On Valuation of Smart Grid Architectures: An Enterprise Engineering Perspective

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Abstract. This paper presents the initial design of a method to value smart grid (SG) architectures from a business point of view. The proposed design relies on the use of the Smart Grid Architecture Model (SGAM) and an adapted version of Bedell's method to assess the strategic importance and effectiveness of SG elements. As an attempt to automate such valuation, we also propose the use of a survey and a decision support system (DSS) that can determine the overall value of SG architectures.

Keywords: Smart grid · Enterprise architecture · Valuation · Decision support system

1 Introduction

Since a smart grid (SG) is an electricity network system that uses digital technology to monitor and manage the transport of electricity from all generation sources to meet the varying electricity demands of end users [7], it can facilitate the integration of renewable sources into the traditional energy value chain [2], e.g. virtual power plants based on solar or wind energy. Despite the benefits, SGs currently face several barriers (e.g. legal, economic and operational) [7]. Among those barriers, the unknown impact of information and communication technology (ICT) is one of the most important (i.e. the shorter life expectancy of some ICT components as well as security and privacy) [7].

Current methods to value renewable energy projects rely mostly on assessing cost-related issues, e.g. Levelized Cost of Electricity (LCOE), Levelized Avoided Cost of Electricity (LACE), System LCOE and System Value [8,14]. These approaches, however, overlook or simplify valuation issues related to the impact of ICT that usually supports and increasingly influences the functioning of such SG projects [2,7]. A complete valuation of these projects, therefore, needs to be complemented with an assessment that also takes into account the impact of ICT aspects. Such an assessment should not only cover costs related to software

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& hardware installation, maintenance and operation but also business-oriented issues such as strategic importance and effectiveness of ICT elements, which are significant and relevant to achieve SG goals (e.g. CO_2 reductions).

To achieve this assessment, enterprise architecture (EA) models can be applied since they provide a holistic approach that simultaneously looks at business and ICT aspects. Although these architectural models provide tools for supporting design and modeling, they usually lack tools to perform thorough analysis of the architectures.

As a first attempt to fill such gap, we **sketch the design** of a method that allows to assess the value of smart grid projects using EA models. The method adapts Bedell's method [13] to value the strategic importance and effectiveness of SG architectures that are designed using EA models. The method also foresees the use of a decision-support system (DSS) to implement a survey-based approach that exploits the information encoded in the EA models. Likewise, the approach is inspired by valuation techniques that have been already applied in enterprise architecture. Furthermore, in this work, we only focus on the valuation of business issues related to the strategic importance and effectiveness of the ICT elements that compose SG architectures, which are representations/models of real-world SG projects.

The rest of the paper is structured in the following way. Section 2 presents some related work, whereas Sect. 3 briefly describes the methodology we follow and presents the design of a proposed solution. Later on, Sect. 4 provides some discussion and Sect. 5 finishes the paper with general conclusions and future research directions.

2 Related Work

There are several methods to value renewable energy projects. Among the most relevant, LCOE, measures the overall cost of a power generating technology [1]. Although LCOE is widely used, it presents some drawbacks. For instance, as highlighted in [8], LCOE is unable to compute information about *when*, *where* and *how* power is generated, which is specially relevant for DERs [8]. To overcome some of its drawbacks, several metrics have been recently proposed. For instance, LACE [15], System LOCE [14] and System Value [8]. All these traditional (economic) methods, nonetheless, mostly assess cost-related issues while simplifying or neglecting business issues related to the impact of ICT (e.g. strategic importance of components).

There have been, nonetheless, recent efforts trying to economically assess SG architectures using architectural models that include ICT. The European project DISCERN has partially used the so-called Smart Grid Architecture Model (SGAM) to assess the "economic viability" of SG solutions [5].

In a similar vein, Quartel et al. have adapted Bedell's method for the valuation of IT portfolios [12,13]. Managers are expected to provide information not only on the (perceived) importance of business processes to the organization (IBO) and business activities to business processes (IBA) but also on the effectiveness of information systems in supporting business activities (ESA) [12]. Once the information is obtained, the method can estimate the value and cost of a given architecture [12].

In our design, we aim to also adapt Bedell's method to value SG architectures based on SGAM. The later provides a "standardized" way to describe SG architectures, whereas the former offers a step-wise method to value the strategic importance and effectiveness of ICT elements. Understanding the importance and effectiveness of ICT elements is of utmost relevance to stakeholders (e.g. energy utilities and retailers) as both measures provide insights on whether ICT investments might be needed to support new or current operations and which operations might need "extra" support [13]. For instance, demand-side management (DSM) is a paradigm within SGs that aims to intelligently match energy demand and supply by mostly influencing consumption using among other things smart components (e.g. smart meters, controllers) at the customer premises [2]. The addition of all new components, nonetheless, requires understanding the impact they bring to other operations within current SG architectures (e.g. new forms of energy billing to influence consumption).

Furthermore, to gather the information on the importance of ICT elements, we foresee the use of a DSS that will provide a (semi) automated way of collecting data via surveys and facilitate decision making by generating reports on the overall value of the SG architecture under analysis. In this way, the final objective is to provide a "holistic" method to value smart grid (SG) projects based on information collected from experts via surveys.

3 Methodology and Proposed Solution

To design our solution, we follow a design science research (DSR) approach [6,10]. Out of the traditional six steps (problem identification and motivation, definition of the objectives for a solution, design and development, demonstration, evaluation and communication), we only cover the first three as the main goal of this paper is to sketch the design of a potential solution. In this way, Sect. 1 has already identified the need to provide a complementary way to assess the value of SG projects by taking into account the impact of ICT. Likewise, Sect. 2 has defined the objective of a solution, which is presented in the following paragraphs.

To achieve our objective, we propose adapting Bedell's method [13] to value SG architectures that are designed based on SGAM [3]. SGAM supports a holistic description of all the elements within an SG architecture, whereas Bedell's method allows to value the importance and effectiveness of such architecture. By the same token, to collect information required by Bedell's method, we also propose the use of a tailored survey. The following paragraphs elaborate on each one of these elements.

3.1 SGAM

The Smart Grid Architecture Model (SGAM) proposes an enterprise-wide, service-oriented approach to describe an SG architecture [3]. SGAM relies on *domains*, *zones* and *interoperability* layers. SGAM domains support the specification of elements related to the electrical conversion/supply chain (from generation, transformation, transportation all the way to customers). SGAM zones support the definition of different levels of power system management (automated management mostly). SGAM interoperability layers integrate all aspects related to business objectives, functionality, information exchange, communication protocols and ultimately the technical infrastructure of SGs [3].

The main advantage of using SGAM to value SG architectures is twofold: communication and analysis. First, SGAM provides a "holistic language" that facilitates the communication among stakeholders (e.g. it sufficiently covers business and ICT elements). For example, to value the importance of technical elements, one can use the elements from the component and communication layers, whereas business and function layers can be used to value the importance of operational elements. Second, since SGAM has been designed by experts in the electricity domain, it focuses on the elements that are ultimately needed to operationalize SG projects [3].

3.2 Adaptation to Bedell's Method

Bedell's method was originally designed to analyze the contribution of information systems to organizations' business value [13]. The method, nonetheless, has been also adapted to analyze IT portfolios based on EA models [12]. The main idea behind the method can be summarized in three steps. First, to gather information about the *importance* of the elements within an architecture by asking questions to people in charge of the architecture. Second, to use the collected information to compute the *effectiveness* of such architectural elements. Finally, by combining information about importance and effectiveness, we can obtain a holistic valuation of the overall SG architecture.

Figure 1 illustrates the main idea behind using Bedell's method to value SG architectures based on SGAM. As one can see, information related to the Importance of elements is obtained by a survey, whereas information about Effectiveness can be computed using formulas.

Computing Importance Based on a Survey. To compute the importance of bottom layers to upper layers, we propose to conduct a survey that will collect information about the strategic importance of elements *per layer*. In short, as proposed in Bedell's method, we must score the importance of each element within the system by means of a set of questions. Figure 2 shows such a set of questions. Briefly, the idea is to analyze the strategic importance of the following elements (see also Fig. 1).

- **I**mportance of **C**omponents to **C**ommunication protocols (ICC).

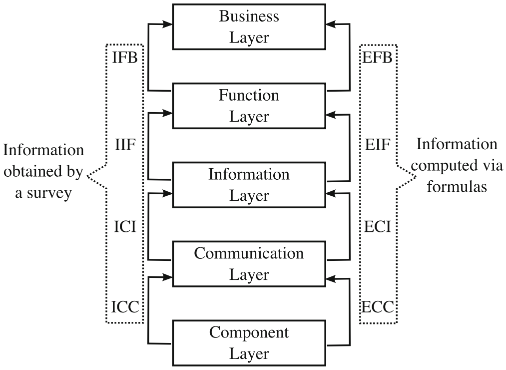

Fig. 1. Overall picture of Bedell's method adapted to value SG architectures based on the five SGAM layers. The **I**mportance of elements at each layer is obtained via a survey, whereas the **E**ffectiveness is computed via formulas.

- **I**mportance of **C**ommunication protocols to **I**nformation sharing models (ICI).
- **I**mportance of **I**nformation sharing models to Business **F**unctions (IIF).
- **I**mportance of Business **F**unctions to **B**usiness Services (IFB).

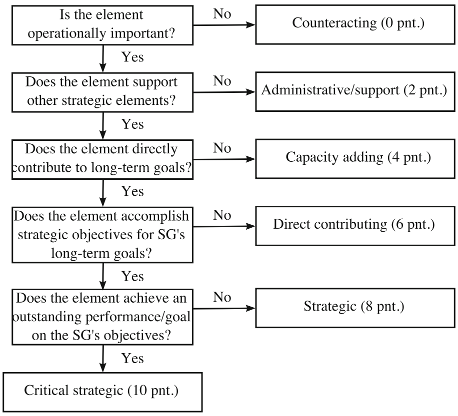

Fig. 2. Determining the strategic importance of elements within the SG architecture, adapted from [13]. Note: it might be needed to (re)adapt these questions per layer.

Computing Effectiveness. As seen in Table 1, the information regarding the effectiveness of each layer can be computed using formulas that use the information gathered in the previous steps (i.e. information about the strategic importance of each element).

Table 1. Formulas to compute the effectiveness per layer (see also Fig. 1)

Effectiveness of	Formula
Component to **C**ommunication	$ECC = \sum ICC$
Communication element to **I**nformation	$ECI = ECC \times \sum ICI$
Information element to **F**unction	$EIF = ECI \times \sum IIF$
Function to **B**usiness	$EFB = EIF \times \sum IFB$

3.3 A Survey to Combine Importance and Effectiveness

We discuss the integration of survey data regarding strategic importance with a decision-support system (DSS). A DSS framework, potentially combined with a rules engine and statistical analysis tools, can be used to analyze the collected survey data and identify individual data that exceed predetermined or adaptive thresholds. A responsive DSS has been proven to enhance decision performance [4]. Moreover, a business process engine can be used to manage the core DSS knowledge base of strategic value of the SG architectures to the business.

A DSS design model for complex domains such as SG architecture requires broader and more integrated viewpoints from different layers of the architecture [9]. The primary role for DSS assessment of survey data is to provide an effective means to reduce the data overload and to provide a means of strategic view to allow appropriate measurement of the importance of the SGAM elements (across layers) to best assess the value of SG architectures. In this way, the DSS system may ultimately influence improvements in the way SG architectures are designed and implemented. Figure 3 illustrates a DSS workflow to compute strategic importance and effectiveness of elements within the layers of the SG architecture. The workflow has been developed based on the BPMN 2.0 notation using Innovator for Business Analysts software.

As depicted in Fig. 3, there are three key stakeholders involved during the assessment of the strategic importance and effectiveness of the SG architecture: *assessment facilitator*, *survey participants* and *decision maker*. The assessment facilitator initiates the process by capturing details of the stakeholders and their roles in the survey. The survey questionnaire is then allocated to the relevant stakeholders (experts) from the DSS database via an interface (web browser or mobile app). As the participants respond to the survey questions, the assessment facilitator can track the survey status. The strategic importance and effectiveness scores are then computed based on the questions described in Fig. 2 and the set of formulas presented in Table 1. Based on associated business rules, the DSS can map questions with associated recommendations when the scores are below an established parameter, i.e. when risks are identified. The scores and associated recommendations are then compiled to generate an assessment report by DSS which is sent to the decision makers by the assessment facilitator.

Finally, the decision makers study the assessment report to determine the value of SG architecture to the business in terms of strategic importance.

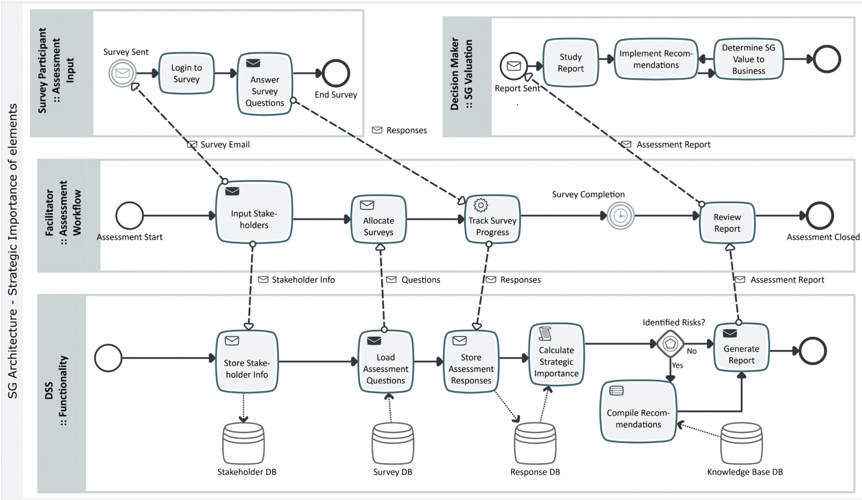

Fig. 3. Determination of Strategic Importance and effectiveness of SG Architectures using SGAM, a DSS and Bedell's method.

Additionally, recommended guidelines from the DSS may be actioned to improve the strategic importance of the architecture to the business. Such recommendations provide a transparent, evidence-based approach while taking a course of action to determine strategic value. We believe that in decision situations where perceptual factors from key stakeholders of a system must be captured, such as the quantitative models illustrated in Fig. 2, a DSS workflow (such as Fig. 3) can be optimized to embed such models, and this can ultimately help managers make better decisions [11].

4 Discussion

We do not call for ignoring LCOE, LACE, System LCOE or System Value but rather aim to complement the valuation of SG architectures by providing an approach that assess the strategic importance and effectiveness of ICT elements, which are key resources to achieve the goals of SG architectures. In this way, the main stakeholders (e.g. energy utilities, retailers) can have a more holistic view on how ICT elements impact SG architectures. For instance, how new paradigms such as DSM can impact current and new operations. In our design we have made several assumptions that might need to be revised in future versions. We have adapted Bedell's method to a different setting for which its value still needs to be validated within real-world cases. In concrete, we assume that strategic importance of SG elements can be assessed adapting the same questions described by the original Bedell's method. By the same token, we also assume that the formulas to compute effectiveness can be easily applied to SG architectures.

5 Conclusions and Future Work

We have described the initial design of a method to value smart grid SG architectures that focuses on the strategic importance and effectiveness of SG elements. Our method uses a DSS and a survey to collect information about the strategic importance and effectiveness of SG elements within SG architectures. It also assumes that SG architectures are described using SGAM.

As next steps we plan to perform four tasks: (1) refine our design by asking potential stakeholders to provide feedback on our current assumptions, (2) develop our DSS using standardized technology, and (3) demonstrate and evaluate our method within a real-world setting in which an energy utility or retailer needs to value an SG architecture.

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