ELMO: AN INTEROPERABILITY ONTOLOGY FOR THE ELECTRICITY MARKET

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Keywords: Ontologies, Semantic Interoperability, Electricity Market.

Abstract: The liberalization of the electricity market in the European Union is a process of significant importance that aims at creating an efficient deregulated internal electricity market within the Union. An important challenge towards that end is definitely the development of effective market mechanisms and regulations that will comprise the operational framework of the market. Equally important, however, we consider the development of an interoperability framework that will enable the effective and unproblematic interaction between the market participants at both human and system level. Towards that direction we propose in this paper the Electricity Market Ontology (ELMO), an ontological model that provides a shared, common understanding of concepts and procedures regarding the electricity market operation. ELMO has been developed for the Hellenic Transmission System Operator (HTSO) and it is currently used by the organization for providing intelligent information access services to people interested in the market.

1 INTRODUCTION

The liberalization of the electricity market in the European Union (Trevino, 2008), (Albers, 2001) is a process of significant importance that aims at creating an efficient deregulated internal electricity market within the Union (Boucher and Smeers, 2001). The ultimate goal is to build a market that will make efficient use of resources and which, through free competition, will be able to guarantee reasonable prices of electricity. Towards that end, and given the fact that the electric energy sector in most EU countries is monopolized by national authorities, an important requirement for the successful operation of the market is the effective and unproblematic interaction between these authorities and the other market participants.

Facilitating such an interaction is primarily a matter of ensuring interoperability within the market, that is ensuring that diverse people, organizations and information systems are able to work together in the market operation context. For the first two, interoperability can be achieved through the development of a commonly accepted market operational framework that everybody understands and implements. For information systems, however, to do that, semantic interoperability is required.

Semantic interoperability is achieved when the meaning of exchanged information is understood by applications and services. For that to happen, the information must be represented in a format that conveys its meaning in an unambiguous and machine-interpretable way. To that end, ontologies can play a vital role.

An ontology is *"a formal explicit specification of a shared conceptualization for a domain of interest"* (Gruber, 1993). As such, it is a way of dealing with ambiguity and heterogeneity in a domain by representing the meaning of the domain's terms through high-level abstract concepts and corresponding semantic relations between these concepts. Formality, namely representation of the ontology by means of some formal computer language, allows for machine-interpretability of the domain's semantics.

For that, we present in this paper the Electricity Market Ontology (ELMO), a semantic model that provides a shared, common understanding of concepts and procedures regarding the operation of the electricity market. The ontology was primarily developed for the electricity market of Greece and according to the Greek legislative framework (Hellenic Ministry of Development, 2005). Nevertheless, the

Alexopoulos P., Kafentzis K. and Zoumas C. (2009).
ELMO: AN INTEROPERABILITY ONTOLOGY FOR THE ELECTRICITY MARKET.
In *Proceedings of the International Conference on e-Business*, pages 15-20
DOI: 10.5220/0002226400150020

latter's conformance to the corresponding EU framework (EU, 2003), the fact that member states have similar market architectures and the generic character of the ontology's structure and content allow, in our opinion, the ELMO ontology to act as as the basis for the development of similar ontologies for the markets of the other EU countries.

Given the above, the structure of the rest of the paper is as follows: In the next section we describe the development approach we followed while in section 3 a high-level description of the ontology's structure and content is provided. In section 4 we give details on how the Hellenic Transmission System Operator used the ELMO ontology for providing the public with semantic-enabled access to market relevant knowledge and in section 5 we summarize the key aspects of our work and we discuss potential future work.

2 OVERVIEW OF OUR APPROACH

The development of the ELMO ontology was part of a project involving the development of an electronic library for HTSO, the Transmission System Operator of Greece. The library, which is currently deployed and available through the URL http://emarketinfo.desmie.gr/htso/user, was to contain documents relevant to the operation of the electricity market and to provide its users access to this content through semantic-enabled search and navigation services.

The ontology's role within the library was to support these services by capturing and encoding the content's semantics which, given the nature of the documents, were in principle the semantics of the electricity market domain. Nevertheless, the development process of the ELMO ontology was mainly domain-oriented rather than application-oriented and had as key objective the construction of an extensible and highly reusable knowledge model that could be used by organizations such as HTSO as:

- The backbone of any knowledge repository that stores market relevant knowledge.
- A comprehensive starting point for developing specialized ontologies and corresponding ontology-based applications that serve market-specific tasks.
- An ontological framework based on which the organization's market related information systems could semantically interoperate with similar systems of other organizations.

Given the above, one of the key decisions in designing the ELMO ontology was to define it through a multi-layered architecture that would effectively divide it into highly maintainable, extendible and reusable modules. More specifically, when a large-scale ontology is composed out of smaller ones then its development and maintenance are easier and more efficient. At the same time, when the independent parts of the ontology are well defined and separated then it is highly possible that these parts can be reused in other similar applications. Finally, a layered architecture makes it far easier to extend the ontology so that it can cover application domains other than the existing ones.

In the case of the ELMO ontology, the basic layering criterion was the geographical applicability range of the ontology's knowledge. More specifically, as mentioned before, the ontology was primarily developed for the electricity market of Greece and therefore it was bound to contain knowledge that was valid only for this country. On the other hand, Greece, as all other member states of the EU, has already adopted and incorporated to its legislation the Electricity directive 2003/54/EC, which is the key European legislation to establish the Internal Market of Electricity. As such, a great part of the ontology was expected to refer to knowledge that was applicable to all EU countries. Separating, by means of different layers, this EU-specific knowledge from the Greece-specific one within the ELMO ontology yields, in our opinion, a number of significant advantages including:

- Easier ontology maintenance as the two legislative frameworks might change at a different rate and way.
- Ability to use the EU-specific layer as an upper ontology for the development of market ontologies for other EU countries.
- Easier mapping between the ELMO ontology and other existing country-specific market ontologies.

Given the above, the architecture of the ELMO ontology consists of five layers, as depicted in figure 1. The two dotted-lined layers are not currently implemented but they will be in the future. The separation of the rest three layers reflects, apart from the usual abstraction criterion, the aforementioned geographical applicability range criterion as well. In the following section an analytical description of all five layers in terms of structure and content is provided.

Finally, it should be noted that the ELMO ontology is formalized using OWL (Bechhofer et al.,), since it is a standard language for representing ontologies on the web, and it has been developed using the open source ontology editor Protégé (http://protege.stanford.edu). Furthermore it has been successfully checked for inconsistencies using the Pellet OWL DL Reasoner (http://clarkparsia.com/pellet).

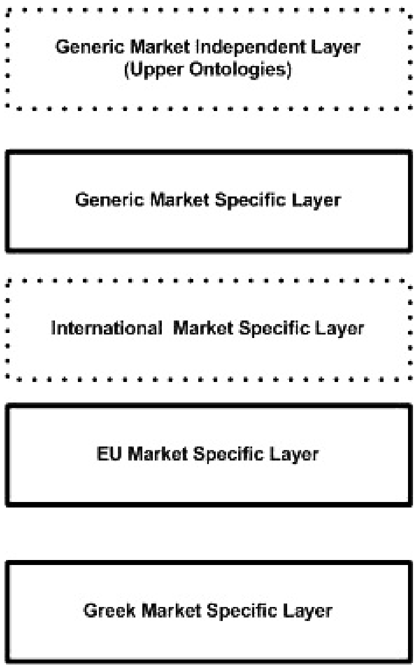

Figure 1: ELMO Layered Architecture.

3 THE ELMO ONTOLOGY LAYERS

3.1 Generic Market Independent Layer

An important design decision in developing ELMO ontology was whether we should define an upper ontology, namely an ontology that covers generic and domain-independent concepts.

In general, an upper ontology provides a starting point, a predefined set of ontological entities and an ontology design pattern for building new, lower-level, domain ontologies. Foundational ontologies such as SUMO or DOLCE (Gangemi et al., 2002) comprise natural candidates for the role of an upper ontology as they have been developed exactly for this purpose. However, choosing the best fitting foundational ontology from about a dozen freely available ones worldwide is a very difficult and time-consuming task while in many cases it might be necessary to create custom foundational ontologies by combining existing ones.

In the case of the ELMO ontology, we recognized the advantages of having an upper ontology, yet time and resource limitations made us postpone the process of evaluating, selecting and perhaps customizing some existing foundational ontology for a future project. In any case, we considered as a first layer of the ELMO ontology architecture the **Generic Market Independent Layer** which is going, in the future, to contain any upper ontology we choose to create or reuse.

3.2 Generic Market Specific Layer

Given the absence of an upper ontology in the ELMO architecture, the respective role can be assumed to play the second layer, namely the **Generic Market Specific Layer** (2). This practically defines the more abstract market-related concepts and relations of the ontology which are made more concrete in the lower level layers.

More specifically, the layer comprises eleven concepts (modelled as OWL classes) which are interrelated through ten relations (modelled as OWL object properties). These are:

- **Classes**
  - **Market Process:** Refers to any process or procedure that is part of the overall operation of the electricity market.
  - **Market Participant:** Refers to individuals and organizations that play some role within the market.
  - **Market Action:** Refers to actions performed by market participants in the context of specific market processes.
  - **Market Right/Obligation:** The two classes refer to rights and obligations of the market participants in the context of the market operation.
  - **Market Rule:** Refers to rules that govern the operation of the market.
  - **Market Unit/System:** The two classes refer to equipment, facilities and systems that are used in the context of the market operation.
  - **Market Specification:** Refers to standards and specifications that characterize the market's systems and units.
  - **Market Information Source:** Refers to any piece of market related information such as manuals, document templates, archives, registries etc.
  - **Market Extent:** Refers to parameters, data, factors, elements and virtually any extent that is relevant with the electricity market.

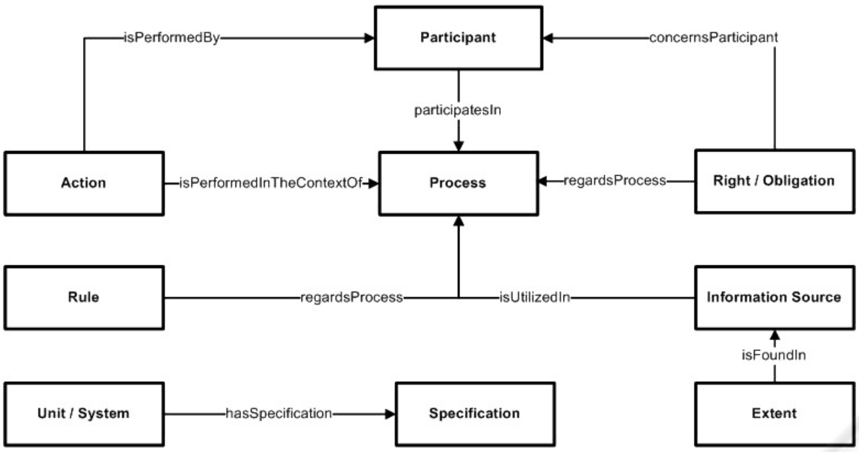

Figure 2: ELMO Generic Market Specific Layer.

- **Object Properties**
  - ***participatesIn*(Participant, Process):** Links market participants with the processes they participate in.
  - ***isPerformedBy*(Action, Participant):** Links market actions with the participants that they perform them.
  - ***isPerformedInTheContextOf*(Action, Participant):** Links market actions with the processes they are part of.
  - ***regardsProcess*(Right ⊔ Obligation ⊔ Rule, Process):** Links rights, obligation and rules with the processes they refer to.
  - ***concernsParticipant*(Right ⊔ Obligation, Participant):** Links rights and obligations with market participants.
  - ***isUtilizedIn*(Information Source, Process):** Links information sources with the processes they play some role in.
  - ***isFoundIn*(Extent, Information Source):** Links extents with information sources they are referred within.
  - ***hasSpecification*(Unit ⊔ System, Information Source):** Links units and systems with their respective specifications.
  - ***isPartOfProcess*(Process , Process):** Links processes with the sub-processes that might comprise them.
  - ***isPartOfAction*(Action , Action):** Links actions with the sub-actions that might comprise them.

The above conceptualization schema provides, in our opinion, a comprehensive and adequately abstract view of the market as almost all interactions that may take place within it and in the context of its operation, can be represented by specializing or instantiating the components of this schema. Furthermore, the deliberate absence of electricity and energy related knowledge from this layer of the ELMO ontology allows the first to be potentially reused as an upper ontology for other markets as well.

3.3 International Market Specific Layer

The international market specific layer is supposed to contain market-related knowledge that is valid and applicable for all the electricity markets of the world. Such knowledge is already contained within the ELMO ontology, however, since currently there is no formal activity towards a common international electricity market exists, the task of extracting internationally applicable knowledge is quite difficult. Therefore, the ELMO ontology does not currently implement this layer but includes it in its architecture so that it can implement it in the future.

3.4 EU and Greek Market Specific Layers

The EU and Greek market specific layers are the richest, in terms of content, layers of the ontology as they contain about two thousand classes and instances and about seven hundred asserted instantiated object properties. These, as suggested in the previous section, are either instances or specializations of the generic layer's components. As a result, the two layers comprise overall a number of class hierarchies, instance taxonomies and, of course, instantiated binary object properties.

An example of a class hierarchy is the one derived by subclassing the **Market Participant** class. A representative snapshot of this hierarchy is the following:

- **Producer**
  - **Dispatchable Unit Producer**
  - **Contracted Unit Producer**
  - **Cold Reserve Unit Producer**
  - **New Generation Unit Producer**
  - **Auto Producer**
- **Load Representative**
- **Meter Representative**
- **Transmission System Operator**
- **Production Licence Holder**
  - **Production License Holder of Contracted Hydro Unit**
  - **Production License Holder of Black Start Unit**

Similarly, an example of an instance taxonomy is the one derived by relating the instances of the **Market Process** class through the ***isPartOfProcess*** object property. A representative snapshot of this taxonomy is the following:

- **Registration with the ENERGY TRANSACTIONS SYSTEM**
  - **Registration with the Participant Register**
  - **Conclusion of Energy Transactions Contract**
- **Daily Ahead Scheduling**
  - **Submission of Load Declarations**
  - **Energy Offer Submission**
- **Dispatch Procedure**
  - **Dispatch Schedule preparation**
  - **Issue of Dispatch Instructions**
- **Imbalances Settlement**
  - **Calculation of Energy Deviations**
  - **Generation Deviations Settlement**
- **Meter and Measurement Administration**
  - **Meter and Meter Representative Registration**
  - **Metering Data Adaptation**
- **Ancillary Services and Supplementary System Energy**
  - **Supplementary System Energy Provision**
  - **Remuneration in the context of Cold Reserve Contracts**
- **Capacity Assurance Mechanism**
  - **Unforced Capacity Table Preparation**
  - **Issue of Capacity Availability Tickets**

In general, deciding whether the specialization of an ontology's concept should be performed by means of subclassing or instantiation, depends on the domain of the ontology, the application scenario the ontology is utilized within and the application specific reasoning that is performed on the ontology. In the case of the ELMO ontology, we made every effort to take in mind only the domain and not so much the application scenario (which was semantic information retrieval) or its reasoning mechanism (which required almost all concepts to be treated as instances).

As far as the distinction between EU-specific and Greece-specific concepts is concerned, this was performed on the basis of the knowledge we were able to extract from the relevant EU legislation documents we had access to. Additionally, many concepts were "giving away" their nationality directly through their name (e.g. **"Unit under Article 35 of Law 2773/1999"** or **"Hellenic Transmission System Operator"**).

In any case, in order to avoid any inaccuracies within the ontology, we initially considered all market specific concepts to belong to the Greek layer and then we began methodically to move concepts to the EU layer. At the moment, this task is still ongoing and we expect that the next versions of the ELMO ontology will comprise a much richer EU-specific layer than the current one.

4 USAGE OF THE ELMO ONTOLOGY

The ELMO ontology is currently utilized within the Hellenic Transmission System Operator as a vital component of the organization's electronic library, a semantic-enabled knowledge portal that provides the public with effective and efficient access to knowledge regarding the Greek electricity market.

More specifically, the available knowledge comprises market-related documents which, due to their size and the lack of proper cross referencing, are difficult for an individual to understand and use. The system tackles the two problems by enabling the storage and retrieval of decomposed parts of the documents (usually paragraphs) as well as navigation across these parts. These services are semantic-enabled in that the system implements them by utilizing the ELMO ontology for capturing and interrelating the parts' semantic content. This allows for significantly more effective information retrieval, in terms of results relevance, as well as for more intuitive navigation across the content through the ontology's semantic structures such as concept taxonomies.

Figure 3: HTSO Electronic Library.

The system was deployed and made available to the public in October 15th 2008 through the URL http://emarketinfo.desmie.gr/htso/user (figure 3). From there one can examine a representative part of the ELMO ontology by using the available taxonomies for content navigation.

5 CONCLUSIONS & FUTURE WORK

In this paper we presented the Electricity Market Ontology (ELMO), a semantic model that provides a shared, common understanding of concepts and procedures regarding the operation of the electricity market. The ontology, though primarily developed for the Greek electricity market, may in our opinion act as an ontological framework based on which similar ontologies for the markets of the other EU countries can be developed as well. This is supported by two key facts: First that the knowledge the ontology contains conforms to the EU legislative framework for the electricity market and second that its architecture is a multi-layered one thus allowing a high degree of extensibility and reusability.

As a future work we intend to continue working on the enrichment of the ontology's EU-specific layer so as to separate it totally from the Greek one and make it highly reusable for other markets as well. Furthermore, we are going to examine the suitability and applicability of several foundational ontologies for our Generic Market Independent Layer and, if necessary, define a custom upper ontologies that will serve our objectives best. Finally, we shall investigate a number of application-specific enhancements to the ontology in order to make it directly usable to several market-related applications.

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