Modelling Information Exchange Network for Open Electricity Market using Object-Oriented Software Development Concepts with UML

Hans-Dieter Kochs & Joseph Olufemi Dada

Universität Duisburg-Essen - Standort Duisburg
Fakultät für Ingenieurwissenschaften/Institut für Informationstechnik
Bismarckstr. 90, D-47057 Duisburg, Germany
(kochs, dada) @uni-duisburg.de

Abstract. Open electricity market requires a dramatic increase in the exchange of information between the market participants. Exchange of information and data in heterogeneous IT's environment of the market participants is very difficult due to different information, data, files, databases and application or calculation model. It is only through the concepts of domain objects that a unified, application independent, and consistent data models can be created and maintained. In this paper, a concept of object-oriented model of the information exchange network in open electricity market is proposed. Open electricity information exchange network is realised with object-oriented software development process. The presented concept makes use of Unified Modelling Language, and its suitability in real system is presented using Germany liberalised electricity market.

1 Introduction

Dramatic changes are taking place in the structure of electric power sectors around the world. The changes are designed to foster competition in generating segment of the industry and to reform the regulation of the transmission and distribution functions, which continue to be view as natural monopolies [1]. Consequently, the traditional vertically integrated utilities are being deregulated and replaced with a competitive market operation.

Open electricity market requires a dramatic increase in the exchange of information between the member of the grid, the energy producers, transporters and retailers not only for the management and monitoring of system security and reliability, but also for the accounting and settlement purposes.

The integration, consolidation, and dissemination of these information and data both inter- and intra-utility have become a critical piece of the deregulation picture

[2]. As the participants in the electricity market exchange data with one another, they need a powerful information infrastructure to automate these transactions.

However, a major problem facing the exchange of information and data is that most of the today's electric utilities in Europe and the new actors in the electricity market IT's environment is truly heterogeneous. They employ their own information, data, files, databases and application or calculation model. The exchange of data and information in a computer-interpreted form is difficult because of different data models, data structures and organisations [3].

The need for data exchange between electric utilities has long been identified by the American Electrical Power Research Institute (EPRI) and by the International Electrotechnical Commission (IEC). These two institutes have defined a standard protocol optimised for the purpose of data exchange between utilities, and it has already been adopted by about 100 utilities world-wide [4]-[6]. This protocol is the Inter Control Centre Protocol (ICCP), also known as IEC Telecontrol Application Service Element 2 (TASE.2).

The problem of data exchange between the EU electric utilities discussed in [2], [7] focuses mainly on data exchange between the network planning programs of electric utilities. The problems of information exchange between the Market Participants (MPs) including the new players in the electricity market were not taken into consideration.

A complete solution to the problem requires independent unified data model. It is inappropriate to align data model to the existing application or corporation data model. Such approach will lack uniformity and will only consider functional requirement of the respective applications or corporations. It is only through the concepts of domain objects that a unified, application independent, and consistent data models can be created and maintained. The data model requires the real-world objects and their relationships. The expandability and adaptability for new or changed requirements must be possible without changes to the existing data models and the applications that use them [8]. Object-oriented concepts overcome the problems traditional software technology has with flexibility, expandability, maintenance and data integrity.

This paper presents an independent unified data model for open electricity market and applies object-oriented approach to the modelling of information exchange network for the electricity market. The paper presents the use case, the analysis and design model as well as a prototype implementation of the information network. It applies the developed information network model concept to real system and shows the suitability of the approach.

We used Unified Modelling Language (UML) [9] for the development of the information exchange network models. UML will be briefly explained with the basic concepts of object-oriented software development process. However, a basic knowl-

edge of the object-oriented approach is assumed in this paper. For the information exchange format, we used Extensible Mark-up Language (XML) [10].

2 Information Exchange in Open Electricity Market

For competition in electricity market to work according to the principle of non-discriminating network access, all the necessary data between the MPs must be exchanged and automated. The automation of information exchange in an heterogeneous IT's environment such as the open electricity market can only be possible with a suitable information system that is based on a method which is technologically neutral. This section describes the requirements for the information network as well as the electricity business processes and information exchange format.

2.1 System Requirements

We developed the information exchange network model based on the following requirements:

- The information infrastructure must be flexible enough to support all kinds of content sources, format, protocols, business rules, and the existing IT infrastructures.

- The system must support all MPs including big, medium and small participants.

- The system must be extensible. For example, the integration of the information systems for the control and co-ordination of distributed energy supply units such as renewable energy units like fuel cells must be possible.

- The electricity MPs must be able to discover and implement electronic interfaces to inter-operate in a secure, reliable and consistent manner.

- The exchange of various data such as transmission schedules, injection schedules, interchange schedules, meter consumption data and accounting information etc. between the market participants must easily be possible.

2.2 Electricity Business Processes

Electricity business is a set of processes. A process can be anything from generation of transmission schedule to calculation of energy imbalance account. Process engineering streamlines and automates processes to improve business efficiency. Electricity business processes can be captured in models and implemented in applications. These applications, which belong to different organisations, can exchange data through a

suitable interoperability mechanism [8]. In order to define an interoperability mechanism, the business process interaction patterns or business collaborations between the MPs must be identified. We identified the collaborations between the MPs in a liberalised electricity market in Germany from the Grid Code, Distribution Code and electricity market model or the „Verbaendevereinbarung II“ [11] - [17]. For example, generation, sending and receiving of the transmission schedule, interchange schedule, injection schedule, energy imbalance account for Balancing Groups (BGs) etc. are some of the business process interaction patterns in liberalised electricity market in Germany.

2.3 Information Exchange Format

Information exchange between different processes belonging to the MPs can be handled by means of message passing paradigm. A message is a structured piece of information sent from one subsystem to another over a communication channel. A subsystem is a high-level system component, defined around a particular function, or utility, or role in the overall system. Electricity Market Information Network, for example might be broken down into a Transmission System Operator (TSO) Information Network subsystem, Balancing Group Manager (BGM) Information Network subsystem, Distribution System Operator (DSO) Information Network subsystem and Power Station Operator (PSO) Information Network subsystem. The overall system can be thought of as a co-ordinated group of subsystems working to accomplish some goal.

We used XML as information exchange format between the subsystems. The XML standard [18] makes transmitting data over the Web inexpensive and efficient. It lets applications communicate regardless of the programming model.

We modelled the business process interaction patterns using UML. The model is converted into XML schema. The XML schema is the basis of information exchange between the MPs. Any new electricity business processes, for example, exchange of power flows data between the TSOs can be identified, modelled, converted and added to XML schema.

3 Object-Oriented Software Development Process

The inadequacy of ad-hoc approaches to the information system modelling is a major factor for the performance deficiency in most application systems. Applications were produced which did not meet user requirements, were inflexible and difficult to maintain. During the past decade, this ad-hoc approach to system modelling has almost been replaced by more formal, engineering-like methods for developing information systems, which attempt to solve these shortcomings [7], [19]. These methods attempt to define explicit blueprints for the system model that is fundamental to all phases of software development. Thus there is attempt to separate logical models of the system

describing the problem domain, produced during analysis phase from the detailed design of a system, describing how a computer solution to the problem is to be produced.

Object-oriented approach regards a system as a set of interacting objects with messages passed between objects. Each object is made-up of private data, internal process and public methods, governing how the object responds to messages. An object's private implementation can be developed without considering other objects or a particular application context, and it can then be used in an application by using only its public interface. Classes are defined to group similar objects together. Class hierarchy can also be developed with subclasses being derived from specialisation of a super class, resulting in a tree-like class structure.

Object-oriented software development process divides software development into four main phases (requirement, analysis, design and implementation phases). During the requirement modelling phase, a requirement model is developed in which the functional requirements of the system are defined in terms of actors and use cases. The result of this phase is a use case model.

In the analysis modelling phase, static and dynamic models of the system are developed. The static model defines the structural relationships among problem domain classes. The classes and their relationships are shown on class diagrams. The object modelling provides a static view of the information aspects of the system. Classes are defined in terms of their attributes and their relationships with other classes. Dynamic modelling provides a dynamic view of the system. The use cases are refined to show the interaction among the objects participating in each use case.

In the design phase, the models from the analysis phase are refined further. The internal details of the objects, the algorithms to be used, business logic and the data structures form the central focus of this phase. Further more, the architecture of the system by considering the technology dependent components (e.g. graphical user interface, database systems, communication between nodes for distribution application systems, hardware etc.) is determined. While the analysis phase describes what to do, the design phase specifies how the problem is to be solved.

The implementation phase represents the conversion of the design model to a program. The choice of the tools especially the programming language plays a very important role at this point. The testing of the created software, which represents the verification of the design model, concludes the implementation phase.

UML provides various notations for describing each of the development phases. UML is a relatively new, general-purpose language, which has emerged from the standardisation efforts within the Object Management Group (OMG) [20]. We will describe the UML notations with the information exchange network model in section 5.

4 Case Study

The German electricity supply industry used as a case study in this work comprises 6 (formally 8) supra regional companies, about 80 regional companies and about 900 local companies (Stadtwerke). The 6 supra companies generate, transmit and in some cases distribute electricity. They are responsible for about 80% of electricity generation by public utilities and distribute directly about 40% of electricity consumed [10].

The regional companies also generate, transport and distribute electricity. They generate less than 10% of electricity from the public utilities and distribute about 30% of the electricity consumed, mainly in rural areas. The local municipal suppliers (Stadtwerke) mostly sell electricity to end-users but can also generate electricity. These companies, which are also involved in other activities such as natural gas, heat and water and public transport, are mostly owned by the municipalities. Some large towns have their „Stadtwerke“ with their own generation capacity [21].

With the German new Energy Law [22], six 6 supra companies have been separated into generation and transmission companies. The 6 transmission companies (Bewag AG, EnBW Transportnetze AG, E.ON Netz GmbH, HEW Hamburgische Electricitaet-Werke AG, RWE Net AG, VEAG Vereinigte Energiewerke AG) which are now the operators of the transmission systems in Germany constitute the German Transmission system operators ,,Deutsche Verbundgesellschaft (DVG)“. As operators of the grid, the interconnected companies are responsible for assuring the technical security and reliability of the interconnected system, and the technical quality of the electrical power supply, and for non-discriminatory access to and use of their transmission systems as specified in the Energy Law.

To fulfil these responsibilities, the TSOs in collaboration with the parent body DVG drawn up technical rules, popularly referred to as the Grid Code - Grid Code for network and system rules, and co-operation rules for German transmission system operators [11]. The Distribution Code [12] and Metering Code [13] were also published to take care of the distribution and consumption parts of the system.

A framework agreement on network access prices and conditions [14] were also concluded in 1998 (“Verbaendevereinbarung I”) between the electricity industrial association (VDEW), the industrial auto-producers and the final industrial electricity consumers, represented by the association BDI. The agreement was later renegotiated and replaced by a second, revised agreement [15], which came into force in January 2000 (“Verbaendevereinbarung II”). Subsequently, the Grid Code and Distribution Code were modified to reflect the revised agreement. The current agreement (“Verbaendevereinbarung II plus”) was concluded in December 2001.

A major aspect of this framework agreement is the formation of BG by the power producers or traders, which is the condition for electricity trading on the German network system. A BG consists of an arbitrary number of injection and/or withdrawal

points (usually metering points for generating units or power stations, and loads) within a control area [16].

A BGM, which may be an energy trader, power Exchange Company or energy producer, is responsible for the organisation of the BG and therefore represents the interface between system users and the TSOs. According to the Grid Code [13], the BGM is commercially and administratively responsible for its BG. Further details about the liberalisation of electricity market in Germany are given in [11]-[17].

5 Information Exchange Network Model

This section describes how the object-oriented development process is used to model the information exchange network. We will demonstrate how the development process with UML can be applied to the modelling of information exchange network using the described case study.

5.1 Use Case Model

A use case is a coherent unit of externally visible functionality provided by the system unit and expressed by sequences of messages exchange by the system unit and one or more actors of the system unit [23]. The purpose of use case is to define a piece of coherent behaviour without revealing the internal structure of the system. An actor normally initiates a use case. An actor is depicted as a stick figure on a use case diagram. A use case is shown as ellipse inside the box. Communication associations connect actors with the use cases in which they participate. Relationships among use cases are defined by means of stereotype *include* and *extend* relationships.

Using the German electricity market, we developed a use case model for the information network based on the system requirements. The main actors in the system are the TSO, DSO, PSO and BGM. The use case model is depicted in Fig. 1.

The main use cases are Prepare Transmission Schedule, Submit Transmission Schedule, Aggregate BG Meter Data, Send Metered Consumption Reports (MSCONS), Calculate and Send Imbalance Account and Prepared and send Injection Schedule use cases.

To further explain the functionality of the system, the activities that are performed during submit Transmission Schedule use case is shown on activity diagram in Fig. 2. Detailed descriptions of all the use cases are given [8].

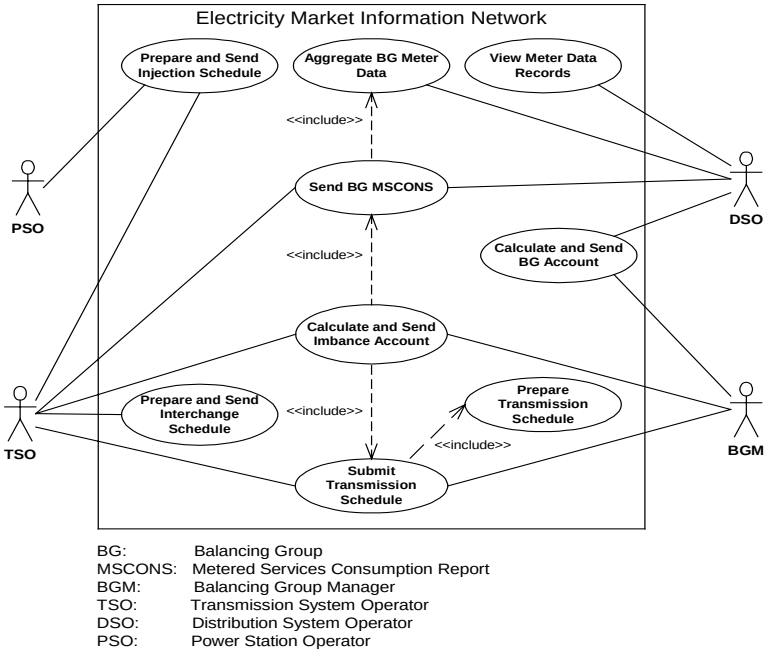


Fig. 1. Use Case Model

5.2 Object Model

The construction of an object model begins with the identification of the relevant object classes from the application domain - the entities of the data models. Object models are shown on class diagrams. Entities such as meter, connection point, market participant, balancing group, energy consumer and energy data etc. are considered. After the identification of the object classes, we identified the associations. Fig. 3 shows the object model for the information exchange network.

5.3 Information Network Subsystem Structuring

For further modelling, it is necessary to structure the system into subsystems. The aim of the structuring is for objects with high coupling among each other to be on the same subsystem, and the weakly coupled objects to be in different subsystems. A subsystem can further be structured into subsystems. A subsystem provides a larger-grained information hiding solution than an object. A subsystem class diagram shows the structural relationship between the subsystems. The dynamic interactions between the subsystems can be shown on a high-level subsystem collaboration diagram as suggested in [23].

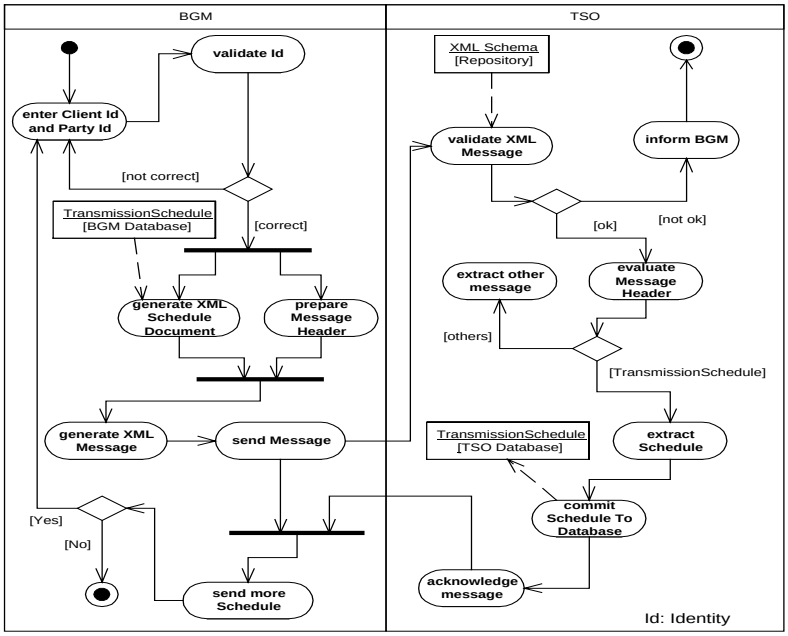


Fig. 2. Activities Diagram for Submit Transmission Schedule Use Case

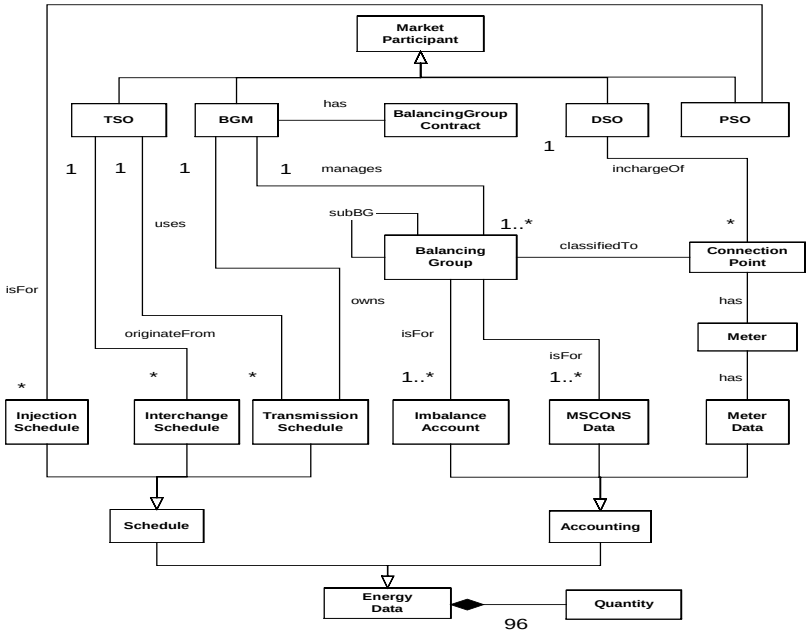


Fig. 3. Object Model of the Information Exchange Network

We structured the information network into subsystems along the functions and roles of the MPs: TSO, DSO, PSO and BGM Information Network subsystems. With the help of generalisation and specialisation concepts, we developed object model for the main subsystems from the conceptual model. The main subsystems are further structured into subsystems. For example, TSO Information Network subsystem is structured into: Messaging Server, Energy Data Management Server (EDMS) and Graphical User Interface (GUI) subsystems.

5.4 Dynamic Model

The Dynamic model describes the dynamic or behavioural aspects of a system. The purpose of the model is to assist in the determination of operations of the individual classes. UML provides various possibilities through which the dynamic behaviour of a system or use case can be investigated in order to determine the operations of the classes, such as sequence diagram, collaboration diagram, and state chart etc. In this work, we used collaboration diagram for the analysis of the electricity market information network.

A collaboration diagram shows how the co-operating objects dynamically interact with each other by sending and receiving messages in order to fulfil the functionality of a system or a use case. A message consists of an event together with data that accompanies the event, referred to as the attributes of the message.

We developed collaboration diagrams corresponding to the earlier described use cases. These depict the objects defined in the object model, the use cases they participate in, and the messages passed among them. The collaboration diagrams for the use cases are later combined to obtain the overall collaboration diagram for the electricity market information network taking into consideration the concurrency in the system. Details of the dynamic model for the information network are given in [8].

5.5 Design of Energy Data XML Schema

The basis of the information exchange between the MPs as earlier explained is the XML schema. An instance of the XML schema is XML document, which is actually exchanged between the MPs. The energy Data eXtensible Mark-up Language (eDXML) schema will normally be kept in a repository. The schema serves as a basis for communication between the MPs. The eDXML schema object model contains object classes for the business process interaction patterns, which modelled the information that are actually exchanged between the MP. The object model (Fig. 4) is converted to XML schema and kept in a repository.

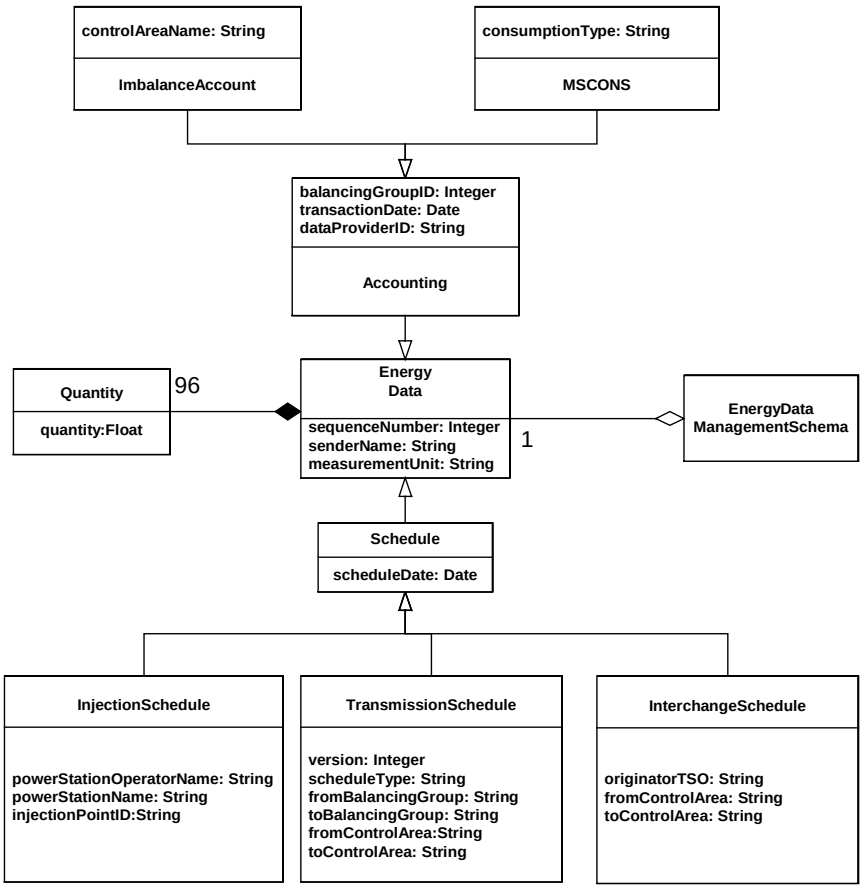


Fig. 4. Object Model of Energy Data

5.6 Design of the Information Network Subsystems

Based on the dynamic model, we identified the operations of the classes for all the subsystems. Relational databases are chosen to manage the data encapsulated by the entity classes for the information network subsystem of the MPs. For accessing the data stored in these databases, database wrapper classes are used [24]. Each entity class maintained at the MP information network subsystem is mapped to both relation (flat file) and a database wrapper class. A database wrapper class provides an object-oriented interface to the class and hides the details of how to access the data maintained in the relations. The attributes of object model entity class are mapped to a database relation, and the operations to access the attributes are mapped to a database wrapper class. Fig. 5 shows an example of the *entity* and *database wrapper* for *TransmissionSchedule*.

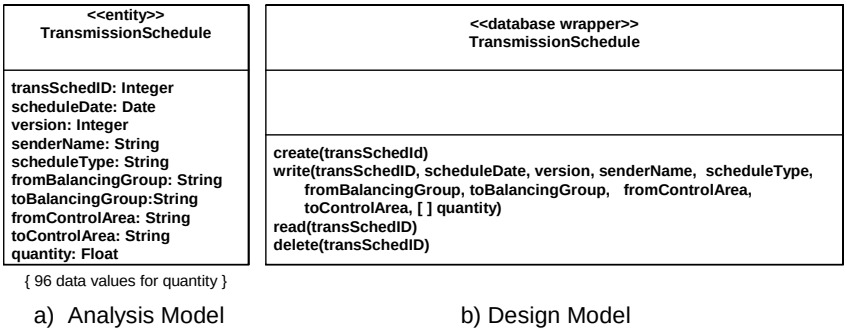


Fig. 5. Example of Database Wrapper

6 System Architecture

The information network is a distributed system. Individual MP has its own autonomous node. The main subsystems or components developed are mapped to physical node for the MPs. The deployment diagram [24] of the information exchange network, which shows the possible physical configuration of the system in terms of physical nodes and physical connections between the nodes, such as network connections, is depicted in Fig. 6. There is one node per each of the MPs.

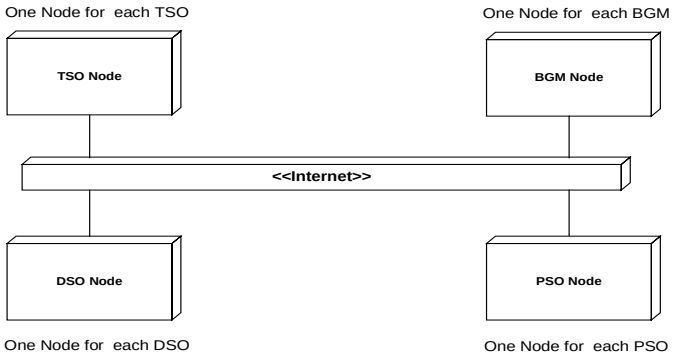


Fig. 6. Deployment Diagram for Information Exchange Network

Information exchange between any two nodes is based on XML document message format. The role of a MP in electricity market determines the type of XML document message that the MP will send to or receive from other MPs. The sending of a message from a communications partner to the other partner begins with the generation of XML document that contains the actual data to be exchange from the persistence layer. Appropriate method on the Messaging Server is then called to send the message

to the appropriate Messaging Server of the communicating partner. The Messaging Server in turn calls the appropriate method on the EDMS, which evaluates the message header and processes the message accordingly.

The components of the information network nodes are shown in Fig. 7. The arrow shows the relationships between the components. The EDMS component is the heart of each of the nodes. The internal compositions of the EDMSs depend on the role and function of the MPs in the electricity market. However, they exhibit certain common characteristics especially in the area of generation and sending of XML messages. It is integrated into the relational database based on database wrapper concepts.

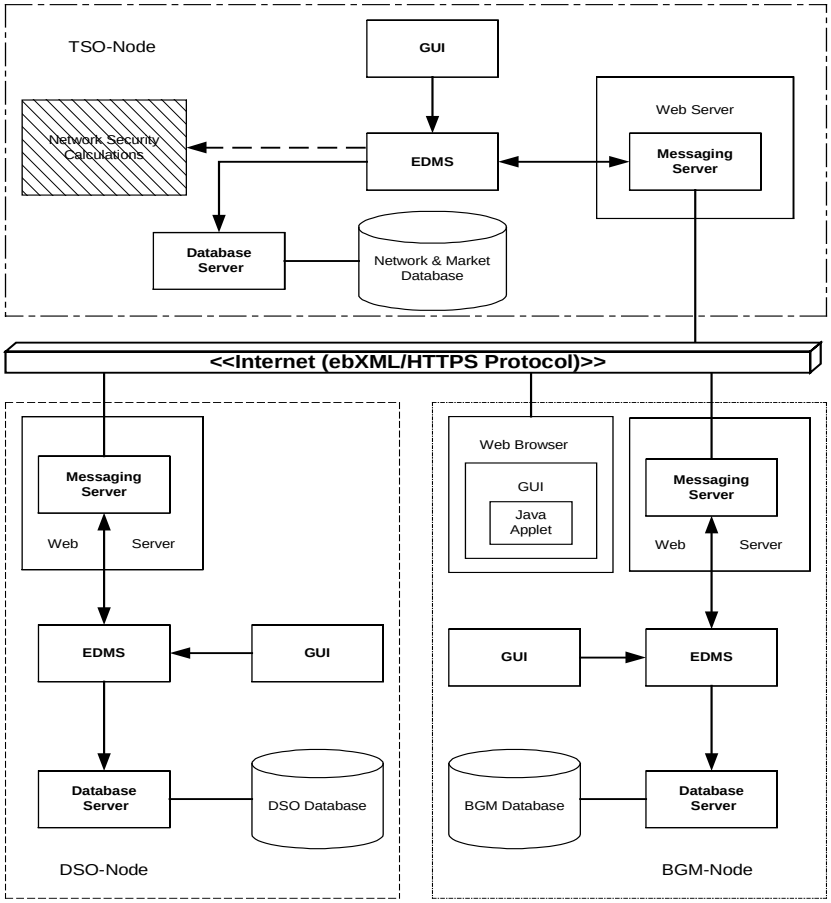


Fig. 7. System Structure of Information Exchange Network (the structure of the node for PSO is not shown in this diagram but it is similar to the node for DSO)

The EDMS can be easily extended to incorporate other new functions of the MPs into the network, for example, the network security calculations for the TSO (the

shaded block) can be integrated into the network as shown in the Fig. 7. Communication between the EDMS and the Messaging Server is through the exchange of messages. By calling appropriate methods on the message server class of the Messaging Server component, a EDMS can sent messages to other EDMS belonging to other MPs and vice visa by using Internet technologies and protocol for communication.

The Messaging Server serves as a Gateway for the information network. The messaging server, which sends and receives messages for the EDMS is implemented as a web application. It is based on Java Servlet technology [25], [26] and the Java API for XML Messaging (JAXM). JAXM enables the packaging, routing and transport of both XML and non-XML business messages across a number of key communications infrastructures, such as those based on HTTP, SMTP, and FTP protocols [27]. JAXM supports XML messaging methods defined in the ebXML [28].

7 Conclusions

Exchange of information and data in heterogeneous IT's environment of the open electricity market participants is very difficult due to different information, data, files, databases and application or calculation model. To overcome the difficulty, we have developed a unified, application independent, and consistent data models for the liberalised electricity market. We applied the object-oriented technique to develop a model for the information exchange network to enable the complex assemblies of market participants to exchange information and data with minimum human interactions.

Object-oriented paradigm provides a unique approach not only for the implementation, but also for the analysis and design of the information exchange network. Object-oriented analysis and design criteria enable the developed information exchange network to satisfy the requirements of flexibility, expandability, maintenance and data integrity by using encapsulation, polymorphism and inheritance. We have shown that the object-oriented analysis and design criteria with UML notations are well applicable to define information flow between the individual MPs in electricity market.

All communication between the components is by means of messages. By using XML as the data representation medium for content exchange between the MPs the data exchange systems can support any content source or data format and automate data extraction, delivery, and management. The HTTP used as the communication protocol for the message transport allows the existing security mechanisms to be used for the protection of data transmission between the communicating partners. HTTP permits the information exchange network to work within the existing firewall of the MPs LAN without any alteration.

New MP can easily be added by implementing the necessary interface. The proposed information exchange network model is easily extensible and can be adjusted to different electricity market models. The authors are currently working on how to ex-

tend the information network to incorporate the control and co-ordination of distributed energy supply systems.

References

1. Chao Hung-po and Huntington Hillard G.: Designing Competitive Electricity Markets, Kluwer Academic Publishers, Boston/Dordrecht/London (1998).
2. Adamiak Mark and Premerlani William: Data Communications in a Deregulated Environment. IEEE Computer Applications in Power, Volume 12, Number 3, July (1999) pp36-39.
3. Leal David, Laresgoti Inaki, Lambrecht Dirk and Bacher Rainer: An Open System Approach to Power Systems Information Exchange. International Conference on Electrical Power Systems Operation and Management, ETH Zurich, Switzerland (1998) EPSOM'98, Vol. 1, Leal-1-Leal-28.
4. Germann Jakob: ICCP Gateway for Information Exchange Between Control Centres, A Project for the Information Exchange between seven electrical power transmission companies. International Conference on Electrical Power Systems Operation and Management, ETH Zurich, Switzerland, Vol. 2 (1998) Germann-16-1-Germann-16-4.
5. Kaib W.: Informationsaustausch zwischen Leitstellen - Tase.2 in Theorie und Praxis. Elektrizitätswirtschaft, Jg. 97 (1998) Heft 14. 22-26.
6. Schwarz K.: Telecontrol application service Element Two (TASE.2). Offene Kommunikationsplattformen fuer die Leittechnik nach IEC 870-6 am Beispiel der Netzleittechnik, etz - Report 28 35-53, VDE-VERLAG GMBH, Berlin (1996).
7. ElectroNet: High Voltage Electrical Network Information Exchange for Planning and Analysis, Esprit Project 22297, http://www.marcello.dircon.co.uk/
8. Dada J. O.: Information Exchange Network for the Liberalised Electricity Market with Object-Oriented and Internet- Based Technologies Fortschritt-Berichte VDI, Reihe 21, Nr. 323, VDI Verlag, Düsseldorf (2002) , ISBN 3-18-332321-4.
9. Booch G., Rumbaugh J. and Jacobson I.: The Unified Modelling Language User Guide. Reading, Mass. Addison-Wesley (1998).
10. W3C Recommendation: Extensible Markup Language (XML) 1.0 (Second Edition) (2000), http://www.w3.org/TR/2000/ REC-xml-20001006
11. Grid Code: Deutsche Verbundgesellschaft e.V. Heidelberg. Netz- und Systemregeln der deutschen Uebertragungsnetzbetreiber, und Kooperationsregeln fuer die deutschen Uebertragungsnetzbetreiber, June (1998).
12. Distribution Code: Vereinigung Deutscher Elektrizitaetswerke -VDEW -e.V., Frankfurt/Main. Netzregeln fuer den Zugang zu den Verteilungsnetzen, Mai (1999).
13. Metering Code: Vereinigung Deutscher Elektrizitätswerke -VDEW -e.V., Frankfurt/Main. VDEW -Richtlinie, Abrechnungszählung und Datenbereitstellung, Mai (1999).

14. VVI: Vereinigung Deutscher Elektrizitaetswerke - VDEW -e.V., Frankfurt/Main. Verbaendevereinbarung (VVI) ueber Kriterien zur Bestimung von Netznutzungsentgelten fuer elektrische Energie (1998).
15. VVII: Vereinigung Deutscher Elektrizitaetswerke - VDEW -e.V. Frankfurt/Main. Verbaendevereinbarung (VV II) ueber Kriterien zur Bestimung von Netznutzungsentgelten fuer elektrische Energie (1999), http://www.strom.de/
16. Gride Code: Deutsche Verbundgesellschaft e.V. Heidelberg. Netz- und Systemregeln der deutschen Uebertragungsnetzbetreiber, Mai (2000) , http://www.dvg-heidelberg.de
17. Distribution Code: Vereinigung Deutscher Elektrizitaetswerke - VDEW -e.V. Frankfurt /Main. Netzregeln fuer den Zugang zu den Verteilungsnetzen, Oktober (2000) .
18. W3C Recommendation: XML Schema Part 2: Datatypes, W3C Candidate Recommendation, 24 October (2001), http://www.w3.org/TR/xmlschema-2/
19. Beynom-Devies P.: Information System Development, Machmilla Education Ltd, Houndmills, Basingstoke, Hampshire, London (1989).
20. OMG: Object Management Group, Framingham Corporate Center, 492 Old Connecticut Path, Framingham MA 01701-4568. Unified Modelling Language Specification, version 1.3, June (1999), http://www.omg.org/cgi-bin/doc?ad/99-06-08.
21. International Energy Agency, Electricity: http://www.iea.org/pubs/reviews/files/germany/11-germ.htm
22. Bundesgesetzblatt 1998. *Gesetz zur Neuregelung des Energiewirtschaftsrechts*, Teil I Nr. 23, 730 ff., April.
23. Rumbaugh J., Booch G., and Jacobson I.: The Unified Modelling Language Reference Manual. Reading, Mass. Addison-Wesley (1999).
24. Gomaa H.: Designing Concurrent, Distribution, And Real-Time Applications with UML., Addison-Wesley (2000).
25. Sun Microsystems, Inc., Standards and technologies driving the dot-com world, http://java.sun.com/pr/2000/12/pr001204-01.html
26. Sun Microsystems, Inc.: The Source of Java Technology, The Java Servlet Technology, The Power behind the Server (2001), http://java.sun.com/products/servlet/?frontpage-javaplatform
27. Sun Microsystems, Inc.: The Source of Java Technology, The Java APIs for XML Messaging 1.0 (2001), http://java.sun.com/aboutJava/communityprocess/jsr/jsr_067_jaxm.html
28. United Nation: Creating a Single Global Electronic Market (ebXML). United Nations for Center for Trade Facilitation and Electronic Business (UN/CEFACT), http://193.194.138.128/ cefact/.