SGAM USE CASE DEFINITION OF AN INFORMATION EXCHANGE ARCHITECTURE

Conference Paper · June 2018

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SGAM USE CASE DEFINITION OF AN INFORMATION EXCHANGE ARCHITECTURE

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ABSTRACT

This paper presents and exemplifies a comprehensive approach for the development of smart grid architectures based on use case methodology and Smart Grid Architecture Model (SGAM) framework. The approach was elaborated in HEILA (Integrated Business Platform of Distributed Energy Resources) project for the definition of the information exchange architecture of the platform. The outcomes of this process are partly demonstrated in this paper as a multi-level description of HEILA use cases associated with flexibility management of geographically distributed microgrids.

INTRODUCTION

Real-world environment that enables multi-layer analysis and practical experiences of new technologies at an early stage of product development is essential for businesses to gain a competitive edge in the market. This environment is especially important for the energy sector, which is going through a rapid transformation process caused by an integration of heterogeneous and geographically distributed energy resources (DERs). This swift transition calls for solutions for energy management systems, ICT architectures, and business models intended to successfully introduce new resources into the existing energy landscape. However, the progress in these fields is impeded by the absence of business ecosystems required for many business models as well as by scarcity and narrowness of real-life demonstrations that would prove the feasibility of new services.

The challenge of establishing a holistic business platform for the development, testing, and piloting new smart grid solutions is addressed in HEILA project. The project aims to link diverse industrial and academic pilots into a united energy system by means of an ICT infrastructure to host a wide range of possible smart grid applications that are intended to integrate DERs into novel business models of energy systems. This goal is being accomplished in the following steps:

- Definition of innovative use cases (UCs) promoting integration of DERs into active grid management and flexibility markets
- Design and deployment of an information exchange architecture for the platform that would enable visibility and controllability of DERs among simulated business actors
- Implementation of the required functionality for the corresponding use cases
- Demonstration of developed smart grid solutions in the platform environment

This paper focuses on the first step, which lays the basis for further development of the platform as it sets the requirements for the information exchange architecture and, moreover, defines the scope of future platform services. However, finding a “one fits all” approach that would take into account the needs of all actors and foresee the appearance of all future services is a complicated task considering the rapid introduction of new innovations into the energy sector. HEILA project utilizes SGAM-based use case methodology to overcome this challenge.

HEILA METHODOLOGY

The SGAM-based use case methodology was initiated by the Smart Grid Mandate M/490 to enhance standardization and development in the smart grid field [1]. This methodology allows analyzing and deriving architecture requirements for an existing electrical grid as well as for future smart grid scenarios in a technology-neutral manner. The adoption of this methodology for HEILA project is built as a continuous iterative and incremental process described in Figure 1, and it consists of the following steps:

Use case aggregation

The main goal of this starting point is to provide a state-of-the-art review of the innovative and envisioned UCs related to the concept of DER integration. At this stage, the generic UCs were gathered into clusters from large EU projects as well as from HEILA work packages (WPs) and workshops (WSs) held on the topic.

Use case extraction

This step is dedicated to the preliminary analysis and elaboration of the UCs obtained through the general level template and refinement process. The objectives here are to define the most promising business cases, identify the objectives and roles of business actors, and determine success scenarios. The outputs of this step should be high-level use cases (HLUCs) required for the implementation of the business goals.

Use case detalization

Each HLUC is represented by interactions of primary use cases (PUCs), which are further described with the IEC 62559-2 template [2]. This detailed template identifies components, functionalities, exchanged information, and technical requirements. The visualization of PUCs is done by the UML use case and sequence diagrams.

SGAM mapping

All detailed UCs are mapped on the SGAM plane with the main focus on identifying the related standards and protocols for the information exchange architecture. The outcomes of this consistent mapping should include a particular architectural solution that delivers the preliminarily described functionality of detailed UCs.

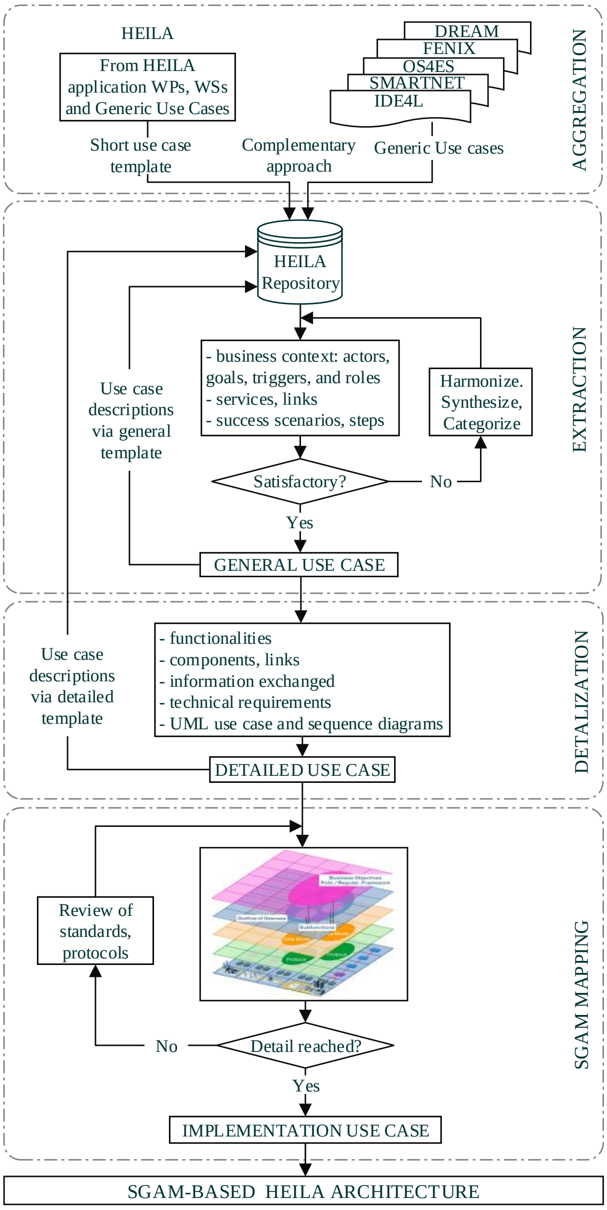

Figure 1. HEILA SGAM-based use case methodology.

FOCAL USE CASES

The topic of smart grids and their applications has been extensively studied in European projects for several years with the aim of harmonizing the European network development. This section presents a review of the focal UCs of the European smart grid projects that were considered most relevant for the HEILA architecture. A summary of these research efforts is presented in Table 1 in the form of generic UCs, which are divided into clusters, HLUCs, and PUCs.

Table 1. Generic use cases from EU projects considered most relevant for HEILA project.

Cluster	HLUC	PUC
Business	Market interaction among Aggregator, DSO/TSO	Demand Response
		Automated energy trading platform for microgrids
		Aggregation of DERs in commercial virtual power plants (VPPs)
		Commercial aggregator asset planning
		Model of local ancillary service market
	Operation interaction among Aggregator, DSO/TSO	Volt/Var Control – Dynamic, Static, Optimization
		LV (MV) cell provision of flexibility
		Shared balancing responsibility model
		Decentralized peer-to-peer control
		Energy management using VPP
Control	Real-time control	Real-time flexibility release for the LV cell
		Local LV control to solve a contingency in emergency situation
		Frequency control – Primary, Secondary, and Tertiary
		Allocation and activation of highly-distributed reserves for balance restoration
	Power quality	Use of flexibility in active power networks
Monitor	Real-time monitoring	LV (MV) network real-time monitoring
		Certified Energy Market

Among dozen of the reviewed projects, HEILA focused mostly on such projects as IDE4L [3], OS4ES [4], DREAM [5], SmartNet [6], and FENIX [7]. Their research initiatives were directed to the development of clean, active, and reliable energy systems by introduction of respective ICT solutions, engaging prosumer participation in the grid management, increasing the level of coordination among the actors, and boosting the DER integration.

GENERAL USE CASES

Following the analysis of the focal UCs of the European smart grid projects described above and generating own UCs, a few general UCs were extracted as being essential in HEILA project. The general UCs are based on processing and exchange of information between the following main actors: DERs, microgrid operators (MOs), aggregators, distribution system operators (DSOs), marketplaces, and third-party service providers. The selected general UCs were microgrid monitoring, participation in the market for frequency containment reserves (FCR), and provision of flexibility services to the DSO.

Microgrid monitoring

The monitoring UC is the simplest but a crucial one. The main actor is the MO, who monitors the DERs of the microgrid. The MO acquires, processes, and stores raw measurements, and extracts and publishes the required information. The main objectives are continuous verification of the states of the flexibility reserves of the microgrid as well as retrieval of information required by aggregators in order to offer microgrid reserves in the flexibility markets. Where needed, the MO uses third-party services, such as weather forecasting, to estimate the expected flexibility in a short time. The monitoring UC also includes provision of technical data to the DSO related to the potential for island or off-grid operation.

Frequency containment reserve (FCR)

This UC enables participation of microgrids and their DERs in a lucrative hourly market for FCR through aggregators. The main actor is the aggregator, who collects and processes the information about available volumes and prices of active power reserves published by the MOs, and prepares and submits price bids to the market for FCR. Having obtained the results of the trading session, the aggregator optimizes the distribution of the to-be-maintained reserves between MOs. Consequently, the MOs perform internal rescheduling of the power flows of DERs within microgrids, and monitor and control the delivery of active power regulation service. Finally, the MOs prepare validation reports for financial settlement.

Flexibility services for DSOs (DSO Flexibility)

In this UC, the primary actor is the DSO, whose main target is to make use of the flexibility services provided by DERs to improve operation of a certain part of the distribution network. The MOs estimate the amounts of flexibility services they are able to offer to the DSO as part of microgrid monitoring process and publish this data for aggregator(s). The aggregators publish area- or microgrid-specific offers for the DSO. The DSO runs an internal process to define the total amounts of services to buy and notifies aggregators of accepted volumes by area or microgrid. The aggregators proceed with distribution of accepted volumes to the MOs, who, in their turn, perform internal rescheduling of DERs and control them to provide the services. Similar to the FCR use case, the MOs prepare validation reports for financial settlement.

When the platform supports FCR and DSO Flexibility it would be ready to support additional use cases. For example, procurement of frequency regulation services by DSO for temporary island operation.

SGAM MAPPING

This section provides a description of the SGAM layers for the FCR use case as an example. Same kind of mapping has been conducted also for the other selected use cases.

Business and Function layer

Figure 2 presents the SGAM business layer that displays the business actors, business UCs, business goals, HLUCs, and relations between them for the FCR use case. In this use case the aggregator acts as a medium between the reserve market and actors providing flexibility. Furthermore, the reserve market links the Aggregator and the TSO. In addition, the MO manages a certain part of Prosumer network.

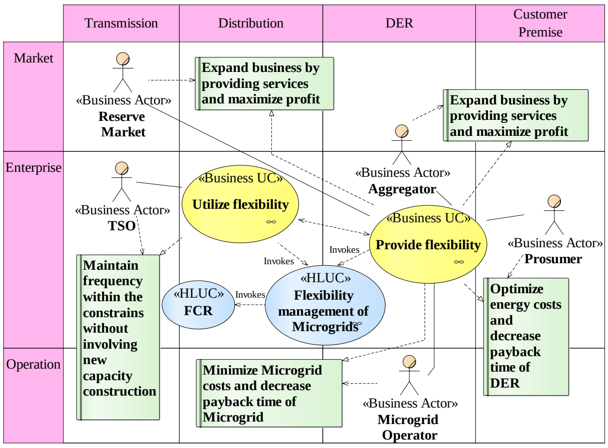

Figure 2. SGAM business layer of the FCR use case.

HLUC Flexibility management of Microgrids, which is superior to HLUCs like FCR, invokes the FCR as shown in the figure. The aggregator and the MO have a contract so that the aggregator offers products that the MO possesses and both benefit in terms of money. The MO can be a company, a housing condominium, or any party equivalent to them who has electrical equipment interconnected with the system.

Figure 3 presents the function layer of the FCR HLUC that depicts the logical actors and functional interrelation between PUCs illustrated by red lines.

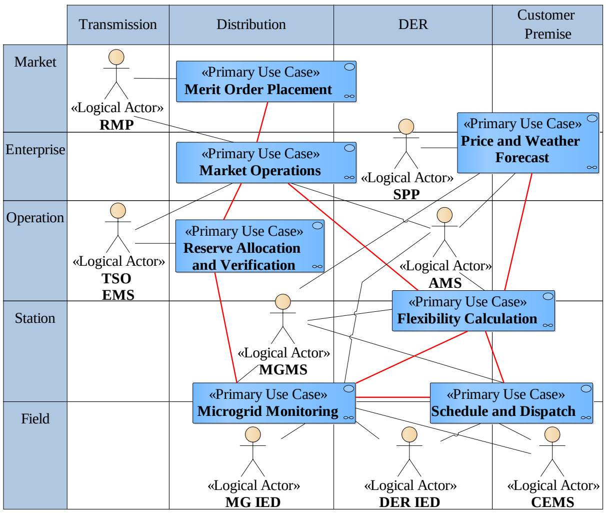

Figure 3. SGAM function layer of the FCR use case.

Market Operations enables interaction between the Transmission System Operator Energy Management System (TSO EMS), the Aggregator Management

System (AMS), and the Reserve Market Platform (RMP). Moreover, it covers participation in the market. Merit Order Placement in the RMP ensures cost-effective use of offered power. With Reserve Allocation and Verification, the TSO determines the necessary amount of reserves as well as verifies their activation and maintenance. Flexibility Calculation uses different forecasts to optimize the calculation of flexibility offers. Schedule and Dispatch operates the microgrid considering its state and signals of Flexibility Calculation. Microgrid Monitoring takes care of delivering measurements, operation plans, and notifications to the Microgrid Management System (MGMS) level for utilization in other PUCs.

Information and Communication Layers

Figure 4 presents the SGAM Information and Communication layers of the FCR use case over the simplified Component layer. This figure illustrates which information and communication standards are used as well as the ICT architecture of the system as a whole.

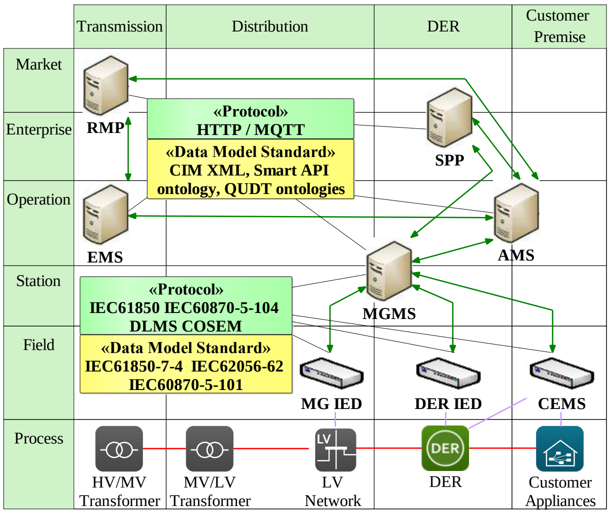

Figure 4. SGAM Communication and Information Layers of the FCR use case.

The communication between the upwards actors is executed by providing semantic programming application interfaces (APIs) using encrypted Hypertext Transfer Protocol (HTTP) POST and MQ Telemetry Transport (MQTT) depending on the case. HTTP POST is a request method based on HTTP. MQTT is a publish/subscribe protocol that builds on top of the Transmission Control Protocol/Internet Protocol (TCP/IP). The protocol is light and it can carry semantic information in the messages.

Semantic information may carry both meaning (by referencing content to description) and value. The information includes concept definitions from semantic data sets such as Quantities, Units, Dimensions, and Data Types (QUDT) ontology, Smart API ontology, and Common Information Model (CIM). Smart API and CIM data sets contain concepts from the smart grid domain. QUDT ontology can be used to express measurement information such as SI units. CIM has a semantic version of it, called CIM XML (eXtensible Markup Language), which allows CIM concepts, or instances, to be used and referenced in semantic information. CIM XML can be used in order to construct new semantic information such as APIs or messages between actors. The CIM standard and other used semantic data can be extended, as the semantic data are extendable by nature.

The internal actor communication is dependent on the UC demonstrations sites, which are represented as MGMS in the figure. The communication methods applied towards devices are widespread IEC 61850, IEC 60870-5-104, and DLMS/COSEM protocols with the corresponding data model standards.

CONCLUSION

The article presented a finalized description of the SGAM-based use case methodology applied in HEILA project. Such a systematic approach allows to achieve the overall concept of ICT architecture considering holistic requirements for novelty, technical feasibility, and interoperability. The steps of this methodology were partly presented for the FCR use case, which will be demonstrated in the platform environment. The provided results are only one part of the architecture procurement, but they convey the basic understanding of the methodology and the information exchange architecture that will be deployed in HEILA project. Moreover, this reference architecture will also be suitable for many other projects aimed at monitoring and control of DERs.

ACKNOWLEDGEMENT

The research project HEILA is funded by Business Finland, funding decision № 1712/31/2017.

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