A data model for energy decision support systems for smart cities.

The case of BESOS Common Information Model

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Abstract: Integrating Energy Management Systems is a necessary task in order to be able to offer a range of services for citizens and public authorities. This task requires integration at the data level in order to expose data coming from different systems in a unified way. In this paper we describe the creation of a Common Information Model to unify disparate Energy Management Systems in the context of the BESOS project. We identify related work, describe design decisions and methodology and give an outline of the data model itself, based on profiling and extending the IEC 61970 standard.

1. TOWARDS AN INFORMATION MODEL FOR EMS MANAGEMENT ENVIRONMENT

1.1 Integrating Energy Management Systems

Energy Management Systems (EMS) deployed today in typical districts that are consuming or producing energy suffer from a major drawback: no matter how well-thought or sophisticated they may be, they lack integration. This drawback hampers their usability for all potential classes of users, as the development of end-user applications and decision support solutions cannot be based on a holistic view of underlying data.

BESOS (Building Energy Decision Support Systems for Smart Cities) is an EU Research and Development project [1] that proposes the development of an advanced integrated management system which enables energy efficiency in smart cities from a holistic perspective. The goal for BESOS is to enable the integration of disparate EMSs to share data and services among themselves and with external third party applications through an open trustworthy platform.

BESOS aims at providing a decision support system to existing neighbourhoods in order to enable a coordinated management of public infrastructures in cities and, simultaneously, to promote energy efficiency and sustainability by providing citizens with relevant information that encourages the change of consumer habits.

In order for this overarching goal to be achieved, the first step is to enable integration of data coming from different EMSs. This is a data integration task, in the context of which a BESOS Common Information Model (CIM) needs to be developed. The BESOS CIM consists of the necessary data models addressing different Smart Grid components and respective information elements of varying granularity that ensures the semantic and syntactic interoperability between the various components comprising the BESOS energy management framework.

Consequently the BESOS CIM establishes the efficient integration of flexible demand with distributed generation within the smart grid through the promotion of standardized interfaces between the Aggregators/ESCOs and the Distributed Energy Management Systems responsible for the execution and monitoring of optimal local control actions. In this paper, we give an account of the work performed in order to deliver the BESOS CIM as a critical aspect towards the interoperability of diverse energy management sources.

The paper is structured as follows. In Section 1, we introduce the domain and establish the need for a common information model. In Section 2, we give an overview of related work and examine its impact on the design decisions made. In Section 3, we outline the data modelling methodology used for the development of BESOS Common Information
Model. Furthermore in Section 4, we present the BESOS CIM itself while we finally conclude and present a future outlook of the work in Section 5.

1.2 The Need for a Common Information Model

The main goal of the BESOS project is to create a centralized infrastructure to deliver services and applications for Smart Cities. More specifically, the project involves a number of Gateways collecting and delivering Smart Grid data from EMSs, a Middleware layer aggregating and exposing that data via APIs and a services layer delivering end user applications on top of the data. The task of the Middleware layer is two-fold: on the one hand, to integrate data coming from different Gateway sources, and on the other to offer Services to the application layer. The Middleware Layer implementation uses a data meta-model for this, based on simple classes: Entity, Metric, Attribute, Message and Strategy which are further adapted on the different applications examined.

The reason for this minimalistic approach is simple and clear: as each Gateway to be integrated has its own data model, it makes for an abstraction over multiple data models, unifying them all under this basic meta model. If a fully blown data model was introduced, it would mean having to map each Gateway data model to the Middleware data model for each new Gateway, which would make Gateway integration a cumbersome and error prone task.

On the other hand, this makes things harder in terms of application development: if everything is abstracted by this meta-model, then application developers have to inspect each feature they receive to figure out what it is and how it is connected to other features in the ecosystem. This is the equivalent of having to learn the data model for each Gateway, which is something that the Middleware is supposed to abstract.

The topic was considered, weighing the benefits and drawbacks for each option: simplicity for Gateway systems integration vs. simplicity over applications development. In the end, simplicity for application development prevailed, as after all the success of the project in the long run depends on it: it would be pretty hard for a healthy application ecosystem to be developed on top of this Middleware if it only supported a meta model.

So the meta model is still used internally to integrate Gateways, but on the upper layer the APIs exposed to application developers use a fully blown data model as defined in the BESOS CIM. Thus, the existing meta model is mapped to the BESOS CIM to provide a semantics-based model.

2. STATE OF THE ART ANALYSIS AND IMPACT ON BESOS CIM

2.1 Introduction

In order to proceed with the design of the BESOS CIM the approaches taken by other projects in the domain as well as related standards were examined. As relevant smart grids projects provide feedback on the methodological approach the main focus of the analysis is on standardization, as the goal was to adopt and further be compatible with the standard(s) of choice in order to promote reusability for the BESOS CIM.
2.1.1 Relevant Data Modelling Work

As the main focus on the E.U. is the provision of a common and interoperable operation of energy management systems, different approaches have been adopted so far. A set of indicative Smart grids projects from EE semantics Working Group [2] was reviewed in terms of data modelling, in order to define a common baseline to be further incorporated within BESOS CIM. A first approach to the definition of a common information model among different system components was defined as part of FIEMSER project. The main objective of the FIEMSER project is the development of an innovative energy management system for existing and new residential buildings, which pursues the increase of the efficiency of the energy used and the reduction of the global energy demand of the building, but without penalizing the comfort levels of the users. FIEMSER introduces a Data Model formalized in UML diagrams, describing the object/relational mappings between the data components, persisted using ORM frameworks such as Hibernate [3]. The approach consisted in (1) categorizing the data handled in Use Cases, (2) modelling data in each identified category and, (3) merging the resulting sub-models into a holistic data model.

The FIEMSER approach informed BESOS methodologically and the respective data model was considered as it has been expressed in UML, and is therefore easy to integrate. In addition, concepts related to User & Groups Permissions were adopted from FIEMSER towards the integration of role of organizations in Energy management systems.

A framework conceptually similar to BESOS is the one provided by the SmartKye Project. SmartKYE proposes the development of an advanced integrated management system which enables energy efficiency in neighbourhoods from a holistic perspective. It specifically targets public authorities responsible for a number of public services demanding energy. The SmartKye data model is defined as XSD models following a meta-modelling approach and its main concepts are Attribute, Entity, Message, Metric and Strategy [4]. Although this approach was not adopted in its entirety, it has informed the BESOS data model in certain modelling aspects.

More specifically, the meta-model approach has informed meta-modelling in BESOS towards a hybrid modeling approach. In addition, concepts related to the market operation, as Strategy related aspects were also defined in BESOS CIM.

A key project towards the incorporation and management of heterogeneous energy assets in district level is COOPERATE. COOPERATE aims to demonstrate the impact and benefits of ICTs to improve the energy management of a neighbourhood, and their environmental performances through an online Neighbourhood Management System. For this purpose an open, scalable neighbourhood service and management platform was developed and a substantial part of it is the Neighbourhood Information Model (NIM), as it serves as a common information source for the developed services [5].

The design of the NIM followed some basic principles that informed the BESOS approach as well: reuse and extension of existing Information Models from related projects and design of a flexible and extensible NIM. COOPERATE also adapted and integrated already existing Building Information Models (BIM) and took a meta-modelling approach, as the NIM has been divided into different logical information groups which served as an inspiration for BESOS data model modularization.

In addition to the common ground methodological approach addressed in the previous references, the KnoholEM project focuses on knowledge-based energy management for public buildings through holistic information modelling and 3D visualization. Its main objective is to elaborate an intelligent energy management solution for energy efficient buildings and spaces of public use. KnoholEM adopts an ontological modelling approach [6] and divides its data model in 2 parts, namely the generic ontology (GO) and the building-specific ontology (BSO). KnoholEM was taken into account towards the modelling of building (commercial & residential) assets. In addition the modelling effort could benefit from the links established mainly with IFC [7], but also with gbXML [8]. BuildingControl related concepts were adopted from IEC 61970 and further included in BESOS CIM, as modelling of Building level controllability is one of the main requirements addressed in the project.

2.1.2 Alignment with Standardization

A key objective for BESOS is the transferability of the whole solution. Therefore, it is critical to define common and reusable interfaces that fully address the majority of existing installations and as a consequence our focus was on the alignment of the proposed data model with common standards in the Smart Grids domain. During the State of the Art
analysis a list of standards was reviewed (VDI, USNAP, CityGML, IFC, BACNET) while IEC 61970 and IEC 61850 are presented as the most important and close to BESOS approach.

The IEC 61970 series of standards [9] deals with the application program interfaces for energy management systems (EMS) and defines a common vocabulary and basic ontology for aspects of power industry. Since there is UML formalization on IEC CIM (including also related standards 61968-Distribution Grid [9] and 62325-Energy Market [10]), it can set the basis for BESOS concepts while integrate attributes and relationships as well. Though IEC CIM is a well documented and massively applied standard, is not adopted as-is in its entirety. Firstly, it is a very extensive model with many of its concepts not being relevant for Smart-cities applications. On the other hand, there are certain concepts (SLAs, Business roles, Contracts), to be modelled in BESOS, that are missing from IEC CIM, therefore the model needs to be extended.

In recent years, IEC 61850 [11] standard for the design of electrical substation automation has raised special interest. The IEC 61850 is comprised of 10 parts, the most relevant of which in terms of data modelling are parts 5 and 7. The main differentiation is the modelling of primary process objects as different standard logical nodes which can be further grouped under different logical devices. The IEC 61850-7-420 [12] has recently been formalized by means of UML, covering some types of DERs. Even though there are not standardized (XMI) artifacts that can be reused for modelling purposes, the details on assets modelling offer a surplus towards the integration on the proposed framework. On the other hand, it is well-known that IEC 61850 and IEC 61970 have inconsistencies [13], making the use of both problematic. There have been efforts for the harmonization of the two standards [14][15] however differences in Configuration and Run Time models (Power Network, Measurement, Control, Protection) mean that the result is not fully harmonized or easy to use. Therefore, and as BESOS defines a district management framework, we have adopted IEC CIM as the anchor point for the BESOS Common Information Model while asset specific attributes coming from IEC 61850 standard are further adapted on the proposed framework.

2.2 BESOS Design Methodology

Following the need for a fine-grained common information model and taking into account the relevant work of a multitude of related research projects and existing standardization on the field of Smart Grids, a common ground methodology has been devised for the definition of BESOS CIM. Towards this direction, the main principles that have been adopted in terms of methodology are presented while a comparative analysis beyond the state of the Art summarizes the methodological section.

2.2.1 Modular Design

For a domain that is extensive, as is the case for BESOS and Smart Grid domain, a modular approach [16] helps organizing data model concepts in more manageable chunks that are easier both for modellers to process as well as for users to comprehend.

While at times it may be convenient to have a single point / file of reference for the entire data model, which would enable its users to inspect and navigate it in its entirety, for a model that is as extensive as the BESOS CIM this becomes impractical. In addition, and though modularization requires effort not only in terms of conceptually grouping appropriate logically related concepts into modules, but also in terms of establishing and maintaining necessary links and references among them, in the long run this option proves best as far as maintainability is concerned.

Thus the modularization approach has also been adopted by the data modelling work in BESOS to the definition of the main concepts of interest.

2.2.2 Common Ground Modelling Approach

While the adoption of advanced domain modelling techniques and formalisms such as ontologies seems feasible, this approach is not preferable for our case due to the requirement for the transferability of BESOS solution. Ontological modelling makes for a powerful and flexible data modelling mechanism, and one that has some key features that make it suitable for integration of different data models (most notably, multiple inheritance). However in the proposed framework, IEC CIM - a UML based modelling approach- set the basis for the proposed model. This, in addition to some related performance concerns lead us to adopt a combination of XML and UML for the data modelling methodology, as elaborated in Section 3.

2.2.3 Meta-modelling Approach

One of the main requirements on the modelling methodology is to proceed with models that are easily adapted to existing software applications. This has in fact been one of the key decisions shaping the
data modelling work, as the contrast between a compact meta-model [17] and an explicit data model was taken into account.

Towards this direction, BESOS CIM covers parts of the domain that are deemed stable and universal (e.g. instances of Power Generating Units) while the ones that are more dynamic in nature (e.g. instances of metrics) are dealt with by means of meta-modelling. Considering the plus and cons for each approach, the decision was reached to go for an explicit data model, while adopting the meta-model approach for parts of the model that are of a truly dynamic nature, displaying 2 key features: the need to record historical values and the need to add future elements that are not known a priori at the time of modelling.

To make this distinction clear, let consider an asset of interest within BESOS – a Wind Generating Unit. As a concept, it is a specialization of a Generating Unit and it was added to the BESOS CIM. Its properties may include ones that are shared among all possible instances (and whose values do not change) such as Rotor Diameter, and others that are either specific to certain instances or have values that are evolving through time (e.g. Total Generated Power). The former is part of the explicit data model (an attribute of a class) while the latter is dealt with by means of meta-modelling (an instance of a meta-model Measurement class associated with Wind Generating Unit).

2.2.4 Integration of Standards

Towards an era of standardization on energy domain, there is a high need on providing a model that fully aligns to the existing mature standards.

As BESOS framework is proposed for the management of assets on smart city level, it became evident that BESOS would not proceed to model Building structure in detail. Therefore, a great deal of standards under consideration (VDI 3813[18], gbXML, CityGML [19] and IFC) became less relevant under this light, as they focus on Building structure. In addition, specific business aspects related to Demand Response (e.g. OpenADR [20]) were not deemed to be critical due to the need to proceed with generic interfaces on application level.

Thus, the choice came down to the - supported by IEC committee [21] - IEC 61850 and IEC 61970, as the standards that are more closely related to the domain that is the focus of BESOS. However, due to the fact that there is well-known semantic incompatibility between them, and in order to avoid getting entangled in the disproportionate effort required to address this issue, the strategic choice was made to base our approach on IEC 61970 (IEC CIM) while to further enhance our model with attributes from IEC 61850-7. This choice was based on a number of important factors:

Adoption and community support Most large electric utilities have had at least one project “try out” of the industry-standard IEC CIM, while a number have even based their large-scale enterprise application integration efforts on it.

Tooling support There is a special tool, called CIMTool, developed to support modellers wishing to use the IEC CIM as a basis for their data models and a specific mechanism called CIM profiling that lets them select an appropriate subset of the CIM. In addition, an active community supports the adoption of IEC CIM on Smart grids applications. This is a tremendous benefit in terms of usability and productivity.

Domain relevance Last but not least, the IEC CIM is the one with which there is the most overlap in terms of concepts and properties needed to model the Smart city domain BESOS deals with. In many cases, concepts could be reused as-is, making for a substantial benefit in terms of portability and adoption potential for the BESOS CIM.

Therefore, the decision was reached to base the BESOS CIM on the existing standards following the tension for alignment of new applications with the existing ones. As this part is a main innovation of the proposed framework, more details on the way IEC CIM has been weaved in the data modelling methodology as well as process and semantics details can be found in the following Sections. Prior to the detailed presentation of BESOS CIM, a beyond the State of the Art Section summarizes the innovation of the proposed framework.

2.3 BESOS CIM beyond the State of the Art

BESOS promotes the efficient integration of flexible demand with distributed generation within the smart grid through a fully fledged Common Information Model that ensures the interoperability (syntactic and semantic) between the applications and the distributed Energy Management Systems (EMS). This is the main innovation of the proposed framework, standing on top of the existing models towards the provision of a unified approach for the management of diverse EMS. In order to highlight the innovation impact of BESOS CIM and further proceed to a comparative analysis with existing models in energy domain, we adopt the Smart grids
map representation as proposed by IEC [22] and CEN / CENELEC [23].

The following tables visualize how the different models and standards adapt to the main domains proposed by IEC. Thus, BESOS CIM is defined as an end-to-end approach covering different attributes from DER management to the prompt market & enterprise operation on Smart-cities era.

Table 1: Domain based Comparative Overview

<table>
<thead>
<tr>
<th>Data Model</th>
<th>DER/Customers</th>
<th>Generation</th>
<th>Distribution</th>
<th>Transmission</th>
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</thead>
<tbody>
<tr>
<td>FIEMSER</td>
<td>X</td>
<td>X</td>
<td>X</td>
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<td>SmarKye</td>
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<td>COOPERATE</td>
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<tr>
<td>KnowlEM</td>
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<td>VDI 3813</td>
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<td>IEC CIM</td>
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<tr>
<td>CityGML</td>
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<tr>
<td>BESOS</td>
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Table 2: Zone based Comparative Overview

<table>
<thead>
<tr>
<th>Data Model</th>
<th>Market</th>
<th>Enterprise</th>
<th>Operation</th>
<th>Field/Station</th>
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<tbody>
<tr>
<td>FIEMSER</td>
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<td>SmarKye</td>
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<td>KnowlEM</td>
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<td>VDI 3813</td>
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<td>IEC CIM</td>
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<td>IEC 61850</td>
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<td>CityGML</td>
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<td>BESOS</td>
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</table>

3. CIM MODELING APPROACH

Developing a data model for an integration project is a complex task, not only because of the complexity of the domain and the scale and multitude of envisioned applications, but also because of the different views on data and related business processes. The methodology used to develop the BESOS Data Model was devised taking into account best practices in the domain, both in terms of techniques and tools as well as in terms of overall approach. The aforementioned high level lessons learned for the data modeling needs on energy domain are further addressed towards a stepwise approach on the delivery of BESOS CIM. The respective steps towards the delivery of BESOS CIM are further analyzed. A state of the art analysis defining the details on the methodological approach and the high level concepts of interest on energy domain was initially performed, as documented in the previous section.

3.1 Consultation with Stakeholders

Following the initial identification of the main assets, a two-fold approach was taken in order to ensure all the aspects related for the data model were considered. On the one hand, partners responsible for managing EMSs to be integrated were asked to define EMS functionality (interfaces) and managed objects (data models) and provide any additional clarifications and insights needed. On the other hand, stakeholders responsible for developing business applications also specify their envisioned functionality (interfaces) and managed objects (data models) and provide additional clarifications.

3.2 Modelling based on IEC CIM

At this phase of the methodology CIMTool [24] was leveraged in order to browse the IEC CIM standard and try to identify concepts that could be adopted by the BESOS CIM. These concepts were subsequently reused in order to cover project specific needs. These cover:
- Concepts corresponding to the ones identified by the stakeholders’ analysis
- Concepts belonging to the IEC CIM required to express domain formalization and hierarchy.

For the most part the adopted concepts (and their attributes - relationships) belonged to the second category, as the modelling approach taken by the IEC CIM was adopted to express BESOS concepts. The profiling mechanism supported by CIMTool was leveraged to generate an IEC CIM profile that was used as the starting point for the next phase.

3.3 Data Model Modularization and Sanitization

CIMTool produces a CIM profile in XSD form, which aligns with the goals set out in devising our methodology. However, this profile is generated in a monolithic form (single XSD file), which is not compliant with our goal of delivering a modular data model. Therefore we introduced a phase in the process in which the contents of the resulting XSD file were divided into a number of separate XSD files referencing each other.

In addition, the XSD produced does not use global element constructs, which are required for the kind of modular design we are aiming for. So part of the modularization process included XSD file
sanitization, whereby local XSD elements were turned to global ones. This phase of the methodology produced a number of XSD files used as input for the next phase.

3.4 Additional Modelling Concepts

At the end of the modularization and sanitization phase, the resulting XSDs contained concepts that were identified in the IEC CIM, as well as internal CIM concepts needed to express adopted ones. Since there were still a few concepts needed to express the BESOS CIM that were not part of the IEC CIM, these had to be added manually in the XSDs. This is the main part of the work that distinguishes the BESOS CIM from IEC CIM while the whole process is provided in line with IEC CIM principles. The goal of this process is to address the whole list of concepts defined by the system stakeholders but still be in line with standardization principles.

3.5 Information Model Visualization

The very last step of the work is provided as a meta-part of the modeling definition as there is no widely accepted format for visualizing and further understanding them. Therefore we adopted an approach in which we formalized and documented the data model using XSD and visualized it using UML. Especially in the Smart cities domain where heterogeneous assets and actors are involved, a visual presentation of data model is needed.

Following the sequential approach on the definition of CIM, the high level concepts and the detailed attributes are defined while a summary of the model is provided in the next section.

4. BESOS COMMON DATA MODEL

BESOS CIM was developed using the methodology introduced in the previous section. The data model was broken down in 7 different logical modules (Location, Users, Assets/Structure, Metrics, Documents, Control) in order to facilitate cohesion and reusability, as having one big monolithic model that includes all concepts would not be very usable. The logical modules correspond to physical ones. In the following, we give an overview for each module while also additional attributes that define the role of each module within BESOS framework are provided.

4.1 Location Module

This module includes concepts used to capture information related to location, as well as general concepts that are used throughout the data model and have been included here for convenience:

**Identified_Object**

This is the concept that most other concepts in the data model extend, either directly or indirectly (base class). It has been adopted from the IEC CIM and is the high level generic object inherited in all IEC CIM classes.

**Status**

This concept is introduced in the IEC CIM to be used as a generic container to hold status-related information. This is also a common object in IEC CIM inherited in BESOS Data model following the standardization principles.

Figure 2: Asset Structure. Blue-shaded classes are external to the module
4.2 Organization & Users Module

This module introduces concepts capturing information about organisations as well as users. The former have been adopted by the IEC CIM and enhanced with additional properties to accommodate BESOS needs. Within BESOS, EMS assets owners, Aggregators, ESCOs and residential users are defined as the main stakeholders of the platform and therefore incorporated in the respective data model.

4.3 Asset Structure Module

This module (Figure 2) includes concepts capturing information about Assets that are examined in BESOS project while also covering general assets of interest in a smart city level. It does not contain information on specific asset types or measurements (included in other modules), rather it defines the concept of an Asset and its main related concepts. Therefore this module is central for the BESOS CIM, defining the parameters to be considered towards the specification of each asset examined. Due to the core role of this module, a detailed view of the main classes is further provided.

The Asset class has been adopted from IEC CIM and is used to represent the logical manifestation of a piece of equipment, as opposed to the physical one for which the Power System Resource is used. An Asset can be part of an Asset Container and it has a Type Asset and a Priority. Assets can also have Location and Status associated with them, while they may optionally have a Time Schedule. Finally Assets have a lifecycle property, used to record lifecycle dates, and an Activity Records property. Therefore Asset is the core entity examined in energy systems and defines the static information that configures any asset as part of the integrated framework.

ActivityRecord has been adopted from IEC CIM. It records activity for an entity at a point in time; activity may be for an event that has already occurred or for a planned activity. It has properties to record createdDateTime, reason, severity, priority type and whether it is an alarm or not.

In addition to activity record, a TimeSchedule is used to describe anything that changes through time and has been adopted from IEC CIM. It has properties to record its recurrencePeriod, recurrencePattern and scheduleInterval while the scope of this class is to define schedules affecting the operation of each asset.

The PowerSystemResource class is used to represent the physical manifestation of a piece of equipment, as opposed to the logical one for which the Asset is used. A power system resource can be an item of equipment such as a switch, an equipment container containing many individual items of equipment such as a substation, or an organisational entity such as sub-control area. Power system resources can generate Measurements and they have a list of AllowedStatuses and a CurrentStatus associated with them. This distinction of Assets from Power System Resources is a main feature introduced by the BESOS CIM as a clear view on how the static and dynamic characteristics of the system are addressed.

As part of the generalization of assets, asset container is defined as an asset that is an aggregation of other assets, adopted from IEC CIM. It extends physical assets addressing the need of grouping towards the provision of aggregated business services.

Each asset is characterized by a specific status of operation, defined as ResourceStatus, to be applied to Power System Resources. Furthermore, each asset defined is characterised by a specific type and therefore a catalogue of generic types of assets that may be used for design purposes is also applied. Within BESOS project, a list of different assets have been selected and therefore a detailed analysis of each type is further presented as part of the data model of the project.

4.4 Assets Representation Module

This module includes concepts capturing information about specific types of Assets. As the physical representation of Assets is used for this purpose, all concepts extend Power System Resource which is 1..1 associated with the Asset class and the logical representation of the whole entities system.

The equipment class, adopted from IEC CIM and extending Power System Resource, represents the parts of a power system that are physical devices, electronic or mechanical. It has properties to record its NominalPower and whether it is normally-In-Service and defines the high level abstraction of each type of asset examined in BESOS. Then, in order to provide an asset specific data model, an overview of the main assets represented in the scope of the project is given.

The GeneratingUnit class, adopted from IEC CIM and extending Equipment, represents a single machine or set of synchronous machines for converting mechanical power into alternating-current power. A wind generating unit extends GeneratingUnit towards the definition of wind power generation. In addition to being able to
generate Measurements, it also has the static properties installedPower, rotorDiameter and numberOfTurbines related to wind turbines management. A **photo-voltaic generating unit** extends the generating unit class and also has the static properties azimuth, tilt and numberOfInverters.

A **point of light** is defined as the asset which is responsible for the management of traffic and public lights. This asset is very important in city level management and therefore is further incorporated in the model to be further examined as part of the holistic energy management framework.

As the numbers of electric vehicles has increased recently, these set a typical asset to be examined in smart city level. An **electric vehicle**, extending Equipment class and able to generate Measurements, has also the static properties hasGPS, loadedMaps and pathRoute in order to align energy with mobility related parameters. In addition to the electric vehicle as a single entity, a **charging station** is defined as an aggregated type of EV assets. We have to point out the distinction of charging stations as geographically defined entities, while each EV is characterized by the mobility pattern.

Towards this direction, the abstract type of **mobility** is further defined in order to provide both VehicleDensity and CarDetected, associated to an existing road management structure. It is of high interest within BESOS project to address both energy and mobility related characteristics under a common management framework and therefore the integration of mobility related parameters in Common Information Model is provided.

In addition to the general types of generation and consumption assets, we need to address also building assets that set the main type examined in a city level. A **public building** asset is characterized as a “prosumer” asset type that incorporates both consumption and generation characteristics. This class structure covers all the respective attributes related to the management of public buildings under a common framework. As mentioned above, a main innovation of BESOS project is the enrollment of citizens as part of the integrated management framework. Therefore, a **residential building** asset type is modelled as a piece of Equipment able to generate Measurements and addresses the citizens also as end users of BESOS platform.

### 4.5 Measurements & KPIs Module

This module (Figure 3) includes concepts capturing information that help keep track of dynamically evolving attributes (metrics) used to display and aggregate as well as KPIs defined utilizing these measurements. Both Measurements and KPIs follow the same pattern: there is a definition, a list of values and a source for each value. KPIs are defined using measurements and define the high level indicators of examined in business layer towards the impact analysis of the proposed framework. Apart for the time stamp definition of metrics and indicators, we also address TimeSeries attributes used to define intervals over which aggregated Measurements are

![Figure 3: Measurements & KPIs. Blue-shaded classes are external to the module](image-url)
calculated, including which measurement to calculate, aggregation type and step.

More specifically, a **measurement** type represents any measured, calculated or non-measured quantity. The PowerSystemResource - Measurement association is intended to capture this use of Measurement, and here the IEC CIM semantics have been changed to allow for a N...N relationship. Measurement is used as a metric definition, while its evolving values through time are captured using its MeasurementValue property, adopted from IEC CIM. Each Measurement has properties to express its unitSymbol and unitMultiplier, as well as its measurementType and the phases for which it applies. There is also an isCalculated property used to designate whether a measurement is calculated.

The **MeasurementValue** class represents the current state for a measurement. A state value is an instance of a measurement from a specific source. Measurements can be associated with many state values. A MeasurementValue's value at timestamp is recorded by means of the respective properties, while there are also properties to associate the MeasurementValueSource and its sensorAccuracy.

Additionally to measurements a reference to **Key Performance Indicator** class is defined, associated with an EMS. KPIs follow the same pattern as Measurements - i.e. they have definitions, values, and sources, in order to help keep track of historical values and multiple sources. A KPI has properties to express its unitSymbol and unitMultiplier, as well as its KPI Type. In addition KPIs are linked to the Measurements used for their definition via the Measurements property as well as to their values via the KPI Values property.

The **KPIValue** class represents the current state for a KPI. A state value is an instance of a KPI from a specific source. KPIs can be associated with many state values, each representing a different instance for the KPI. A KPIValue's value at timestamp is recorded by means of the respective properties, while there is also a property to associate it to its KPIValueSources. In order to proceed with the holistic management framework proposed within BESOS project, there is the need to examine different types of metrics and indicators either as snapshots or as time series. Thus, an analysis of the aforementioned classes through time is defined.

A **TimeSeries** is used to define intervals over which aggregated Measurements are calculated, including which measurement to calculate, aggregation type and step. A TimeSeries is correlated with a Measurement by means of a homonymous property. The same approach is also addressed for the KPIs analysis following the common metrics/indicators modeling framework.

Further to the time series definition, the **Step** class defines a step for use by the TimeSeries while also the **DateTime** defines the time granularity of the analysis. Therefore the calculation of aggregated metrics and indicators is dynamic towards the provision of a meta modeling framework that fully addresses the end users diverse requirements.

### 4.6 Document Types Module

This module (Figure 4) includes concepts capturing information related to the business – strategic

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**Figure 4: Document Types. Blue-shaded classes are external to the module**
Aspects of BESOS. One of the main innovations within BESOS framework is the identification of different business services and models to be provided by the system stakeholders and business actors. Towards this direction, the modeling of dynamically defined business services is considered as a critical parameter for BESOS CIM. More specifically, modelling of concepts having to do with Service Level Agreements and Strategies are defined as part of the work.

Adopted from IEC CIM, Document is a parent class for different groupings of information collected and managed as a part of a business process. Therefore, this class defines the abstract layer for the whole business layer modeling. Document has a number of properties inherited by its children and used to keep track of its subject and role. Formal agreement between two parties defines the terms and conditions for a set of services.

The SLA concept represents the Service Level Agreements between 2 organizations as examined in BESOS project, specifying related terms (monitored via KPIs) and assets. It has properties pointing to Assets for which the SLA has been created, KPIs involved in monitoring and verifying the SLA, the Owner organization that contracts the SLA, and the SLA’s priority. On the other hand, the StrategyAction represents one request from a municipality end user – e.g. “Operate in eco-friendly mode”. It is modelled as a subclass of Agreement to designate its semantics and inherit properties. It has properties pointing to Strategy Constraints and Strategy Goals applicable to this strategy action (both of type Strategy Element) as well as a Priority.

The Strategy Element concept is used to model specific strategic sub-objectives as part of the strategy actions. This refers to both goals and constrains. For example one strategy element could be “Light consumption should be less than X” (goal) while another strategy element can be “points of light should be kept on in a specific area between 12 a.m. and 6 a.m.” (Constraint). It has properties pointing to target value, Assets involved, a KPI or a Measurement the desired value of which is within the goals of this strategy and a Strategy Relation Type signifying the relation with the specified KPI / Measurement (greater, equal, etc).

As the Strategies and Service Level Agreements are defined for a specific time period, a TimeSeries class is also inherited in the model. An interval between two date and time points, adopted from IEC CIM, is defined pointing to start and end date of the interval addressing the character of Service Level Agreements as examined in smart cities era.

4.7 Control Module

This module includes concepts capturing information related to control commands as delivered from the Application level to the EMS level in order implement the control strategies defined. This is a core modeling aspect addressed within BESOS data model. As the type of message during a control command is not of a unique type, a hybrid approach has been followed within data model, addressing both generic message types (to be further interpreted in EMS level) while also Asset specific control commands towards the definition of the set point of operation. The aforementioned control types are aligned with assets and strategies in order to provide a detailed view on the definition of control commands.

Within this section, a list of high level modules has been defined and further described in details towards the definition of the BESOS data model. The incorporation of specific classes and attributes on the IEC CIM model and further the definition of a meta modeling approach in order to cover additional parameters has led to the transferability of the proposed model and facilitated integration of additional assets as part of the BESOS framework. Therefore the modules definition is provided fully addressing the high priority requirement for an approach, fully traceable by the end users and also the developers of the platform.

The source (XSD) files for all the modules can be accessed at [25] (a temporary location until they are transferred to the BESOS project web site).

5. CONCLUSION AND OUTLOOK

We have introduced the rationale behind building a data model used to integrate disparate Energy Management Systems and examined the process through which it has been constructed and the design choices that have driven it. We have answered the most crucial dilemma in terms of modelling (the use of an explicit data model versus a minimal meta-model) by adopting a middle ground based on lessons learned from other projects and also addressing the main requirement needs. When compared to other data models we took into account in the state of the art, we can identify certain points of differentiation for the BESOS CIM.

To begin with, BESOS CIM focuses on the domain of energy management at the city level, as opposed to IEC 61970 that covers a broad array of domains. Furthermore, compared to IEC 61970 and IEC 61850 BESOS CIM covers both the network
level and the EMS level connecting these distinct layers of the smart grid. BESOS CIM also extends the standards by adding new assets such as Electric Vehicles and Point of Light, as well as covering aspects of security and priority on assets (covered in standardization by IEC 62351). Last but not least, as opposed to IEC 61968 and other standardization efforts, BESOS CIM introduces the role of ESCOs and Aggregators as stakeholders in an open energy domain. By making the modelling process and the model itself publicly available we hope that they can be of use to anyone facing a similar task. The goal of BESOS platform is to provide a holistic solution for energy and mobility management that will be easily transferable and towards this direction, the BESOS CIM is provided in a way that could be easily adopted and further mapped in any part of integration process.

As the BESOS project evolves, the data model will incorporate lessons learned in the field as well as additional modelling to make sure it is always up to date.

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