INNOVATIVE METHODOLOGY TO DEFINE STAKEHOLDERS' REQUIREMENTS FOR SMART SYSTEMS

Mr. Juan Jacobo PERALTA
CEMOSA – Spain
jacobo.peralta@cemosa.es

Dr. Noemi JIMÉNEZ
CEMOSA – Spain
noemi.jimenez@cemosa.es

Prof. Augusto CASACA
INESC-ID/INOV - Portugal
augusto.casaca@inesc-id.pt

Mr. Francisco MELO
EDP Distribuição – Portugal
francisco.melo@edp.pt

Dr. Krzysztof PIOTROWSKI
IHP – Germany
piotrowski@ihp-microelectronics.com

ABSTRACT

The presented methodology aims at facilitating the definition of stakeholders' requirements for new system architectures. It is composed of 4 steps which allow identifying the links between stakeholders and/or systems and writing the necessary information. A preliminary step is necessary and focused on the conceptual map and template design. The former is a block diagram that includes all the stakeholders, management units and energy systems and their relations. The latter is a self-questionnaire to describe the requirements. This approach has allowed defining 204 requirements for the 28 use cases of the e-balance project by 10 researchers of different expertise areas without ambiguities. The requirement details have also allowed prioritizing the most relevant requirements with a statistical approach, what has allowed optimising the project planning. Finally, both the methodology and the first outputs and conclusions obtained of the requirement implementation in e-balance are explained.

INTRODUCTION

The definition of users' requirements is one of the first tasks and the cornerstone to design any smart system or application. Most often, standardisation committees composed of expert groups deal with this issue when they try to describe the basis of systems, what requires long roundtables and hours to achieve a definitive agreement [1]. Even when such common approach seems to satisfy every stakeholder, legal framework, market rules and unforeseen constraints may disrupt and slow down the deployment. However, this issue is not only triggered by institutional organisation, but for any company willing to introduce a new product in the market.

Regarding the electricity market and the electric system, the current smart-grid/cities approach forces the creation of new products and services that satisfy the needs of different stakeholders at the same time. For example, the demand-side management concept requires some responsible party retrieving the energy flow information of every associated end-line customer at near real-time, what evocates some management unit that allows both users interact with each other through price signals, power limits, etc. In addition, this kind of interaction has a direct effect on other stakeholders and systems, for instance customers sharing the same line, Distribution System Operators (DSOs), energy suppliers or the status of energy loads, capacity of secondary substations, etc. Therefore, the complexity of the electric system makes the suitability of any new statement or approach be evaluated in depth before introducing in the market.

Although the presence of multidisciplinary teams enriches and benefits the development of successful and innovative ideas, the definition of requirements depends strongly on the social aspect, i.e. culture, education and expertise area of the authors, what generates ambiguities and improper concepts.

One of the main goals of e-balance project is to develop an Information and Communication Technology (ICT) architecture that may enable new services for electric grid users. One of the first activities has been the definition of all the stakeholders' requirements under a smart-grid approach. However, the working team is composed of industrial and ICT engineers, business researchers, utilities experts and psychologists, what required a preliminary management work in order to find a cost-effective way to guide the definition and validation of requirements. Within this context, the methodology presented in this paper was designed to collect all the ideas and definitions, using a common structure (template), minimising potential ambiguities with neutral flow diagrams and simple concepts and including a validation step based on general review and comparison with the legal and market framework.

METHODOLOGY DESCRIPTION

As mentioned above, the current methodology has been designed to define stakeholders' requirements within the e-balance project activities. This methodology is composed of 4 steps that allow defining and validating a set of requirements under different point of view without ambiguities.

A preliminary step is necessary and focused on the design of a conceptual map and template design. The former is a block diagram that includes all the stakeholders, the management units and the energy system components and their relations. In our case (Fig 1), this block diagram is composed of 3 types of blocks: stakeholders (blue), energy system components (orange) and management units (grey). Two types of arrows represent permanent (e.g. energy and information flows) or temporal links (e.g. installation or support of devices). For instance, the relation between the home appliance vendor and the ICT provider with the customer is temporal during the installing and commissioning of devices, sensors or management units, whilst the information from the weather agency is necessary in every moment.

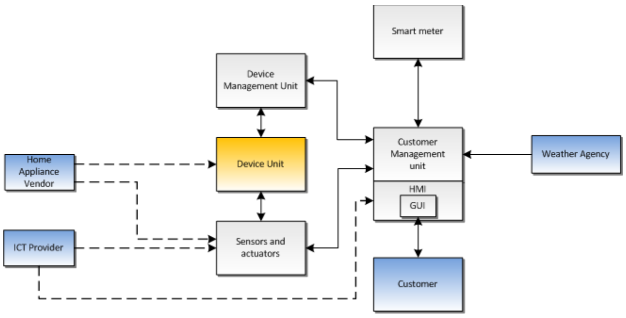

Fig 1. Sample of block diagram (e-balance project)

The mentioned template is a matrix aiming at collecting and classifying all the descriptions, what allows developing further analysis as identification of critical requirements, prioritizing for planning strategies of deploying such requirements, etc. This template is used in the 3rd step of the methodology to write the stakeholders' definitions and must contain at least the following fields, though can be adapted to other contexts:

Main stakeholder: the most benefited user.

Type (functional, non-functional and constraints):

- A functional requirement is an action that the system must take if it is to be useful to its users. Functional requirements arise from the work that stakeholders need to do. Almost any action (calculate, inspect, publish, or most other active verbs) can be a functional requirement.
- Non-functional requirements are properties, or qualities, that the system must have. In some cases, non-functional requirements (these describe such properties as look and feel, usability, security, and legal restrictions) are critical to the system's success.
- Constraints are global requirements. They can be constraints on the project itself or restrictions on the eventual design of the system.

Priority (low, medium, high): Subjective opinion. Low is recommendable but not necessary; medium is necessary and high is paramount.

Requirement description: this is indeed the definition. Some suggestions are showed to write understandable and accurate requirements:

- Keep sentences and paragraphs short. Use the active voice. Use proper grammar, spelling, and punctuation. Use terms consistently and define them in a glossary or data dictionary
- Read it from the developer's perspective; that helps to see if a requirement statement is sufficiently well defined.
- Authors often struggle to find the right level of granularity. A general strategy is to think on the kind of tests you need to validate the requirement. If many different kinds of tests are envisioned, maybe several requirements have been lumped together and should be separated.
- Conjunctions like "and/or" in a requirement suggest that several requirements have been combined.

Rationale: a brief explanation why this requirement is necessary for the system.

Security impact (optional): According to [2], five security impact levels have been defined for the e-balance project and other approaches can be suitable:

- Low: No sensitive effects or consequences if the requirement is not satisfied.
- Medium: can make unwanted effects but not dangerous for devices/appliances, deviation from expected energy costs or manipulation of information.
- High: can be dangerous for devices, higher costs or manipulation of operative or privacy information.
- Critical: can unbalance the LV-grid.
- Highly critical: can unbalance the MV-grid.

Rationale of security impact (optional): a brief explanation why this requirement presents such security impact level.

Methodology steps

Once the preliminary stage is completed, the methodology is based on the following steps:

1st Step "Selection of stakeholders and links". When a selected use case is evaluated, the procedure starts identifying stakeholders and management units in the conceptual map. Use cases are the different scenarios a system is designed for. When a use case is defined, users, devices and their interaction are described in order to achieve a goal. The identification of stakeholders, management units and energy systems in the conceptual map is the first step to obtain a whole perspective of the concept.

2nd Step "Connections of a selected use case". The arrows between each element allow identifying paths involved in the evaluated use case. All the stakeholders must be connected using all the possible paths (arrows). In this way, the researcher can realise information flows, energy flows, among others. The following picture (Fig 2) shows as example all the possible connections between the customer and the ICT provider through the management and energy units.

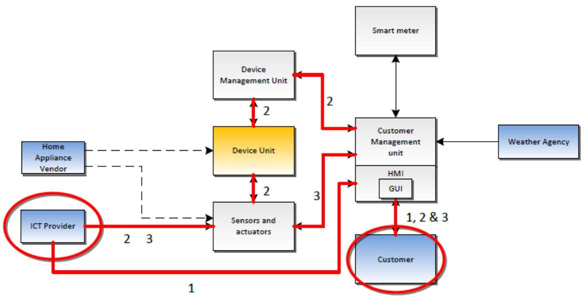

Fig 2. Different paths (1, 2 and 3) connecting the customer and ICT provider

3rd Step "Self-questionnaire". For each requirement, the template offers several questions that should be answered with a description or selecting an option. This is the most creative step since the researcher should transform the connections identified in the conceptual map into descriptions required from the template. The different options and classifications help the researcher to think about new requirements.

4th Step "Validation". The requirement should be checked according to legal, market and technical barriers of each country. If some barrier does not allow its implementation, the researcher should come back to the 3rd step until all the restrictions are satisfied. Just in the case all the restrictions cannot be satisfied due to an inevitable reason, this could be considered as a potential recommendation for legal or market framework.

E-BALANCE PROJECT RESULTS

The e-balance project is composed of 28 use cases [3] classified into 4 groups: energy balancing, neighbourhood balancing, energy forecast and energy storage penetration. For each use case, a set of stakeholders' requirements has been defined following the methodology introduced in this paper and according to the legal and energy market frameworks from Poland, Netherlands and Portugal. This procedure has allowed describing **204 requirements for 10 kinds of stakeholders**: prosumer (consumer that can consume or produce energy), energy supplier or aggregator, energy retailer, city municipality, DSO, ICT provider, home appliance vendor, local country regulator, weather forecast agency and user of simulation software.

Furthermore, though this amount of information seems to be difficult to manage, the priority and security fields from the self-questionnaire allow prioritizing the following activities according to the criteria of the researcher. In this project, an additional term named **relevance factor** has been defined to emphasize which of the use cases must be developed firstly. The criteria selected to mark the list of use cases are based on the average priority and average security impact with respect to the number of requirements. Each level of priority and security impact has been weighted from 1 to 3 and 1 to 5 respectively. For example, the first use case of e-balance project has 13 requirements and the corresponding results are shown in the Table Table 1 and Table Table 2 (see Appendix I for use cases' definitions).

Table 1: Example to define average security impact

Use Case 1	Security Impact				
	Low	Medium	High	Critical	Highly Critical
Number or requirements	0	1	9	3	0
Mark	1	2	3	4	5
Number * Mark	0	2	27	12	0
Sum	41				
Average	**41/13 = 3.15 (High)**				

Table 2: Example to define average priority

Use Case 1	Priority		
	Low	Medium	High
Number or requirements	0	1	12
Mark	1	2	3
Number * Mark	0	2	36
Sum	38		
Average	**38/13 = 2.92 (High)**		

Finally, the relevance factor has been defined as the root of the sum of squares of both values (4.30) and is compared with the rest of use cases' values according to a standard distribution (Mean: 3.70; Standard deviation: 0.65), what finally indicates this use case has a medium relevance. The Table Table 3 summarises all the results for all the use cases.

Table 3: Relevance value of each project's use case

	Priority	Impact	Total	Relevance Factor
UC1	2.92	3.15	4.30	Medium
UC2	2.71	2.50	3.69	Medium
UC3	3.00	2.20	3.72	Medium
UC4	**2.80**	**3.40**	**4.40**	**High**
UC5	2.36	2.86	3.70	Medium
UC6	2.73	2.64	3.79	Medium
UC7	3.00	2.00	3.61	Medium
UC8	3.00	3.00	4.24	Medium
UC9	2.82	2.91	4.05	Medium
UC10	3.00	1.67	3.43	Medium
UC11	2.17	3.00	3.70	Medium
UC12	3.00	3.00	4.24	Medium
UC13	2.67	3.33	4.27	Medium
UC14	**3.00**	**3.25**	**4.42**	**High**
UC15	**3.00**	**3.63**	**4.71**	**High**
UC16	**3.00**	**3.67**	**4.74**	**High**
UC17	3.00	3.00	4.24	Medium
UC18	2.00	1.60	2.56	Low
UC19	2.20	2.20	3.11	Medium
UC20	2.77	2.31	3.60	Medium
UC21	2.00	2.67	3.33	Medium
UC22	**3.00**	**3.50**	**4.61**	**High**
UC23	3.00	3.00	4.24	Medium
UC24	3.00	2.00	3.61	Medium
UC25	1.67	1.67	2.36	Low
UC26	2.25	2.25	3.18	Medium
UC27	3.00	1.00	3.16	Medium
UC28	2.43	1.00	2.63	Low

Through this methodology and classification, four use cases have been identified as high priority to be developed respect to the entire group (number 4, 14, 15, 16 and 22). Other potential approaches and strategies can be used to take advantage of this way of classification.

CONCLUSIONS AND FINAL REMARKS

The definition of requirements in the context of new architectures and infrastructures for energy systems is a complex activity that needs the support of methodologies and procedures to organise and manage the information effectively. The participation of many users, systems and technologies can become even harder this task, since it increases the amount of combinations and restrictions. The on-going project e-balance is an example of this fact and has generated more than 204 requirements for 10 different users/stakeholders, 28 use cases, several smart facilities (electric vehicles, PV-panels, washing machines, TV…), different electric grid levels (LV-grid, MV-grid, substations…), management units, etc.

The methodology explained in this paper has allowed addressing the definition of requirements and managing all the generated information to support developer's efforts. In addition, this methodology is independent of the researcher's field and can take the advantage of multidisciplinary teams in order to focus the functionalities of new systems on the stakeholders' requirements effectively.

Furthermore, this methodology is compatible and complementary with other approaches and layouts like BPMN (business process model and notation), ICT architectures, UML (unified modelling language), etc., what allows using it in multiple fields.

In the context of the e-balance project, the work team has been composed of 10 researchers from different companies and fields that have spent 2 months to deliver 204 requirements, what demonstrates the time saving obtained and the cost saving thereof.

Acknowledgments

This work has been partially funded by the project e-balance (project number: 609132), http://www.e-balance-project.eu, within the European Commission 7th Framework Programme (FP7-SMARTCITIES-2013) and by the Portuguese national funds through Fundação para a Ciência e a Tecnologia (FCT) with reference UID/CEC/50021/2013.

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APPENDIX I: DEFINITION OF E-BALANCE USE CASES

The following use cases have been defined inside the e-balance project activities. For further information, see the on-line document [3].

Energy balancing use cases

Use case #1	**Strategy-driven decision on the use of produced energy**
The customer that produces energy shall have a choice of the use of the energy in order to implement some defined strategy, e.g., to maximize the profit.	
Use case #2	**Energy consumption priorities in case of delivery limitations**
The customer shall be able to specify the energy consumption priorities for his appliances.	
Use case #3	**Distributed generation balancing and resilience**

Automatic controlling and monitoring of the distributed generation allows avoiding failures in the grid and thus, increases the quality of service	
Use case #4	**Energy consumption and production agreement/contract**
The customer and the energy supplier may agree on a fixed amount of energy to be produced and consumed by the customer in a specified period of time.	
Use case #5	**Strategy-driven decision on charging or discharging the energy storage**
A customer is able to store energy either coming from local production by the customer or from the grid, e.g., from power plants or renewable sources. This energy can be further used by the customer or it can be sold as customer's own generation	
Use case #6	**Electric vehicle as mobile energy storage**
Due to this mobility feature, the electric vehicle can be connected to different points in the distribution grid at different times.	
Use case #7	**Customer interfaces for better efficiency and interaction**
In order to provide a better interaction with the customers and to achieve higher efficiency a diversity of user interfaces has to be provided with different range of data and interaction.	
Use case #8	**Handling of current and historical customer data for improved safety and privacy**
The customer shall have the influence on the way his data is collected, processed and stored.	
Use case #9	**Intelligent home appliance energy consumption balancing**
A typical home appliance consumes a given amount of energy to fulfil a defined task. Further, some of its components may also generate energy. And in order to provide fine grained energy control the logic of the appliance has to know the specific energy parameters and requirements of its components as well as the time necessary involve each component to fulfil the given task.	
Use case #10	**Additional sensors for appliance energy consumption balancing**
In order to achieve even better energy efficiency the customer may define a strategy and dependences for the appliance control depending on the data from additional sensors, e.g., the light in the room shall be switched off as soon as all persons leave the room; or temperature and air humidity sensors to control the heating more efficiently.	
Use case #11	**Microgrid energy balancing**
The energy balancing is similar to energy balancing for a single customer. In case of multiple customers their data may have to be handled differently due to potentially different data handling preferences and the accounting has to be realized for each customer individually.	
Use case #12	**Multiuser privacy management in energy grid**
Due to that the data sets to different stakeholders may be shared on the same ICT system components, different other stakeholders may have access to the data owned by others. It is of utmost importance that the data is protected from unauthorized access even if needed for common processing.	

Neighbourhood monitoring use cases

Use case #13	**Neighbourhood power flows**
Recognition of energy power flows within the Low Voltage Distribution Grid.	
Use case #14	**Distributed generation power flows**
Recognition of energy power flows of renewable generation within the Low Voltage Distribution Grid.	
Use case #15	**Optimized power flow**
The energy management system calculates the optimal power flow topology based on electrical grid capacity, demand and distributed generation energy flows.	
Use case #16	**Economic dispatch**
The energy management system performs calculation of power levels with the objective of minimization of total generation cost.	
Use case #17	**Power flow state estimator**
The energy management system calculates and estimates the technical condition of energy flows and electrical infrastructure assets when assessing different topology configurations for the energy distribution grid.	

Electrical distribution grid monitoring

Use case #18	**Quality of supply measurement**
The energy management system processes information from neighbourhood households and determines the quality of service Key Performance Indicators (KPIs) according to the data retrieved from ICT devices.	
Use case #19	**Energy efficiency measurement**
The energy management system processes information from neighbourhood households and determines the energy efficiency of each energy customer.	
Use case #20	**Fraud detection**
Energy management system processes information from neighbourhood households and determines fraud probability occurrences in each neighbourhood	
Use case #21	**Losses calculation**
The energy management system processes information from ICT devices and determines energy losses within energy grid assets.	
Use case #22	**LV fault detection and location**
Detection and awareness of energy faults in electrical distribution grids in Low Voltage Grids.	
Use case #23	**Fault detection on fused luminaires**
This use case considers two different types of energy faults: public lighting luminaires which are not consuming energy according to the expected timetable and circuit failure when a large number of luminaires are not consuming energy during the expected night period.	
Use case #24	**Fault prevention (LV)**
The energy management system calculates the loads for each distribution grid asset and determines the probability of fault occurrence	

Energy forecast use cases

Use case #25	**Demand prediction**
The prediction of demand is required as input for the demand side management algorithms that are used by the Building Energy Management system. These predictions are made both on device level when possible and for the entire household otherwise. For both cases, the predictions are made for one day ahead in the future. A planning is based on this prediction.	
Use case #26	**Prediction of renewable energy generation**
The generation of renewable energy is predicted for the next day. For this, the weather forecast is used as input.	

Energy simulation use cases

Use case #27	**Energy storage penetration**
The impact of the location and amount of energy storage is simulated. Both distributed and centralized energy storage are evaluated.	
Use case #28	**Electric vehicle and distributed generation penetration simulations**
The impact of the location and amount of distributed generation, together with the number of electrical vehicles is simulated.	