A semantic model for data integration of offshore wind farms

Trinh Hoang Nguyen*, Andreas Prinz*, Trond Friisø**, Rolf Nossum*
* Faculty of Engineering and Science, University of Agder
Serviceboks 509, NO-4898 Grimstad, Norway
{trinh.h.nguyen, andreaz.prinz, rolf.nossum}@uia.no
** Origo Solutions AS
N-4604 Kristiansand, Norway
trond.friiso@origo-solutions.com

Abstract

Operation and maintenance play an important role in extracting power from the wind, especially, in offshore wind energy where wind farms are located far off the shore and under harsh weather conditions. Improved operation and maintenance is likely to reduce costs as well as hazard exposure of the employees. Implementation of advanced information technology is thus crucial for operating offshore wind farms effectively and efficiently and hence improves operation and maintenance. However, information availability and reliability are key issues for their use in the offshore wind domain. This paper describes the development of a semantic model for offshore wind data integration in order to facilitate date exchange and enable knowledge sharing between concerned partners.

1 Introduction

Rising of sea levels, acidifying of oceans and melting of ice caps are happening quicker than expected. Therefore, it is expected that the EU and other industrialized regions must reduce domestic greenhouse gas emissions by 80-95% until 2050. In order to obtain such a target besides banning carbon emissions from new power plants installed after 2015, the EU's renewable energy policy is expecting 34% renewable electricity in 2020 and 100% renewables by 2050. Wind energy alone could provide 50% of Europe's electricity by then [1].

It is apparent that moving wind farms from onshore to offshore brings huge benefits for wind energy production due to high stable wind and large scale of wind turbines. It also reduces environment impact as well as little noise and visual disturbance to people. However, the offshore wind industry is facing some challenges, such as high costs for wind turbine installation, maintenance and operation. With more data available, it is possible to make better decisions, and thereby improve the recovery rates and reduce the operational costs. Nevertheless, seeking for an approach to make more data available is still a challenging activity. On the one hand, many partners will have their own applications and own data formats. It is therefore hard to enable data exchange. On the other hand, many actors are reluctant to share data about their equipment, or to let third parties collect such data. Additionally, the process of agreement only happens at the end of the development when the partners encounter integration problems with other partners. This process is time-consuming. It must be noted that some of the data are in use for decades and are one of the main assets. Organizational units and information technology systems last rarely more than a few years. The most stable elements in this environment are the terminologies used in the business domains along the value chain. The idea of creating an offshore wind ontology (OWO) from the terminologies in order to share, reuse knowledge, and reason behaviours across domain and task, is important. Since the ontology is used to facilitate integration of processes within and across business domains, creation of autonomous solutions, and ability to store data over time. An ontology is needed to make an abstract model of the phenomena by having identification of the relevant concepts of that

This paper was presented at the NIK 2011 conference. For more information see http://www.nik.no/

phenomena [2]. In the abstract model, the concepts and constraints are explicitly defined.

This paper contributes a semantic model for data integration of offshore wind farms. In the model, the offshore wind ontology is considered a core. The rest of the paper is organized as follows: section 2 introduces challenges and solution of data integration for offshore wind farms. The semantic model is proposed in section 3. Finally, section 4 contains a summary of the paper and gives comments on future work.

2 Data integration for offshore wind farms

Most components of a wind power plant (WPP) are produced by different vendors or companies. Each component has its own software and perhaps its own database. As a result, a software environment of a WPP consists of multiple applications having incompatible interfaces and data formats and not being able to communicate with each other. Figure 1 displays data coming from various sources that are diverse in their purposes, underlying models and enabling technologies. For instance, data from the operational WPP, data from existing databases which have been collecting for several years, or data from sensors embedded in a WPP. The data sources are considered as autonomous, distributed and heterogeneous systems so that data reside in many incompatible formats and cannot be systematically managed, integrated and unified. Moreover, semantic inconsistency has become an even greater problem for the explicit information or knowledge sharing among users or applications. Therefore, the integration and utilization of information resources has become one of the most challenging problems faced by offshore wind communication today.

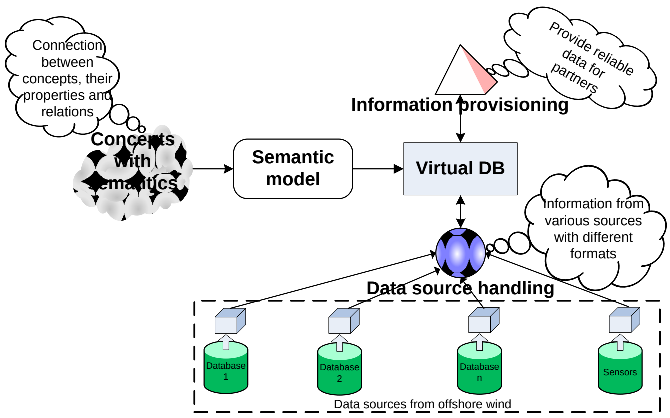

Figure 1 Data integration challenges

With today technologies, point-to-point communication between applications is no longer recommended due to difficulty in reconstructing the system and costs of implementing change. A new solution has been proposed based on semantic technology in which all communications will be handled through a semantic model which allows integrating and sharing the huge amount of data. Resolving semantic heterogeneity not only gives users a unified access to distributed data but also facilitates monitoring processes, hence performance of the WPP might be improved. The semantic model covers the key concepts in the offshore wind domain and their semantic relationships. It is considered a core for data integration. An instance of the model, for instance, a virtual database can be developed. Input data for the database are provided by offshore wind partners. Output data from the database will be provided for the other partners for different purposes such as visualization, documentation and analysis. The acquisition of relevant data underpins the lifecycle of the offshore wind farm, through the project phases of feasibility analysis, development, engineering, construction, operation and maintenance, decommissioning and post decommissioning. Data are necessary to support decisions throughout the project lifecycle.

3 The semantic model

A semantic model is considered a core for data integration. It shares the common understanding of domain concepts. Additionally, it plays as an agreement between offshore wind partners on data exchange, in particular what kinds of data to exchange. Figure 2 shows an overview of the semantic model.

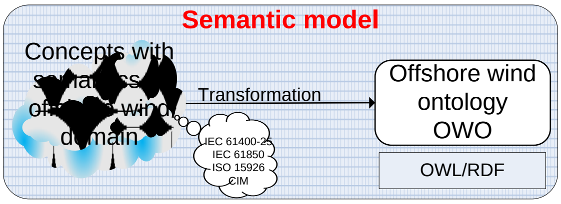

Figure 2 The semantic model

A typical problem for data exchange is a misunderstanding between sender and receiver. Approved standards are recommended to use in order to make the data exchange process clear. There are some relevant standards developed by the IEC (International Electrotechnical Commission) for example the common information model (CIM), IEC 61850, IEC 61400-25. Unfortunately, those standards have been developed by different working groups and therefore lack some harmonisations although they have to be used in context [3]. Additionally, the semantic techniques imposed by the CIM are not properly used [4]. Thus, IEC 61400-25, IEC 61850, and CIM could be good reference standards for the OWO development. Moreover, there is a standard called “ISO 15926 – industrial automation systems and integration. Integration of life-cycle data for process plants including oil and gas production facilities” which provides an ontology for oil and gas. Building an ontology based on ISO 15926 brings not only benefits for the offshore wind ontology development but also can make it easier for the oil and gas industry to enter the wind energy business. The ontology can be present using RDF (resource definition framework) and RDFS. However, a number of other features are missing such as local scope of properties, boolean combinations of classes, cardinality restrictions. OWL (web ontology language) would be an extension of RDF schema, in the sense that OWL would use the RDF meaning of classes and properties [5].

The OWO is built by defining an ontology for each wind turbine component (ontology for WT generator, WT rotor, WT tower, etc.). Most concepts and properties of the offshore wind domain are clear and given by approved standards (IEC 61400-25, CIM). However, new concepts are always proposed owing to increasing research on offshore wind energy. Therefore, the ontology developing will start with the core of basic terms, and then specifying and generalizing them as required. We start with the most important concepts first, and define higher level concepts in terms of them. These higher level categories arise naturally and thus are more likely to be stable [6], [7]. In order to make the OWO easy for maintenance, the development should follow a methodology. The “METHONTOLOGY” methodology developed within the ontology group at Technical University of Madrid is used to build the OWO. According to the methodology, there are 11 tasks [6] as shown in Figure 3. Even though METHONTOLOGY recommends WebODE as a support tool, we selected Protégé-OWL, because it supports various plug-ins and it is platform-independent and open source.

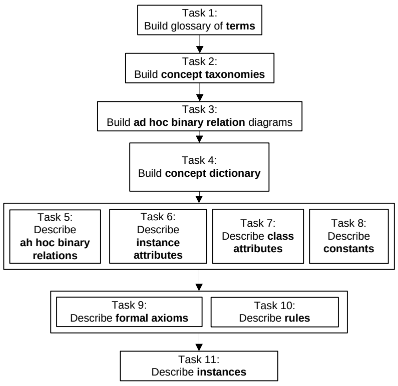

Figure 3 Tasks of conceptualization according to METHONTOLOGY

4 Conclusions and future work

In this work, we introduced our semantic model which is a core of data integration in the offshore wind domain. The purpose of the proposed semantic model is to facilitate knowledge sharing and data exchange between offshore wind partners, and hence improved operation and maintenance. We also highlighted that the core of the model is an offshore wind ontology which is based on existing standards, such as IEC 61400-25, IEC 61850 from the power domain, and ISO 15926 from the oil and gas domain. A methodology and a tool have been selected to support the ontology development process. Now, agreement is to be reached with domain experts from mechatronics, and from electrical engineering.

Acknowledgement

This work has been funded by the Norwegian Centre for Offshore Wind Energy (NORCOWE) under grant 193821/S60 from the Research Council of Norway (RCN). NORCOWE is a consortium with partners from industry and science, hosted by the Christian Michelsen Research.

References

[1] EWEA, EU Energy Policy to 2050, March 2011.

[2] Studer R, Benjamins VR, Fensel D (1998) Knowledge Engineering: Principles and Methods. IEEE Transactions on Data and Knowledge Engineering 25 (1-2):161-197.

[3] Uslar, M. 2006. The common information model for utilities: An introduction and outlook on future applications. In R. Eckstein & R. Tolksdorf (Eds.), Proceedings of the XML-Days 2006 in Berlin, XML-clearinghouse.de (pp. 135-148).

[4] Uslar, M., Gruning, F., Rohjans, S. 2010. A use case for ontology evolution and interoperability: the IEC utility standards reference framework 62357. DOI: 10.4018/978-1-60566-894-9.ch009

[5] Antoniou, G., Harmelen, F. 2009. Web ontology language: OWL. Handbook on Ontologies, International handbooks on information system, DOI 10.1007/978-3-540-92673-3. Springer-Verlag Berlin Heidelberg 2009.

[6] Gomez-Perez, A., Fernandez-Lopez, M., Corcho, O.: Ontological Engineering, Springer, ISBN1-85233-551-3, 2003.

[7] Ushold, M., Gruninger, M.: Ontologies: principles, methods and applications. Knowledge engineering review 11(2):93-155, 1999.