Smart Grid Services Framework for Building Management Systems

Anna Medve, Attila Magyar, Katalin Tömördi
Department of Electrical Engineering and Information Systems
University of Pannonia
Veszprém, Hungary
e-mails: {medve.anna, attila.magyar, tomordi.katalin}@virt.uni-pannon.hu

***Abstract*— We present a research position for mapping use cases of smart grid services from their textual descriptions based on reference models in order to obtain a reusable modeling framework as a basis to analyze and evaluate alternative implementations of a smart grid service. We start from use cases' textual descriptions based on smart grid architecture from International Telecommunication Union Focus Group on Smart Grid, and goal descriptions based on European Conceptual Model for the Smart Grid. We apply our previous results on goals and scenarios modeling methodology. A case study of building energy management systems services from the Customer domain is given. We work to complete the proposed framework with all detailed use cases for the Customer domain's functions, and to present scenarios on reusing this framework for transition of information system from an existing legacy architecture to a new smart grid-driven architecture.**

Keywords-smart grid reference models; smart grid services; BEMS; use case models; goals and scenarios; BUSITEV; URN.

I. INTRODUCTION

Smart Grid is a complex system of systems, as well a network of information networks, for which a common understanding of its major building blocks and how they interrelate are broadly shared. Smart Grid [1] services are related to energy bulk and distribution enabled by information technologies, whose objectives are the consumption-oriented generation and the generation-oriented consumption. Smart grids evolve by collaborative work of many organizations among financial options of distributed energy generation and consumption, in order to promote energy efficiency with quality and security of supply and safety.

Our focus is on goals and strategies of smart grid services, and on functional modeling them for effectiveness of their management at the customer side. We follow goal and scenario modeling technologies for use case modeling to obtain functional description of strategies, processes, environment properties which needed to support integrated change with simulation of goal satisfaction and risks reduction analysis.

To develop or to understand smart grid services, developers need to model and analyze interactions between those systems, which are involved in exchanges of goods and services. The International Telecommunication Union Telecommunication Standardization Sector (ITU-T) Focus Group on Smart Grid (FG Smart Grid) published the smart grids architecture and services use cases [3] based on smart grid standards issued by collaboration of international companies and institutes [1], [2].

The goals and strategies in order to promote energy efficiency, we find in the European Community's Smart Grid Energy Efficiency Directives (2006/32/EC, 2009/72-73 EC) [1], which regulates the dynamical interoperation for decentralized energy distribution networks cooperation.

The rest of this paper is organized as follows. Section II describes the smart grids viewpoints, Section III describes our research position for goal and functional modeling of smart grid' uses cases. Section IV addresses the related works. The acknowledgement and conclusions close the article.

II. SMART GRIDS VIEWPOINTS AND APPLICATIONS

The Smart Grid is a complex system of systems. At present, there are many activities running in parallel which are related to the field of smart grid standardization, with some overlapping and duplication of activity and opportunities for learning from the work of others. The main initiatives are presented in [1] from which we follow the Smart Grids European Technology Platform [1] and ITU-T FG Smart Grid [2] reference models. The key of standardization is interoperability, which can be achieved through standardization of communications in terms of interfaces, signals, messages and workflows.

A. Smart Grids European Technology Platform (2006/32/EC, 2009/72-73 EC)

The European Technology Platform (ETP) Smart Grids [1] was set up in 2005 to create a joint vision for the European networks of 2020 and beyond. It has identified clear objectives and proposes strategy for the Smart Grids vision about Europe's electricity networks that must be flexible, accessible, reliable, and economic.

ETP identified the services that Smart Grids are expected to offer to all electrical network users in Europe over time. The implementation of the services allowed by functionalities must be deployed and assessed at National level, taking also into account the initial status of networks and their "smartness".

ETP for SGs starting from Community objectives for SGs has introduced 6 groups for high-level services of SG with 33 functionalities, which are detailed for their intra actions with SG infrastructure and actors. An important tool is the ETP M/441 mandate for smart metering [1] to improve information and services to customers and enable customers to better manage their consumption.

Smart grids deployment will be a continuous learning process. The acceptability of new services by the customers is a main concern. ETP recommends encouraging member states to address communication and education of citizens involving all types of customers: industrial, commercial and residential consumers. To include residential customers in the energy efficiency improvement process, smart metering systems are a key factor with the functionalities as defined in mandate M/441.

B. *NIST Smart Grid Conceptual Reference Model*

The National Institute of Standards and Technology (NIST) coordinates the development of a framework of standards for Smart Grid [2] to propose use cases and architectures for the SG information networks and identified industry. The NIST Smart Grid Conceptual Reference Model identifies seven domains to analyze use cases: bulk generation, transmission, distribution, markets, operations, service provider, and customer. Main stakeholders are Consumers (residential, commercial, and industrial), Electric transportation and utility stakeholders, Electricity and financial market traders, Information and communication technology (ICT) Service Providers and Application developers, and others.

C. *ITU-T Reference Models for Smart Grid*

ITU-T Focus Group on Smart Grid (ITU-T FGSG) works for defining clear the common objectives of a Smart Grid, and to analyze *the ICT perspective* and identify *requirements and architectural considerations*.

The ITU-T FGSG architectural view [2] highlights the fact that Smart Grids are formations through ICT, and expands the NIST framework with communication domain, defining the SG architecture as formed from Energy and Service/Application planes according to their functionalities, and controlled and connected by Communication plane functionalities. ITU-T FGSG introduced more than 90 power-related and communication–related definitions and more than 60 abbreviations, for defining a smart grid *architecturally*, starting from the NIST Conceptual Reference Model [3]. FGSG defined 12 high level and 82 detailed level use cases [2].

III. Smart Grid Services and Applications Modelling Framework Based on SG Reference Models

We present our research position on a reusable modeling framework for Smart Grid Services and Applications (SGSAMF). We implemented the framework for Smart Grid (SG) customer services use cases to provide benefits for the configuration management of SG systems. The underlying MDE methodology applied it pushes people to think about the actual energy usage state, and to concentrate on outcomes and results before an eventually implementation of changes of management and infrastructure. This helps decision makers to invest accordingly in information systems and other aspects of changes. In this paper we provide case study for building energy management services use cases.

The BUsinesS and IT EVolution (BUSITEV) methodology [4][6] we applied to provide tools and concepts [7-10] for stakeholders to construct and maintain their proper Smart Grid Services and Applications Modeling Framework (SGSAMF) to serve as a basis:

- to analyze and evaluate alternative implementations of an SG architecture;
- to support planning for transition from an existing legacy architecture to a new smart grid architecture.

A. *Generic goal models for EC TFGS high-level services and functionalities*

Conforming to the European Conceptual Model for the Smart Grid, each stakeholder today has a different view on smart grids. Our work is related to customers' view.

Our focus is on functionalities from E and F groups defined for consumer related services numbered from 20 to 33 [1]. Fig. 1 shows a Goal-oriented Requirements Language (GRL) [7] partial model of goal-oriented requirements specification for EC TFSG high-level services and functionalities. The detailed services for F group of high-level services are modeled as actors, goals, soft goals decomposed on their realizations by tasks and resources. Relationships used are contributions, logical operators (And/Or). For modeling intents the content of this goal graph is captured from EC TFSG Studies Group 1 report at pages 6-19 in [1], which are textual description of objectives and high-level functionalities, and detailed services for SGs.

B. *Generic models for Building Energy Management System (BEMS)*

Our focus is on the 16 detailed use cases of Customer domain defined by ITU-T FGSG, which cover the functionalities of Building Energy Management System (BEMS).

BEMS is a system technology for managing the building facility and component operation focused specially on energy improved by sensing, metering and controlling devices based on ICT hardware and software technology [2].

The Customer system is technically formed by in-home displays (IHD), programmable communicating thermostats (PCT), direct load control devices (DLC), and web portals. *Information technologies* provide customers with the opportunity to manage their electricity consumption by providing them with data about, their electricity consumption and costs through mobile devices, IHDs, and web portals. *Control technologies* provide customers with the opportunity to manage their electricity consumption through load control devices, such as PCTs. Smart meters are fundamental components which allow electricity consumption information to be captured, stored, and reported in intervals of 60 minutes or less to both utilities and their customers.

Smart energy services in building domain are supported by introducing the smart grid infrastructure technology into building domain and it configuring for communication with the BEMS system technology. The in-building SG infrastructure includes detailed metering, detailed electricity control, Energy Service Interface (ESI), Distributed Energy Resource (DER) and electric vehicle (EV).

 ISBN: 978-1-61208-363-6

C. *BEMS functionalities*

BEMS manages electric usage for building operation and maintenance by dynamic pricing information transfer to BEMS through ESI. When external public grid needs to reduce demand by consumer with reaching to peak demand is realized a DR (demand signal) message transfer to BEMS through ESI, and BEMS controls the usage conform BEMS energy management algorithm and policy. Based on the DR message and/or dynamic pricing information from utility BEMS is able to control any energy consuming component intra building area through ESI. Based on some information including dynamic pricing message and/or DR message from utility, BEMS is able to control charge/discharge of EV's.

Fig. 2 shows the BEMS processes supported by SG services modelled into Use Case Maps (UCM) [7] scenario-based functional model. The model elements are expressed with usual basic workflow signs and the elements required to structure the business process model with regards to information passing and modularity in root-map and sub-map diagrams. The process flow takes place along directed path. Loops and circles are allowed in the path direction. We can provide their consistency with structure division by stubs (diamond), and with conditions during validation.

The textual requirements which cannot be built in functions, activities or conditions are collected by categories and are shown as notes with reference to stubs. Organizational cross-cutting events are highlighted by bounded path with components (rectangle), which model actors and divisions. For quality expectations we can give idioms for timing, pairing, constraints, limits and asynchrony-synchronic functions suported by User Requirements Notation (URN) tools [8].

The checking of the wellness of processes and concrete use cases take place with simulations in the form of scenarios supported by URN technologies [7-9].

Textual description of use cases is from the pages 53-57 in Appendix III. Use Cases for Building Management in "Use Cases for Smart Grids" from Smart-O-31Rev.7, ITU-T FGSG, Geneva, 18-21 December 2011, published at [2].

IV. RELATED WORK

Smart Grid-enabled applications present several examples of use cases to include real-time consumer control over energy usage; controls for large-scale energy storage; mobile billing for charging electric vehicles. Görbe et al. [11] propose user related services to apply EV batteries. Wang et al. [14] propose energy management modeling based on interpreted Petri Nets formalism for smart grid communication between buildings and public grid. Peruzzini et al. [13] propose an information management model to make an extended virtual enterprise to provide energy-control services. Kato et al. [12] provide a Home EMS for integrating of information and energy which aims to analyze user behavior to provide life-support services appliances. Those and other publications not provide help and reusable models for assessing services from SG reference models.

We applied the BUSITEV Framework [4], [6] based on MDE technologies and URN [7] mapping techniques that assure quality and improve testability. This way the modeling of the business processes results in the optimization of the processes and the changes of the organization at the same time as well as the required software maintenance for the problem generating change management. Applying this framework to design of SG services framework [6] provides to control and assess the conformance to the standards and reference models.

V. CONCLUSION

This position paper proposes a Smart Grid Services and Applications Modeling Framework (SGSAMF). Goals and scenarios models built following smart grids' reference models support valid domain-specific architectural decisions, and form a traceable library for business process models with reusable repositories of use cases for SG Customer Domain. This help decision makers and developers to apply European Reference Models for SG and ITU-T SG reference Architecture [1], [3].

As is shown in Section 3 the smart grids deployment will be a continuous learning process, when supporting standards and their appliances are crucial.

Our previous work on BUSITEV Framework [4] offers a good basis for modeling SG strategies and use cases to manage services strategies for smart grid developments and support the stakeholder's communication

Future work needs to complete the SGSAMF Framework with all detailed use cases for Customer domain's functions to support services management development. This framework support end-users trainings for customer acceptance of smart grids in order to make self-configuration of their usage strategies in home energy management systems.

ACKNOWLEDGMENT

We acknowledge the financial support of this work by the Hungarian State and the European Union under the TÁMOP-4.2.2.A-11/1/ KONV-2012-0072 project.

REFERENCES

[1] European Commission – European Smart Grids Technology Platform [retrieved: 05, 2014] http://ec.europa.eu/energy/gas_electricity/smartgrids/taskforce_en.htm - Deliverables - ExpertGroup1.

[2] ITU-T Focus Group on Smart Grids [retrieved: 05, 2014]. http://www.itu.int/en/ITU-T/focusgroups/smart/Pages/Default.aspx

[3] NIST Smart Grid Interoperability Panel (SGIP (2007, 2010) [retrieved: 05, 2014]. Available from: http://www.nist.gov/smartgrid/

[4] A. Medve, "Model-based Framework for Integrated Evolution of Business and IT Changes. In S. Hammoudi, M.van Sinderen, J. Cordeiro (Eds.): ICSOFT 2012 - Proceedings of the 7th International Conference on Software Paradigm Trends, Rome, Italy, SciTePress, July 2012, pp. 255-260.

[5] A. Medve, "Model-based Framework for Change Management and Integrated Development of Information Security", International Journal of Management & Information Technology, vol.5/3, Aug. 2013, pp. 586-597.

[6] A. Medve, A. Magyar, A. Göllei, and K. Tömördi, "Goal-oriented Modeling of Business Processes for Design of Smart

Grids Services" Invited OGIK'2013 conference paper for publishing in SEFBIS 2014/1, in press.

[7] ITU-T Recommendation " Z.151 User requirements notation (URN). Language definition" Geneva, 2011.

[8] JUCMNav 5.4 URN tool, [retrieved: 05, 2014]. http://jucmnav.softwareengineering.ca/ucm/bin/view/UCM/UcmNav

[9] URN Virtual Library, [retrieved: 05, 2014]. http://www.UseCaseMaps.org/

[10] M. Weiss and D. Amyot, "Business Process Modeling with URN" International Journal of E-Business Research, vol. 1(3) Mar. 2005, pp. 63-90.

[11] P. Görbe, A. Magyar, and K. Hangos, "Reduction of power losses with smart grids fuelled with renewable sources and applying EV batteries", J. of Cleaner Production, in press.

[12] T. Kato, H.S.Cho, D. Lee, T. Toyomura, and T. Yamazaki, "Appliance Recognition from Electric Current Signals for Information-Energy Integrated Network in Home Environments " Ambient Assistive Health and Wellness Management, LNCS 5597, pp 150-157, 2009.

[13] M.Peruzzini, M. Germani, A. Papetti, and A. Capitanelli, "Smart Home Information Management System for Energy-Efficient Networks" Collaborative Systems for Reindustrialization IFIP AICT 408, Oct. 2013, pp 393-401.

[14] B.C.Wang, M. Sechilariu, and F. Locment, "Power flow Petri Net modelling for building integrated multi-source power system with smart grid interaction" Elsevier Mathematics and Computers in Simulation, vol. 91, May 2013, pp. 119–133.

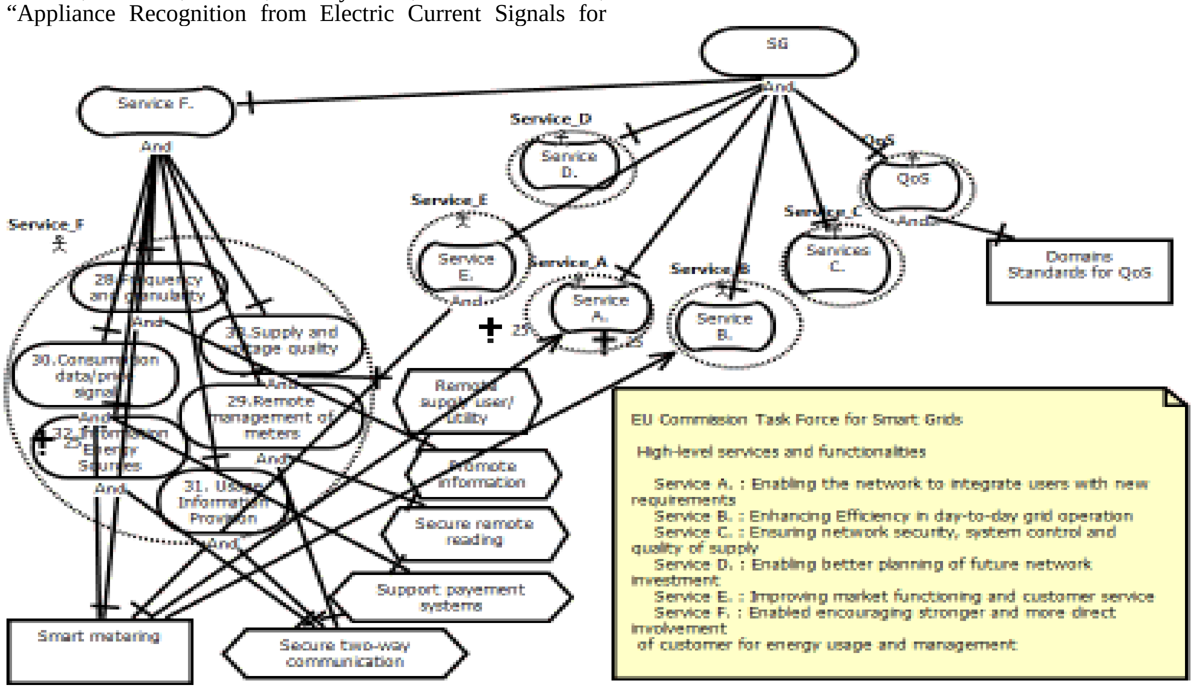

Figure 1. GRL goal-oriented requirements specification of TFSG high level services and functionalities (F group of ECTF for Smart Grids)

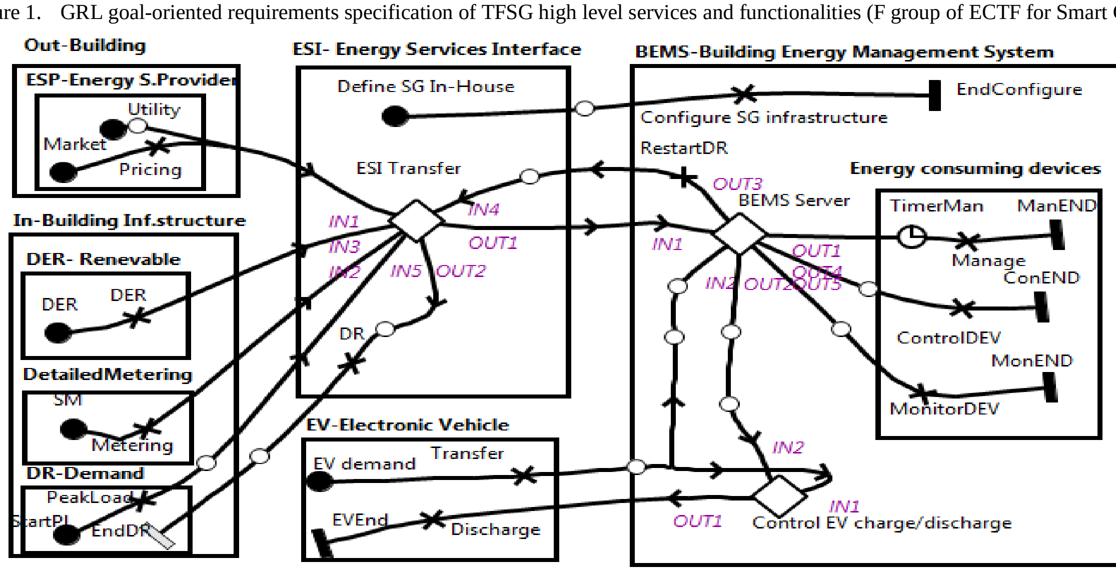

Figure 2. UCM functional model for BEMS processes supported by SG services defined at ITU-T FGSG