Building a bridge between CIM and PLIB ontologies via IEC62656 on data parcels

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Abstract

While CIM(Common Information Model) described by IEC61970/61968 standards is recognized as the Smart Grid ontology, the Common Dictionary Model defined by IEC61360/ISO13584 standards, acronymed as “PLIB”, has been widely used as the common basis for representing product ontologies in many ISO-IEC communities. This model has been referenced in many international standards of both ISO and IEC that describe domain ontologies and their applications. Among them are ontologies for measuring instruments, mechanical fasteners, optics and photonics, electro-electronic components, plant devices, and environmental declaration. In addition, the standardization of ontology for low voltage switchgear and controlgear has been started as IEC 62683, and the result will be maintained in IEC 61360 online database being supervised by IEC SC3D. This means a broader spectrum of classes and properties necessary for Smart Grid are actually available through PLIB ontology registers, and the interoperability between CIM and PLIB ontologies is imperative for real use. IEC62656 introduced in this paper is a new series of standards in IEC SC3D that enables the representation of CIM ontology in PLIB data model, decomposing CIM ontology into a set of tables of atomic ontology concepts where each of which may be exchanged as a spreadsheet, called “data parcel”.

1. INTRODUCTION

Importance of having a map of related technologies in a domain of industry in a form of product ontology model is getting understood as a prerequisite for consistent development of the technical standards and applications in the domain. IEC61970/61968 often noted as CIM is expected to play such a role as an ontology standard in the domain of technology, so called “Smart Grid”, for efficient and environment-conscious operation and maintenance of the power grid, comprising various types of equipment and facilities.

On the other hand, the IEC61360/ISO13584 standards sometimes acronymed as PLIB are multi-part standards developed conjointly by IEC SC3D and ISO TC184/SC4, and they provide a common product ontology description model, but published separately as IEC61360-2 and ISO13584-42, with different organizational logos. Moreover, the ISO/IEC guide 77 published in 2008 recommends the use of IEC61360/ISO13584 as the first choice for the electronic description of product classification and properties, in brief, an ontology specific to a domain of technology, in all technical hemispheres. Currently, a dozen of TCs/SCs are engaged in developing or maintaining a product ontology standard, or in a little easier term, a “reference data dictionary” standard, as depicted in Figure 1.

Originally defined using EXPRESS language(ISO10303-11) however, IEC61360/ISO13584 standards jointly provide several exchange file formats, including one in XML-schema as ISO13584-32, and another in spreadsheets as ISO13584-35 or IEC62656-1 as an extension, besides STEP (ISO10303-21) files. As seen from the Figure 1, one of the largest groups in IEC, i.e. IEC SC65E that specializes in the description of plant devices, such as measuring instruments, actuators, and their control systems is busy standardizing the electronic description of their plant device hierarchy and the properties associated with each product class, in a form conformant to IEC61360. In addition, IEC SC17B that covers low voltage switchgears has joined in the effort to complete their part of definitions.

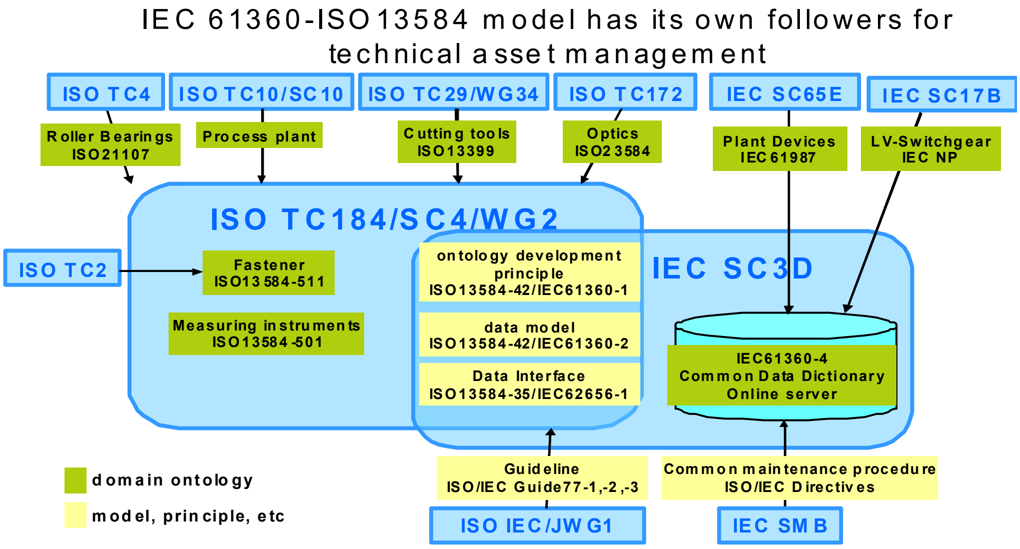

Figure 1 Collaboration and cooperation with IEC SC3D for IEC61360 CDD

The both committees intend to register the dictionary definitions in IEC 61360 CDD (Component Data Dictionary), an online database of ontologies maintained by IEC SC3D in collaboration with IEC Central Office (IEC-CO) for IT-infrastructure. Separately, in IEC TC111 environmental properties necessary to be declared for manufactured products are designed to keep basic interoperability with IEC61360/ISO13584, and a plan to register the specification of the properties in IEC61360 CDD is underway. The reason behind this is that IEC61360 CDD is allowed to maintain and update its content though a database procedure stipulated in IEC directive annex-J, and this allows an update of content within 4 to 6 months. If a change request is submitted and approved, it will become an integral part of IEC61360 CDD immediately without normal IEC documentation and publication process at IEC Central Office. This fits well with the purpose and requirements of industrial ontology registry, where a wide range of products are already in service, new types of products are put on the market every month, and new requirements on products or new use of products are introduced or discovered in a short term. For example, a wind turbine is not yet listed as an equipment type in CIM standard, however some countries are already planning to test a type of wind turbine on a float in the sea. Thus even if a wind turbine is already an item in the CIM, it may require additional properties to be standardized for efficient performance and maintenance of the equipment, such as wave height or sea level for the equipment in a very short time frame.

Meanwhile, in private sectors, several industry consortia maintain data dictionaries in a form compatible with IEC61360/ISO13584. One of such organizations is eCl@ss in Europe and another is JEITA/ECALS which latter concentrates on the definition of electric/electronic parts in Japan. A consortia of organizations including EdF, Renault, PSA as members in France has been engaged in building a ISO 13584 based simple dictionary, accumulating the product classes and their properties for production equipment and facilities.

Unfortunately, the CIM standardization started well before the publication of the guide 77, and consequently, its ontology model is defined in UML (Unified Modeling Language) and RDF Schema is principally used for exchange of ontologies. Thus, the two standards are structurally incoherent, and no effort for bridging the two structures has been tried nor planned until this day.

Thus the aim and scope of this paper is to show first why the interoperability between the two standards is so critical for the success of the Smart Grid. Secondly, to illustrate the additional advantages to be accrued from having a central repository of relevant data dictionaries and keeping the information flow among the applications and domains. And thirdly to introduce IEC62656, in particular the part3 of the series, as a means to bridge the gap between CIM and PLIB.

2. CIM AND ITS LIMITS

2.1. Current CIM as observed

When we observe CIM in comparison with other ontological models, the following points are notable:

a) References among objects are made by names.

b) Each object or relation has no version.

c) No object by object update is foreseen.

An implication of these is that CIM is designed with rare occasional and holistic update in mind.

A simplified view of the basic CIM structures extracted from an RDF version of CIM, i.e., IEC61970-501 is illustrated in Figure 2, whereas the original CIM model is defined in IEC61970-301 standard using Rational Rose, a commercial graphic design tool of UML, marketed by IBM corporation. Such specification of the name of a commercial tool in an International Standard is very rare, but from the description in Part301, it seems the use of the tool is prerequisite for an accurate and effective update of the CIM model. And it seems there is an assumption that all the components of a power grid, or at least their descriptions as parts of an ontology, can be updated simultaneously. This looks like quite an optimistic assumption in real use. When the model is used only for a limited number of installations of software, say in case of a few EMS' s, it may be guaranteed that all software installations and their applications in a micro-grid may correspond to one version of CIM. However, an intelligent electric device or a facility in a power grid has considerably a long life span and some parts of the software functions might be hard-wired or tightly embedded into the equipment and facilities as integral elements. In this case, it is not likely that all these software components in a power grid will be updated all at once, even if some packages of CIM in a UML may be updated in a tool. Then a situation may arise where the software components in a power grid correspond to different versions of CIM. This means operations on added attributes, classes, and relations by a control device designed with a newer CIM may not function properly on some electric devices or facilities as the power grid becomes older.

This becomes all the more complex when the role of reference to an object is not separated from the role of the name meanwhile the role of identification and the role of reference of an object are not clearly separated. To be more precise, reference among the entities is done by the name-inclusive ID, namely URI(Uniform Resource Identifier).

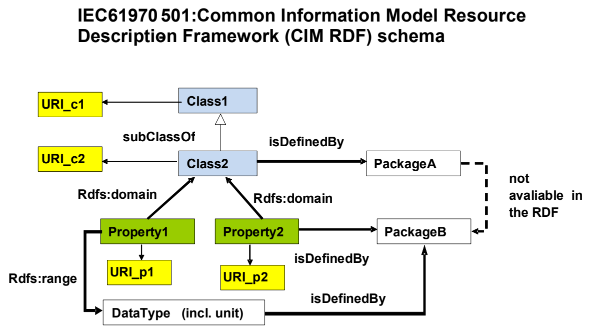

Figure 2 simplified view of CIM data model

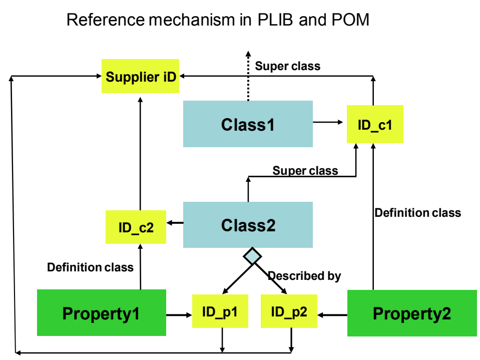

Figure 3 Simplified view of PLIB and POM data model

2.2. Current PLIB as observed

In contrast in PLIB (also in POM), a name and an identifier are two different functionalities and are completely separate. In fact, PLIB supposes there may be different appellations for the same object in each domain and in language, thus an ontology network is constructed in reference to a global ID including a version as its essential element, not by a name. This means each meta-object(class, property or relation) is defined with an appropriate version as one of its attributes.

From more a pragmatic viewpoint, one of the conspicuous shortfalls of the UML is that UML itself is not an ontology definition language but a graphical programming language, thus a limited capability exists for fully accounting the definitions of the classes and properties as an ontology. Moreover, when a difference between 2 ontologies is sent in a file from one party to another, the difference is not guaranteed to be processible as a UML, since the result might be an orphanated attribute, and difficult to be displayed as a UML graph. In other words, a semantic block of ontology that needs to be analyzed and a syntactic block of a programming language that can be displayed by UML are not the same. This poses a significant question if UML is the best form of definition for CIM, from the viewpoint of continuous maintenance and rapid expansion of the definitions of the CIM as ontology. It seems rather distantiating those who fully understand the grid ontology and could contribute to its expansion. Additionally, it can be also pointed out that the present CIM has only one version for the whole ontology, and element by element update, such as insertions of a new class or property is not foreseen. This slows down both the qualitative and quantitative extension of the CIM standards, and reduces the opportunities for harmonizing with other standards: An ontology standard must have a sophisticated version control mechanism as a whole as well as for its parts.

2.3. Ontology modeling with POM

For any product ontology to be used, not for an academic pursuit or publicity, but for a day to day industrial activity, the following conditions must be squarely addressed:

a) Ease of integration with other domain ontologies.

b) Ease of extension for new entries

c) Ease of use and application for domain engineers.

The Parcellized Ontology Model or POM in short is one of the new standard frameworks to address the above. The POM has four layers of ontology representation each of which consists of pairs of abstraction levels; M4-M3, M3-M2, M2-M1, and M1-MO in the terminology of Meta Object Facility (MOF) of OMG. Each layer comprises a header section and a data section that can be represented in a table or matrix form, as depicted in Figure 4.

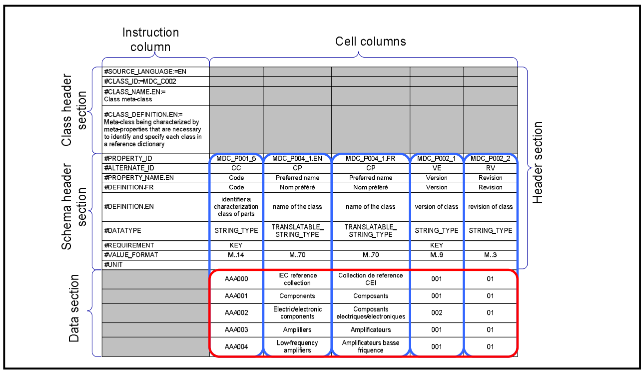

Figure 4 Parcel Example

The four layers of POM are short named as AO, MO, DO, and DL that represent respectively Axiomatic Ontology, Meta Ontology, Domain Ontology, and Domain Library in IEC62656 series of standard. One of the unique features of POM is that a layer of ontology is represented as instances of the layer directly above. Thus the four layer structure of POM forms a hierarchy depicted schematically as in Figure 5.

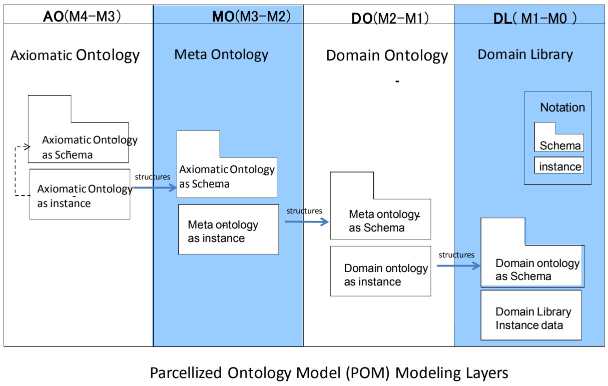

Figure 5 POM object modeling layers

Note that a model for a domain ontology at DO is defined as a set of instances of an upper layer MO. This means if we modify the instances of the upper layer, i.e., MO, then the model of a domain ontology at DO will be largely affected. For constraining the changes at MO, however, there is AO, thus all the changes must be consistent and conformant with the framework set by AO.

2.4. Theoretical basis of POM

The above layered ontology structure, starting from AO to DL, is an application of a well known theorem in mathematical logic i.e., Reduction Theorem as part of a proof of Completeness Theorem of Kurt Gödel.

Let's say A is a logical formula containing a free variable in mathematical logic, the following theorem is known as substitution theorem:

$$\vdash A \rightarrow \exists a A ,$$

where $\vdash A$ means A is assumed to be true.

Namely, if A is assumed true then there must be at least one instance a such that replacing x by a in A makes A true.

Now let a theory A^j be a logical formula, with k free variables $x = [x_1, x_2, \cdots, x_k]$. Then the formula may be rewritten as; $A^j = A^j[x_1, x_2, \cdots, x_k]$.

If there is $a = [a_1, a_2, \cdots, a_k]$ such that assignment of a to x makes A^j true, then we may rewrite this as; $a \;\; A^j$.

Applying the substitution theorem one by one to k free variables we obtain,

$$A^j \rightarrow \exists a A^j ,$$

where $\exists a$ means $\exists a_1 \exists a_2 \cdots \exists a_k$.

Now we further assume A^{j-1} is a logical formula that is made up of a finite number of logical conjunction or disjunction of the terms; $a_1, a_2, \cdots, a_k$.

Note that when $a_{i\in[1,k]}$ is true, the result of any number of logical conjunctions of a_i is true and the result of any number of logical disjunctions of a_i is true, thus A^{j-1} is true. This means,

$$A^j \rightarrow \exists a A^j \rightarrow A^{j-1} .$$

Assume that A^{j-1} still contains some other free variables a' . Then we apply the above process to , A^{j-1} and we have

$$A^{j-1} \rightarrow \exists a' A^{j-1} .$$

In a repeated application of the above process, we will have

$$\vdash A^j \rightarrow \exists a A^j \rightarrow \exists a' A^{j-1} \rightarrow \cdots \rightarrow \exists e A^1 ,$$

where $e = [e_1, e_2, \cdots, e_k]$ signifies a list of the values of real world objects, or constants, such as

[100, 2.3, Yokohama, IEC62656] ,

that is made up of constants (individuals) and no more reducible. Or we can replacing a' with a^{j-1} , the above may expressed the same formula for $j = 4$ as ;

$$\vdash A^4 \rightarrow \exists a^3 A^4 \rightarrow \exists a^2 A^3 \rightarrow \exists a^1 A^2 \rightarrow \exists e A^1 .$$

And the readers are easy to see, that $\exists a^{j-1} A^j$ corresponds to either one of four layers of POM, namely;

$$\text{AO} \Leftrightarrow \exists a^3 A^4 ,\ \text{MO} \Leftrightarrow \exists a^2 A^3 ,\ \text{DO} \Leftrightarrow \exists a^1 A^2 ,$$

and

$$\text{DL} \Leftrightarrow \exists e^0 A^1 .$$

This implies POM is very deeply founded in mathematical logic, unlike its easy outlook as "spreadsheets". And because of this 4 layer architecture, the POM is a meta-language for many modeling languages including POM itself. For POM, CIM is just one of such languages to be modelled and PLIB is another.

3. ONTOLOGY BY DATABASE PROCEDURE

As noted earlier, an ontology register with the scope spanning all the ranges of electrotechnical products and services are maintained at IEC SC3D as IEC 61360 CDD through the IEC database procedure described in IEC supplementary directive annex-J. Figure 6 gives a simplified view of the procedure in contrast with the paper based standardization process.

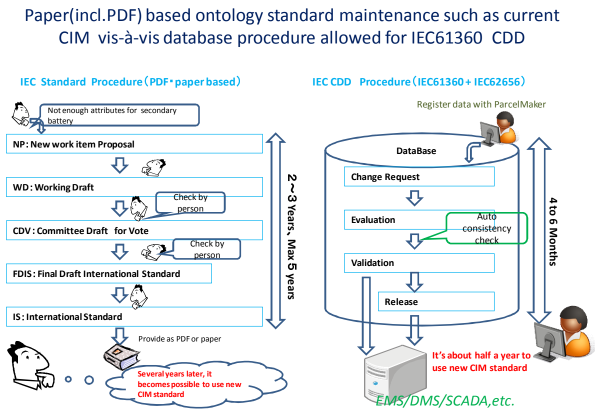

Figure 6 Database procedure at a glance

Currently, the dictionary upload/download interface is being switched into IEC62656-1/ISO/TS 13584-35 based one for the ease of compilation of data by domain experts. Since the physical format of the Parcel format is the spreadsheet, the format can be easily processed by many commercial spreadsheet tools such as MS-EXCEL®[1]. There are a few organizations that have developed a tool to process data parcels. ParcelMaker™ is one of such tools that is available from TOSHIBA Corporation as an add-in program to MS-EXCEL®, and all those who are engaged in an ontology standard development conformant to IEC61360 via IEC 62656-1 may obtain a copy without charge. A screen copy of the class hierarchy view of CIM generated by ParcelMaker™ is shown in Figure 7, while the Figure 8 shows the base ontology data implemented in a class meta-class spreadsheet conformant to IEC62656-1 obtained as an early result of the experiment for translating CIM into POM, i.e., IEC 62656-1 format. In our implementation using the tool, we found that the entire CIM ontology can be translated into POM based ontology with few functional extensions to the IEC/CD 62656-1, and may cohabitate with

[1] MS-EXCEL is a registered trademark of Microsoft Corporation.

ISO13584-42/IEC61360-2 conformant ontology definitions in an extended IEC CDD. All these additional modeling constructs are included in IEC/CDV 62656 and all the mapping principles and rules to transplant CIM defined ontology data into IEC CDD will be standardized as Part3 of the IEC62656 series.

The prime advantage of translating the CIM content into Parcel based expression is that the latter can be easily integrated with other ontology definitions available in IEC CDD. For example, switchgear definitions will be available and more than 50 technical properties already defined for secondary batteries in IEC CDD are reused or imported or referenced for use in Smart Grid including CIM definitions.

Secondly, because IEC CDD is maintained by the database procedure, the ontology build-up and its maintenance are much easier and faster than current CIM. Moreover what is modified by change request and approved by online vote will immediately have an IS status, and available to users.

Lastly, since the full definition can be treated in a spreadsheet, it is easy to process the data for domain experts.

Moreover, the data can be preprocessed or post-processed easily from other applications. This will eventually serve as an efficient and standardized interface for asset management of CIM related products and services. Figure 9 shows the current map for the integration of various ontologies that are being or planned to be transformed into POM and interfaced or directly transplanted into an extended IEC CDD.

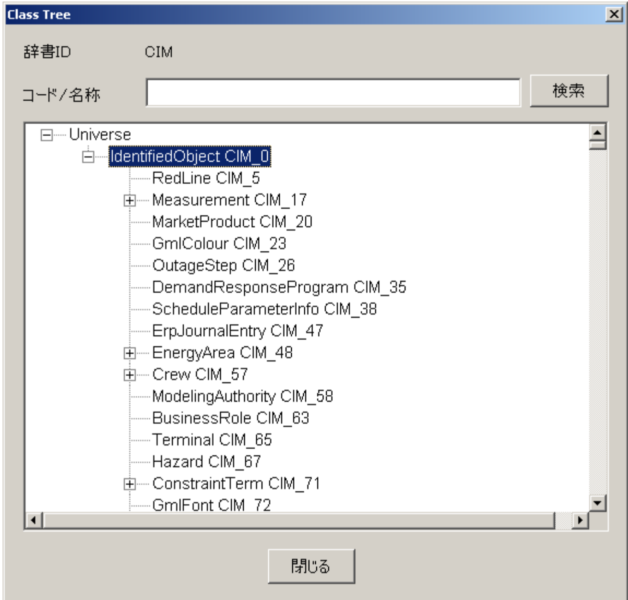

Figure 7 CIM class

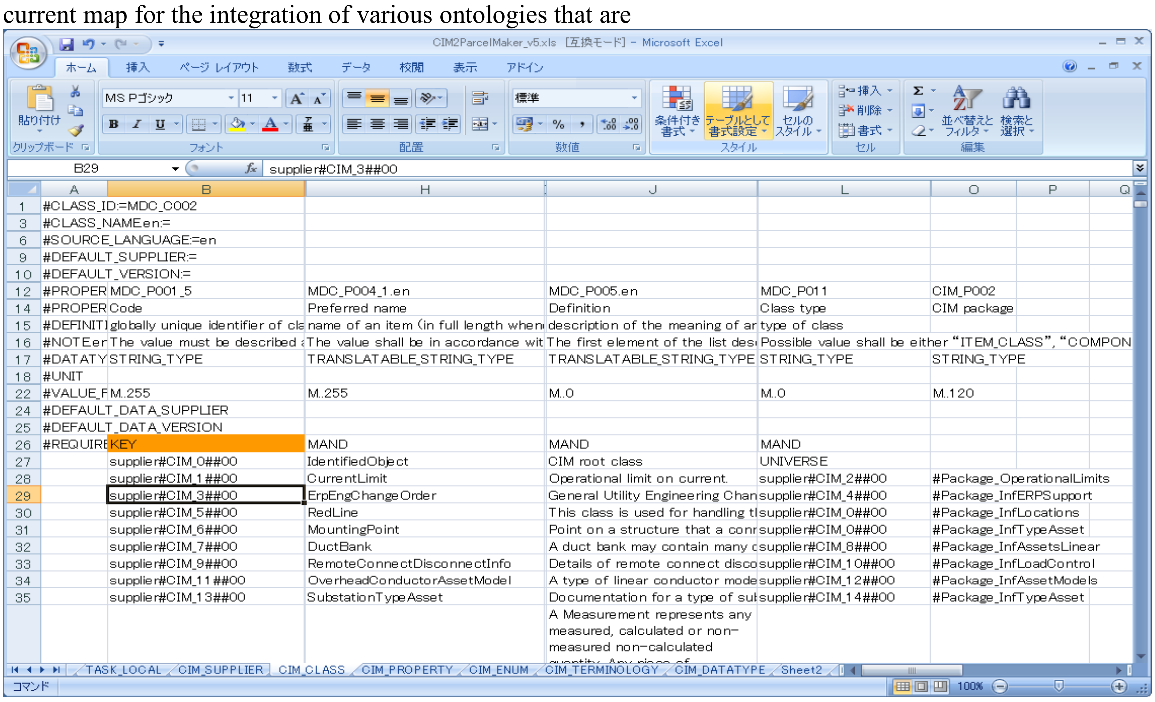

Figure 8 Class meta-class implemented as a spreadsheet on MS-EXCEL

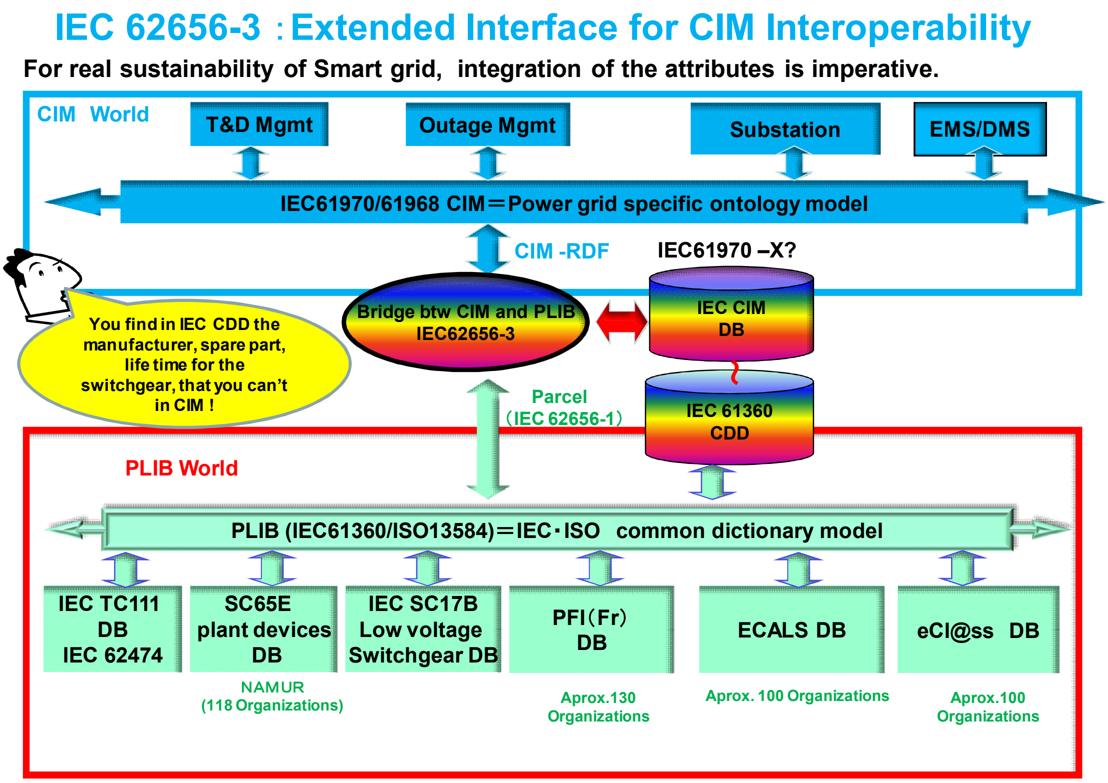

Figure 9 Map for integration of product ontologies via IEC62656

4. SUMMARY

IEC SC3D and TC57 are in a move to set up a formal liaison relationship. As precisely described in IEC SMB-SG3 Roadmap[9], "This would, inter alia, promote the extension of existing (technical) properties in the existing data models of IEC 61850/61968 and 61970 to other applications and would open the path to new applications.

Conversely, the interoperability of the CIM and PLIB standards will bring much benefit to those who need ontologies in an electric power industry, because the engineers in the industry will be able to access through a standardized interface and standardized identification methods the information about non-power-electric properties of the equipment and facilities in electric grids, such as material of equipment, environmental conditions, engineering information, or spare parts information that are indispensable for effective maintenance of the Smart Grid facilities. For this, we have illustrated throughout this paper that POM should play a pivotal role in mapping and interfacing the two standards, because POM has a meta-ontology layer to model and map different ontologies, and can express those different domain ontologies in a consistent and harmonious manner in the same framework. Additionally, ontology in a spreadsheet format will bring about practical convenience to the domain experts. For this, IEC 62656 Part 3, as an extended interface for CIM interoperability is being standardized at IEC SC3D. Needless to say, that the reuse of the definitions of classes and properties available from IEC CDD or from CIM in the other standard will considerably reduce the cost of standardization in both committees.

Lastly but most importantly, we propose that the future maintenance of CIM content be in an extended IEC CDD database, conformant to the IEC database procedure. This will bring about agility in the response of the smart grid community to various change requests from industry to substantiate or correct CIM. This agility will also help harmonize the CIM with IEC61850 series of the standard in a shorter time frame. Because not only CIM but also the essential data structures of IEC61850 may be useful for registration as IEC CDD definitions.

We hope that the US Smart Grid communities will study the possibility of harvesting the fruit of IEC CDD and apply the means and methods of the collective ontology maintenance developed by IEC SC3D over years.

Reference

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[6]IEC 61970-301:2010,*"Energy management system application program interface(EMS-API)-Part301:Common Information Model(CIM) Base"*

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[9]2010,"*IEC Smart Grid Standardization Roadmap*", *SMB Smart Grid Strategic Group (SG3)*

Biography

Mr. Hiroshi MURAYAMA is a chief research scientist at Toshiba corporate research center. He is also serving as chairman of IEC SC3D, a horizontal subcommittee of IEC, in charge of development and maintenance of technical standards for product properties and classes and their identification, for all electro-technical domains. He has led the development of several International standards as project leader in both ISO and IEC communities over a decade.

Ms. Lan WANG is a research engineer at Toshiba corporate research center, who is now preparing Part3 of the IEC 62656 series standard with her colleagues, as an interface standard between CIM and IEC CDD. She also takes care of analyzing the present content of CIM and transplanting into IEC CDD test database via Parcel tools. The Part3 will allow the representation of CIM and PLIB ontologies on the same IT-infrastructure.

Mr. Akira HOSOKAWA is a research engineer at Toshiba corporate research center, who is currently leading the development of Part2 of the IEC 62656 series standard, designed as an implementation guide for the logical model defined in Part1. The standard will be particularly useful for registering an ontology of product classes and properties in IEC CDD, an online database maintained by IEC Central Office. He also leads the development of an editing tool in the company, named ParcelMaker^{TM}, for practical spreadsheet-representation of ontologies.