Ontology-Based Development of Smart Grid Co-Simulation Scenarios

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Abstract. As the transition of the power system to renewable energies leads to a rise in complexity, co-simulation is used to test new technologies with interdisciplinary simulation models. For this, experts from different domains have to cooperate in the development, execution, and evaluation of co-simulation scenarios. To assist the stakeholder in this process, we propose to integrate domain knowledge and structure the process based on ontologies. This approach aims to allow the high-level development of simulation and automated integration of its information in the specification and execution of concrete co-simulation scenarios.

Keywords: Co-Simulation · Energy scenarios · Information model · Smart grid · Ontology

1 Introduction

The transition of the power system towards more decentralized plants and intelligent devices in a smart grid leads to a demand for new technologies and increasing dependencies between different domains. Thus, the power system can be considered neither detached from the ICT system nor ecological, economic, or sociotechnical systems. In these different domains, specific software, programming languages, and paradigms are typically used. Co-simulation is an important approach in order to handle this complexity in the development of new technologies . It permits the execution of diverse simulation models, which are developed in different tools, in individual runtime environments and synchronizes them in a joint simulation scenario [2]. In this paper the following two challenges of the development and specification of co-simulation scenarios are addressed.

Firstly, simulation experts work together with experts from the different simulation models in the development of co-simulation scenarios. This collaboration of simulation and domain experts can be a complex task, because in discussions the used terminology may be unclear. Therefore, it would be a benefit to directly integrate external domain knowledge.

Secondly, co-simulation scenarios are developed manually by simulation and domain experts. Central elements of this process are the parameters, dependencies, and data flows of simulation models. An increasing number of simulation models make the development more complex and error-prone. Therefore, it is essential for the specification of complex large-scale co-simulation scenarios to gain assistance in terms of automation and validation.

2 Approach

To deal with the previously stated challenges, we propose to use ontologies for knowledge integration and also for representation and structuring of the development process in co-simulation. An overview of the approach is shown in figure 1. To deal with the first challenge, the integration of existing ontologies allows the reuse of existing definitions and descriptions of terms. For example, in the energy domain the Common Information Model (CIM) can be used as vocabulary for the definitions of terms used in co-simulation. Another example of the integration is the Ontology of units of Measure (OM) [1], which can be used for the definition of units. The structure for the development process addressing the second challenge is shown as follows.

2.1 Information Model

The approach is based on the information model of the Sustainability Evaluation Process (SEP) described in [3]. It supports the information exchange in the process of development and evaluation of co-simulation scenarios, as it allows the modeling of dependencies and data flows.

The structure of the information model is depicted in figure 2. On the left-hand side the domains of interest are modeled with objects, which are described by attributes. On the right-hand side the evaluation function is categorized into facets and criteria. The connection between the two sides is established through transformation functions from attributes to the evaluation criteria.

The information model is modeled in a mind map to facilitate the participation of domain experts without previous knowledge of ontologies. The use of a mind map has a twofold effect: the implementation of brainstorming within a project team, and the systematic collating of information in the structure of the information model. For the ontological representation a base ontology representing the information model structure has been developed. In addition, the mind map tool XMind[1] was extended to transform the content of the mind map to RDF, based on the base ontology. For this transformation the structure of the mind map has to comply with the specific structure of the information model.

[1] https://www.xmind.net/

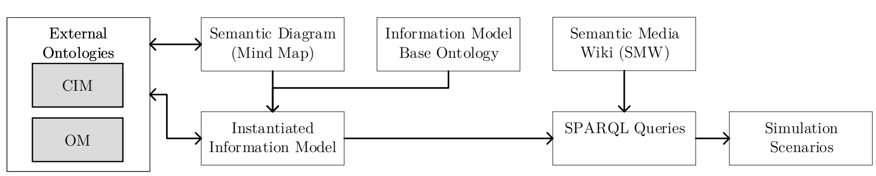

Fig. 1: Overview of the approach.

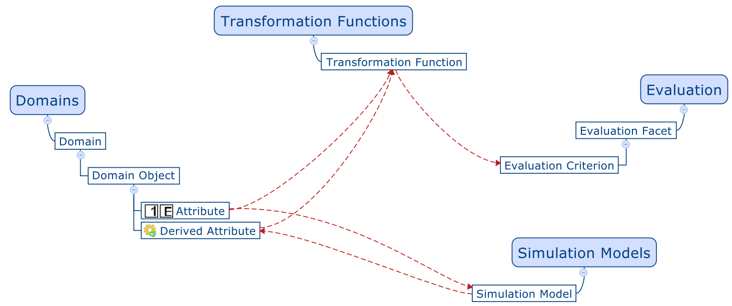

Fig. 2: Structure of the SEP information model.

2.2 Semantic Media Wiki

To specify concrete simulation scenarios, applicable simulation models have to be selected and coupled based on the high-level scenarios modeled in the information model. To support this process, a Semantic MediaWiki (SMW) is used to collect available simulation models in a catalog. The catalog in the SMW is used to facilitate the participation of users without experiences in ontologies.

2.3 Example Query

The use of ontologies provides the structure for querying the content of the information model and the catalog in the SMW with SPARQL. Thus, the development of simulation scenarios can be assisted in several ways.

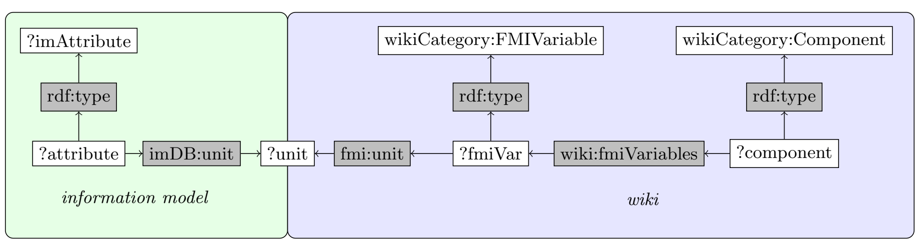

Fig. 3: Visualization of example query.

In figure 3 an example query is visualized. It assists the user in finding simulation models suitable for the high-level scenario defined in the information model. Manually done, this can be a complex task because there may be a vast amount of simulation models available which are usually developed by the domain experts and not the simulation experts. For this query, the attributes defined in the information model (*?attribute*) have to be annotated with a unit (*?unit*) to find matching FMI variables (*?fmiVar*) and the corresponding simulation models (*?component*) from the catalog in the SMW.

Based on the information model structure the user can also be assisted in the planning of the evaluation of the high-level scenario. Especially, in a large scenario with many objects, queries can show objects with missing in- and outputs and offer recommendations. Additionally, the simulation models in the SMW can be queried to assist the coupling. For this, the technical interfaces and characteristics of the simulation models stored in the catalog in the SMW are checked for compatibility.

3 Conclusion

In this paper we proposed an approach for the use of ontologies for development of smart grid co-simulation scenarios to assist the stakeholder in this process. Our approach provides ontology-based structures for the modeling in an interdisciplinary context and allows the reuse of existing knowledge from external ontologies. It can be instantiated in a mind map in collaboration of interdisciplinary domain experts and permits the integration of external ontologies for definition of terms and referencing external works. Additionally, a catalog of simulation components in the SMW has been developed, which can also be integrated for querying in order to assist the simulation expert in finding suitable simulation models for the specification of co-simulation scenarios.

This approach was developed and used in the project NEDS. It was used to assist the development of interdisciplinary future scenarios for the power supply of the German federal state Lower Saxony and the following simulation and sustainability evaluation of the scenarios [3].

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