

Interaction of EMS related systems by using the CIM standard

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Abstract: Energy distribution companies nowadays use different IT-systems from vendors within their infrastructure. Those systems often use proprietary data exchange formats and must be connected to other systems. Building specialized adaptors for interconnection between the systems is the most common and time-consuming task for IT-departments at energy companies. The Common Information Model (CIM) establishes a common language and domain model for energy management systems and related data structures. Instead of connecting all systems and building up a meshed net, it is possible to connect the systems to an integration platform using the CIM as a common language. This paper will discuss the CIM and its benefits and focusses on a current industrial project conducted by the authors which integrates CIM as a standard for data exchange between energy management related systems.

Keywords: Common Information Model, CIM/XML, RDF, data exchange, power system modeling

1 Introduction

There have been different generations of energy management systems (EMS) till today. The first generation normally was a SCADA (Supervisory Control and Data Acquisition) system based on special electrical computers and operating systems

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[XYX02]. Those systems normally did not serve as applications and could only provide fundamental functions like real-time data collection and processes. At the beginning of the 1980s, those systems had matured and became almost perfect in implementing SCADA functions and even developed several application functions. From the beginning of the 1990s, systems were replaced by UNIX-based systems. Those systems benefited from emerging technologies like relational databases and improved graphical display technology. As compared to every previous generation, the functions and stability had been improved significantly. But with the growth of vendors and an increasing pool of applications which had to be integrated, several factors showed up which had negative impact on EMS. The systems had a poor user interface openness, their architecture was far too old to satisfy the demands of energy nets with high growing rates for consumers and producers and the maintenance became more and more difficult. But the most important deficit was the lack of widely-spread accepted industrial standards for interoperating the various EMS-related systems [Po99, p. 1].

Looking at various systems used within energy companies, we can identify several systems used to run the business. For the motivation of using CIM, we take a look at four different systems normally used within the company. The SCADA is used to monitor the current status of the energy distribution. Typically, data about the net's topology is stored within a geo information system (GIS) and must be transferred into the SCADA. The SCADA system itself is connected to the distribution management system (DMS) in order to track and control the power flow. Furthermore, the SCADA is connected to the customer service system (CSS) in order to guarantee the distribution according to the contract of each customer. The customer's master data is linked via the GIS to track the subnets each customer might be connected to. Having each system connected to each other to exchange system data, we have to build six adaptors on a basis of data exchange for four systems. Mathematically speaking, we can calculate the number of adaptors for a fully-meshed net with N systems roughly as $0.5 * N^2$.

Having a number of e.g. ten systems which have to be interconnected, a fully-meshed net requires a total number of approx. 50 adaptors. The number of systems within an energy company is much higher than ten although it must be taken into account that there are systems from the same vendor having the same formats and not every system is linked to all others. When using a common language, we have to build only ten adaptors to connect the ten systems which leads to the point that the number of adaptors to build is N when using a common language.

A common language can save time spent on developing adaptors which can be used to improve the applications themselves. A common language used within the energy management and distribution domain is the Common Information Model, abbreviated as CIM [Cr03, p. 728ff].

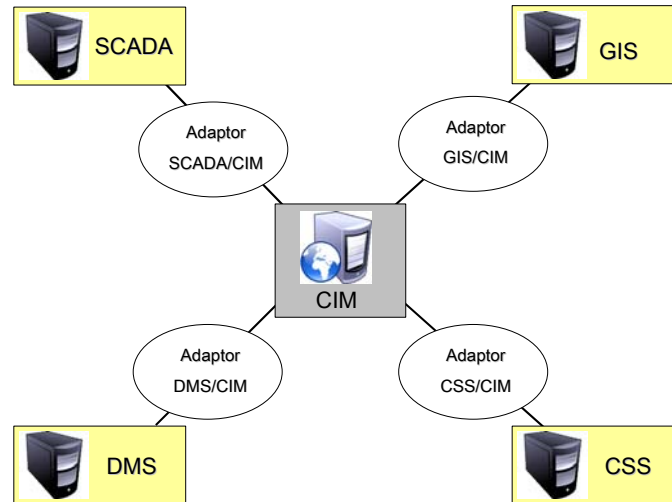


Figure 1: Needed Adaptors between different systems within an energy company using a common language

The contribution of this paper is to discuss the CIM as a data model used to exchange power system data and to present a concept using the CIM within an enterprise application integration project. Section 2 of this paper will discuss fundamentals of the CIM showing facets of its implementation from three different IEC Standards with a focus on the CIM XML Standard IEC 61970-503 [IE04b]. Section 3 provides an example of the format and its predecessors. A current example of a project for distributed energy generation using CIM is presented in section 4. Section 5 will provide further perspectives and an outlook for the CIM concerning control and scheduling of distributed energy generation.

2 The Common Information Model

2.1 The CIM data model

Different standards evolved over the years representing power system exchange data. In 1968, the IEEE first established the so called Common Format used to exchange data [IE73]. It was a line based format grouping the content of the lines into sections and giving headers to each section. Data items were entered in columns, no blank items were allowed, they had to be replaced by zeros instead. Although in wide use, other line based formats PTI and WSCC appeared as proprietary and vendor specific formats. Those three formats became the very standards in data exchange within the power systems domain [DU04, p. 27]. With

the deregulation and the upcoming needs for exchange of power data between companies using systems of different vendors connected via web technologies, the need for a common model for power data representation and an exchange format became more and more evident. The old formats were difficult to parse, data was not self-describing and could only to be understood by experts knowing the exact columns and rows of each format. The special extensions and tiny changes made by every energy company could not be tracked and led to failures and troubles in exchanging data [BLS99].

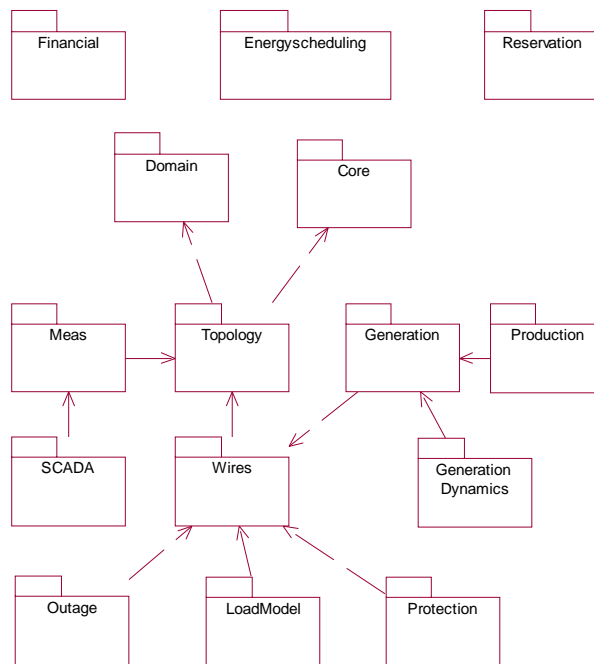


Figure 2: Package overview of the CIM including packages from the standards IEC 61970-301, -302 and -303.

To integrate different system from different vendors, the EPRI (Electric Power Research Institute) proposed an integration framework called CCAPI. The most essential part of this framework is the so called CIM [IE03]. The CIM represents all major objects normally used within an electric utility enterprise and is maintained by the IEC TC 57 using an UML-based Rational Rose™ model. The objects are represented as classes having attributes and relations to other classes. Included objects bundled in packages cover equipment, topology, load data, generation profiles, measurement and scheduling. The following paragraph will provide a very short overview of the packages which are shown in figure 2.

The basic CIM data model [IE03] consists of about twelve packages structuring the data model. The *Core* package provides the basic objects like *PowerSystem-Resource* or *ConductingEquipment* which are needed by nearly all applications implementing the CIM. The *Domain* Package defines basic datatypes used for attributes within the CIM like scope definitions or curve types. Extending the *Core* package, the *Topology* Package provides Connectivity Ports to connect objects from the *Core* package via the *Wires* package. While the previous mentioned packages provide a facility to model static data, the flow of electricity and the dynamic status of a topology gather data which can be modeled via the *Meas* (short for measurement) package. The *Generation* package covers two sub-packages, *production* and the *generation dynamics*. Using those packages, it is feasible to model all different types of energy generators and their special characteristics and dynamic load data. Furthermore, generation requires obviously new asset units in secure and next adherent system space to make sure all the needed generators can be modeled by the CIM. The feasibility of modeling dynamic data is completed by the *LoadModel* and *Outage* Package. Energy consumers and their characteristics like system load, parameters for different times of the day and associated data can be modeled. Therefore, the CIM can be used as a data model for load estimation and management. Outage features objects being used to model the current and future net topology's situation or status.

Modeling the protecting devices and their characteristics in order to provide a proper simulation or supporting power grid failure detectors is possible by dealing with objects from the *Protection* package. Based on the basic IEC 61970-301 standard, further packages have been developed and presented in later substandards. The exchange of data between companies has been very much the focus of the standard IEC 61970-302. It covers three packages. The *EnergyScheduling* package exists in order to support the exchange of electricity. It provides the capability to schedule and account for transactions for the exchange of electricity between energy utility companies. It includes transactions for power which is generated, consumed, lost, passed through, sold and purchased. The *Financial* package covers settlement and billing. It represents the legal entities that participate in (in)formal agreements. The last package from the substandard, *Reservation*, includes information for transaction scheduling for energy, generating capacity and transmission. The IEC 61970-303 standard focusses on the Supervisory Control and Data Acquisition and its components and data. It consists of only one package containing entities to model information used by SCADA applications. Supervisory control supports operator control of equipment, such as opening or closing a breaker. Data acquisition gathers telemetered data from various sources.

This paragraph could only provide a glimpse of the functions and objects of the basic CIM model, for more information, please refer to [Po99, p.1ff], [IE03] or [Mc02].

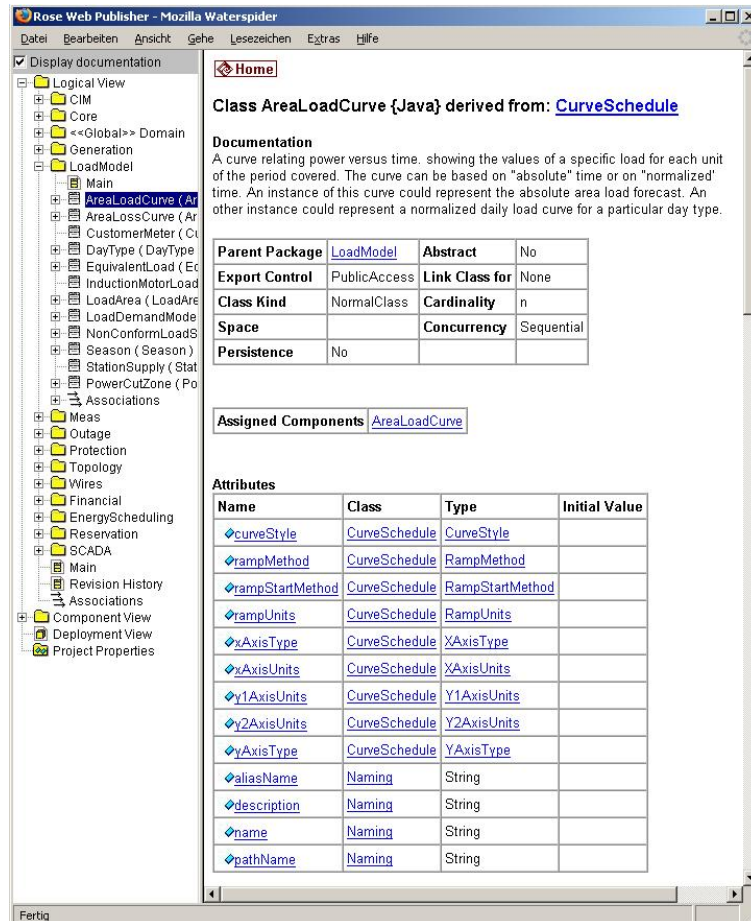


Figure 3 : The CIM logical view of the AreaLoadCurve Class provided by Rational Rose™ WebPublisher

2.2 Representing CIM using RDF

Although the CIM itself modeled as an UML diagram provides useful insight to the important objects within the power industry, it is difficult to exchange data due to the fact that object related databases are available but not widely in use. Instantiated objects must be represented via serialization formats which can exchange data in binary or ASCII format. The IEC proposed an RDF schema as a proper way to exchange data in a common format [IE04a]. The CIM RDF schema is documented as the IEC standard 61970-501. Like any other XML-based format, it has several advantages over binary formats. Due to XML based mechanisms, it is possible to extend the CIM with versioning mechanisms and, more important,

with namespaces as a mechanism which is easily extensible and supports site-specific needs. CIM RDF is both machine and human readable and self-describing although it is primarily intended for programmatic access by tools which support the Document Object Model (DOM) API. Current web standards can be met when using a RDF based representation of the data providing more semantics than plain XML.

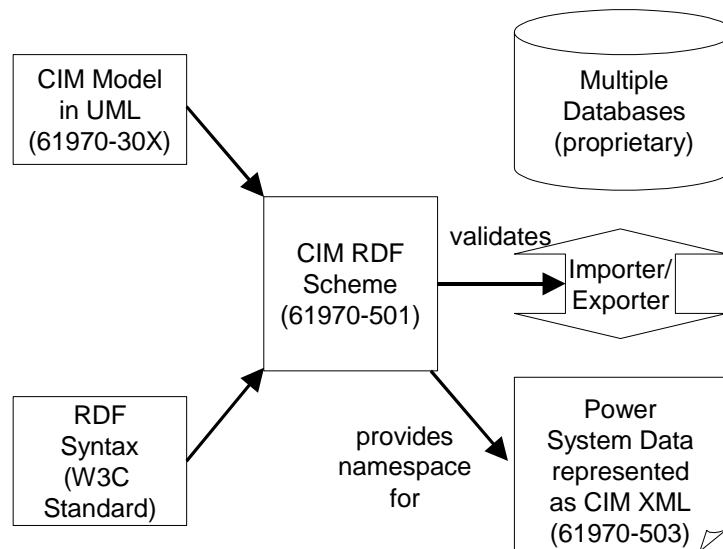


Figure 4: XML-based IEC-related data exchange

IEC standard 61970-501 defines standard mechanisms to convert the UML model into an RDF scheme. The conversion of the Rational based UML file can be done manually or tool-supported by the Xpetal converter⁴. It reads the .mdl file and creates RDF or XML schemes from the corresponding model. Therefore, an easy validation of productive data against the schemes can be assured. Still, one valid RDF representation can differ from other valid representations. Furthermore, CIM RDF models often tend to become quite complex having nested tags and a large overhead of administrative meta-data compared to the actual data used. Often, large files describing topologies have to be exchanged while e.g. only some of the breakers have changed. The IEC standard 61970-503 therefore defines a simplified RDF syntax being an actual subset of RDF and an differential model providing the chance to exchange tiny subsets of changes instead of complete model status snapshots.

⁴ available online from Langdale Consultants at <http://www.langdale.com.au/styler/xpetal/>

2.3 The simplified CIM/XML representation

The amount of data exchanged between energy management systems or even companies can become very large. Processing this data is sometimes time-critical. Nested tags instead of a simple serialized structure lead to slower processing times [dR01]. At implementation level, the IEC proposed a slightly changed syntax as a RDF representation, the so called simplified CIM XML exchange format [IE04b]. RDF provides many ways to represent the same set of data, e.g. an association between two resources can be written either with a resource attribute or by nesting one element within the other. This makes processing via XSL tools sometimes a bit more difficult. The reduced syntax is still compatible with available RDF-deserialization software but provides a generally faster access to the data. The first improvement of the data structure is useful for the exchange of partial or full model data. Another improvement in processing speed can be achieved by optimizing the amount of data transferred between companies. After the initial data is exchanged, only updates need to be exchanged [de00].

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<?xml version="1.0" ?>
- <rdf:RDF xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#"
  xmlns:cim="http://iec.ch/TC57/2000/CIM-schema-cimu09b#">
- <cim:Substation rdf:ID="_28159176D77E2467">
  <cim:Naming.name>LEGAZZI</cim:Naming.name>
  <cim:Substation.MemberOf_SubControlArea
    rdf:resource="#_55D3DE366B2AD032" />
</cim:Substation>
- <cim:EnergyConsumer rdf:ID="_2963867E4A4B1669">
  <cim:EnergyConsumer.pfixed>19.78</cim:EnergyConsumer.pfixed>
  <cim:EnergyConsumer.qfixed>06.10</cim:EnergyConsumer.qfixed>
  <cim:EnergyConsumer.LoadArea
    rdf:resource="#_9C1602456B178B75" />
  <cim:Equipment.MemberOf_EquipmentContainer
    rdf:resource="#_A9D1427B3784CD78" />
  <cim:Naming.name>4711</cim:Naming.name>
</cim:EnergyConsumer>
</rdf:RDF>

```

Figure 5: A sample CIM/XML file modeling idle power (q) and effective power (p) at a corresponding substation

The changes can be defined as a differential file using a special namespace. This provides a useful way to exchange small portions of data containing only relevant information about updates of the initial model [dWZ01].

The mechanisms for exchange of power data with CIM based XML-files have proven to be quite effective within different application domains. The following

section is going to provide examples of application for test feeders, security advisor data exchange or graphical representation of topologies before showing several advantages using the CIM for data exchange between energy management systems connected by an integration platform.

3 Using the CIM and its facets

The CIM as an universal data model has evolved during the years and brought up several domains and applications where the CIM is used or could be used. This paragraph will provide a short overview of conducted projects dealing with the CIM showing the importance of this standard for the energy management system domain.

The IEEE radial test feeders documents have been converted to CIM based XML documents in order to extend the CIM for the modeling of electrical distribution and fulfilling requirements for modeling distribution lines, distribution loads and distribution devices [WSN03]. In the USA, the Independant System Operators (ISO) securing the power operations in cooperation with the Regional transmission Organizations (RTO) need to exchange their operational power models. Earlier models lacked some required details due to a bus/branch oriented representation. Therefore the North American Electric Reliability Council (NERC) proposed an model extending the CIM XML format [dWZ01]. Other approaches deal with the CIM used to create generic graphical user interfaces for all kinds of EMS-related graphic data, often based on scalable vector graphics (SVG) [SMH02]. While the CIM focusses on control center data, the IEC 61850 standard implements the data exchange in substations. There is a need for a mapping between those two standards which is realized by an UML extension of the IEC 61850 substation configuration language SCL. This approach provides a deeper integration of the CIM in the operational data exchange [KPF03] at field level. Power system simulation can be based on real CIM data being loaded into the PSS/E based simulators using adaptors from CIM to PSS/E format [Mc04]. Further technical applications using the CIM can be found at [Li00], [LS00] or [WS00].

Nowadays, many important software projects focus on legacy integration and enterprise application integration of old EMS related systems (compare [Zh00], [Ro02a] and [Ro02b]). Within the context of a project conducted by the authors, an integration of functional systems used for management of decentralistic energy consumers and producers is focussed not only at the level of connecting, but more on information integration and process application flow.

4 Application of the CIM for an energy management system

This section will focus on a possible application area of the CIM standard in practice. As an example, an energy management system is taken which (as is often the case in modern system architectures) does not provide a monolithic system but is indeed composed of a set of different subsystems and services building the whole functionality of the entire system. Every subsystem itself is a special solution developed for a particular subtask, while different system platforms and data formats are used.

The following parts can be seen as possible components for such an energy management system compound:

- Applications for the calculation of schedules for disponsible energy producers and consumers within a power grid,
- Power grid simulators which create (on a basis of corresponding stimulus data) an estimation of the grid's state at a certain time which provides the possibility to forecast grid problems like overvoltage etc. and
- Forecast systems which provide the possibility to forecast the future load of energy consumers or producers in a particular area and a particular timeframe.

Although those systems may be products from different vendors working on different system platforms and data exchange formats, there is the need to exchange data between the subsystems. For example, a subsystem A having to calculate optimized load schedules for a power grid provides input data for a subsystem B which calculates corresponding load estimations for the distribution power grid. Furthermore, subsystem A might provide its calculated load schedules to a netsimulator subsystem called C which verifies the schedules through simulation and re-delivers the results to subsystem B.

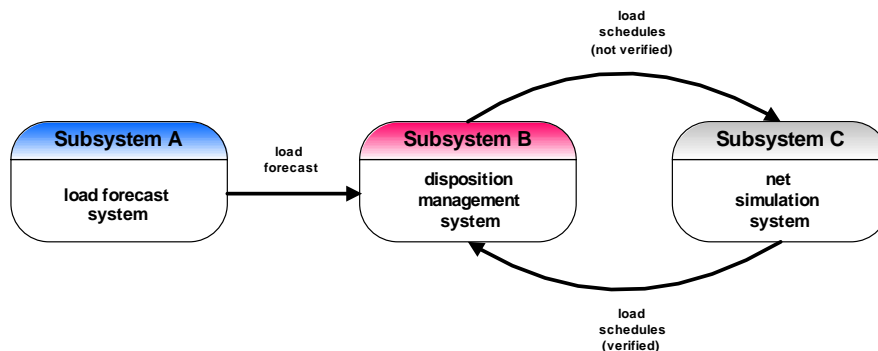


Figure 6: Communication inside an EMS (example)

For sure, this short example only represents a small part of the entire communication that may happen inside an EMS. In general, it will become more difficult to establish an automated data exchange mechanism between subsystems the more heterogenous the corresponding IT-landscape actually is.

The following paragraphs explain further advantages of the application of the CIM standard for the aforementioned EMS.

4.1 Support of a service-oriented architecture by using a common language

When realizing an EMS integrating many subsystems, it is helpful to use enterprise application integration (EAI) techniques combined with service-oriented architectures. A communication and integration platform can be used to provide communication and data exchange between the different subsystems in a heterogenous environment. This approach is based on a special service-oriented architecture. The integration platform itself is able to invoke services from external systems and provides services for other systems in the form of e.g. web services. For the communication to work properly, it is necessary to build corresponding adaptors used for the transformation between the data formats of each participating system in order to get the data interpreted and processed. Creating such adaptors is a very costly, time consuming and fault-prone process.

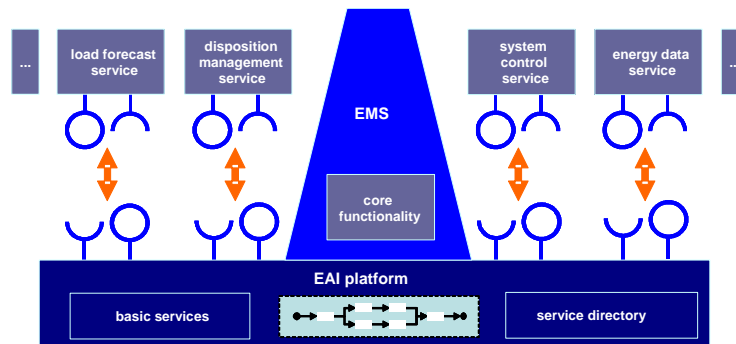


Figure 7: Service-oriented architecture of an EMS by using an EAI platform.

Using the CIM reveals potentials for improvements because CIM provides numerous options to support communication between systems in a heterogenous system environment. If all systems connected to the EMS could provide their internal data (e.g. power grid topology) according to the CIM and provide external

CIM-compliant interfaces, less data conversion routines would be necessary within the adaptors. All systems would rather work on the same data model. The used enterprise application integration platform could get data from the associated external subsystems, check the data for validity to the CIM-standard data model and in case push the data directly forth to other subsystems using the specific model.

A service-oriented architecture could therefore be supported by using the CIM-standard in a project employing an integration platform for connecting subsystems and can be used to run processes via web services being orchestrated by business process modeling languages.

4.2 Improved commercialisation

The relevant factors for using CIM described in paragraph 4.1 lead to an another, rather important advantage. Commercial products have better market opportunities when they either set a standard themselves or implement a standard.

In general, the commercialisation of a system depends not only on the provided functionality but also on its flexibility to integrate with other systems. In order to ensure a long-term commercialisation, it is useful to keep it open for future developments. Subsystems should be coupled as flexible and loose as possible. This ensures a possible exchange of old components against new, more efficient components without having to do a lot of integration efforts or compromising the overall system performance.

The proposed approach using the CIM provides a chance to create configurable models for today's and future use in order to gain a flexible and future-proof system.

4.3 Legal unbundling in the energy domain

On the basis of the legal unbundling laws passed in 1998 by the EU, energy utility companies have to dissemble their monopolistic functions like transport und distribution of electricity which could be competetively organized. In Germany, those laws have already been fully established. One particular important issue is the unbundling of commerce and distribution of electricity. Unbundling provides the only possibility in the eyes of the legislator to establish a proper and fair intense competition on the energy market. Energy utility companies have to deal with many different changes required by the unbundling, most of them cover the organisation of the company itself, the power grid operating company has to be divided from all other company parts in relation of legal form and organisation, e.g. distribution must be seperated from generation.

Although the unbundling leads to an independent acting of the subdivisions, it is important with regard to the overall result of the company to coordinate the unbundled subdivisions and their data. The “internal” exchange is still necessary and has to be supported even more by a possible coordinating data exchange platform. This platform has to connect the internal systems and has to provide interfaces to external systems of other energy utility companies which become customers of the power grid operating department. They use the power grid to conduct their electricity to the consumer having the ability to choose between its electricity providers.

4.4 Problems and risks of this approach

Regarding problems of this approach, we have to name the usual suspects of EAI projects like difficulties of identifying the relevant system interfaces or databases, specifying their semantic data and mapping these to the common information model. Furthermore, when implementing a service-oriented architecture, it can be difficult to define the processes which should be orchestrated by the platform. All of those factors have a strong background in organisation and are domain related so much time must be spend talking and evaluating the platform with the user and the corresponding specialist departments. One particular problem lies with the necessity to adhere to the legal constraints of unbundling without losing to much performance of the optimized platform.

5 Conclusion and Outlook

Energy utility companies use different systems which often have to be integrated. This can be needed by two main reasons. First of all, legacy systems have to be integrated with systems from new manufacturers or data between two formerly unconnected systems has to be exchanged. This leads to the need of a standard exchange format making work less concentrate on the adaptors but rather on the application logic and processes. The Common Information Model can be regarded as a pragmatic und standardized approach to define a data exchange format. Being able to express CIM objects with a serialized XML format, is is easily possible to exchange data via current web standards. The described project makes use of the CIM in an EAI platform which connects decentralized energy management functions via web-services using the CIM. This provides a better exchange of data between projects, a standardized data model used for all applications and improved legacy integration. Apart from a simple connection and data exchange, an EAI based solution can provide a platform to run processes via BPEL4WS on a service-oriented architecture using web services as a further perspective. This integrates the systems used and their common data model further into the

organisation-wide architecture and provides useful inter-organisational interfaces needed due to the legal unbundling to connect to other electricity vendors. Another perspective is due to the very integration of the CIM and the language used for substation data exchange, the SCL. This could lead to an easier exchange and elicitation of data because the technical systems provide their current status and values themselves CIM-compliant.

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