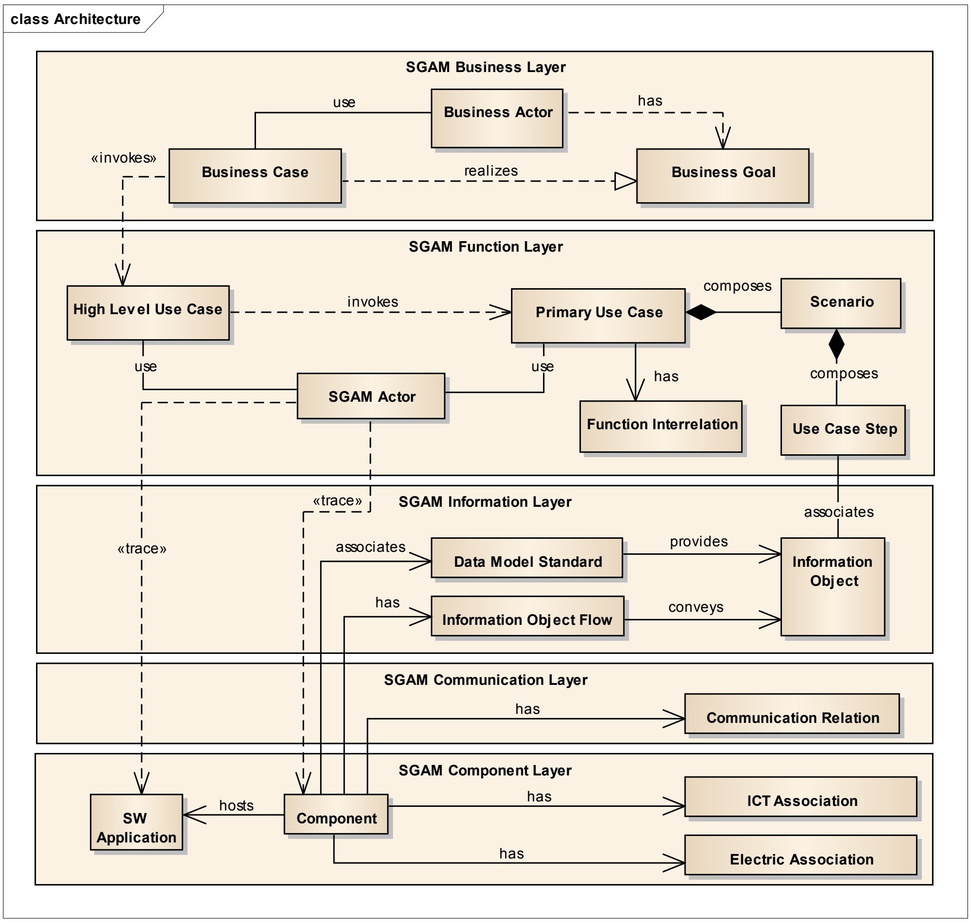
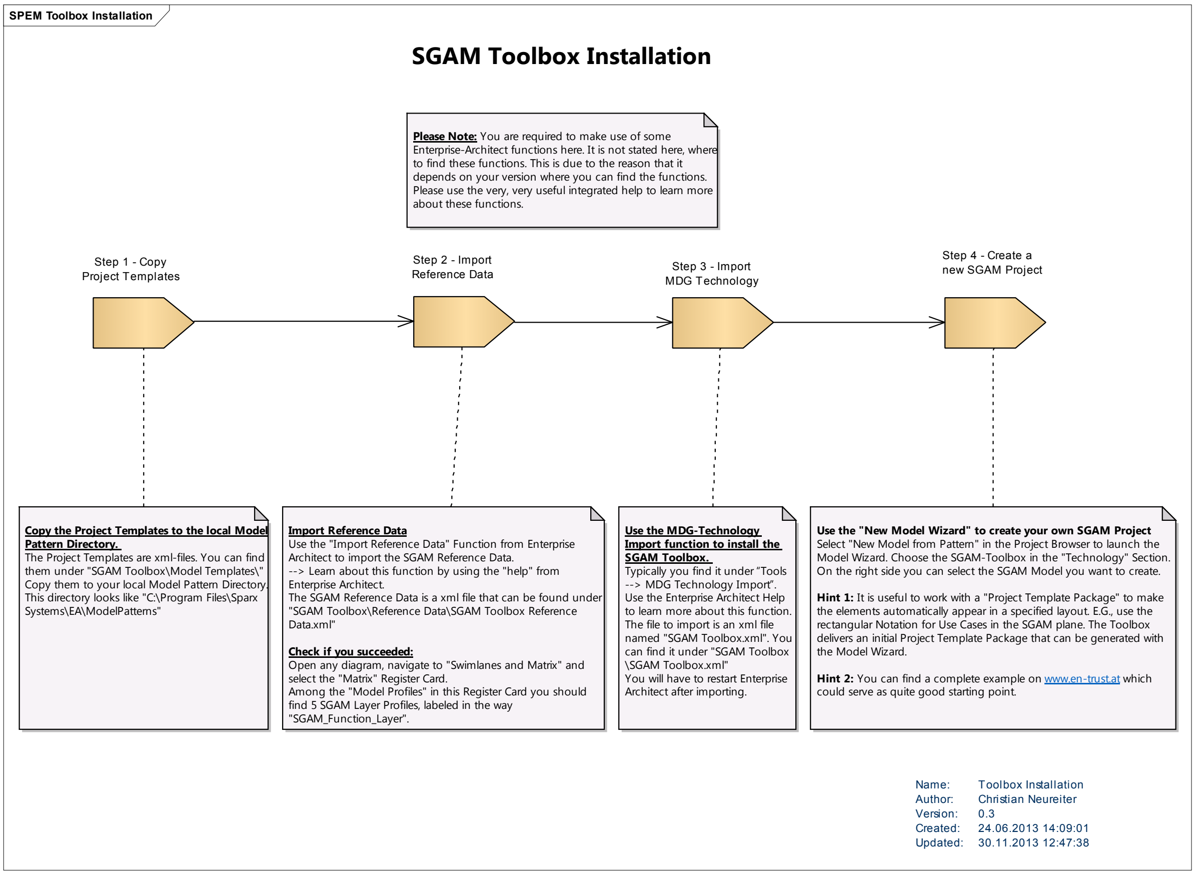


Figure 3 - The SGAM Metamodel

4. SGAM Toolbox Installation

The Toolbox Installation Package describes the necessary steps on how to install the SGAM Toolbox. The Toolbox itself consists of a folder labeled "SGAM Toolbox". The folder's subfolders and elements are structured according to the Toolbox Architecture, which can be found in Figure 2 - The SGAM Toolbox Architecture.


SPEM Toolbox Installation
SGAM Toolbox Installation
Step 1 - Copy Project Templates
Step 2 - Import Reference Data
Step 3 - Import MDG Technology
Step 4 - Create a new SGAM Project

Please Note: You are required to make use of some Enterprise-Architect functions here. It is not stated here, where to find these functions. This is due to the reason that it depends on your version where you can find the functions. Please use the very, very useful integrated help to learn more about these functions.

Copy the Project Templates to the local Model Pattern Directory.
The Project Templates are xml-files. You can find them under "SGAM Toolbox\Model Templates\"
Copy them to your local Model Pattern Directory.
This directory looks like "C:\Program Files\Sparx Systems\EA\ModelPatterns"

Import Reference Data
Use the "Import Reference Data" Function from Enterprise Architect to import the SGAM Reference Data.
--> Learn about this function by using the "help" from Enterprise Architect.
The SGAM Reference Data is a xml file that can be found under "SGAM Toolbox\Reference Data\SGAM Toolbox Reference Data.xml"

Check if you succeeded:
Open any diagram, navigate to "Swimlanes and Matrix" and select the "Matrix" Register Card.
Among the "Model Profiles" in this Register Card you should find 5 SGAM Layer Profiles, labeled in the way "SGAM_Function_Layer".

Use the MDG-Technology Import function to install the SGAM Toolbox.
Typically you find it under “Tools --> MDG Technology Import”.
Use the Enterprise Architect Help to learn more about this function.
The file to import is an xml file named "SGAM Toolbox.xml". You can find it under "SGAM Toolbox\SGAM Toolbox.xml"
You will have to restart Enterprise Architect after importing.

Use the "New Model Wizard" to create your own SGAM Project
Select "New Model from Pattern" in the Project Browser to launch the Model Wizard. Choose the SGAM-Toolbox in the "Technology" Section. On the right side you can select the SGAM Model you want to create.

Hint 1: It is useful to work with a "Project Template Package" to make the elements automatically appear in a specified layout. E.G., use the rectangular Notation for Use Cases in the SGAM plane. The Toolbox delivers an initial Project Template Package that can be generated with the Model Wizard.

Hint 2: You can find a complete example on www.en-trust.at which could serve as quite good starting point.

Name: Toolbox Installation
Author: Christian Neureiter
Version: 0.3
Created: 24.06.2013 14:09:01
Updated: 30.11.2013 12:47:38

Figure 4 - SGAM Toolbox Installation

Please Note: You are required to make use of some specific Enterprise-Architect functions here. It is not stated here, where to find these functions. This is due to the fact that it depends on your version of Enterprise Architect where to find the functions.
Please use the very, very, very useful Enterprise Architect Help to learn more about these functions.

Element	Notes
Step 1 – Copy Project Templates	**Copy the Project Templates to the local Model Pattern Directory.** The Project Templates are xml-files. You can find them under "SGAM Toolbox\Model Templates\" Copy them to your local Model Pattern Directory. This directory looks like "C:\Program Files\Sparx Systems\EA\ModelPatterns\"
Step 2 – Import Reference Data	**Import Reference Data** Use the "Import Reference Data" Function from Enterprise Architect to import the SGAM Reference Data.

	--> Learn about this function by using the "help" from Enterprise Architect. The SGAM Reference Data is a xml file that can be found under "SGAM Toolbox\Reference Data\SGAM Toolbox Reference Data.xml" **Check if you succeeded:** Open any diagram, navigate to "Swimlanes and Matrix" and select the "Matrix" Register Card. Among the "Model Profiles" in this Register Card you should find 5 SGAM Layer Profiles, labeled in the way "SGAM_Function_Layer".
Step 3 – Import MDG Technology	**Use the MDG-Technology Import function to install the SGAM Toolbox.** Typically you find it under “Tools → MDG Technology Import”. Use the Enterprise Architect Help to learn more about this function. The file to import is an xml file named "SGAM Toolbox.xml". You can find it under "SGAM Toolbox\SGAM Toolbox.xml" You will have to restart Enterprise Architect after importing.
Step 4 – Create a new SGAM Project	**Use the "New Model Wizard" to create your own SGAM Project** Select "New Model from Pattern" in the Project Browser to launch the Model Wizard. Choose the SGAM-Toolbox in the "Technology" Section. On the right side you can select the SGAM Model you want to create. **Hint 1:** It is useful to work with a "Project Template Package" to make the elements automatically appear in a specified layout. E.G., use the rectangular Notation for Use Cases in the SGAM plane. The Toolbox delivers an initial Project Template Package that can be generated with the Model Wizard. **Hint 2:** You can find a complete example on www.en-trust.at which could serve as quite good starting point.

6. Proposed Development Process

The proposed development process is inspired from the Use Case Mapping Process (UCMP) as introduced by [1].

It basically consists of three phases, where the first two phases reflect the main tasks of the UCMP, but in an adopted schedule.

First, during the System Analysis Phase, the systems functionality is to be described. This is done by executing a Use Case Analysis, developing the SGAM Function Layer and developing the SGAM Business Layer.

Next, during the System Architecture Phase, the development of the Component, the Information and the Communication Layer is done.

The Design & Development Phase, which addresses the realization of individual systems, is not SGAM specific and hence can be done by means of classic systems engineering methods. It is conceptualized as iterative phase to highlight the idea of suggested agile development.

The following sections describe the steps to be performed in more detail.

Please refer to the provided video tutorials to learn more about the application of this development process and the steps that have to be done during the execution of each task.

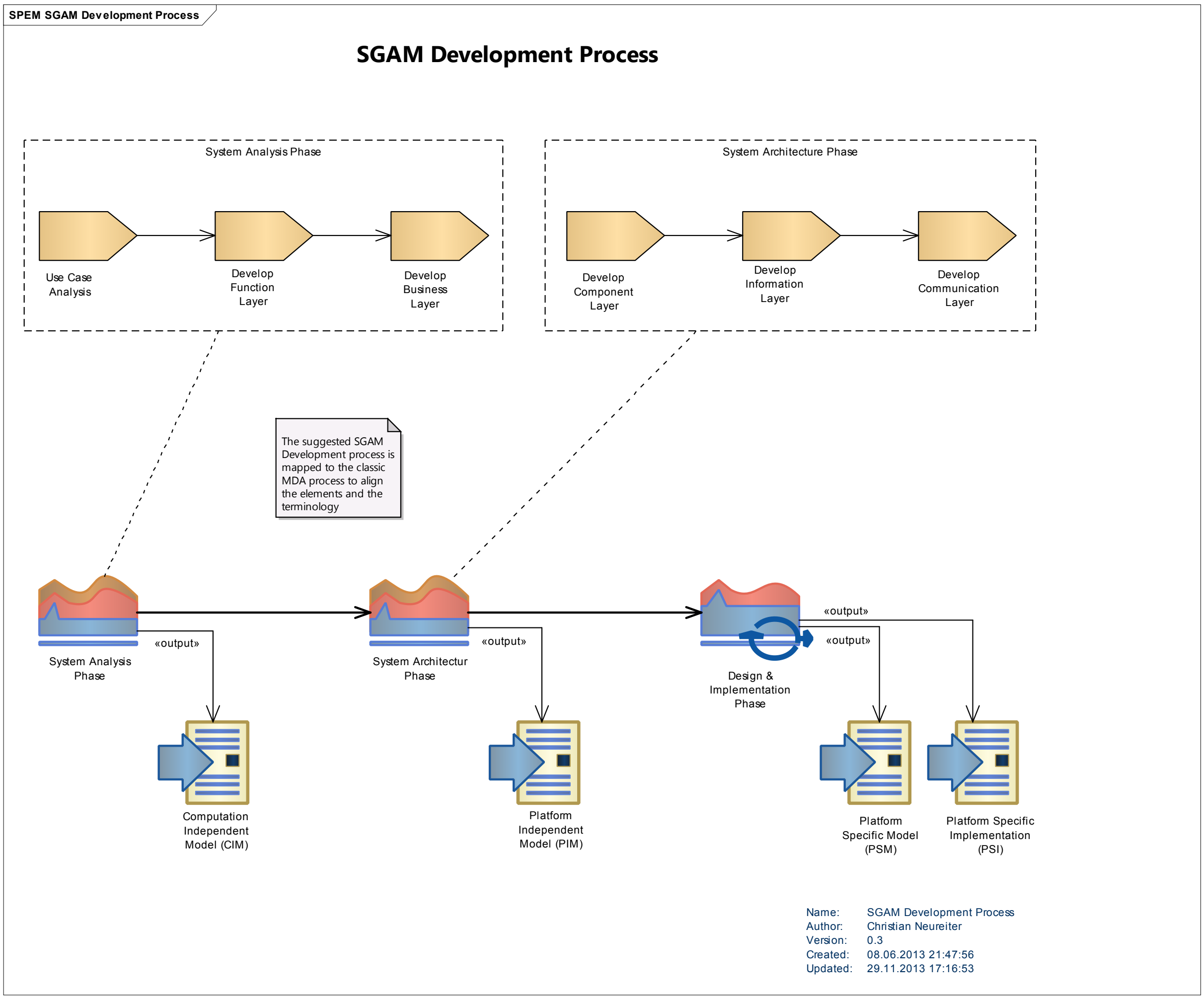

SPEM SGAM Development Process
SGAM Development Process
System Analysis Phase
Use Case Analysis
Develop Function Layer
Develop Business Layer
System Architecture Phase
Develop Component Layer
Develop Information Layer
Develop Communication Layer
The suggested SGAM Development process is mapped to the classic MDA process to align the elements and the terminology
System Analysis Phase
«output»
System Architectur Phase
«output»
Design & Implementation Phase
«output»
«output»
Computation Independent Model (CIM)
Platform Independent Model (PIM)
Platform Specific Model (PSM)
Platform Specific Implementation (PSI)
Name: SGAM Development Process
Author: Christian Neureiter
Version: 0.3
Created: 08.06.2013 21:47:56
Updated: 29.11.2013 17:16:53

Figure 5 - SGAM Development Process

Element	Notes
System Analysis Phase	During the System Analysis Phase the specification for the system to be built has to be developed. Therefor it is necessary to identify the project-roles, the stakeholder and their individual requirements and the interrelation of the project with its environment and its project context.
Computation Independent Model (CIM)	The Term "Computation Independent Model" is taken from Model Driven Architecture (MDA). It focuses on the desired behaviour and function of a system without mentioning how the system is implemented (Separation of concerns).
System Architectur Phase	The System Architecture Phase is used to map the prior defined functionalities to a basic architecture. This basic architecture consists of the major function blocks and the concerning interfaces of the whole system.
Platform Independent Model (PIM)	The "Platform Independent Model" aims to identify major function blocks without relating them to a concrete implementation
Design & Implementation Phase	The Design & Implementation Phase is designed as iterative process. The underlying idea is to support agile development aspects. During this phase, a prior developed architecture is designed and implemented.
Platform Specific Model (PSM)	The "Platform Specific Model" describes the design for the specific components. The design is done with respect to the selected plattform.
Platform Specific Implementation (PSI)	The "Plattform Specific Implementation" is the last Layer of the MDA deliverables. As the name mentions, it depicts the implementation itself.

7. System Analysis Phase

7.1. Use Case Analysis

The execution of the Use Case Analysis is one of the key tasks that has to be performed. It focuses on the identification of involved actors and goals and on the decomposition of the Product-Owner inputs into single Use Cases. As the identified model elements state the basis for all further modeling, this is a very crucial task and should obtain the necessary attention.

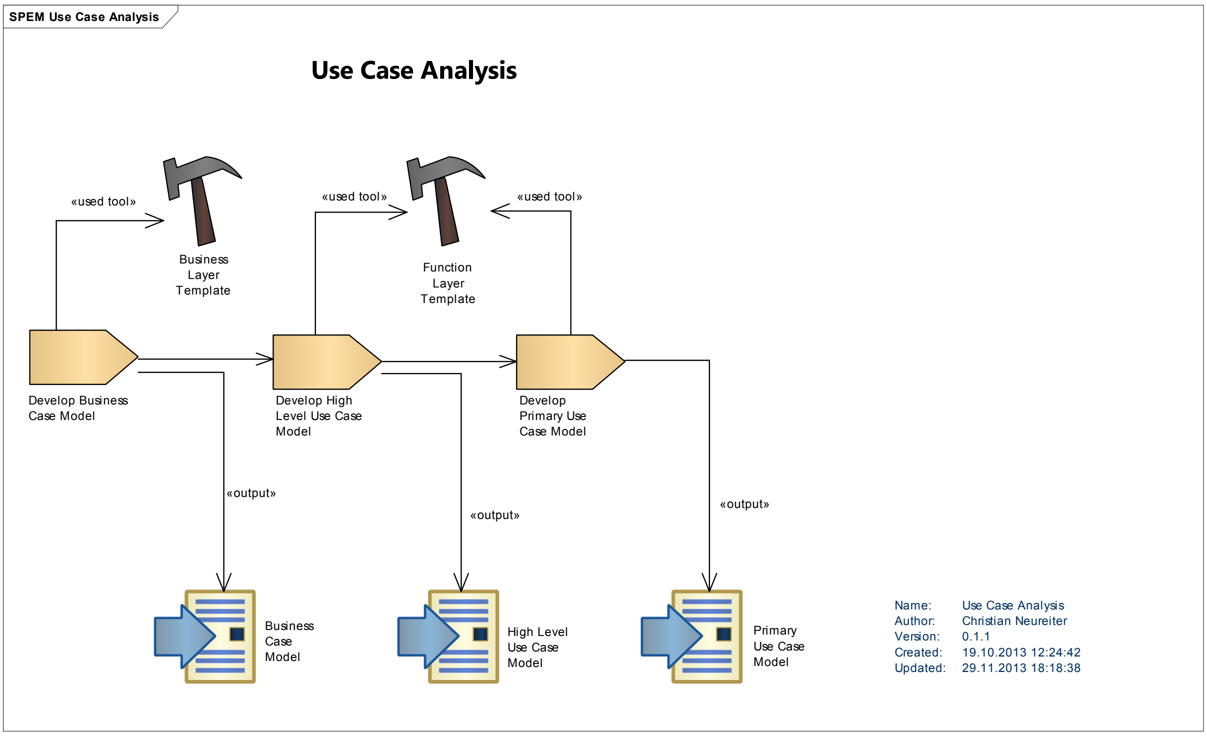


Figure 6 - Use Case Analysis

The three tasks of the Use Case Analysis are described in the following subsections in detail.

7.1.1. Develop Business Case Model

Focus of this task is the identification of involved *Business Actors (BA),* their assigned *Business Goals (BG)* and individual *Business Cases (BC)* that are performed by the BA in order to reach the individual BG. In addition, *High Level Use Cases (HLUC)* are identified and modeled that are included by the BC.
After creating a new Enterprise Architect project with an empty model you can make use of the *Model Wizard* to get a template for the development of the Business Case Model.

1. *Start the Model Wizard (Menu → Project → New Model) and select "SGAM Toolbox" as Technology and "SGAM Business Layer" as model template. Of course you can also create the single packages and diagrams manually, but for the beginning the template is useful to get an idea about the concept.*

This step creates a new package named "SGAM Business Layer" within your model. The content of this package is an example that illustrates, how a Business Case Model looks like.

Developing your own Business Case Model comprises the following steps:

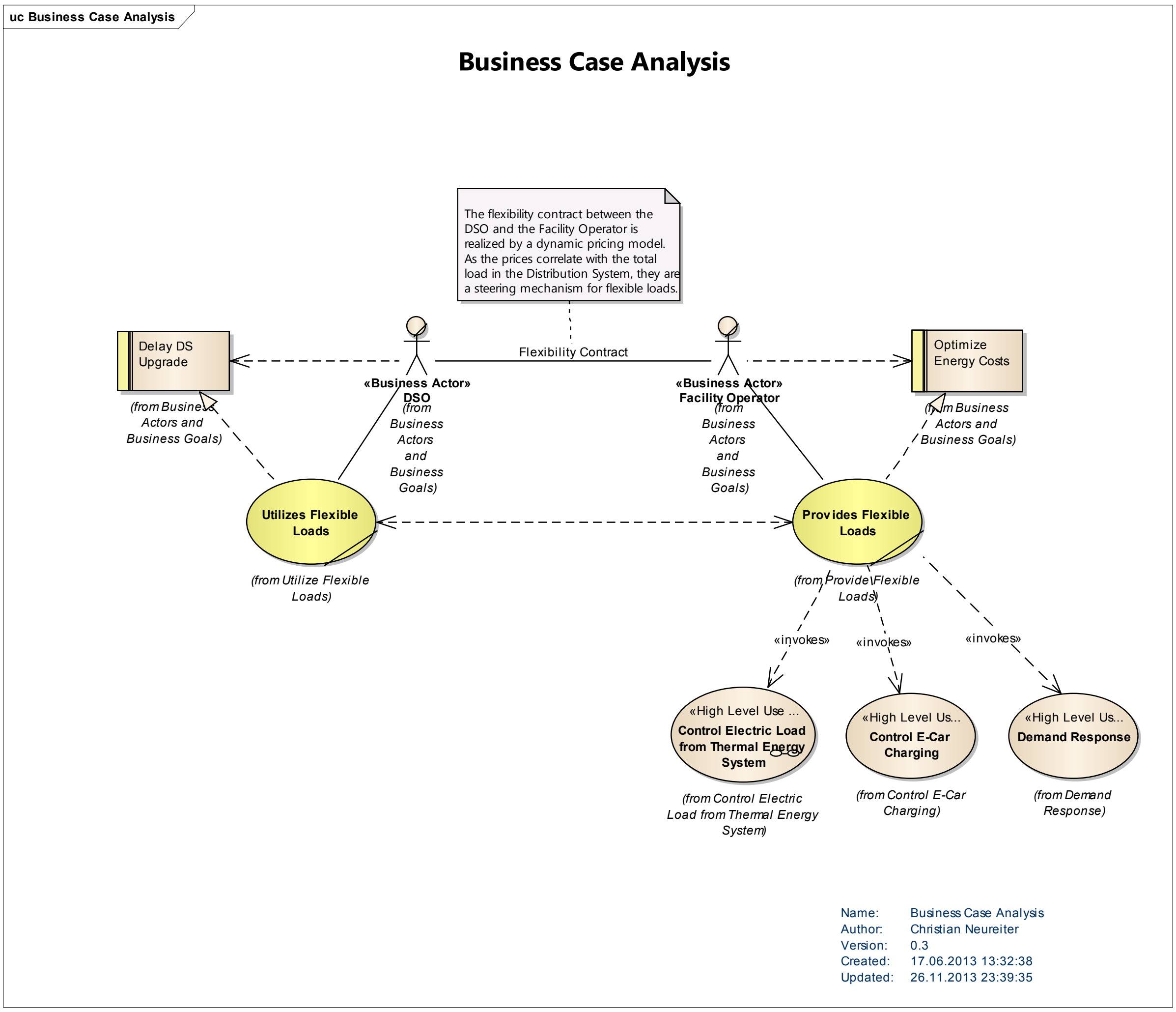
2. *Model the identified **Business Actors** by making use of the Model Element “Business Actor”. This element can be found in the View “Toolbox” and placed by drag and drop onto the diagram.*

3. *Model the individual **Business Goals** for every Business Actor by using the element “Business Goal”. Bring them into relation with the concerning Business Actor by making use of the “dependency” relation.*

4. *Model the **Business Cases** that are performed by the Business Actors in order reach the individual Business Goals. The relation between Business Actor and Business Case is of type “use”; the relation between Business Case and Business Goal is of type “realize”. Typically numerous Business Cases exist. You can make use of all UML Use Case relations to model the dependencies between them. It is also a good practice to make diagrams composit in order to reduce complexity.*

5. *Identify and model specific **High Level Use Cases** by making use of the element “High Level Use Case”. Bring them in relation with individual Business Cases by making use of the “invoke” relation. Say, a Business Case invokes High Level Use Cases.*

Please note that every Business Case from the template is linked to an individual SGAM Business Layer Diagram. These diagrams will be modeled after finishing the SGAM Function Layer, as there will be defined which domains and zones are affected by each related High Level Use Case.


uc Business Case Analysis
Business Case Analysis
The flexibility contract between the DSO and the Facility Operator is realized by a dynamic pricing model. As the prices correlate with the total load in the Distribution System, they are a steering mechanism for flexible loads.
Delay DS Upgrade
(from Business Actors and Business Goals)
«Business Actor» DSO
(from Business Actors and Business Goals)
Flexibility Contract
«Business Actor» Facility Operator
(from Business Actors and Business Goals)
Optimize Energy Costs
(from Business Actors and Business Goals)
Utilizes Flexible Loads
(from Utilize Flexible Loads)
Provides Flexible Loads
(from Provide Flexible Loads)
«invokes»
«invokes»
«invokes»
«High Level Use ... Control Electric Load from Thermal Energy System
(from Control Electric Load from Thermal Energy System)
«High Level Us... Control E-Car Charging
(from Control E-Car Charging)
«High Level Us... Demand Response
(from Demand Response)

Name: Business Case Analysis
Author: Christian Neureiter
Version: 0.3
Created: 17.06.2013 13:32:38
Updated: 26.11.2013 23:39:35

Figure 7 - Business Case Model (Example)

7.1.2. Develop High Level Use Case Model

After the identification of the involved High Level Use Cases (HLUC) in the prior executed task they need to be described in more detail. The description of the HLUCs consists of two basic steps. First, model the relations between the individual HLUC's by making use of the standard Use Case relationships from the UML. Next, decompose every single HLUC in more granular Primary Use Cases (PUC) and describe their cooperation.
These modeling tasks are performed at the level of the SGAM Function Layer. For the ease of use, the SGAM Toolbox provides some adequate templates which can be used for modeling as described below:

1. *Start the Model Wizard (Menu → Project → New Model) and select "SGAM Toolbox" as Technology and "SGAM Function Layer" as model template. Of course you can also create the single packages and diagrams manually, but for the beginning the template is useful to get an idea about the concept.*

This step creates a new package named "SGAM Function Layer" within your model. The content of this package is an example that illustrates, how a model of HLUCs and PUCs could look like. Besides the model itself the package shows the best practice for structuring your model: Inside the package is a SGAM Function Layer diagram located that is used to depict the relations between the single HLUCs. For every HLUC an individual Sub-Package with the name of the corresponding HLUC and the stereotype "*HLUC"* is integrated.
Each of these Sub-Packages holds two diagrams of type SGAM Function Layer. The first diagram is used to decompose the HLUC into more granular PUCs and to describe their relations. The second diagram is used to locate the involved PUCs within the SGAM plane, consisting of domains and zones. Again, for every PUC an individual Sub-Package with the name of the PUC and the stereotype *"PUC"* exists.
To create your own High Level Use Case Model follow the steps below:

2. *Place all HLUC's you identified during the prior task on the Top-Level Diagram in the SGAM Function Layer Package and model the relations between them.*

3. *To keep your model clean and to enhance the readability of the later on generated reports, create a package structure as described above and move the HLUCs from the SGAM Business Layer package to the corresponding Sub-Package in the SGAM Function Layer Package.*

4. *For every HLUC Sub-Package create a diagram of type "SGAM Function Layer"*

5. *Decompose the HLUC into more granular PUCs and describe their cooperation. It is good practice to make use of Activity Diagrams to do so. To create compact information you can also place the Activity Diagram itself on this diagram. Depict functional interrelations between single PUCs by making use of the "Functional Interrelation" relation.*

6. *Hint: You can automatically generate an Activity Diagram from the HLUC. To do so, you have to invoke the single PUCs within the "Scenario" description of the HLUC. Please learn more about "Scenarios" and "Generate Diagrams" in the Enterprise Architect Help.*

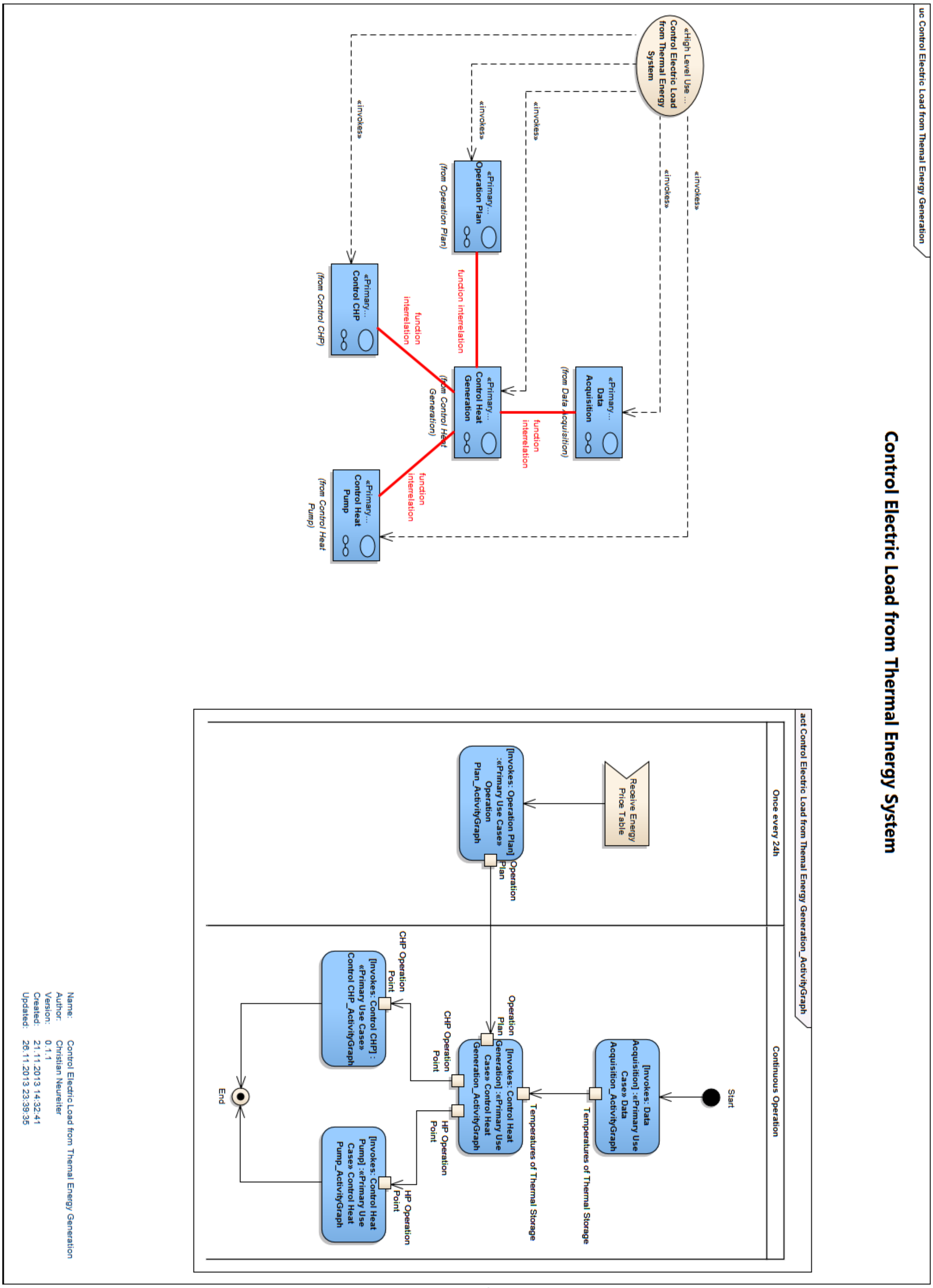

uc Control Electric Load from Thermal Energy Generation
Control Electric Load from Thermal Energy System
«High Level Use ... Control Electric Load from Thermal Energy System
«invokes»
«invokes»
«invokes»
«invokes»
«invokes»
«Primary... Operation Plan
(from Operation Plan)
«Primary... Data Acquisition
(from Data Acquisition)
«Primary... Control Heat Generation
(from Control Heat Generation)
«Primary... Control CHP
(from Control CHP)
«Primary... Control Heat Pump
(from Control Heat Pump)
function interrelation
function interrelation
function interrelation
function interrelation
act Control Electric Load from Thermal Energy Generation_ActivityGraph
Once every 24h
Continuous Operation
Receive Energy Price Table
[Invokes: Operation Plan] :«Primary Use Case» Operation Plan_ActivityGraph
Operation Plan
Start
[Invokes: Data Acquisition] :«Primary Use Case» Data Acquisition_ActivityGraph
Temperatures of Thermal Storage
Temperatures of Thermal Storage
Operation Plan
[Invokes: Control Heat Generation] :«Primary Use Case» Control Heat Generation_ActivityGraph
CHP Operation Point
HP Operation Point
CHP Operation Point
HP Operation Point
[Invokes: Control CHP] :«Primary Use Case» Control CHP_ActivityGraph
[Invokes: Control Heat Pump] :«Primary Use Case» Control Heat Pump_ActivityGraph
End
Name: Control Electric Load from Thermal Energy Generation
Author: Christian Neureiter
Version: 0.1.1
Created: 21.11.2013 14:32:41
Updated: 26.11.2013 23:39:35

Figure 8 - High Level Use Case Model (Example)

7.1.3. Develop Primary Use Case Model

The aim of this task is a more detailed description for every single Primary Use Case (PUC) developed in the prior task. Basically it is valid to make use of any possibility that helps understanding the functionality of the PUC. In praxis it is useful to describe all PUCs in a similar way. A proven method is to describe the PUCs by using Activity and Sequence Diagrams. Enterprise Architect comprises a very powerful possibility for an automated generation of these diagrams. Creating the descriptions that way is a very efficient approach for modeling the PUCs. To make use of this possibility follow the steps below:

1. *Create a SGAM Function Layer Diagram within every PUC Sub-Package and place the corresponding PUC in it.*

2. *Describe the functionality of the PUC in any text editor (or use the available Product-Owner description). Write in a way, that every sentence represents one step or Activity of the PUC and write every sentence in a new line. Try to create sentences that hold the name of every involved actor and every exchanged information. For example instead of "Actor A sends Voltage Measurement to Actor B. Actor B responds with the new operation point" write "Actor A sends Voltage Measurement to Actor B. Actor B transmits Operation Point to Actor A.". Now, copy the written text to the clipboard.*

3. *Open the properties dialog of the corresponding PUC and select "Scenarios" from the "Rules" menu on the left. Here, select the "Structured Specification" tab and right click into the Action description field. Now you can select to "create structure from clipboard text". Doing this, creates for every sentence written before a single step in the Use Case description. After this, you can close the property.*

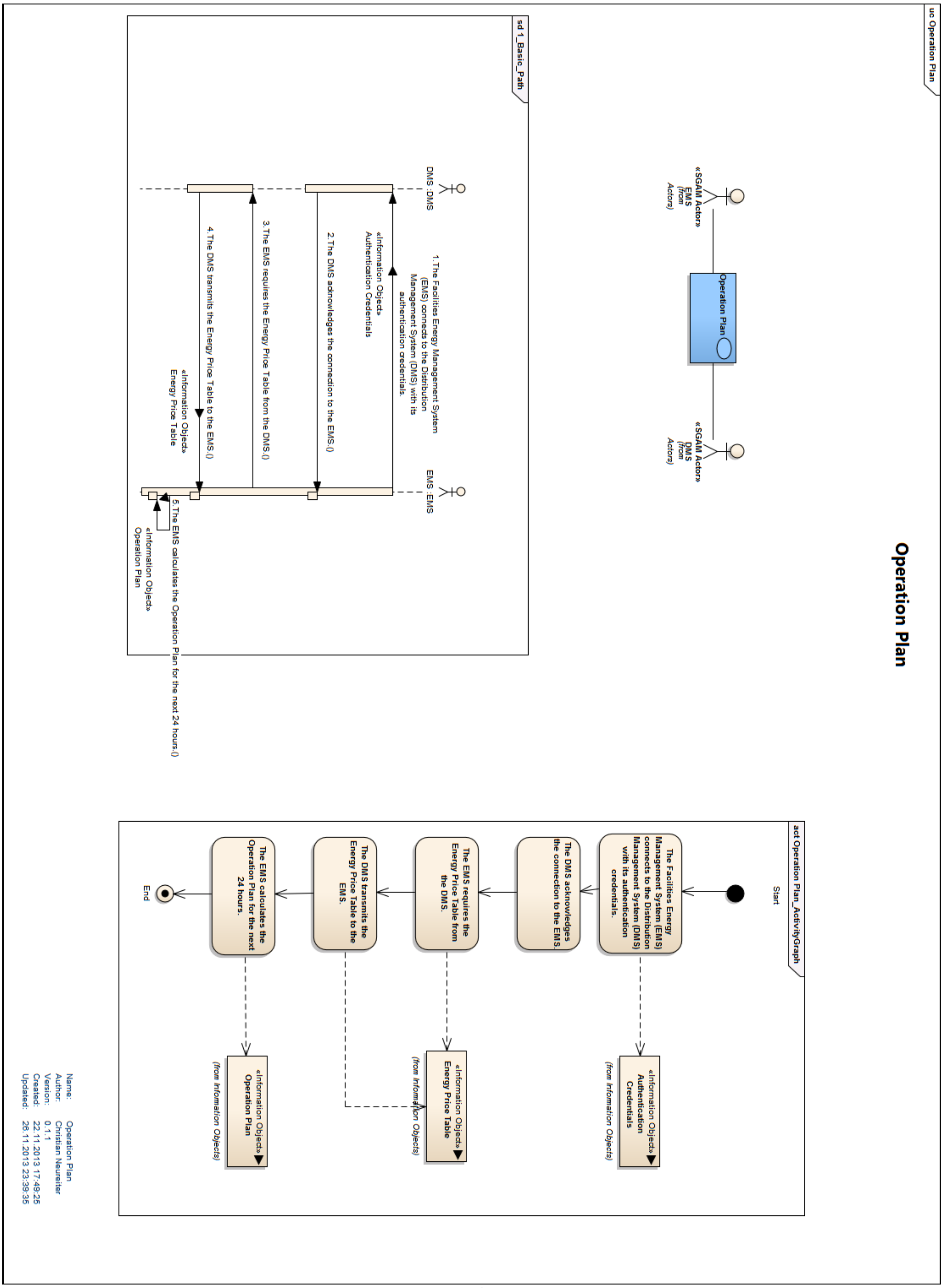
4. *Create for every Actor involved the corresponding Model Element (SGAM Actor) and link it to the PUC. Take care to name the actors the same way as they are called in the textual description. Of course, if the Actor already exists in your model, do not create it again but place and link the existing one. If you open the Scenario Description within the PUC properties dialog again, you will see that the name of the connected actor is now underlined.*

5. *Having all involved Actors linked to the PUC, you can generate an Activity and Sequence Diagram automatically. In the menu bar of the "Structured Specification" tab you can find the Icon for "Generate Diagrams". Here you can select which type of diagrams you want to generate.*
   Please Note: The described functionality is very powerful and enables you to describe Use Cases in a very efficient way. You can manipulate the activity diagram and update the structured description with the changes. Of course it is also possible to create alternate and exception paths and much more. Please refer to the very valuable Enterprise Architect Help to learn more about these capabilities.

6. *In the generated Activity Diagram you can analyze the PUC and create model elements for every Information Item transmitted. Use the element "Information Object" for this task. As this diagram is of type "Activity Diagrams" you won't find this element in the toolbox. You have to select the SGAM Function Layer toolbox by clicking on "More tools…" at the top of the toolbox and selecting "SGAM-Toolbox / SGAM Function Layer". Depict the relation between a single Activity (Use Case Step) and the Information Item by means of the "dependency" relation.*

7. *In the generated Sequence Diagram you can attach the created Information Items to the corresponding sequence. Right click on the corresponding connection and select "Advanced/Information Flows Realized". In the appearing dialog click on "click to create new information flow…". A package browser opens where you can select the referred Information Item. Again, please refer to the Enterprise Architect Help to learn more.*

8. *You can place the generated Activity and Sequence Diagrams directly in the PUC diagram simply by using "drag and drop". This helps, as you have all relevant description – the PUC and it's involved actors, the algorithmic aspect (activity diagram) and the communication aspect (sequence diagram) – in one diagram that will be used during reporting.*



uc Operation Plan
Operation Plan
«SGAM Actor» EMS (from Actors)
Operation Plan
«SGAM Actor» DMS (from Actors)
sd 1_Basic_Path
DMS :DMS
EMS :EMS
1.The Facilities Energy Management System (EMS) connects to the Distribution Management System (DMS) with its authentication credentials.
«Information Object» Authentication Credentials
2.The DMS acknowledges the connection to the EMS.()
3.The EMS requires the Energy Price Table from the DMS.()
4.The DMS transmits the Energy Price Table to the EMS.()
«Information Object» Energy Price Table
5.The EMS calculates the Operation Plan for the next 24 hours.()
«Information Object» Operation Plan
act Operation Plan_ActivityGraph
Start
The Facilities Energy Management System (EMS) connects to the Distribution Management System (DMS) with its authentication credentials.
The DMS acknowledges the connection to the EMS.
The EMS requires the Energy Price Table from the DMS.
The DMS transmits the Energy Price Table to the EMS.
The EMS calculates the Operation Plan for the next 24 hours.
End
«Information Object» Authentication Credentials (from Information Objects)
«Information Object» Energy Price Table (from Information Objects)
«Information Object» Operation Plan (from Information Objects)
Name: Operation Plan
Author: Christian Neureiter
Version: 0.1.1
Created: 22.11.2013 17:49:25
Updated: 26.11.2013 23:39:35

Figure 9 - Primary Use Case Model (Example)

7.2. Develop Function Layer

The SGAM Function Layer describes the location of all involved Primary Use Cases (PUC) and Actors for a specific High Level Use Case (HLUC). Hence, it has to be developed for every HLUC separately. The steps below describe how to create the SGAM Function Layer for a single HLUC.

1. *Use the SGAM Function Layer Template to create a new SGAM Function Layer Diagram inside the "HLUC" package.*

2. *To make the SGAM Plane (domains and zones) visible, open "Diagram" in the pull down menu and select the "Swimlanes and Matrix" dialog. Within the register card "Matrix" you can select a Model Profile. Select the "SGAM Function Layer" Profile and activate the Check-Box "activate" at the top.*

3. *Place all involved PUCs and Actors in the diagram and arrange them in respect to the corresponding domains and zones.*

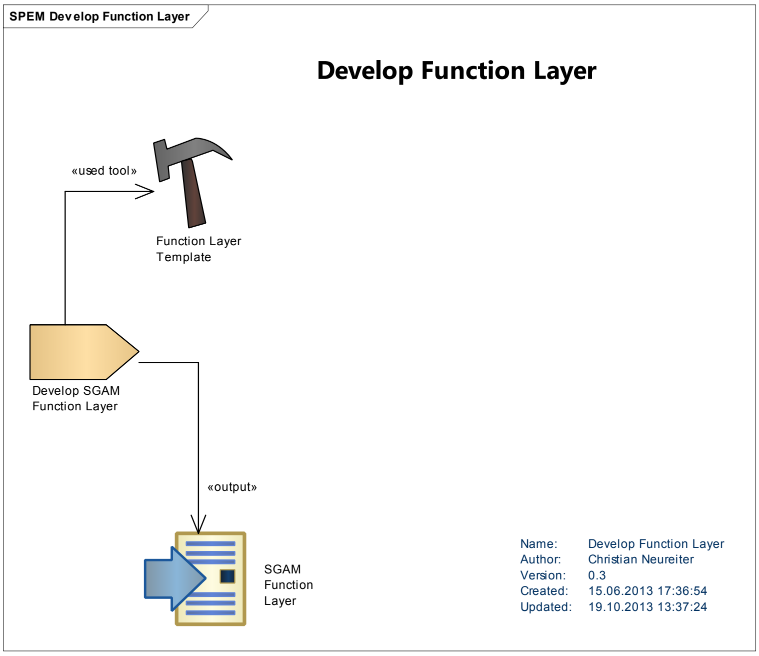

SPEM Develop Function Layer
Develop Function Layer
«used tool»
Function Layer Template
Develop SGAM Function Layer
«output»
SGAM Function Layer
Name: Develop Function Layer
Author: Christian Neureiter
Version: 0.3
Created: 15.06.2013 17:36:54
Updated: 19.10.2013 13:37:24

Figure 10 - Develop Function Layer

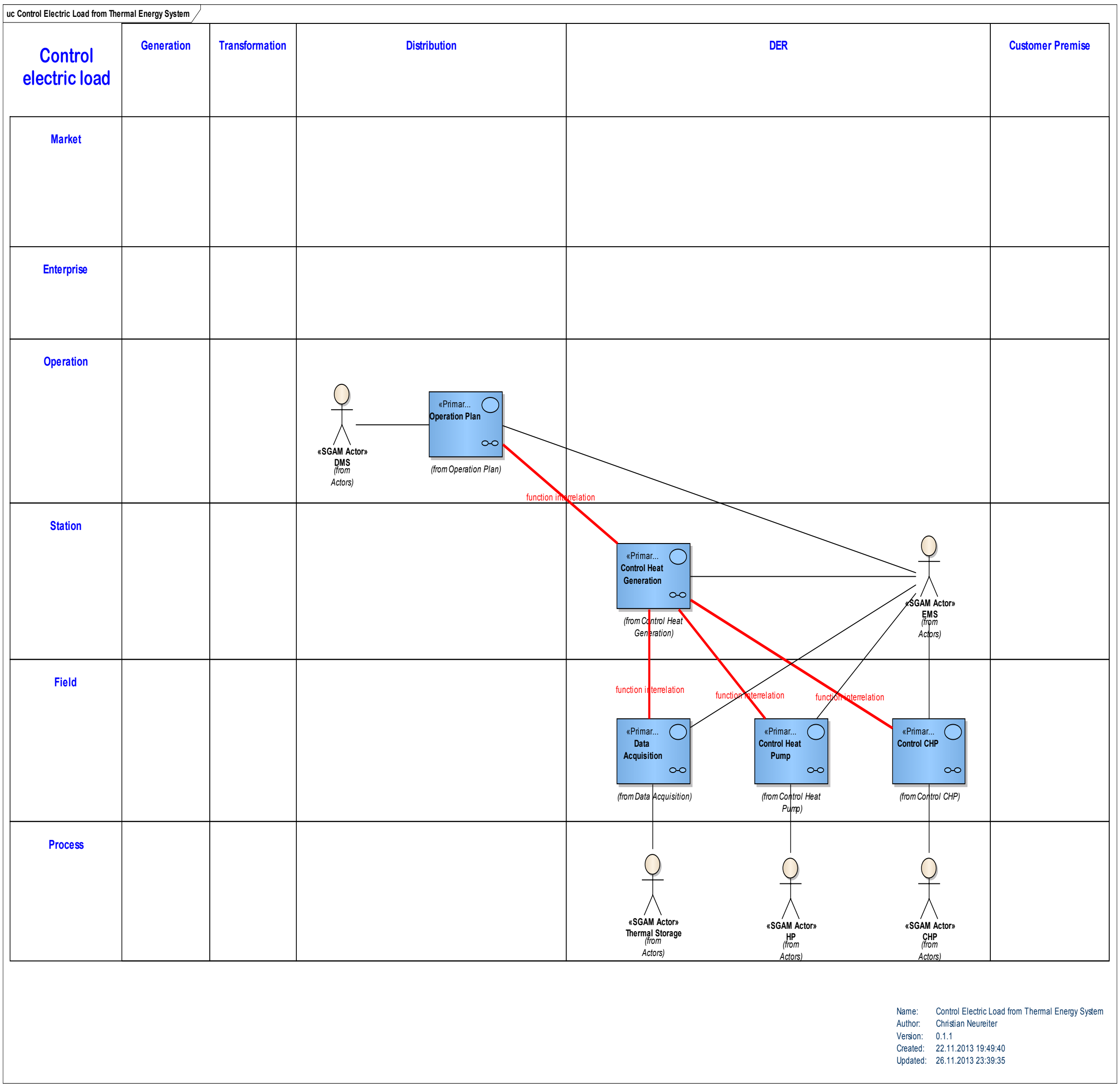

uc Control Electric Load from Thermal Energy System
Control electric load
Generation
Transformation
Distribution
DER
Customer Premise
Market
Enterprise
Operation
Station
Field
Process
«SGAM Actor» DMS (from Actors)
«Primar... Operation Plan (from Operation Plan)
function interrelation
«Primar... Control Heat Generation (from Control Heat Generation)
«SGAM Actor» EMS (from Actors)
function interrelation
function interrelation
function interrelation
«Primar... Data Acquisition (from Data Acquisition)
«Primar... Control Heat Pump (from Control Heat Pump)
«Primar... Control CHP (from Control CHP)
«SGAM Actor» Thermal Storage (from Actors)
«SGAM Actor» HP (from Actors)
«SGAM Actor» CHP (from Actors)
Name: Control Electric Load from Thermal Energy System
Author: Christian Neureiter
Version: 0.1.1
Created: 22.11.2013 19:49:40
Updated: 26.11.2013 23:39:35

Figure 11 - SGAM Function Layer (Example)

7.3. Develop Business Layer

The focus of the SGAM Business Layer is to show the affected domains and zones for every Business Case and hence has to be modeled for each of them. It is suggested to use the involved High Level Use Cases as model elements. The steps below describe how to model the SGAM Business Layer for a single Business Case.

1. *Use the SGAM Business Layer template to create a new SGAM Business Layer diagram for every Business Case (New Diagram/SGAM Toolbox/SGAM Business Layer)*

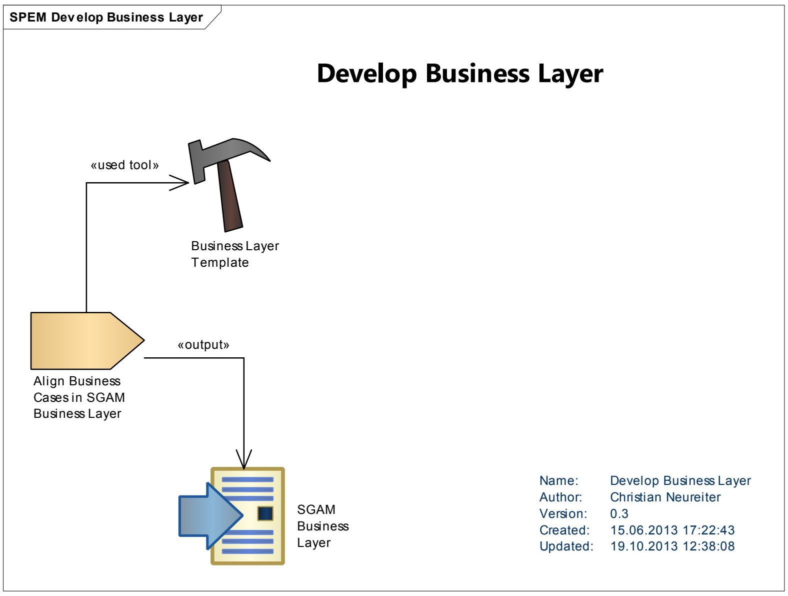
2. *To make the SGAM Plane (domains and zones) visible, open “Diagram” in the pull down menu and select the “Swimlanes and Matrix” dialog. Within the register card “Matrix” you can select a Model Profile. Select the “SGAM Business Layer” Profile and activate the Check-Box “activate” at the top.*

3. *For every invoked HLUC open the SGAM Function Layer diagram and analyze which domains and zones are affected.*

4. *Go to the SGAM Business Layer diagram and place the corresponding HLUC in it. Switch the appearance of the HLUC to rectangular (right click / Advanced / Use Rectangular Notation)*

5. *Locate and resize the HLUC according to the affected domains and zones. Having done this for all HLUCs, you see which domains and zones are affected by the Business Case in total.*

6. *Place the Business Case in the diagram (at the bottom of the Z-Order), switch to rectangular notation and resize and locate it according to the totally affected domains and zones.*



SPEM Develop Business Layer
Develop Business Layer
«used tool»
Business Layer Template
Align Business Cases in SGAM Business Layer
«output»
SGAM Business Layer
Name: Develop Business Layer
Author: Christian Neureiter
Version: 0.3
Created: 15.06.2013 17:22:43
Updated: 19.10.2013 12:38:08

Figure 12 - Develop Business Layer

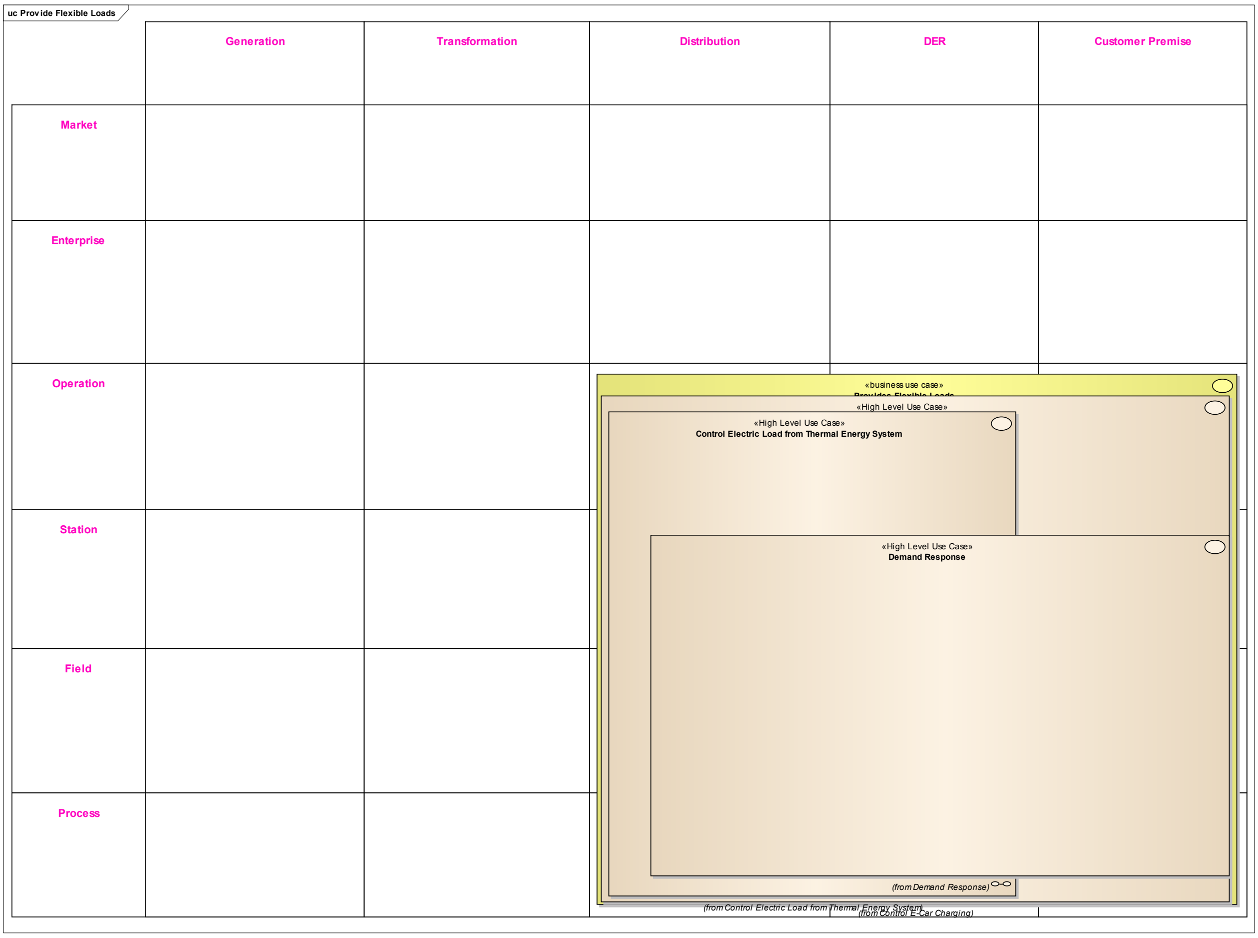


Figure 13 - SGAM Business Layer (Example)

8. System Architecture Phase

8.1. Develop Component Layer

The development of the SGAM Component Layer represents the model transformation from the Computational Independent Model (CIM) to the Platform Independent Model (PIM). This transformation maps the functional description of the system to a general, architectural solution.
Hence, in a first step a mapping from logical actors to physical components has to be done. Next, the identified physical actors are utilized to create the SGAM component layer.
Both steps can be executed by usage of the supplied Component Layer Template.

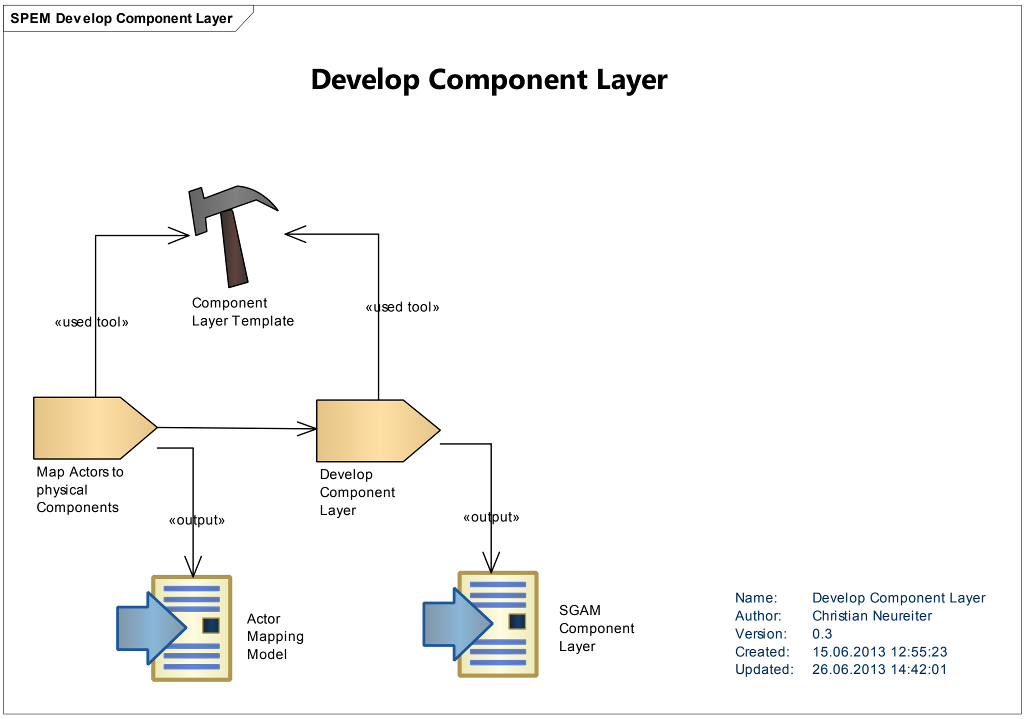

SPEM Develop Component Layer
Develop Component Layer
Component Layer Template
«used tool»
«used tool»
Map Actors to physical Components
Develop Component Layer
«output»
«output»
Actor Mapping Model
SGAM Component Layer
Name: Develop Component Layer
Author: Christian Neureiter
Version: 0.3
Created: 15.06.2013 12:55:23
Updated: 26.06.2013 14:42:01

Figure 14 - Develop Component Layer

8.1.1. Map Actors to physical Components

To perform the mapping of the logical Actors (as created in the Function Layer) to physical Components follow the steps below:

1. *Use the SGAM Component Layer template to create a new SGAM Component Layer diagram*
2. *Place all involved logical Actors to the diagram*
3. *Create a physical representation (component) for every Actor. This physical representation can either be a specific component or a Software Application. You can use the appropriate model elements from the toolbox for this step. Use the "trace" relation to depict the model transformation step. You can also create new Components by using the general "Component" element. It is also possible to use your own images for these Components. Please use the Enterprise Architect Help to learn more about this possibility.*
4. *If a Software Application is introduced, you need to create a "Computer" Component as well. Use the "hosts" relation to show, which computer hosts which Software Application.*

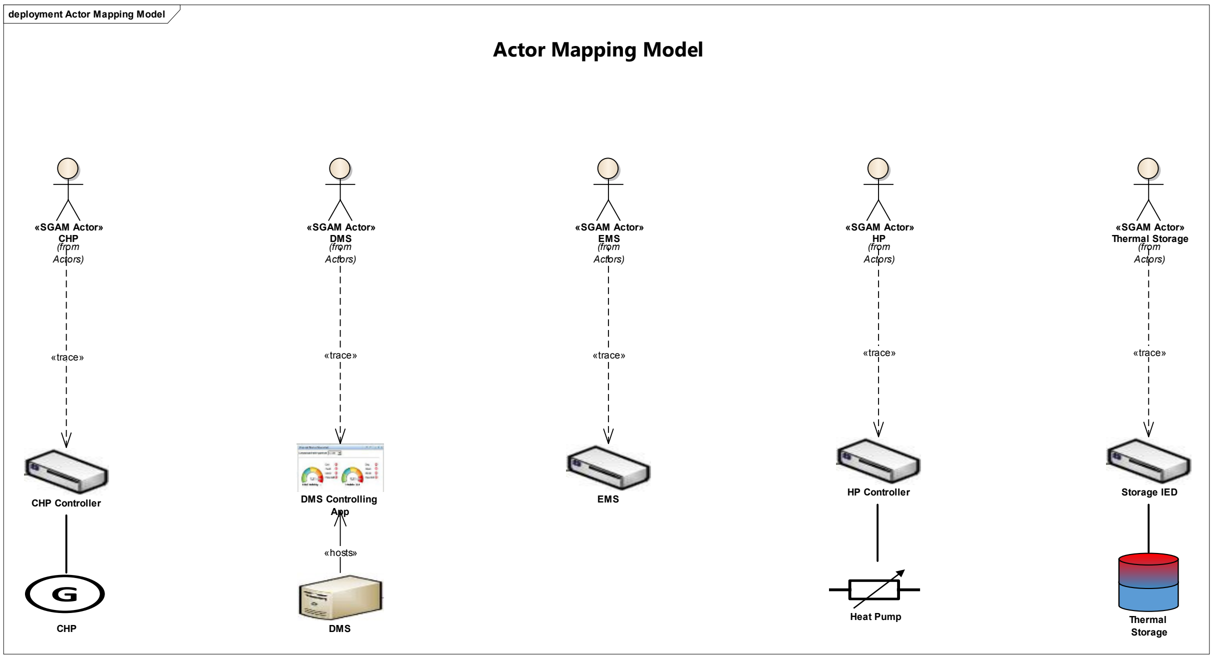

deployment Actor Mapping Model
Actor Mapping Model
«SGAM Actor» CHP (from Actors)
«SGAM Actor» DMS (from Actors)
«SGAM Actor» EMS (from Actors)
«SGAM Actor» HP (from Actors)
«SGAM Actor» Thermal Storage (from Actors)
«trace»
«trace»
«trace»
«trace»
«trace»
CHP Controller
DMS Controlling App
EMS
HP Controller
Storage IED
«hosts»
G
CHP
DMS
Heat Pump
Thermal Storage

Figure 15 - Actor Mapping Model (Example)

8.1.2. Develop Component Layer

The development of the SGAM Component Layer can be done by following the steps below:

1. *Use the SGAM Component Layer template to create a new SGAM Component Layer*

2. *To make the SGAM Plane (domains and zones) visible, open "Diagram" in the pull down menu and select the "Swimlanes and Matrix" dialog. Within the register card "Matrix" you can select a Model Profile. Select the "SGAM Component Layer" Profile and activate the Check-Box "activate" at the top.*

3. *Place all prior created physical components within the plane in the corresponding domain and zone.*

4. *Create additional necessary components, like ICT-Networks (represented as clouds), Electric Networks (e.g. "Medium Voltage Network") or electric components like Transformers. Following the modeling-concepts you can of course make single components like for example ICT-Networks "composite" and describe them in more detail. Please refer to the Enterprise Architect Help to learn more about this possibility.*

5. *Model the relations between the individual components. You can use the "Electric Association" relation to depict electric connections, especially along the electric conversion chain in the process zone, and "ICT Association" to model ICT connections.*

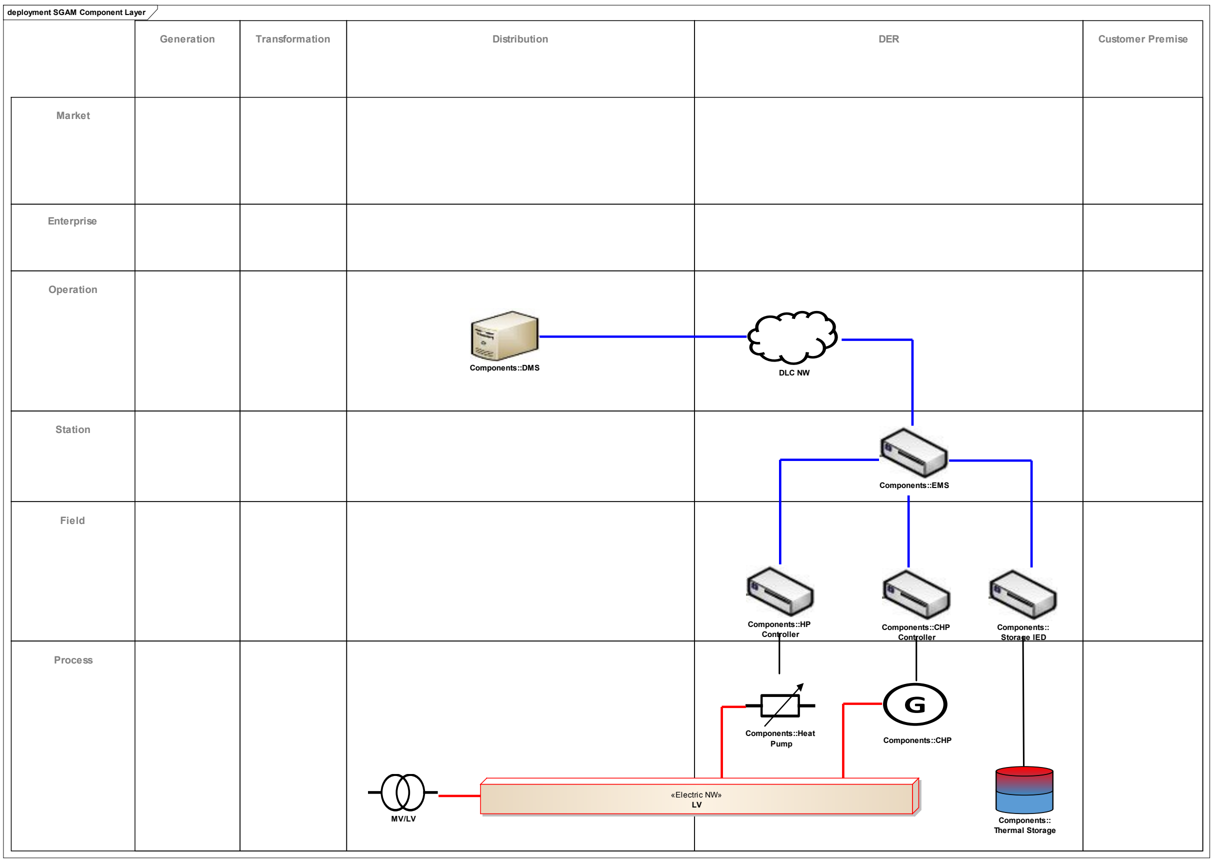


Figure 16 - SGAM Component Layer (Example)

8.2. Develop Information Layer

Focus of this task is to model the information object flows between the single components and to identify proper data model standards that are suitable to reflect these information objects.
The development of the Information Layer consists of three consecutive tasks as described in the following subsections.
You can make use of the Model Wizard to create the involved diagrams automatically:

1. *Start the Model Wizard (Menu → Project → New Model) and select "SGAM Toolbox" as Technology and "SGAM Information Layer" as model template. Of course you can also create the single packages and diagrams manually, but for the beginning the template is useful to get an idea about the concept.*

This step creates a new package named "SGAM Information Layer" within your model. The content of this package is an appropriate sub package for each of the three necessary steps.

8.2.1. Develop Business Context View

The Business Context View models the information object flows between individual components. It can be developed following the steps below:

1. *Open the "Business Context View" Diagram as created from the Model Wizard or create this diagram manually*

2. *Place all components in the diagram. Hint: If you copy the elements from the Component Layer, you will have arranged them in the same way as in the Component Layer*

3. *Hide Relations. After placing the components in the diagram, all relations (e.g. ICT Associations, Electric Associations) as introduced so far will be visible. As we are not interested in these relations within the Information Layer, you can make them invisible. Open the “Diagram” Drop-Down Menu, select “Advanced” → “Visible Relations” and deselect all relations. Do not accidently delete these relations instead of making them invisible. Deleting them will delete them not only from the diagram but from the model, so you won’t see them in the original diagrams anymore.*

4. *Create Information Object Flows. In the Primary Use Case Diagram we identified which Information Objects are to be communicated between logical actors. Use the “Information Object Flow” Relation to model these flows here as well and select the appropriate “Information Objects” in the Pop-up window. Note: This step is some “copy” task, in a future version of the SGAM Toolbox this will be automated.*

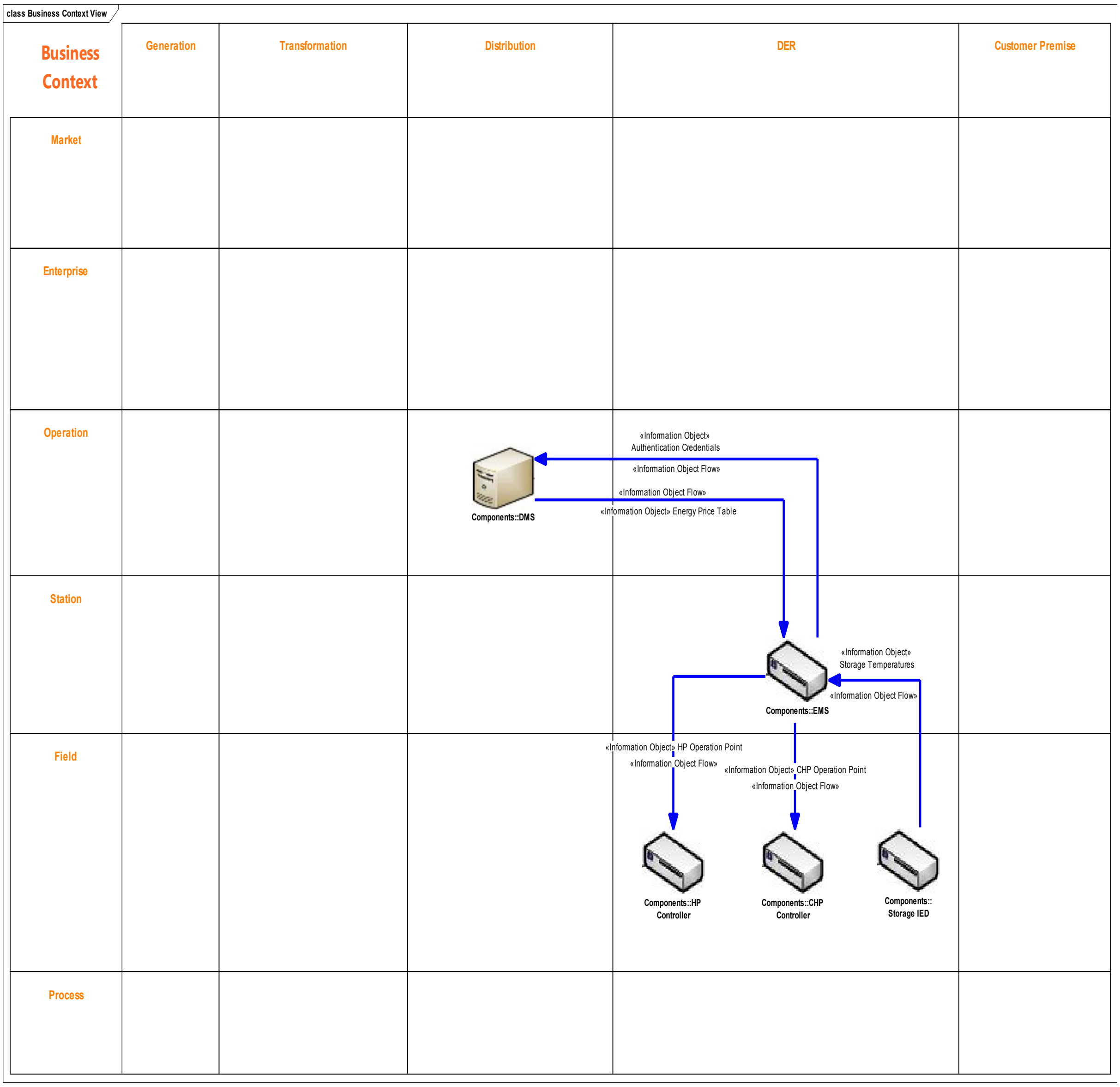

class Business Context View
Business Context
Generation
Transformation
Distribution
DER
Customer Premise
Market
Enterprise
Operation
Station
Field
Process
Components::DMS
«Information Object» Authentication Credentials
«Information Object Flow»
«Information Object Flow»
«Information Object» Energy Price Table
Components::EMS
«Information Object» Storage Temperatures
«Information Object Flow»
«Information Object» HP Operation Point
«Information Object Flow»
«Information Object» CHP Operation Point
«Information Object Flow»
Components::HP Controller
Components::CHP Controller
Components:: Storage IED

Figure 17 - Business Context View (Example)

8.2.2. Perform Standard and Information Object Mapping

1. *Open the “Standard and Information Object Mapping” Diagram as created from the Model Wizard or create this diagram manually*

2. *Place all components in the diagram. Hint: If you copy the elements from the Component Layer, you will have arranged them in the same way as in the Component Layer*

3. *Turn the visibility of all relations – except the Information Object Flows – off*

4. *Create appropriate “Data Model Standard” Elements and associate the related components with them by using the “Associates Data Model Standard” relations.*

5. *Place all used Information Objects in the diagram and state the relations between Data Model Standards and Information Objects by using the “Provides Information Object” relations.*

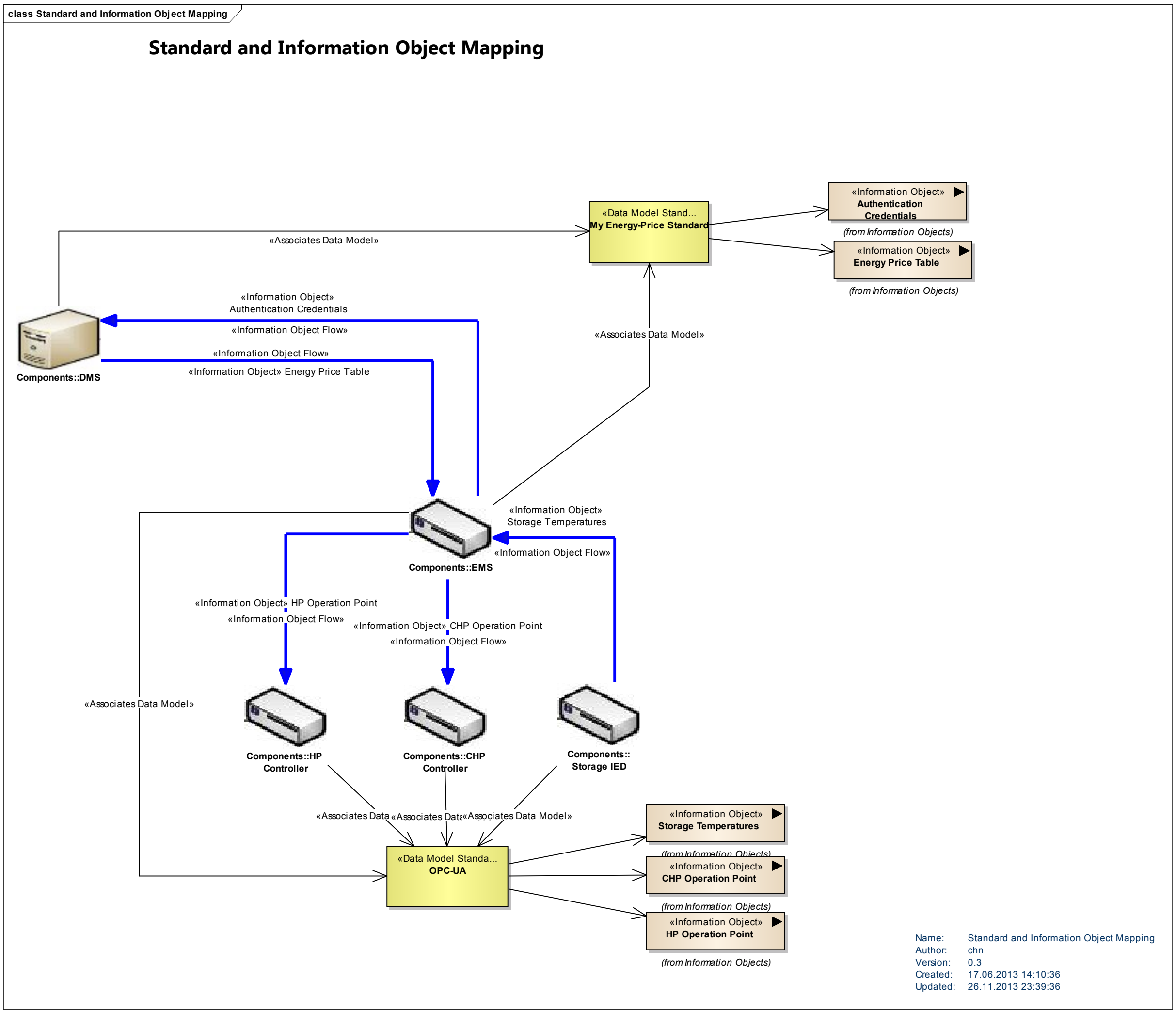

class Standard and Information Object Mapping
Standard and Information Object Mapping
«Data Model Stand...
My Energy-Price Standard
«Information Object»
Authentication Credentials
(from Information Objects)
«Information Object»
Energy Price Table
(from Information Objects)
«Associates Data Model»
«Information Object»
Authentication Credentials
«Information Object Flow»
«Information Object Flow»
«Information Object» Energy Price Table
Components::DMS
«Associates Data Model»
«Information Object»
Storage Temperatures
«Information Object Flow»
Components::EMS
«Information Object» HP Operation Point
«Information Object Flow»
«Information Object» CHP Operation Point
«Information Object Flow»
«Associates Data Model»
Components::HP Controller
Components::CHP Controller
Components:: Storage IED
«Associates Data
«Associates Data
«Associates Data Model»
«Data Model Standa...
OPC-UA
«Information Object»
Storage Temperatures
(from Information Objects)
«Information Object»
CHP Operation Point
(from Information Objects)
«Information Object»
HP Operation Point
(from Information Objects)
Name: Standard and Information Object Mapping
Author: chn
Version: 0.3
Created: 17.06.2013 14:10:36
Updated: 26.11.2013 23:39:36

Figure 18 - Standard and Information Object Mapping (Example)

8.2.3. Develop Canonical Data Model View

1. *Open the “Canonical Data Model View” Diagram as created from the Model Wizard or create this diagram manually*

2. *Place all components in the diagram. Hint: If you copy the elements from the Component Layer, you will have arranged them in the same way as in the Component Layer.*

3. *Place all related “Data Model Standard” Elements in the diagram*

4. *Resize and arrange the “Data Model Standard” Elements over domains and zones according to their associated components*

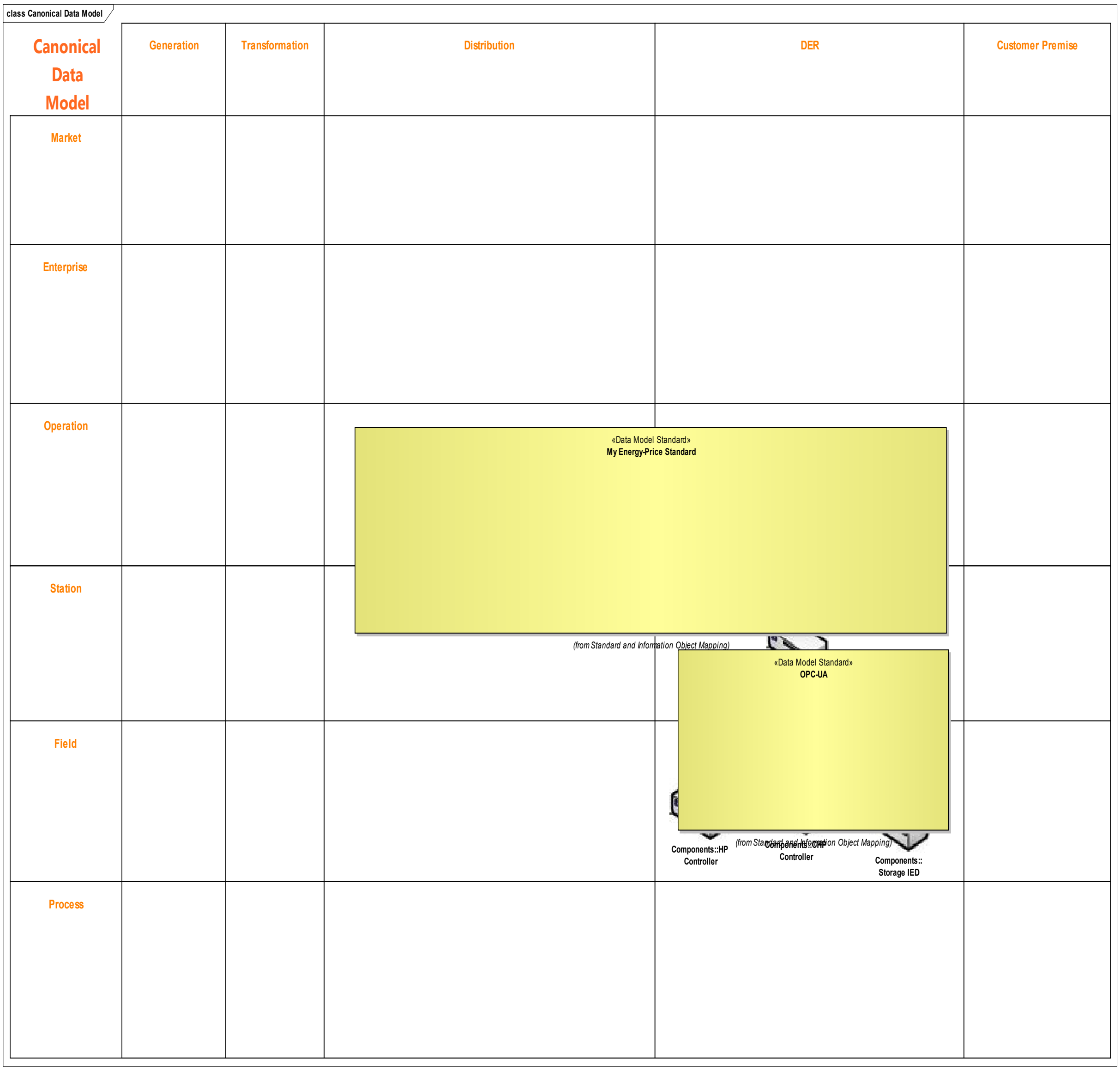


Figure 19 - Canonical Data Model View (Example)

8.3. Develop Communication Layer

The focus of the Communication Layer is to depict the used technology and protocols for the communication between single components.
You can model this layer by following the steps below.

1. *Start the Model Wizard (Menu → Project → New Model) and select "SGAM Toolbox" as Technology and "SGAM Communication Layer" as model template. Of course you can also create the single packages and diagrams manually, but for the beginning the template is useful to get an idea about the concept.*

2. *Place all components in the diagram. Hint: If you copy the elements from the Component Layer, you will have arranged them in the same way as in the Component Layer.*

3. *Hide Relations. After placing the components in the diagram, all relations (e.g. ICT Associations, Electric Associations) as introduced so far will be visible. As we are not interested in these relations within the Information Layer, you can make them invisible. Open the "Diagram" Drop-Down Menu, select "Advanced" → "Visible Relations" and deselect all relations. Do not accidently delete these relations instead of making them invisible. Deleting them will delete them not only from the diagram but from the model, so you won't see them in the original diagrams anymore.*

4. *Use the "Communication Path" Relations to model the communication paths between the components*

5. *For every communication path define the protocol and the technology as tagged value*

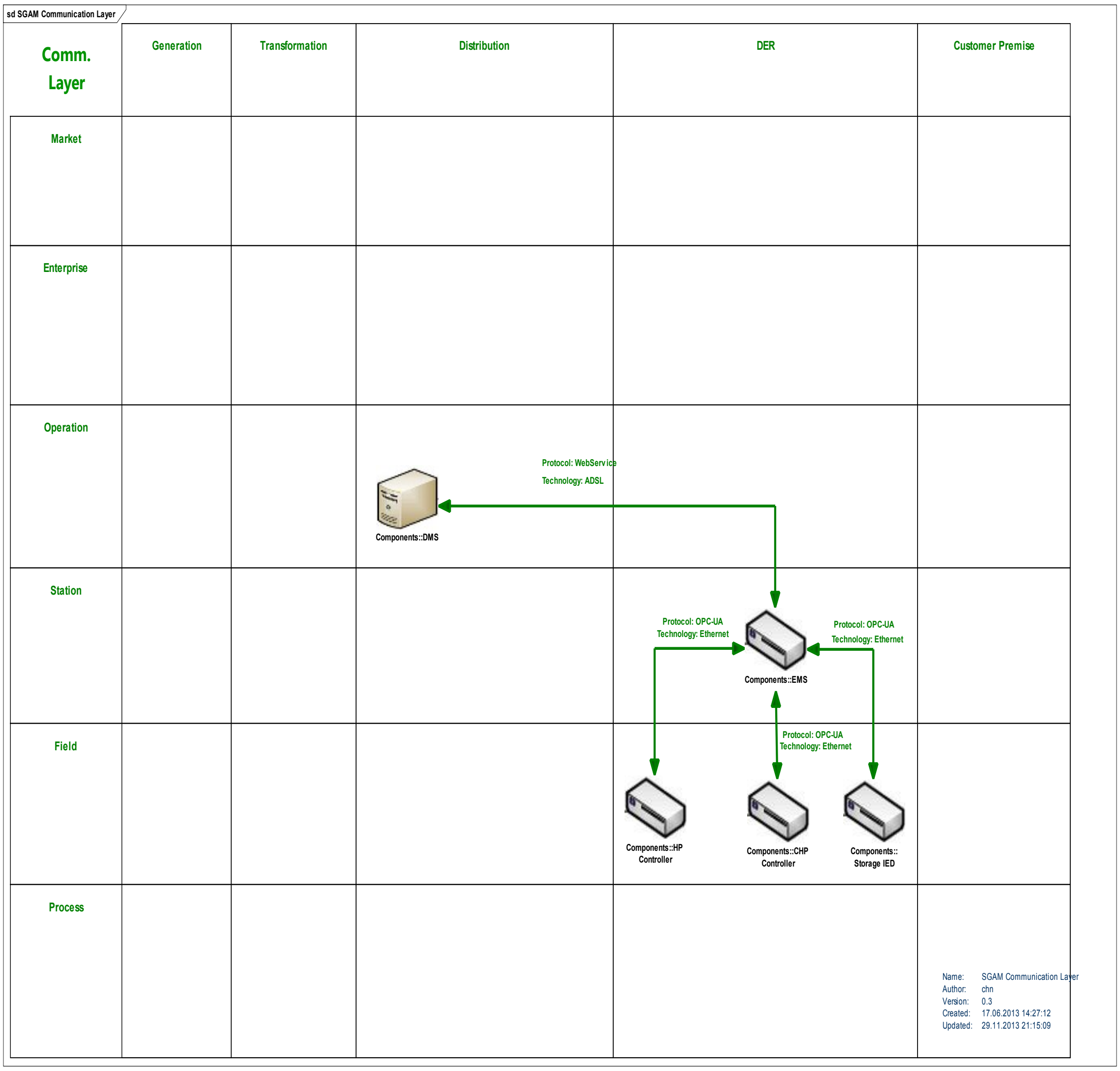


Figure 20 - SGAM Communication Layer (Example)

9. Design and Development of single Components

The development of all five SGAM layer delivers a big picture of a distributed smart grid system. For every component it is defined, which functionality it has to deliver and how it interacts with its surrounding components over all interoperability layers.
For the development of one, specific component out of this distributed system you could say that the systems' context and the systems' interfaces are defined. The system (component) itself is yet treated as black box. During the development of this system, the black box now is to be turned into a white box.
To start the development one component it is a very valuable possibility, to show the functionality and all interfaces over all interoperability layers in one diagram. This can easily achieved by following the steps below:

1. *Make the system (component) of interest composite and create a new diagram*
2. *Place the component in this diagram*
3. *Right click on the component and select "insert related elements". Now all related elements and the relations are placed into this diagram.*

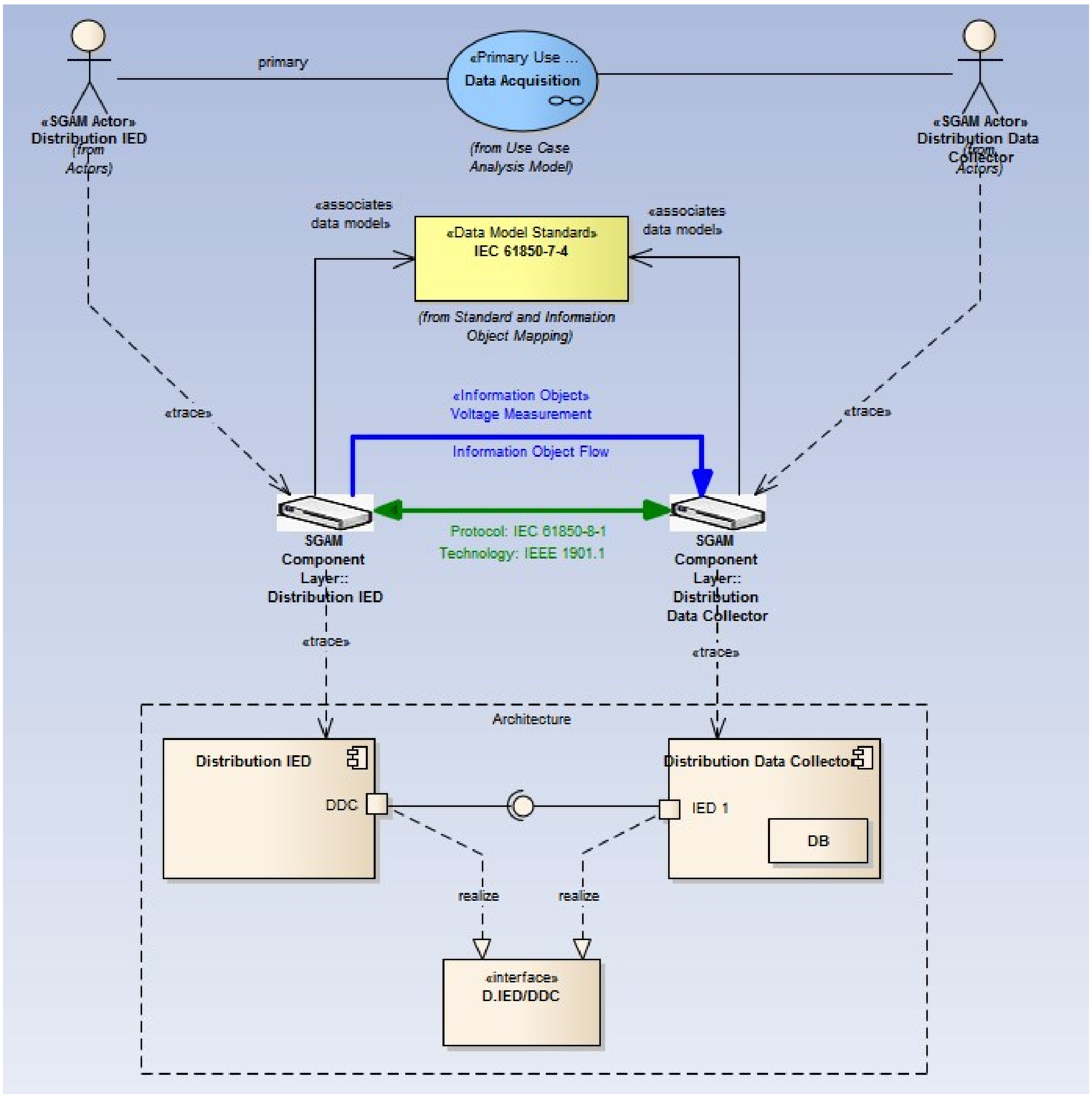


Figure 21 - Component Responsibility Model (Example)

10. Non-Functional Requirements

The afore mentioned issues describe how to architect Smart Grid Systems with focus on their functionality, which is denoted by means of Use Cases.
However, in such systems do not only have to meet functional requirements but also non functional requirements like Reliability, Availability, Maintainability, Safety, Security and Privacy.
This section should give you an idea how to approach these issues.

10.1. Security Requirements

Due to the nature of the Smart Grid as "critical infrastructure", Security is of central interest. In this subsection is discussed, how to obtain, analyse and maintain Security Requirements for a certain Smart Grid System. First, the theoretical background is outlined on basis of a Conceptual Framework. Subsequent to this it is illustrated, how the SGAM Toolbox can support the Requirements Engineering Task.

10.1.1. Theoretical Background

All security considerations are built around a certain "Asset" that could be subject to an attack. Every Asset implicitly has some Vulnerabilities that potentially can be exploited. Say, every Vulnerability is potentially exploited by a certain Threat. An Attack is the actual exploitation of a Threat, so an Attack is the realization of a Threat by a certain Attacker.
In order to mitigate the existing Vulnerabilities we want to implement some specific Countermeasures. These Countermeasures can be seen as the Realization of the Security Requirements we are going to determine during the Requirements Engineering task.
Figure 22 shows the relations between these entities.

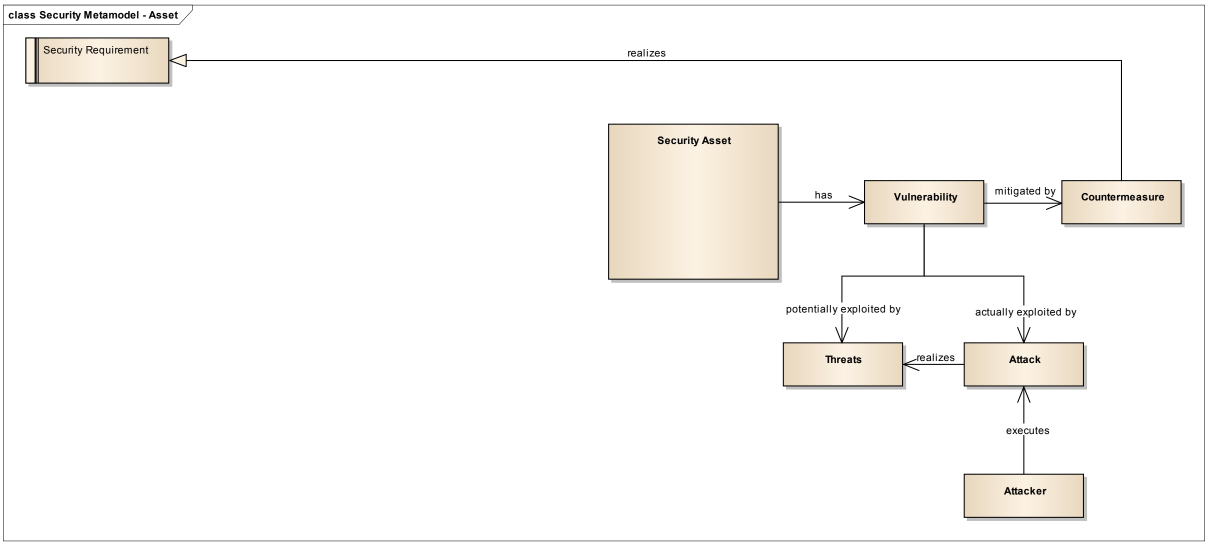


Figure 22 - Security Asset

Before the individual Security Requirements can be determined, it is necessary to more closely describe the "Security Asset" entity.
If we take a closer look to Attacks, we can say a successful attack manipulates or compromises a certain system. This means that some data (includes malicious commands) is introduced or extracted from the system. A system typically has two types of interfaces to

it's environment, which we call "System Context". First, a User Interfaces provide the possibility for direct interactions with users and second Communication Interfaces allow communication with other systems.
This considerations deliver two types of Assets that can be attacked in order manipulate a system:

- System Security Asset
- Communication Security Asset

Before an Attack to these Assets can be executed it is necessary for an Attacker to get access to a System's interfaces. This means whether physical access to a certain system or network access. As Network Access also comprises physical Access to a network, we combine them to one single Asset:

- Network Security Asset

This concept is depicted in Figure 23.

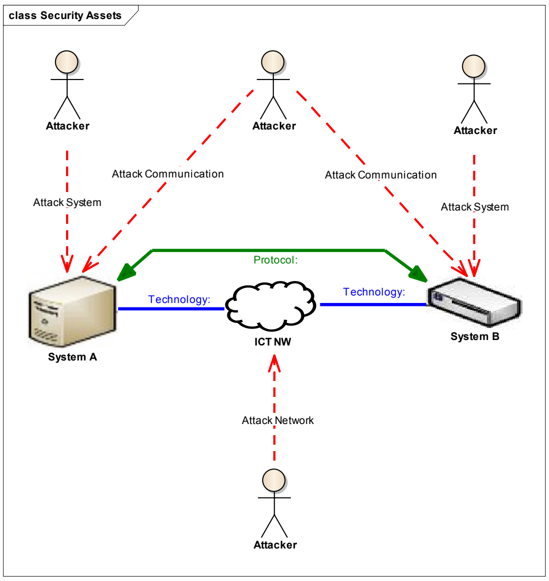


Figure 23 - Security Assets

Back to our Conceptual Framework this shows, that Security Assets can be categorized - according to their originating elements – in three different categories.

1) System
2) Communication
3) Network

Hence, each of these Asset Categories, needs it's specific Security Requirements. Classifying Assets into these three categories delivers a certain benefit: As the natures of elements within a category are quite similar, a basic set of Security Requirements for every Asset Category can be formed and used as starting point.
The aggregate of these Security Requirements reflects the Realization of an individual Security Strategy. The Security Requirements Pattern integrated in the SGAM Toolbox are based on a four layer strategy. Thus, all individual Security Requirements can be mapped to one of the four security Layer

- Policy
- Technical Measures
- Detection and Forensics
- Containment

Figure 24 shows the Conceptual Framework, extended by Security Requirements for every Asset Category and the composition of Security Requirements by Requirements of all layer.

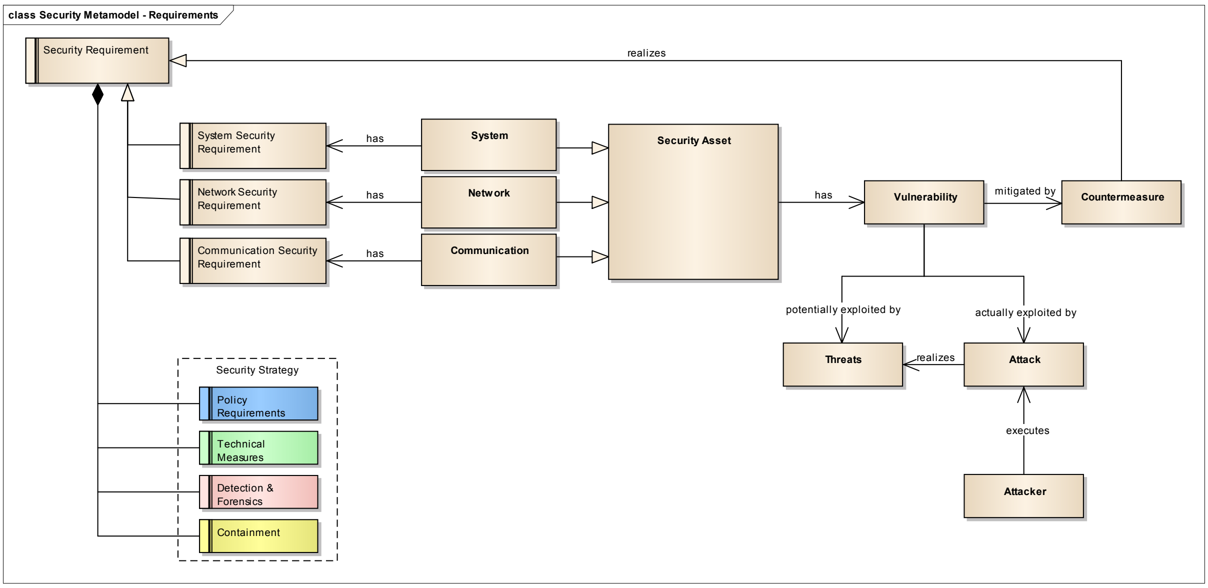


Figure 24 - Security Requirements

Of course, the individual Requirements for every element will differ and hence, the general “Requirement Patterns” can only serve as “qualitative” starting point, like for example “Authentication”.
To turn the general requirements for every system into more specific, say quantitative requirements like “ Authentication with Username/Password” or “Authentication with physical Token and PIN code” it is necessary, to determine the Risk, every Asset is facing.
Basically, the Risk is built upon the potential Loss or harm that can be delivered by a compromised system and the Likelihood of a successful Attack.
Figure 25 shows the extended Conceptual Framework.

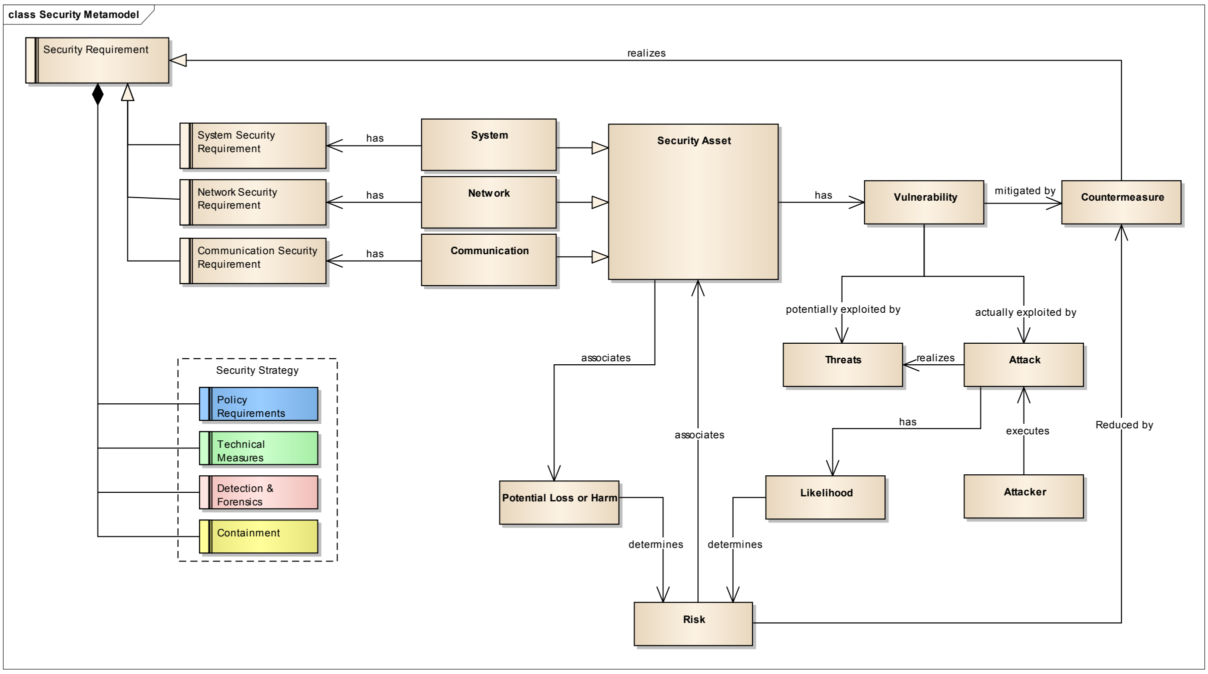


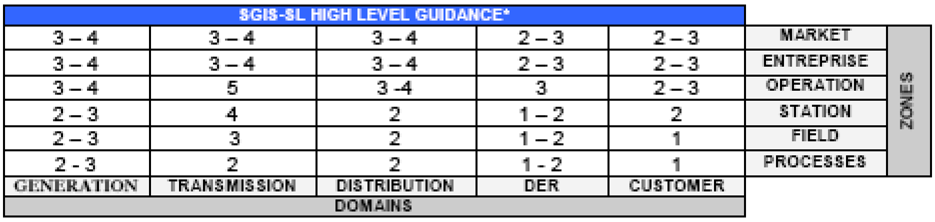
Figure 25 - Risk

To calculate the Risk for every system, a very simple formula is suggested:

$$Risk = SL * 2^{DOE} * \sum_{i=1}^{n} API_i$$

SL… Security Level (from M/490 SGIS): Criticality of a System
DOE…Direct Operational Effects {0,1}
API… Attack Probability Indicator

The formula basically multiplies the potential harm with an indicator for the probability of a successful attack. The value for the potential harm is determined from the "Security Level" as provided as guidance from the M/90 SGIS working group. It is directly related to an elements position within the SGAM plane as depicted in Figure 26.



SGIS-SL HIGH LEVEL GUIDANCE*						
3 – 4	3 – 4	3 – 4	2 – 3	2 – 3	MARKET	ZONES
3 – 4	3 – 4	3 – 4	2 – 3	2 – 3	ENTREPRISE	
3 – 4	5	3 -4	3	2 – 3	OPERATION	
2 – 3	4	2	1 – 2	2	STATION	
2 – 3	3	2	1 – 2	1	FIELD	
2 - 3	2	2	1 - 2	1	PROCESSES	
GENERATION	TRANSMISSION	DISTRIBUTION	DER	CUSTOMER		
DOMAINS						

Figure 26 - SGIS Security Level Guidance (from M/90 SGIS working group report)

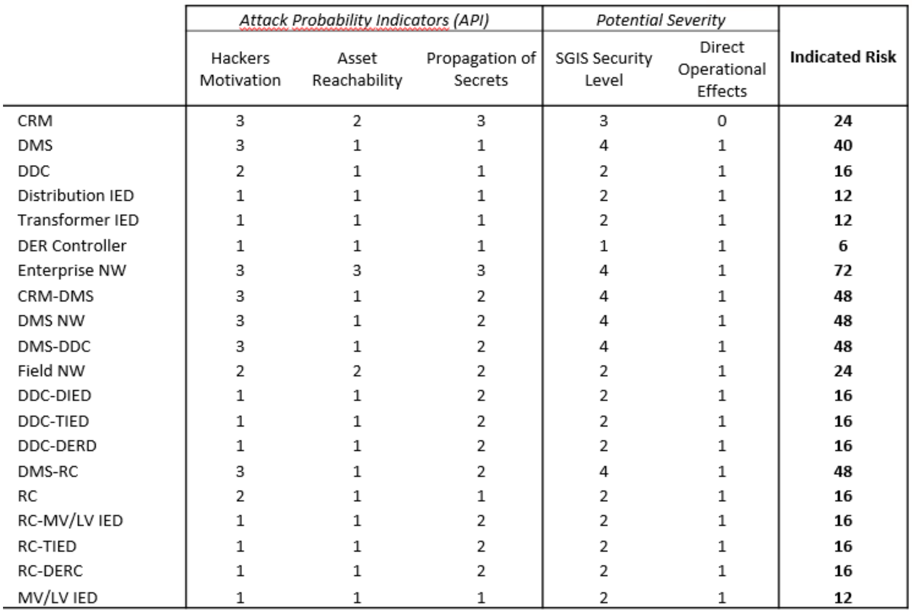
In addition to the Security Level we introduced a factor (2^{DSO}) to incorporate whether direct operational effects to the grid are to be expected or not.

Contrasting to the potential harm, the probability of a successful attack is harder to get. However, to get an idea about the probability we suggest the usage Indicators to get a qualitative value. The main indicators are:

- Hackers Motivation (How much effort is an attacker willing to spend?)
- Assets Reachability (How easy is the system reachable for attacks?)
- Propagation of Secrets (How many participants have legally access?)

To make the assessment of the single indicators practicable and to obtain smiliar results from different assessors we suggest to only use values from 1 to 3 for every indicator.

An example for such a Risk Assessment is given in Figure 27.



	Attack Probability Indicators (API)			Potential Severity		Indicated Risk
	Hackers Motivation	Asset Reachability	Propagation of Secrets	SGIS Security Level	Direct Operational Effects	
CRM	3	2	3	3	0	**24**
DMS	3	1	1	4	1	**40**
DDC	2	1	1	2	1	**16**
Distribution IED	1	1	1	2	1	**12**
Transformer IED	1	1	1	2	1	**12**
DER Controller	1	1	1	1	1	**6**
Enterprise NW	3	3	3	4	1	**72**
CRM-DMS	3	1	2	4	1	**48**
DMS NW	3	1	2	4	1	**48**
DMS-DDC	3	1	2	4	1	**48**
Field NW	2	2	2	2	1	**24**
DDC-DIED	1	1	2	2	1	**16**
DDC-TIED	1	1	2	2	1	**16**
DDC-DERD	1	1	2	2	1	**16**
DMS-RC	3	1	2	4	1	**48**
RC	2	1	1	2	1	**16**
RC-MV/LV IED	1	1	2	2	1	**16**
RC-TIED	1	1	2	2	1	**16**
RC-DERC	1	1	2	2	1	**16**
MV/LV IED	1	1	1	2	1	**12**

Figure 27 - Risk Assessment Example

Please note, that all the mechanisms according the evaluation of the Risk, especially the formula and the API's are only a "first version" suggestion that should demonstrate the mechanisms behind the process. Of course, all of them can and should be adopted to your individual needs!

10.1.2. Requirements Engineering

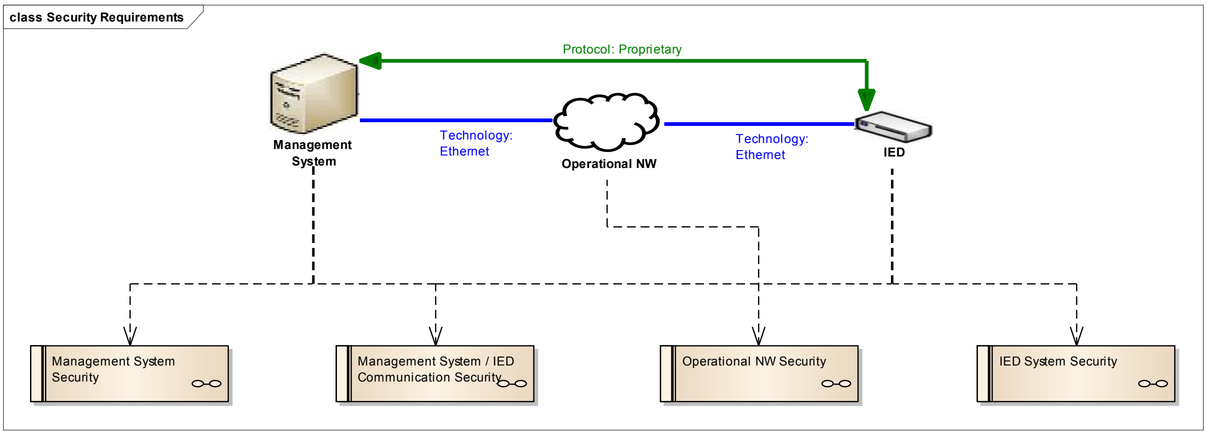
The Requirements Engineering Process can basically be divided in to three separate steps:

1) Identify the Security Assets and apply the according qualitative Requirements Pattern
2) Assess the Risk for every Asset
3) Refine the Security Requirements for every System according to the existing Risk.

To start the Requirements Engineering follow the steps below:

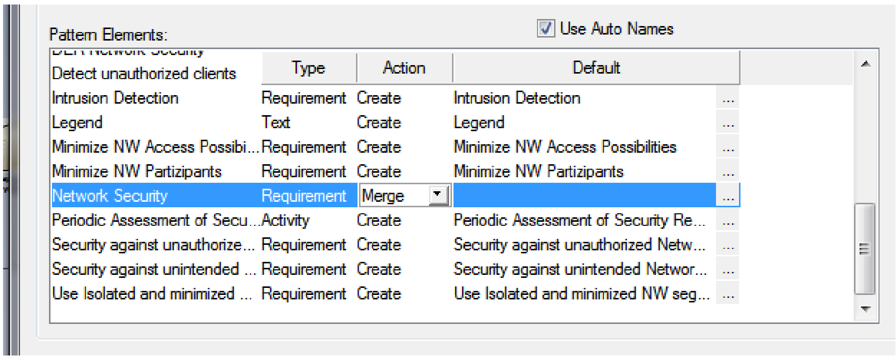
1. *Create a new Security Requirements Diagram place all components and networks there and make all ICT Connections and Communications visible.*

2. *Apply System Security Requirements, Network Security Requirements and Communication Security Requirements to every associated Component.*



To apply the Requirements Pattern, follow the steps below:

1. *Open the Composite Diagram of a Requirement and place the Requirement in the Diagram*
2. *Select the appropriate pattern in the toolbox and drop it to the diagram*
3. *Merge the pattern with the existing Requirement: In the "Insert Pattern" Dialog navigate to the top level Requirement of the pattern, e.g. "Network Security", select the Action "Merge" and navigate to the individual Requirement. The pattern's top level requirement will be replaced with the existing, individual requirement.*



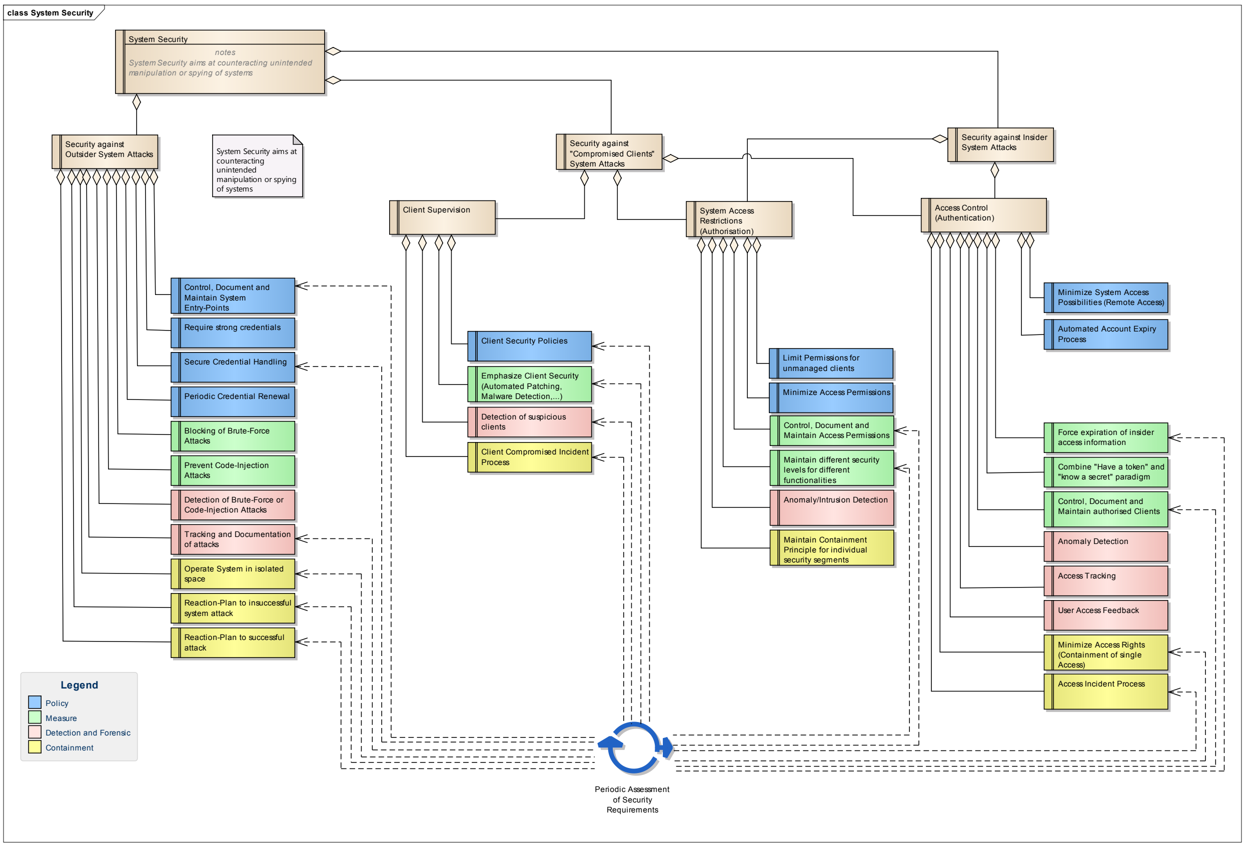
Pattern Elements:

☑ Use Auto Names

DER Network Security

Detect unauthorized clients	Type	Action	Default
Intrusion Detection	Requirement	Create	Intrusion Detection
Legend	Text	Create	Legend
Minimize NW Access Possibi...	Requirement	Create	Minimize NW Access Possibilities
Minimize NW Partizipants	Requirement	Create	Minimize NW Partizipants
Network Security	Requirement	Merge	
Periodic Assessment of Secu...	Activity	Create	Periodic Assessment of Security Re...
Security against unauthorize...	Requirement	Create	Security against unauthorized Netw...
Security against unintended ...	Requirement	Create	Security against unintended Networ...
Use Isolated and minimized ...	Requirement	Create	Use Isolated and minimized NW seg...

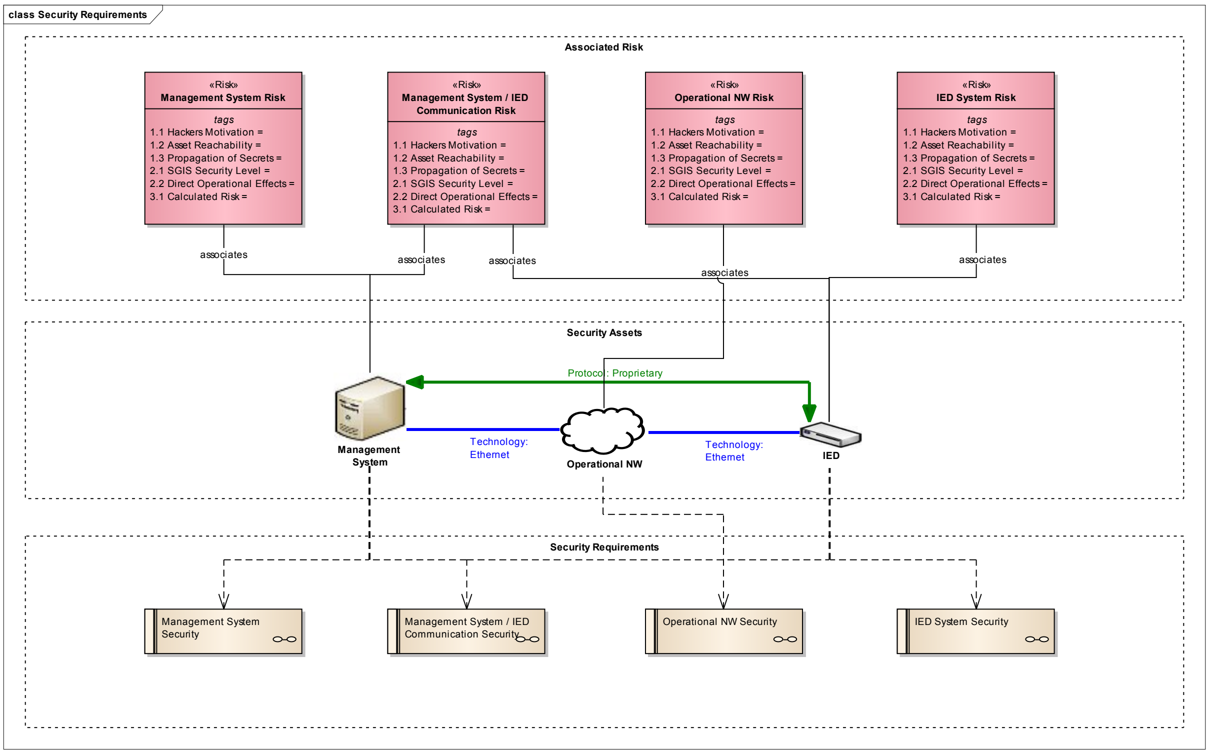
Figure 28 - Merge pattern with existing element



class System Security
System Security
notes
System Security aims at counteracting unintended manipulation or spying of systems
Security against Outsider System Attacks
System Security aims at counteracting unintended manipulation or spying of systems
Security against "Compromised Clients" System Attacks
Security against Insider System Attacks
Client Supervision
System Access Restrictions (Authorisation)
Access Control (Authentication)
Control, Document and Maintain System Entry-Points
Require strong credentials
Secure Credential Handling
Periodic Credential Renewal
Blocking of Brute-Force Attacks
Prevent Code-Injection Attacks
Detection of Brute-Force or Code-Injection Attacks
Tracking and Documentation of attacks
Operate System in isolated space
Reaction-Plan to insuccessful system attack
Reaction-Plan to successful attack
Client Security Policies
Emphasize Client Security (Automated Patching, Malware Detection,...)
Detection of suspicious clients
Client Compromised Incident Process
Limit Permissions for unmanaged clients
Minimize Access Permissions
Control, Document and Maintain Access Permissions
Maintain different security levels for different functionalities
Anomaly/Intrusion Detection
Maintain Containment Principle for individual security segments
Minimize System Access Possibilities (Remote Access)
Automated Account Expiry Process
Force expiration of insider access information
Combine "Have a token" and "know a secret" paradigm
Control, Document and Maintain authorised Clients
Anomaly Detection
Access Tracking
User Access Feedback
Minimize Access Rights (Containment of single Access)
Access Incident Process
Periodic Assessment of Security Requirements
Legend
🟦 Policy
🟩 Measure
🟥 Detection and Forensic
🟨 Containment

Figure 29 - Example for instantiated Requirements Pattern

To start with the risk assessment, open the Security Requirements Diagram and create "Risk" elements for every identified asset.
For the assessemt of the Risks it is a good praxis, to export all Risk elements to a CSV file and make the Assessment in a single Excel sheet. After the Assessment, the values for the individual Attributes can be reimported to the model again.
An appropriated Specification for CSV Import/Export of Risk elements is integrated in the SGAM Toolbox.



After having the basic requirements attached to the systems and having the individual Risks assessed, the refinement of the created requirements can be done, which of course is a manual task.

Please recognize the "Security Assessment" Elements within the Requirements Patterns. These elements and their link to selected requirements give you the possibility to easily access and create some "Check-Lists" for periodic Security Assessments, which are a vital element for security.

11. Generating Reports

The generation of reports is a very powerful possibility delivered by Enterprise Architect. You can both, create HTML reports (Click through the whole model in an ordinary Internet Browser) or create documents.
The toolbox provides some useful templates which directly can be used for the generation of reports or which can be extended according to the individual needs. These templates are available in the “Resources” View under the section “Templates → Document Templates → SGAM Toolbox”.

As the possibilities for automated generation of reports are vast and hence, introduce a certain complexity, the publication of a video tutorial according this task is scheduled in near future.

12. Acknowledges and Future Work

The financial support of the Josef Ressel Center by the Austrian Federal Ministry of Economy, Family and Youth and the Austrian National Foundation for Research, Technology and Development is gratefully acknowledged.

Funding by the Austrian Federal Ministry for Transport, Innovation and Technology and the Austrian Research Promotion Agency (FFG) under Project 838793, ``INTEGRA'', is gratefully acknowledged.

As the SGAM Toolbox appears to be a very useful help for architecting Smart Grid Systems continuous development is planned. The features for the next iteration will be selected according to the gained experience during application in various projects.
However, a few feature requests already exist as you can find below:

- Integration/Import of the Intelligrid Use Case Template
- Visualization
- Integration of Libraries
    - ENTSO-E Role Model
    - M/490 Use Case Management Repository
    - M/490 Actor List
    - ICT Component Library
    - Data Model Standards
    - Protocol/Technology Standards
    - …
- Automate Model Transformations
    - Use Case <–> Component Mapping
    - Information Object Flows
- Logic Mapping of Elements to Domains/Zones
- Element Attribute Refinements

13. References

[1] Smart Grid Coordination Group, „Smart Grid Reference Architecture,“ CEN/CENELEC/ETSI, 2012.