An Ontology Driven Model approach for the creation and evaluation of models in the electricity retail market: A research in progress

Geovanny Poveda
University of Applied Sciences Western Switzerland
Rue de TechnoPole 3, Sierre, 3960, Switzerland
Email: geovanny.poveda@hevs.ch

René Schumann
University of Applied Sciences Western Switzerland
Rue de TechnoPole 3, Sierre, 3960, Switzerland
Email: rene.schumann@hevs.ch

***Abstract*—Agent Based Simulation has enabled economist to model and analyse strategic decisions of participants as well as political decision markers by using social-behavioural and economic technical aspects simultaneously. While Agent-based Simulation has had a significant contribution to the study the energy market by allowing economists and researchers to model the complexity and dynamics of real electricity markets, it has proved to be limited in some ways: Agent-based models do not involve methodological aspects for enabling the creation of models from a participative multi-disciplinary perspective. In many cases, modellers (programmers, economists or researchers) need to assume the knowledge of multiple domain areas for designing and implementing the models, they must have the ability to handle different domain such as sociology, economy and computer science. This paper shows how the use of an Ontology Driven Model approach in conjunction with methods from the Agent Computational Economics and other complementaries methodological aspects can contribute to improve such shortcomings.**

I. Introduction

Over the last years the global electricity industry has been experienced significant changes toward a deregulation and decentralization. Energy market liberalization (EML) has been one of the most representative reform initiatives on the European energy market. EML has enabled suppliers, consumers and retailers to be involved in an institutional arrangement which provides an enhanced array of services, products and opportunities to ensure a better individual match energy market preferences. As a result of the EML process, deregulated electricity markets have emerged. Deregulated electricity markets are complex adaptive systems, consisting of a large number of participants (e.g. generators, consumers and other participators) involved in multiple parallel local interactions. They are characterized by having asymmetric information, imperfect competition, strategic interaction, collective learning and have multiple equilibria [22]. Aforementioned features have enabled players to adapt and change their behaviours, business strategies, risk preferences and decision models according to the dynamics of the market.

During the last years, several lines of research have been devoted for modelling the electricity markets and their interactions. Among these, Agent Based Simulation (ABS) has become one the most prominent approaches for studying and modelling deregulated electricity markets. ABS is a computer assisted technique for modelling the dynamics of complex systems and complex adaptive systems which enables mechanisms for describing the physical, social and human components of real complex situations [14]. ABS is a suitable approach for studying deregulated electricity markets since it allows researchers to model socio-technical systems, in which not only economical and technical features are included in the models, but also social-behaviours. Furthermore, they represent the basis of a normative research methodology named Agent Computational Economics (ACE), which uses a set of agreed specialized economic methods for exploring how changes in structural conditions, institutional agreements and/or human decision process affect market outcomes over time. While ABS has had a significant contribution to the study the energy market by allowing researchers and domain experts can model the complexity and dynamics of real electricity markets, relying on a cross-disciplinary approach, It has proved to lack the uniformity of approach. Agent-based models do not involve methodological aspects for enabling the creation of models from a participative multi-disciplinary perspective. In many cases, modellers (programmers, economists or researchers) need to assume the knowledge of multiple domain areas for designing and implementing the models. They must have the ability to handle different domain such as sociology, economy and computer science. Thus, difficulties can exists for assuring that models really implements real socio-technical features from the electricity markets.

Aforementioned lack, may cause to maintain the electricity agent-based models could be expensive since there are not suitable methods for involving a multidisciplinary and dynamic perspective that includes members, artefacts and systems with specialized roles for designing and evaluating electricity markets. Despite the fact that ABS approach provide a valuable supplement to the electricity market modelling, software engineering techniques, as well as software engineering methodologies are required for facilitating and improving the development of electricity agent-based simulation systems. In the electricity market modelling it is desirable to advocate for the use of methods, techniques and tools that allow economist and researchers to meet the requirements needed to build evaluable, interoperable and adaptable models. It is desirable to provide methods and techniques for improving the modelling and evaluating of electricity markets when cognitive, social and specialized business features are included on models.

In this sense, we argue the use of an Ontology Driven Model (ODM) approach can cope with such shortcoming, since it can provide mechanisms for creating well-defined modelling scenarios that are conceptually close to the domain experts. ODM uses ontologies to drive the creation of simulation models from a shared knowledge understanding. Ontologies not only provide the basis for creating a standardized and agreed set of concepts around domains, they also can be used to communicate domains information and model tools with limited human intervention [19]. This paper will shows how the use of a ODM approach in conjunction with methods from the ACE and other complementaries methodological aspects can contribute to facilitate the construction of evaluable, interoperable and adaptable electricity markets, but most of all, how to contribute to develop computational electricity market models more human and social behaviour like fashion.

The paper outline is as follows. In Section II an overview of the most representative Ontology Driven-based models is presented. The overview includes a description of approaches based on formal semantic representations and approaches for model-based domain-specific language focused on multi agent systems. Section III presents an overview of the ODDM approach and its contribution for modelling and evaluating electricity markets. Section IV-A introduces our proposed ODM approach by describing their phases. Next, section V introduces an ontology for modelling electricity retail market (ERMO). Finally, section VI concludes and points out possible future research directions.

II. Related Works

This section describes the related works. We have included two main categories: (1) approaches based on formal semantic representations and (2) approaches for model-based domain-specific language focused on multi agent systems. Interesting studies such as: [21], [23] and [24] have highlighted the importance of using ontologies for modelling domain specific meta models. In [24] Walter et al. they have explored the use of ontologies for modelling domain specific languages through the creation of framework able to define enriched DSLs by formal class descriptions (OntoDSL). They have designed a metametamodel based on a layered OMG architecture composed of a KM3 [13], OWL2 [15] and OCL [25] meta models for providing DSL designer and DSL users guidance during the modelling process. Since their framework includes a OWL2 metamodel, it provides automated reasoning services that can be used by DSL designers and DSL users. Thus, they can be provide with suggestions during building domain models and progressive evaluation of domain constraints. In [21] Tairas et al they have created a model for assisting the phase of the domain understanding during the development of domain specific languages through a case study in which the scope of the domain is defined. They argue the use of the ontology development in the early stages of the DSL development provide a well-defined and structured process to determine the concepts of a domain and the commonalities and variabilities for a DSL, which can be use for generating class diagram and subsequently a Context-free grammar from the information. They highlighted the benefits of using ontologies in the early stages of the domain specific modelling by arguing with such approach there is no need to start from scratch the DSL development. In [4] Čeh et al. they have introduce an approach focused on how an ontology-based domain analysis can be incorporated into the DSL design phase. They have developed an ontology-based framework to help transform ontology to a DSL grammar incorporating concepts from a domain (Ontology2DSL). Ontology2DSL enables the automatic generation of a grammar from a target ontology. This framework accepts OWL files as input and parses them in order to generate and fill internal data structures. Then following transformation patterns, execution rules are applied over those data structures.

Another interesting studies such as: [6], [7] and [11] have highlighted the importance of using domain the semantics of domain specific languages for supporting the modelling and evaluating of ABS models. In [6] The authors have created a model in which a Domain Specific Language is integrated with a ABS platform. They have covered a case study for designing and implementing a DSL grammar on agent-based e-barter system [6]. In this framework, the authors have adopted an approach for generating the automatic application of predefined transformations for enabling developers to to achieve executable code for the agent system that is intended to use the domain specific design. In [11] the authors argue the advantages of using a Model Driven Development approach in multi agent systems by discussing how a domain specific modelling language provides a clear syntax and semantics to define agent-based systems. Moreover, they discuss about how it can be used to automatically derive code from its design through model transformations. Hahn et al. they have developed a platform independent domain specific modelling language for MAS called Dsml4mas, which allows modelling agent systems in a platform independent and graphical manner.

III. Ontology Driven Model: An approach for designing and evaluating Agent-based Systems

Ontology Driven Model uses ontologies to drive the creation of models from a knowledge shared understanding. Ontologies provide three important features for the modelling process: (1). they are able to provide the basis for building interoperable models; (2). they enable mechanisms for generating automated adaptation and extension of structural changes on models; (3). they provides formal methods for describing and relating concepts around multiple domains [3]. Furthermore, ontologies can be useful for checking integrity and consistency of models designed, as well as, for enabling mechanisms for improving the evaluation of electricity market models by means of "conceptual" business rules. In addition to above mentioned features, ontologies also enable reasoning mechanisms for providing checking model consistency and detecting coherence fault, both, during the design process and simulation runtime. The use of ontology driven model allows domain experts to raise the problem of creating unstable and ambiguous models. ODM enables auto-assisted techniques for providing a systematic guidance over the design of electricity models, i.e., by means domain specific languages (DSLs).

As it has been outlined in section I, current approaches for modelling electricity market models have a limited computer-aided supporting for including specialized definitions on the early stages of the modelling process. Many of these models lack the ability to include formal representations (formal semantics) and a formal domain analysis. Domain Specific Languages (DSL) have become one of the most representative alternatives for modelling languages. They are high levels which provide abstractions and notations for better understanding and easier modelling of applications of a special domain [24]. While DSLs are languages tailored to a specific application domain which offer substantial gains in expressiveness and ease of use compared with general purpose programming languages in their domain of application, it is has been shown that DSLs still remains some drawbacks: (1). interoperability with other languages, (2). formal semantics representation, (3). learning curve and (4). domain analysis [24]. The use of ontologies in the development of domain specific languages (DSL) is a prominent approach for providing guidance on the early stages of the electricity market simulation process. By using a set of semantic operations and OWL axioms, DSLs can be checked for restrictions and dependences between concepts and objects properties.

IV. An Ontology Driven Model approach for modelling electricity markets

In an attempt to narrow down the shortcomings explained in section I and following the approach explained in section III, a conceptual model-driven approach has been designed. The basis of the stated model includes an electricity market ontology (further explained in section V) and a set of tools, methods and procedures able to support the creation of electricity retail market scenarios from a multi-disciplinary perspective, as well as, the creation of models from an automated code generation process. The proposed model consists of two major phases: (1). conceptual modelling design phase, which includes a knowledge domain modelling sub-phase; and (2). agent design phase.

A. Conceptual Modelling design phase

In this phase, modellers (economists and researchers) are able to define the strategic management features to be included in the electricity market models by using a ODM approach. It is an approach in which high level languages such as DSLs are designed on the basis of formal semantic representations. ODM enables modellers and designers to be guided during the modelling process through the progressive construction and evaluation of models. For satisfying the requirements of uniformity of approach and interoperability of the conceptual modelling process, an electricity market ontology, a DSL grammar, as well as, a set of transformation rules have been defined. It is important to mention that DSL grammar and rules have been defined on the basis of a methodology that includes some of the most relevant concepts around the analysis and design of ODM-based models [5].

We have designed a simplified meta-model for describing the behaviours, actions, states and transactions around the electricity retail market, in particular, for describing all strategic management features related to bilateral contracts. [1]. In contrast to several DSL design approaches in which textual constraints notation are based on specialized constraints languages such as object constraint languages (OCL) or self validation constraints, we have adopted an approach in which constraint definitions are based on the set of properties restrictions defined in the stated electricity market ontology (further explained in section V). In order to involve an approach for transforming the different model representations and adapting the constraints definitions restrictions, we have followed some methodological aspects from [18].

In this phase, modellers are able to execute two major activities: (1). a knowledge capture process which involves an ontological model instantiation activity and, (2). a process for describing the behaviours, activities of agents as well as their sequence of communication. That is, the conceptual model.

1) Knowledge capture process: In this phase, a systematic approach has been involved for addressing the transformation and adaptation of ontological constructs to DSL meta models. We have involved an approach which is composed of a set of transformation rules, directives and design patterns for deriving ontological and grammar models. In a first stage, a transformation of formal domain ontologies to DSL grammar is required. For enabling such transformation, two activities are required: (1) the use of OWL / Object parser mechanisms for retrieving concepts expressed in the object oriented paradigm. (2) code generation of OWL constructs. Since the semantic basis of both languages may be different, overall in the case of owl constructs: object properties and property restrictions, some additional restrictive conditions need to be placed on the domain ontology structure. That is, an alignment of meta models of DSL and domain ontologies is required. For ensuring consistency of alignment, we have defined a set of mapping rules among the ontology constructs and DSL meta-models constructs.

The grammar generated is obtained from a set of transformation rules that match OWL patterns to transform them into the DSL grammars (symbols and productions). It is a method in which symbols and productions are generated by using an iterative and recursive process that explore all subconcepts from the OWL THING axiom to insert grammar as

[1]Bilateral contracts consist essentially in direct negotiations of energy prices, volumes, time of delivery, duration, among other possible issues, between two heterogeneous and autonomous traders [2]

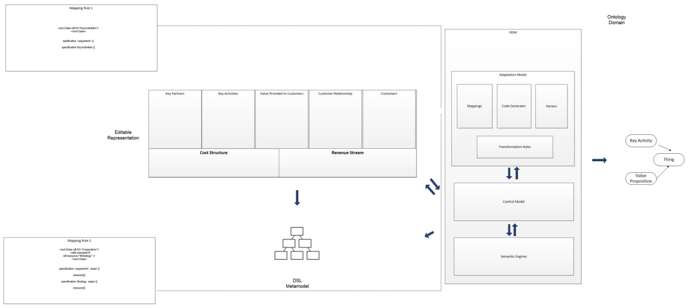

Fig. 1: Model transformations

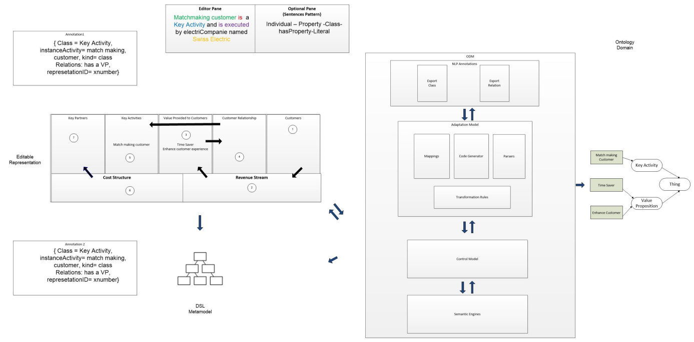

Fig. 2: Conceptual model creation

many elements as the number of construct that are hierarchy connected to the THING axiom. Figure 1 shows the flow of transforming and adapting ontological constructs to DSL meta models.

2) Describing the conceptual model: In this phase, an NLP-based approach [20] has been involved for addressing the definition of conceptual models from a domain specific meta model. In this approach, the set of mapped / transformed DSL constructs described in section IV-A1 are used for generating conceptual models expressed in the OWL syntax. For enabling such definition, three activities are required: (1). the use of NLP-based mechanism able to create annotations from the DSL constructs, (2). the use of DSL/OWL parser mechanism for retrieving concepts expressed in the object oriented paradigm, (3). the use of a mechanism able to generate the OWL constructs. There is a mechanism responsible for building annotations from a DSL grammar-based wizard tool and provide a mapping between the NLP and domain annotations, but at the same time, between the NLP and ontology constructs.

We have defined two major annotators: the first is an annotator for defining the export relations between entities and the second is annotator for defining which document annotations need to be exported, and to which ontology class). To generate the correspondent OWL constructs, the mapping process explained in section IV-A1 has been extended for providing model transformation in an opposite way, that is, from DSL meta-models constructs to ontology constructs. The grammar-based wizard is based on a function which suggests the patters in which the sentences can be built semantically. It suggests the member classes that can be used as individuals, as well as, the object properties, data properties and literals allowed for the construction of the conceptual model. Figure 2 shows the flow of creating the conceptual model from strategic management instances.

B. Agent Design phase

The purpose of simulation design phase is to translate the conceptual models into the simulation models (programs). We have involved a systematic approach which is composed of a set of transformation rules, directives and design patterns for deriving executable agent models from ontological representations. We have defined a set of directives to support the mapping process from the ontology domain (classes, object properties, properties, properties restrictions) to the multi agent oriented paradigm (classes, attributes, associations and roles). Design patterns and transformation rules are used during the mapping the ontological axioms. To derive objects from domain ontology-based conceptual models, we have enabled a directive in which each ontological class must have its equivalent in a class of a selected object-oriented programming language. In this directive, the Java architecture for OWL binding has been used [1]. In this directive, we are focused on two major features: (i). how to map property restrictions and (ii) how to generated automated model translations. To enforce class-specific restrictions on properties, we have proposed a set of constraint-checker classes that register themselves as listeners on the property inside the class definition. Thus, they are invoked upon property access to enforce the corresponding restriction. To generate automated translations, a method for Java bean generation and their corresponded interfaces has been included. In this method, there exist a mechanism which generates a source code of the equivalent class for each ontological class. That is, an skeleton in Java programming language. The classes generated contains attributes equivalent to ontological class properties with get, set, and add methods.

C. General Workflow

Figure 3 shows the iterations between the domain knowledge and the domain meta model for generating executable conceptual models. This diagram shows how a set of tools, methods and procedures facilitates each transactions. Initially, the model provide a process for addressing the transformation and adaptation of ontological constructs to DSL meta models. Then, a semantic-based tool enables mechanism and methods for assisting modellers during the creation of the strategic management features as they identify the order and conditions to be satisfied for the instantiation of concept according to the evaluation of a set restrictions and constraints from the ontological model. After specifying the stated concepts, the modellers model the conceptual model to be implemented and deployed as agents. A semantic-based tool enables modellers to be assisted during the model specification stage. There is a method responsible for providing modellers the order and conditions to be satisfied when a concept or relation is involved

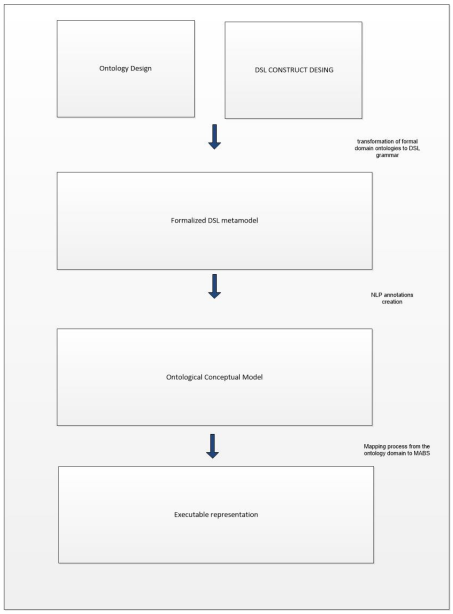

Fig. 3: Overflow of the Ontology Driven Model

from the meta model. For example, when a modeller is trying to instance the concept "RevenueStreams" a restrictions is warned for indicating before to instance such class, first, it is necessary to define the concepts and relations around the "Customer" concept. Section V-C provides details of property restrictions. Furthermore, the stated semantic-based tool provide a function for suggesting the member classes that can be used as individuals, as well as, the object and data properties allowed. The tool is able to show how sentences, actions and behaviours of the conceptual model, have created and interpreted (member class, object property or literal) and immediately suggest the set of options for continuing making the model. The output of this procedure is file expressed in the OWL syntax. Finally, a translation process based on the features explained in is executed for generating Java code.

V. An Ontology for the electicity retail market: ERMO Ontology

In attempt to create a standardized and agreed set of concepts around the electricity retail market domain, an ontology has been designed and coded. Modelling and design phases have followed the guidelines and procedures of an important number of sources and guides. Among those: (1). the analysis of academic related works; (2). analysis of commercial electricity simulators frameworks such as: Ecams [17], Sepia [12] and STEMS-RT [26]; and, (3). analysis of related electricity market ontologies such as: Upper Ontology [16] and BMO ontology [8]. As a result of such process, it has been possible to define an ontology model scheme. This ontology is named ERMO (Electricity Retail market Ontology).

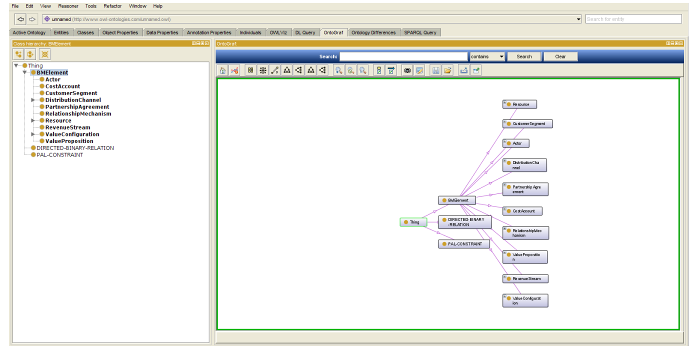

Fig. 4: ERMO Ontology class design overview.

A. *Ontology Namespaces*

An entire model scheme with a single name space,(ERMO), has been created. Specialized electricity retail market concepts have been included by using external name spaces from different knowledge representations. The use of external name spaces will be focused mainly on the use of the specialized concepts, such as: (1). consumer behaviour and (2). business strategies; and (3). human physiological behaviour in business markets . In order to support the validation and checking of restrictions and dependences between concepts and objects, we have included property restrictions on models.

1) Name space for business strategies.
2) Name space for business consumer model.

B. *Ontology Classes*

As we mentioned before, ERMO ontology will describe some of the most important concepts around the simulated electricity retail market life cycle. By following the principles of Gruber et al. [9], it has been possible to identify the basis of the ontological model. ERMO ontology will offer a model in which strategic management features and specialized business knowledge (business consumer models and business strategies), as well as, specialized physiological descriptions will be included as the core elements of the ontological business model. ERMO ontology has currently defined a high hierarchy classes. Figure V shows a partial view of such classes, attributes and relations.

C. *Ontology Property restrictions*

A property restriction is a special kind of class description which describes an anonymous class of all individuals that satisfy a restriction [10]. OWL distinguishes two kinds of property restrictions: value constraints and cardinality constraints. A value constraint puts constraints on the range of the property when applied to this particular class description. A cardinality constraint puts constraints on the number of values a property can take, in the context of this particular class description. One of the most important reasons to use property restrictions in the electricity market modelling, is because it makes possible to support the validation and checking of restrictions and dependences between concepts and objects properties. The use of property restrictions able mechanisms for assisting modellers over the different phases of the simulated scenarios. Property restrictions aim to minimize the definition of "unwell-formed" simulated electricity market models, since they allow users to include all possible conceptual basis for running efficient simulated models.

VI. Conclusions

In this paper, we have focused on the presentation of a conceptual model-driven approach for the modelling and evaluation of electricity retail markets. The limitations of modelling electricity market by using methods purely based on the agent system paradigm have been examined and an ontology driven simulation approach has been introduced as a potential contribution. We have presented and explaining their different phases and mechanisms involved in all of them. The conceptual model is still under design and development. Currently, the model supports the instantiation of the strategic management and creation of conceptual models by following a set of directives and transformation patterns based on semantic features. The continuing design and development of the model is a part of our future work. Particularly, we will focus on mechanisms for studying mechanisms for adapting the concepts and relations created by domain experts on the ontology model.

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