Toward a model-based approach for analyzing information quality requirements for smart grid

Toward a Model-based Approach for Analyzing Information Quality Requirements for Smart Grid

(Research-in-Progress)

Mohamad Gharib, Paolo Lollini, Andrea Bondavalli
University of Florence - DiMaI
Viale Morgagni 65, Florence, Italy
{mohamad.gharib,paolo.lollini,andrea.bondavalli}@unifi.it

***Abstract*—Nowadays, most developed countries need to optimize their electricity production and consumption, which has led to the development of the Smart Grid (SG) concept. SG has a main objective of optimizing the generation, consumption, and management of electricity via information and communication technology. However, the vast amounts of information generated and processed in SG environments raise the issue of Information Quality (IQ). Accordingly, IQ has become an increasingly prominent issue in SG, since IQ can directly affect the services quality, reliability, and availability of an electric power supply. Despite this, the current IQ related issues in SG are still addressed in an ad-hoc manner. Without considering IQ requirements during the design of SG, it will be vulnerable to faults arising from depending on low-quality information, which may influence the dependability, reliability and efficient performance of SG. In this track of research, we aim at tackling this problem by developing a model-based approach for modeling and analyzing IQ requirements for SG.**

***Keywords*-Smart Grid, Information Quality, Data Quality, System-of-Systems, SoS**

I. Introduction

The importance of electric power has grown steadily over the past century [1], and the electricity system has become one of the most critical infrastructures with a strong impact on many other infrastructures [1], [2]. In particular, electric power plays an important role in the development of modern economy and society [3], which forces most developed countries to optimize their electricity production and consumption [2]. This has led to the development of the Smart Grid (SG) concept, which has been developed to optimize the generation, consumption, and management of energy via intelligent information and communication technology [2], [4].

On the other hand, the vast amounts of data/information[1] generated and processed in SG environments raise the issue of Information Quality (IQ) [2], [4]. According to Chen et al. [3], IQ has become an increasingly prominent issue in SG, since IQ can directly affect services quality, reliability, and availability of an electric power supply [1]. IQ is also closely related to the safety and reliability of the power system operation and management based on data-driven decision support [3].

Additionally, IQ is also of great importance for the efficient performance of some systems that are essential for the reliability of Smart Grid such as Wide Area Monitoring, Protection, and Control (WAMPAC), Supervisory Control and Data Acquisition Systems (SCADA), Flexible Alternating Current Transmission System (FACTS), and Feeder Automation System [5]. Despite this, the current IQ related issues in SG are still addressed in an ad-hoc manner [4]. Without considering Information Quality (IQ) requirements during the design of SG, it will be vulnerable to faults arising from depending on low-quality information, which may influence the dependability, reliability and efficient performance of SG.

In this track of research, we aim at tackling this problem by developing a model-based approach for modeling and analyzing IQ requirements for SG. In particular, SG is defined as a complex System of Systems (SoS) according to the Smart Grid Reference Model (SGAM) [6], where a SoS can be defined as an integration of a finite number of independent and operable Constituent Systems (CSs) that are networked together to achieve a certain higher goal [7], [8].

Several models for analyzing IQ based on its various dimensions (e.g., accuracy, completeness, etc.) have been proposed (e.g., [9]–[12]). We highlighted the limitations of these models for analyzing IQ for SoS in our previous work [13], and we proposed a conceptual model for analyzing IQ for SoS in terms of four IQ dimensions[2] (e.g., accuracy, completeness, timeliness, and consistency) that tackles the limitations of existing IQ models.

However, our previous model is specialized for modeling IQ requirements for SoS, i.e., it is not a domain specific for SG. Moreover, it was not equipped with any kind of automated support as this activity was left for future work. To this end, a model-based approach for modeling and analyzing IQ requirements for SG that tackles the previously mentioned problems would constitute a great step forward in designing a more dependable and reliable SG.

The rest of the paper is organized as follows; Section II presents the problem statement and research challenges, while we present and discuss our agenda for tackling the research challenges and propose a solution in Section III. Finally, we conclude the paper in Section IV.

[1]Data and information are synonyms in our work

[2]These four dimensions have been considered as the core dimensions in most of the existing IQ models [9]–[11]

II. PROBLEM STATEMENT AND RESEARCH CHALLENGES

In order to propose a model-based approach specialized for modeling and analyzing IQ requirements for SG, we need to tackle the following Research Challenges (RCs):

- *RC 1. What are the special characteristics of SGs with respect to their IQ requirements?* Like all other current complex systems, SGs have their own characteristics. Therefore, SGs need to be studied and understood in order to identify these characteristics, and based on these characteristics, the IQ requirements of SGs can be identified.
- *RC 2. How can we capture the IQ requirements for SGs?* After identifying the special characteristics of SGs and in order to design efficient and dependable SG, we need to identify the main concepts that can be used for capturing these characteristics (e.g., aspects) along with the IQ requirements of SGs.
- *RC 3. How can we model the IQ requirements for SG?* Based on the concepts and relationships to be identified in *RC 2*, we need to propose a modeling language that offers constructs, which can be used for modeling IQ requirements for SG.
- *RC 4. How can we verify the correctness and consistency of IQ requirements models?* Usually, we cannot rely only on the semantics of the modeling language to guarantee the correctness and consistency of the produced model. However, defining a set of logical constraints that govern how the constructs of the modeling language can be used to produce valid IQ requirements models can solve this problem.
- *RC 5. How well does our proposed artifact (e.g., the model-based approach) perform when applied to realistic settings?* In other words, how can we assess the adequacy of our artifact for modeling and analyzing IQ requirements for SGs.

III. PROPOSED SOLUTION AND DISCUSSION

In this section, we present and discuss our research agenda along with our ideas to tackle the research challenges. The research agenda has been structured in a process of five steps (depicted in Fig. 1), with some iterations to refine the output of some of these steps. Each of these steps aims at tackling its corresponding research challenge:

- *Step 1. Concepts identifications.* This step is composed of two sub-steps: *Step 1.1. SG concepts* and *Step 1.2. IQ concepts*, which aim at identifying key concepts and relationships for capturing the main aspects of SG and IQ respectively. This will be done by surveying the related literature and identify such concepts and relationships. In particular, we start by identifying the key concepts of SG and then we identify the IQ related ones. Note that, we also need to identify the IQ dimensions (e.g., accuracy, completeness, consistency, etc.) that need to be considered for analyzing IQ for SG at this step. In particular, IQ is a hierarchical multi-dimensional concept that can be analyzed based various dimensions [4], [9], [14]. Therefore, which of these dimensions we need to consider will be identified based on the characteristics of SG. More specifically, whether we need to consider only the four IQ dimensions identified in [13], a subset of them, or we need to extend them by considering other dimensions (e.g., believability, trustworthiness, etc.).
- *Step 2. Definition of the domain model.* A domain model should include a set of fundamental language constructs that represent the key concepts of the domain along with the relationships among them. In this context, the main purpose of our domain model is providing simple and expressive concepts for capturing (modeling and analyzing) IQ requirements for SG. As previously mentioned, our previous IQ model [13] was not domain specific. Therefore, we have to incorporate the key concepts and relationships identified in the previous step into the domain model. Note that some of these concepts may need to be adapted/modified to fit the needs of SG.
- *Step 3. Formulating the modeling language.* Usually, a system development requires models that represent the system-to-be [15]. Therefore, a modeling language that describes the conceptual construct underlying the system-to-be is needed [16]. To this end, we are planning to adopt the Unified Modeling Language (UML)[3] to develop our domain-specific modeling language. UML is a general-purpose modeling language that is highly-adopted by both academia and industry. Moreover, UML provides the profile concept that can be used for developing domain-specific modeling languages based on its set of general language concepts. In particular, we are planning to follow the guidelines proposed in [17] to formulate a UML profile for modeling IQ requirements for SG. More specifically, we will depend on the concepts and relationships that will be identified in the domain model in Step 2 to define the stereotypes and tagged values of the profile. Moreover, we plan to implement the profile depending on Eclipse-Papyrus[4], which allows designers to use its various stereotypes for modeling IQ requirements for SG.
- *Step 4. Constraining the modeling language.* This step aims at defining a set of logical constraints (we call properties of the design) that govern how the constructs and relationships of the models can be used to produce valid IQ requirements models. In particular, these constraints will be defined with the help of domain experts taking into consideration the main aspects of the targeted domain (e.g., SG). After defining these properties, we plan to formulate them relying on the Object Constraint Language (OCL) [18] that is a declarative language, which can be used to describe rules applied to UML models. OCL was developed as a formal specification language extension for UML, and now it is part of the UML standard. Therefore, we can enrich the profile we

[3]https://www.omg.org/spec/UML/2.0/
[4]https://www.eclipse.org/papyrus/

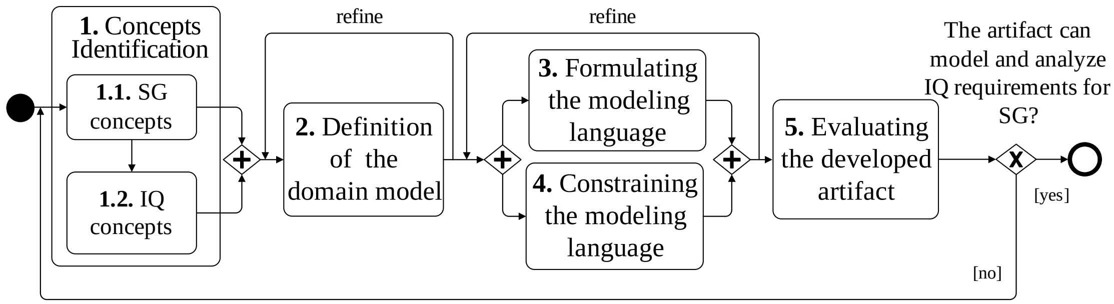

Fig. 1. The research process

will implement relying on Eclipse-Papyrus by integrating these constraints in it. This allows for automatically verifying the correctness and consistency of the models relying on these constraints. If all of them hold, the model is considered correct and consistent with respect to the properties of the design. While if any of them has been violated the designer needs to modify the model to address such violation.

- *Step 5. Evaluating the developed artifact.* Evaluation aims at providing evidence that the design artifact achieves the purpose for which it was designed [19]. Therefore, we will evaluate the adequacy of the profile by applying it to model and analyze the IQ requirements of various realistic SG scenarios. If the result of the evaluation was not satisfactory, we will restart the process from the concepts identifications step trying to improve and tackle the detected shortcoming in the profile design. Otherwise, the profile will be considered adequate for modeling and analyzing the IQ requirements for SG.

IV. Conclusions

In this short paper, we highlighted the importance of capturing IQ requirements for SG during the design phase, which prevents vulnerabilities arising from depending on low-quality information (e.g., inaccurate, incomplete, etc.). Then, we motivated the need for a model-based approach for modeling and analyzing IQ for SG, and formulated several research challenges that need to be tackled in order to develop such approach. Finally, we have presented and discussed a research agenda that propose solutions for each of the research challenges with main objective of developing a model-based approach for modeling and analyzing IQ for SG.

Acknowledgment

This work has received funding from the REGIONE TOSCANA POR FESR 2014-2020 SISTER “SIgnaling & Sensing Technologies in Railway application”, and the European Union’s Horizon 2020 research and innovation program under the Marie Sklodowska-Curie grant agreement No. 823788 - ADVANCE project.

References

[1] C. Gellings, M. Samotyj, and B. Howe, “The future’s smart delivery system [electric power supply],” *IEEE Power and Energy Magazine*, vol. 2, no. 5, pp. 40–48, 2004.

[2] M. R. Abo and A. Even, “Managing the Quality of Smart Grid Data,” in *IEEE International Conference on Emerging Technologies and Innovative Business Practices for the Transformation of Societies (EmergiTech)*. IEEE, 2016, pp. 5–8.

[3] W. Chen, K. Zhou, S. Yang, and C. Wu, “Data quality of electricity consumption data in a smart grid environment,” *Renewable and Sustainable Energy Reviews*, vol. 75, pp. 98–105, 2017.

[4] M. Ge, S. Chren, B. Rossi, and T. Pitner, “Data Quality Management Framework for Smart Grid Systems,” in *International Conference on Business Information Systems*. Springer, 2019, pp. 299–310.

[5] S. Chren, B. Rossi, B. Bühnova, and T. Pitner, “Reliability data for smart grids: Where the real data can be found,” in *2018 Smart Cities Symposium Prague, SCSP 2018*. IEEE, 2018, pp. 1–6.

[6] CEN-CENELEC-ETSI, “Smart Grid Reference Architecture,” Tech. Rep., 2011.

[7] M. Jamshidi, “System of systems engineering - New challenges for the 21st century,” *IEEE Aerospace and Electronic Systems Magazine*, vol. 23, no. 5, pp. 4–19, 2008.

[8] M. Mori, A. Ceccarelli, P. Lollini, B. Frömel, F. Brancati, and A. Bondavalli, “Systems-of-systems modeling using a comprehensive viewpoint-based SysML profile,” *Journal of Software: Evolution and Process*, pp. 1–20, 2017.

[9] B. Bovee, M., Srivastava, R., and Mak, “A conceptual framework and belief-function approach to assessing overall information quality. Paper presented at the Proceedings of the 6th International Conference on Information Quality,” *International Journal of Intelligent Systems*, vol. 18, no. 1, pp. 51–74, 2001.

[10] L. Liu and L. Chi, “Evolutional data quality: A theory-specific view,” in *7th International Conference on Information Quality ICIQ*, 2002, pp. 292–304.

[11] M. Gharib and P. Giorgini, “Modeling and Reasoning About Information Quality Requirements,” in *Requirements Engineering: Foundation for Software Quality*, vol. 9013, Springer. Springer, 2015, pp. 49–64.

[12] M. Gharib and P. Giorgini, “Dealing with information quality requirements,” in *Lecture Notes in Business Information Processing*, vol. 214. Springer, 2015, pp. 379–394.

[13] M. Gharib, P. Lollini, and A. Bondavalli, “A conceptual model for analyzing information quality in System-of-Systems,” in *12th System of Systems Engineering Conference, SoSE17*. IEEE, 2017, pp. 1–6.

[14] L. L. Pipino, Y. W. Lee, and R. Y. Wang, “Data quality assessment,” *Communications of the ACM*, vol. 45, no. 4, pp. 211–218, 2002.

[15] B. Nuseibeh and S. Easterbrook, “Requirements engineering: a roadmap,” in *Proceedings of the Conference on the Future of Software Engineering*. ACM, 2000, pp. 35–46.

[16] R. F. Paige, J. S. Ostroff, and P. J. Brooke, “Principles for modeling language design,” *Information and Software Technology*, vol. 42, no. 10, pp. 665–675, 2000.

[17] B. Selic, “A systematic approach to domain-specific language design using UML,” in *10th IEEE International Symposium on Object and Component-Oriented Real-Time Distributed Computing, ISORC 2007*. IEEE, may 2007, pp. 2–9.

[18] OMG-OCL, “Object Constraint Language,” Tech. Rep. May, 2014.

[19] J. Venable, J. Pries-Heje, and R. Baskerville, “A comprehensive framework for evaluation in design science research,” in *International Conference on Design Science Research in Information Systems*. Springer, 2012, pp. 423–438.