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Harmonizing the International Electrotechnical Commission Common Information Model (CIM) and 61850

Key to Achieve Smart Grid Interoperability Objectives

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EPRI Project Manager

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NOTE

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Product Description

The Electric Power Research Institute (EPRI) has sponsored the development of a number of international standards that provide the basis for information exchange to support power system management. One of the most important standards is the International Electrotechnical Commission (IEC) Common Information Model (CIM), which is rapidly gaining acceptance throughout the world as a common semantic model to unify and integrate the data from numerous systems involved in the support of real-time electric utility operations. Another is the IEC 61850 series of standards for substation automation that EPRI initially sponsored as well.

This report describes the work accomplished in 2009 and early 2010 to harmonize the CIM and 61850 standards through the creation of a unified information model that provides a common set of semantics for use by both the CIM and 61850 standards. Utilities should be able to exchange information between systems and devices using a common language supported by both, regardless of the specific interface involved. This can be achieved by having a common semantic model from which the specific information to be exchanged can be derived, thus avoiding the proliferation of endless point-to-point links, each based on a different set of semantics. While mapping is still required from a system's native representation of data to the standards-based common language for information exchange, this approach ensures that an accurate and lossless transformation occurs at every interface to another system where the common semantic model is applied. This is, in fact, the stated vision for the National Institute of Standards and Technology (NIST) Smart Grid Interoperability Framework.

Results and Findings

A unified information model expressed in UML was developed by extending the existing IEC 61968/70 CIM UML model to incorporate extensions needed to support the IEC 61850 semantic concepts defined in 61850-6 Substation Configuration Language (SCL) since there was no UML information model in 61850. Although the goal was to minimize changes to the existing SCL standards, some changes are proposed to SCL to address differences in modeling approaches and functionality. The conclusion was that it is possible to create a common unified model that supports both the CIM and 61850 standards for generating information exchanges expressed in either CIM/XML files/messages or 61850 SCL XML.

Challenges and Objectives

Both the CIM and 61850 are published IEC standards. The recommendations and proposals contained in this report need to be reviewed and incorporated into the applicable CIM and 611850 standards by the appropriate IEC TC57 working groups. Another challenge is to gain acceptance by other standard development organizations (SDOs), such as OASIS, IEEE, and ANSI, who are also working on development of semantic models and/or other approaches to harmonization. The objective is to have the proposed unified UML model accepted as the basis for a common semantic model that can be applied broadly throughout the system interfaces identified in the NIST Smart Grid Conceptual Framework.

Applications, Value, and Use

This work contributes directly to ongoing work in IEC TC57 WG19 to harmonize the CIM and 61850 standards. It differs from previous attempts to harmonize these standards by basing the harmonization on the creation of a common unified UML model that essentially extends the CIM UML model, which has been recognized by TC57 as the best modeling approach for creating common semantics for use throughout TC57. Furthermore, the proposed harmonization approach conforms to the TC57 Reference Architecture, with the unified UML model used as the information model in Layer 1 and definition of profiles in Layer 2 to define the information exchange requirements for specific system interfaces, which can be used to generate both CIM-based files/message payloads as well as SCL XML documents for 61850.

As mentioned earlier, this work also contributes directly to solutions for several of the Priority Action Plans (PAPs) defined for the NIST Smart Grid implementation.

EPRI Perspective

The new Smart Grid initiatives are re-emphasizing the need for interoperability between various vendors' products to share information in a timely fashion where and when it is needed. EPRI is committed to ensure that this need can be met in the area of data exchange and data management. The approach to harmonizing the CIM and 61850 standards is a major step to achieving this objective. It builds off well-accepted international standards and contributes directly to IEC TC57 objectives to achieve this harmonization. Having a common unified model for both sets of standards improves efficiency by eliminating the need to enter substation configuration design data more than once and improves accuracy of data exchanged by ensuring a lossless and consistent mapping of data between systems using different standards for all interfaces where both standards are in view.

Approach

The approach was to first define specific use cases and interfaces where harmonization of CIM and 61850 standards are needed, then address and resolve the modeling issues involved in those interfaces. The proposed unified UML model supports all the information exchange requirements for these specific use case interfaces considered. The next step is to finalize the UML model and profiles that specify exactly which part of the unified model must be supported by each interface and that can be implemented by system software for file/message exchange.

Keywords

Application program interface
Common Information Model (CIM)
Harmonization
IEC 61850
IEC 61968/70
UML

Abstract

EPRI sponsored a project in 2009 to harmonize the International Electrotechnical Commission (IEC) 61970 Common Information Model (CIM) standards with the IEC 61850 substation automation standards. Although both of these series of standards were developed within IEC TC57 Power Systems Management and Associated Information Exchange, they were developed independently and historically have not shared a common model or modeling approach. Unlike previous efforts at harmonization of these standards, this project followed the approach for interoperability recommended by the National Institute of Standards and Technology (NIST) Smart Grid Roadmap, which recommended development of a common semantic model to be used for the Smart Grid. This report describes the issues discovered in creating a unified UML model that supports both the CIM and 61850 standards for the definition of system interface profiles. Use cases for key system interfaces were defined and used to identify specific system interfaces where harmonization was needed. A unified model was developed in UML that permits both CIM XML files/message payloads and 61850 SCL XML files to be defined. Specific recommendations for extensions to the CIM and changes to the 61850 SCL are presented. Preliminary results have been presented to the appropriate IEC TC57 working groups in preparation for their review and acceptance of these proposals. Additional work is needed to finalize both the unified UML model and interface profiles as well as to conduct interoperability tests to prove the proposed model and profiles.

Preface

As expressed by NIST, interoperability is the key to achieving the Smart Grid vision. The NIST Interoperability Framework identifies numerous system interactions both within and between major domains. For many of these interactions, there are existing standards available which were identified in the Smart Grid Roadmap developed by EPRI for NIST. Unfortunately, most were developed independently to address the integration of systems and/or devices within a limited domain of application and so do not share a common model of the data or even a common modeling approach. As a result, every interface between systems that are not covered by the same standard requires a mapping or transformation from one standard's format to another in addition to the mapping from proprietary formats to standard formats when a system interface does not support any standard at all.

In recognition of this problem, NIST identified as one of five cross-cutting and overarching issues the need for a common semantic model for application level communications in several key areas of the Smart Grid, for example, the integration of utility Transmission and Distribution field operations with Information Technology and Back Office Systems and ultimately with Customer Premise Systems.

This report presents the initial results of the EPRI CIM 61850 Harmonization project initiated in 2009. The goal of this report is to provide a solution to the harmonization of these two key standards that is based on a common semantic model created by extending the existing CIM UML model to include key concepts/objects from the 61850 standards. The goal here, unlike previous harmonization efforts, is to create the ability to use a common unified model to define a 61850 profile that could be used to generate IEC 61850-6 Substation Configuration Language (SCL) files in a fashion already used to create CIM XML files and message payloads for the IEC 61668/70 CIM standards. Additional work is needed to finalize the unified UML model and specific interface profiles as well as to conduct interoperability tests to demonstrate and validate the changes proposed in this document. The final step is to support the review and acceptance of these proposals to the appropriate SDO, in this case IEC TC57 Power System Management and Associated Information Exchange and later to other collaborating SDOs and industry organizations.

David L Becker
EPRI
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Contents

List of Figures

List of Tables

1 INTRODUCTION

EPRI sponsored a project in 2009 to harmonize the IEC 61970 Common Information Model (CIM) standards with the IEC 61850 substation automation standards. Although both of these series of standards were developed within IEC TC57 Power Systems Management and Associated Information Exchange, they were developed independently and historically have not shared a common model or even modeling approach. Unlike previous efforts at harmonization of these standards, this project followed the approach for interoperability recommended by the NIST Smart Grid Roadmap which recommended development of a common semantic model to be used for the Smart Grid.

This report is an interim draft report on progress to date which includes a proposed unified UML model based on the CIM information model and supporting use cases. The project when completed will include a finalized version of the unified UML model, the definition of a profile based on the unified model for the use cases considered to generate 61850 artifacts, and validation of the harmonized results through a demonstration of at least one of the use cases considered. These results have already been delivered to the IEC TC57 as draft proposals for how the CIM and 61850 standards could be harmonized to achieve the NIST SG interoperability vision.

NIST Smart Grid Roadmap Recommendations for Common Semantic Model

The NIST Smart Grid Interoperability Framework has identified a large number of standards to support the Smart Grid interoperability vision. While there are standards yet to be developed, a majority of the standards needed already exist. Unfortunately, most were developed independently to address the integration of systems within a limited domain of application and so do not share a common model of the data or even a common modeling approach. As a result, every interface between systems that are not covered by the same standard requires a mapping or transformation from one standard's format to another in addition to the mapping from proprietary formats to standard formats when a system interface does not support any standard at all.

In recognition of this problem, NIST identified as one of five cross-cutting and overarching issues the need for a common semantic model (see Reference 1, Section 6.1.3):

> *A common semantic model for application level communications is necessary in several areas of the Smart Grid. Key areas, for example, are the integration of utility Transmission and Distribution field operations with Information Technology and Back Office Systems and ultimately with Customer Premise Systems*

To address this need, they further identified as a key action the development of a Common Semantic Model:

> *NIST should work with IEC TC57, NEMA, ASHRAE SPC 135, and OASIS to devise a common semantic model (using, for example, XML Schema and XML). The objective will be to unify the models of CIM (IEC61970, IEC61968, MultiSpeak) and IEC 61850 including correspondences with ANSI C12.19 and ASHRAE 135 to form a common representation of information models constructed by these standards efforts for the Smart Grid.*

This report focuses on the development of a common semantic model for the IEC 61968/70 CIM standards and the IEC 61850 substation automation standards. Other separate efforts are underway to harmonize MultiSpeak with the CIM.

The NIST report also identifies other benefits of having a common semantic model:

1. "Extending the IEC 61968 CIM and MultiSpeak standards for DER. The CIM needs DER and PEV models, but should be harmonized with the existing DER object models in IEC 61850-7-420, as well as all on-going DER 61850 development. IEC 61850-7-420 has architectural issues to be addressed."
2. "Extending the IEC 61850 standard from substation to control center. Since the data in the many substations uses the IEC 61850 information model, this data should be reported to the control center using the same information model. This will also simplify the harmonization efforts between the models of data collected from the field and the CIM [representation of field data for use by SCADA and back office systems]."

As may be seen, the NIST SG Roadmap clearly defines the business need for having a common semantic model for the CIM and 61860 standards. It is this need that drove the work described in this report to create a unified UML model for the CIM and 61850 to achieve this common model and benefits.

Background

EPRI has been in the forefront of efforts to harmonize the CIM standards with the 61850 standards – both developed within IEC TC57. Past efforts have focused on identifying the use cases that drive the need for this harmonization, and then focusing on just those areas (i.e., interfaces) where it is important that both sets of standards be supported. The reason for this approach was that there was no common model or modeling approach behind these standards, and given the fact that most of these standards are already published IEC International Standards, significant rework would be required to solve this bigger problem.

Since then, IEC TC57 WG19 has articulated a vision for the TC57 Reference Architecture, which includes a guiding principle that all TC57 standards should be model-driven and metadata-driven to ensure they share a common semantic model. The assumption is that it would be based on the CIM UML plus necessary extensions. They have also embraced a layered architecture based on internationally accepted concepts, such as those specified by the UN/CEFACT Modeling Methodology (UMM) and Core Components Technical Specification (CCTS) to include:

1. An abstract information model which is independent of any specific applications or business function. This layer should provide a way to combine information models from different sources in a seamless fashion to define utility semantic model.
2. A business context layer to restrict the abstract information model to suit specific enterprise information requirements.
3. Business entities that can be related directly with business process objects.

The goal of developing a unified model to harmonize the CIM and 61850 standards then is to adhere to these guiding principles adopted by WG19 by developing a unified information model for all TC57 standards as needed for identified business use cases. This would then permit similar processes to be followed in WGs 10, 17, and 18 for specifying the various exchange documents or interfaces as is already done in WGs 13 and 14 (i.e., via the specification of profiles and message implementation technologies (e.g., XML, RDF, SCL, GID, ACSI, etc.).

Previous CIM 61850 Harmonization Projects

EPRI has sponsored previous harmonization projects (see References 2 and 3). Each provided a set of recommendations as to how the CIM and 61850 standards could best be harmonized. These recommendations were presented to the IEC TC57 WG19 to implement.

Reference 1 provided detailed proposals and recommendations that could be used by utilities in specifying new design and engineering tools and by vendors in developing new tools that incorporate these standards for exchanging data. This report provided specific recommendations for the IEC to use in the harmonization of the TC57 standards. The goal was for the IEC to incorporate these recommendations into both the CIM and 61850 standards, leading to reduced costs in the purchase of products through the minimization of custom interfaces as well as reduced costs in the testing necessary to ensure interoperability between the different systems engaged in information exchange to support utility operations. However, additional work was needed to close the gaps identified and move toward a future architecture with few or no seams between models used for information exchange.

Reference 2 defined a series of use cases dealing with planning, configuration, commissioning, operation, and asset management. The goal was twofold:

1. Enable the exchange of configuration information for both substation automation systems as well as O&M systems and the environment between so that there would be no duplicate manual entry of the same information, and
2. Enable the exchange of run time information via automatic mapping of the information between the models.

Achieving these goals required that the relation between CIM and 61850 standards be described unambiguously and be machine readable. A series of recommendations were developed to achieve these relations.

Both of these EPRI reports were reviewed to provide a starting point for this project. In addition, there are other published papers on CIM/61850 harmonization that were reviewed for applicability to the objectives of this project.

Technical Approach – Unified UML Model

One of the goals of this project is to evaluate how the 61850 standards could also be made to conform to the TC57 reference architecture. This would lead to CIM and 61850 standards that are actually based on the same unified UML model, thus achieving true harmonization. Since both the CIM and 61850 standards along with other related standards will be the basis for power system automation in the future, successful harmonization will reduce integration costs for projects employing both sets of standards as well as providing guidance as to where and when to employ these standards.

The key steps to achieving these goals that were followed for this project were:

1. Develop a unified information model by extending the CIM UML model to include key concepts/objects from the 61850 standards. The goal here, unlike previous efforts, is to create the ability of using the unified model to define a 61850 profile that could be used to generate IEC 61850-6 Substation Configuration Language (SCL) files.
2. Create the ability to import an SCL file into modeling applications based on the unified model so that a load flow model can be appropriately updated with field changes made by a substation engineer during actual installation or equipment replacement. This would include topology updates as well as changes in equipment properties, such as operational limits.
3. Create the ability for CIM applications to use objects previously defined in IEC 61850 and the inverse, thereby minimizing the amount of duplication within the standards.
4. Evaluate these new developments with a demonstration based on selected use cases. Use cases being considered are described in the next chapter.

The work on this project was accomplished by a team of Xtensible Solutions and SISCO lead by Xtensible Solutions.

Business Case and Benefits

There is already precedence for creating a unified model. IEC TC57 WG13 and WG14 have two separate series of standards (e.g. IEC 61970 and IEC 61968) but there is one unified common UML model shared by them, with a shared responsibility for maintenance of this model. This unification has been very beneficial and allows a much wider scope of information exchange to occur than would be possible if there were not explicit linkages between the WG13/WG14 models.

It was this requirement to exchange information between different systems, and different vendor's implementations, that drove the need for these explicit linkages and a single way to represent the model.

In a similar manner, a unified 61850/CIM model offers the possibility to create an environment that can be used to automatically configure SCADA communication interfaces and to be able to exchange the communication related information to other systems. It is this information exchange between disparate vendor's implementations that is one of the primary rationales for standardization of a unified model. Another is the possibility of entering substation configuration data only once where it originates and sharing it via information exchange based on the unified model without reentry. For example, if the Planning department originates a new network extension, say a new substation, the model developed in a CIM environment can be passed to a 61850 System Configurator for assigning of service functions to IEDs. In a similar fashion, field updates stored in SCL files can be exported to a power system network model manager where the updates can be applied to the power flow network model used by EMS and SCADA applications.

In discussions with various vendors and users, most believe that the unified model offers the best solution that will lead to interoperability (e.g. due to appropriate information exchange) for the industry.

With the precedence of the unified model of IEC TC57 WG13 and WG14, and different information exchange techniques, there are no technical issues with adding the appropriate linkages and 61850 related packages to the model. Those issues, methods to accomplish the merger, and methods to maintain the various parts of the model are well understood and applied in the development of the unified model presented in this report.

Organization of Report

This report is organized into the following Chapters:

Chapter 1 introduces the EPRI CIM 61850 Harmonization project and presents the objectives and scope of this report plus its relevance to the NIST Smart Grid Interoperability Framework vision.

Chapter 2 describes the use cases and intefaces that provided the requirements for the unified model.

Chapter 3 addresses the issues and methodologies proposed to reconcile the differences in the semantics for the CIM and 61850 SCL.

Chapter 4 provides specific recommendations for a common definition for each element of the interface profile dealing with substation-related classes and attributes that would be adopted by both the CIM and 61850 standards to create a common set of semantics to be used in the unified UML model. Other model differences in equipment containers, loads, etc. are also addressed with recommendations for changes to both the CIM UML and 61850 SCL.

Chapter 5 describes general SCL design changes needed to reconcile differences in naming and identification of specific instances of equipment and containers.

Chapter 6 describes the proposed changes to create a unified UML model which would support both the CIM and 61850 standards.

Chapter 7 provides a brief discussion of future activities to put these recommendations into effect in the appropriate SDOs.

Appendix A contains a list of data elements from the SCL file exchanged at the identified use case interfaces.

Appendix B provides am example demonstrating how the proposed unified model and 61850 SCL profile is used to generate SCL files that can be used to automatically configure a SCADA system.

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2 USE CASES AND INTERFACES

Rather than approach the development of a unified model for CIM and 61850 from an academic perspective by exhaustively analyzing each and every object modeled in the CIM and 61850 and then finding a way to develop an equivalent representation that accommodates all properties of both, the approach was to define the high priority use cases driven by business needs, and then develop a unified model and interface definitions to support those use cases. This approach results on harmonization of only those elements and properties in both the CIM and 61850 standards that need harmonizing as defined by the use cases.

This chapter describes the use cases that were considered and the system interfaces where the harmonization is needed. The goal is to be sure that all data elements to be exchanged over those interfaces in a message payload or file are derived from a common unified UML model that builds off the existing CIM UML model with extensions as needed to accurately model any additional 61850 object properties that cannot be mapped to the existing CIM model.

Network Extension Composite Use Case

Figure 2-1 is a scenario diagram showing the major systems and information exchanges involved in a network extension use case developed on an earlier harmonization project (see Reference 3). In reality this is a composite of multiple use cases, three of which were the focus of this project as explained in the next section. The information exchanges are numbered to show the approximate sequence of exchanges from the first output of network planning through to the updating of the operational model when the new parts of the network included in the scope of the network extension are energized for the first time. The elapsed time from top to bottom may actually cover several years, as it often takes that long to get approval for new transmission lines. Distribution projects would take much less time, but still follow roughly the same flow. The processes involved and information exchanges resulting from completion of each process are explained in the next subsections.

Planning Processes

As described in the Network Extension Use Case in detail in Reference 3, Appendix A, the use case begins with a request for additional line capacity. Steps 1-2 actually encompass several design and analysis activities resulting in an incremental update to the existing network for that project. In Figure 2-1, these are represented by the business processes Network Planning, Line and Transformer Engineering, and Planning Studies and the information exchanges numbered 1-5. An initial cut at the new network extension is completed and stored in a project repository, the Network Model Manager and Repository (NMMR). Next this project is combined with other projects for a specific time in the future and applied to the as-built network model for conducting planning studies, such as conducting steady state power flows, short circuit analysis, dynamic studies, and contingency analyses. Historical data from operational base cases may be incorporated in this study. The results of these studies are requested changes to the project network design.

All of this activity takes place in the planning department using bus-branch oriented network models, which may be exchanged among various planning applications as part of the study and evaluation.

Substation Design and Engineering Processes

The next series of use case steps deal with the processes and information exchanges involved in the substation design and engineering (steps 3 – 10). In Figure 2-1 these are represented by the business processes Substation Engineering/Protection Engineering, 61850 System Configurator, IED Configurator, and Communications Engineering and information exchanges 6-13. Today substation engineering is largely a manual, paper based process with few tools to assist with the design (AutoCAD is typical) and few automated information exchanges. Protection engineering does utilize software tools with operator entry of configuration data. Once the protection engineering is completed, the IEDs for substation automation are selected, each IED is configured using the IED manufacturer's software and proprietary interface protocol.

Communications engineering provides the connectivity needed between IEDs and secondary devices within the substation fence as well as supervisory and control links to the engineering department outside the fence. Reporting outside the fence is constrained to individual silos of information exchanged between a field device or IED and the manufacturer's software application in engineering, with no opportunity for sharing with other enterprise applications.

SCADA Engineering and Control Center Cutover

The final steps in the use case (steps 12-17) are concerned with assigning the measuring, control, and metering points in the new substation configuration to SCADA telemetry points by SCADA Engineering and updating the operational network model for this extension project with the telemetry points. Next the substation RTU or SCADA supervisory communications links to the control center EMS are configured and the EMS updates its SCADA system and EMS network model, and once all is verified for correct operation, the new substation and line are energized and real time monitoring is initiated. This is represented by the sequence of information exchanges 14-17 in Figure 2-1.

Current Information Exchange Technology

In most utilities today the information exchanges shown in Figure 2-1 are accomplished by a variety of techniques, including database access, proprietary protocols, CSV file formats, spreadsheets, and paper, resulting in multiple operator entries of the same data for the planning, substation, engineering, and operations departments. The opportunity to share data managed by one application with other enterprise applications is either non-existent or severely restricted.

Individual CIM 61850 Harmonization Use Cases

As mentioned above, the network extension use case comprises multiple individual use cases that were the focus of this project to permit concentration of the harmonization effort on specific interfaces key to achieving the interoperability goals involving the CIM and 61850 standards. These individual CIM 61850 Harmonization use cases included the following:

Use Case 1 - Generate an SCL file from a unified UML model and new SCL profile. This would validate that all the necessary elements of an SCL file can be generated from the CIM UML unified model as modified to include the required 61850 objects in UML. This would also demonstrate conformance of 61850 to the TC57 Reference Architecture.

Use Case 2 - Update a small EMS load flow model imported via CIM/XML with 61850 configuration data. This would demonstrate how field changes made by a SS engineer to a 61850-configured SS could be used to automatically update a load flow model without having to re-enter the data manually. This use case would validate that all the necessary harmonization has been done to permit 61850 configuration data to be used to update CIM models.

Use Case 3 – Real-time SCADA data import from 61850 devices.

Use Case 4 (future) - Asset and Condition Based Maintenance (CBM) application import of data from 61850 substation devices. This use case would validate that the data contained within the SS fence needed by this application could be made available to applications in a CIM format.

The key interfaces for each of these use cases is shown in Figure 2-1. However, there are several interfaces that are also covered by dealing with these three interfaces.

The contents of the files exchanged at each of these interfaces and required file format is summarized in the label for each interface. For example, the Interface for Use Case 1 involves the exchange of files from Substation/Protection Engineering to a 61850 System Configurator containing one-lines, primary, secondary, and protection equipment specifications in the 61850 SCL-SSD format.

Functionality Supported by Use Cases

In order to understand the need for standardization at the system interaction points described above, there must first be an understanding of the functionality that these interfaces would need to support. In order to accomplish this, the base functionality of the various key applications needs some level of definition.

SCADA/EMS

The typical SCADA/EMS system contains subsystems to generate alarms and process data received from the substation and 61850 devices. In order to fully process this data, there are functions contained with the SCADA/EMS system to maintain the **topology** and **connectivity** of the transmission, distribution or generation models as well as storing the **measurements**. The **communication** system provides interfaces to TCP/IP and other protocols to enable the system to communicate with the Subsystem and 61850 devices in the field.

The **topology** and **connectivity** contained within the SCADA/EMS system must match each Substation in the field sufficiently to allow the systems to receive the measurement data for storage and processing. Without a very close match between the two systems, the SCADA/EMS system would not be able to use the data received from the field devices to monitor and report the status of the electrical grid.

Using the **topology**, **connectivity** and **measurements**, the SCADA/EMS systems provide the data to allow state estimation, power flow and automatic generate control subsystems/applications to examine the health of the electrical system and provide automated controls for use by the dispatchers in the event something in the field requires intervention. These systems increase the reliability of the electrical system and provide a mechanism for the SCADA/EMS system to request and receive device status from the field.

Without these systems, the reliability of the grid and the ability of the system to function at the speed required would be impossible to achieve. And, in order to achieve this, a synchronized **topology** and **connectivity** must be maintained within the SCADA/EMS and the Substations and the communications must provide accurate and reliable **measurements** from the field into the SCADA/EMS.

Substation Configuration

The following text is an extract from IEC 61850-6 regarding the Substation Configuration Language (SCL). SCL is the document structure that is used as the configuration interface for 61850 substations and systems.

> *It allows the formal description of the relations between the substation automation system and the substation (switchyard). At the application level, the switchyard* ***topology*** *itself and the relation of the switchyard structure to the SAS functions (logical nodes) configured on the IEDs can be described. SCL allows the description of an IED configuration to be passed to a* ***communication*** *and application system engineering tool, and to pass back the whole system configuration description to the IED…*

Exchanges Required

To achieve the synchronization of the topology and the connectivity between the SCADA/EMS system and the Substation, changes to the substations must be input into the SCADA/EMS system as accurately and seamlessly as possible. In addition, these changes must be made in a synchronized way to allow the **measurements** from the field to be used by the SCADA/EMS system immediately after the device is energized.

This coordination is crucial to the maintenance of the electrical grid. In the past, this has been accomplished with much consternation including the coordination of many teams to get the field devices installed but not energized until the topology and connectivity of the SCADA/EMS system could be implemented and be ready to receive data from the field devices. If the SCADA/EMS systems are not in sync with what is in the field, the power engineering required to maintain a reliable system is in jeopardy.

The rate of expansion of the electrical system today places the automation of the changes and synchronization between the SCADA/EMS and the substation in the critical path of utility operations. In order to keep up with the demands of this changing environment, there must be automated systems that will allow exchange of topology, connectivity and measurement data between the control center and the substation.

Systems of Record

The analysis of the exchange requirements, in the end, vary depending upon the view of which system/configuration has the most accurate and up-to-date configuration relating to the topology, measurements, and communication information relating to one or more substations. The requirement to harmonize 61850 and CIM in a standardized manner results from the need to un-ambiguously exchange information between two (2) such systems of record in a lossless manner. It is through the creation of such a lossless exchange that both CIM and 61850 repositories/representations can be utilized.

If one evaluates the comparison of SCADA/EMS applications and IEC 61850 SCL, one finds that there are overlaps within the standards arena and additional overlaps of functionality due to implementation. The following Table 2-1 attempts to depict this information.

Table 2-1
SCL and CIM Support for Data

Item	Substation SCL	SCADA/EMS CIM	Vendor Implementation
Communication	X		X
Topology	X	X	X
Measurements	X	X	
Validation	X	X	X
Ratings		X	
Merging of Changes		X	X

There is no standardized representation within CIM to convey communication information. It is a vendor specific implementation issue within the SCADA/EMS environment. However, it is important that the information found in SCL be able to be stored and reconstructed as needed from a SCADA/EMS system of record.

Where the table indicates that both the SCL and CIM standards maintain similar information (e.g. Topology, Measurements, and Configuration), it is important that information exchanges between the two system of record technologies be un-ambiguous and lossless. This means that:

- Topology: Topological element terminology must be unified and for any class/definition defined in either SCL or CIM, there must be a 1:1 method of transforming/storing this information for exchange with the other type of system of record.
- Measurements: There needs to be a 1:1 method of transforming/storing measurement definitions for exchange with the other type of system of record.

It is worthwhile to note that the Ratings information for Assets (e.g. Transformer Ratings, etc.) is currently only available in a standardized manner within CIM. However, as substations are commissioned and dynamic ratings/de-ratings are determined within a substation, there is an argument that exchanges of this type of information may be needed between the two different systems of record types in an automated manner.

SCADA/EMS and CIM-based systems have implemented methodologies that allow for new instances of elements/objects to be identified as being additions or just changes. However, SCL does not have any such capability as it currently utilizes user assigned naming for instance identification. In order to create an automated exchange mechanism, the solution must provide a well defined mechanism for each interface identifying new objects versus changes to existing objects.

The rest of this chapter describes the use cases in more detail and identifies the key interfaces served by each. A detailed list of data elements required for each interface is contained in Appendix A.

Use Case 1 - SCL File Generation from Unified UML Model

The goal of this use case is to generate a 61850 SCL file from a unified UML model and a new SCL profile defined as part of this project. The objective is to facilitate the entry of substation configuration data once where it first originates. In this case where this use case is part of a composite network extension use case, the new substation configuration originates in the planning and substation engineering departments, where the CIM standards are used.

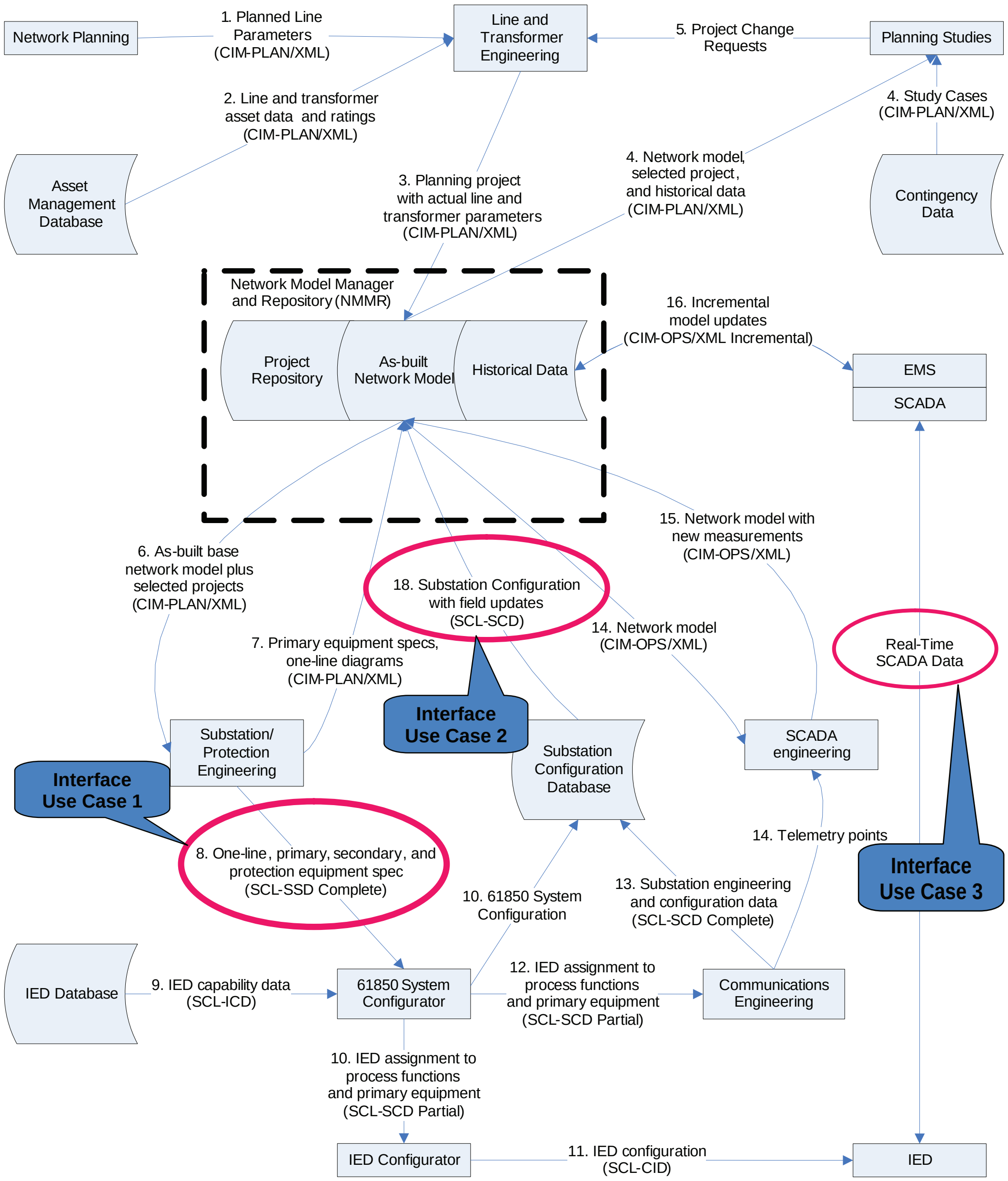


Figure 2-1
Harmonization Use Case Interfaces

Scope

- The scope of this use case is as follows:
- Extension of an existing network model to include a new substation.
- The SCL files in view are the SSD and SCD files.
- The scope of the files exchanged are a single substation (complete model). Lines and connectivity for multiple substations are not in scope at this time.

Interfaces

The primary interface in view for this use case is the system interaction shown in Figure 2-1, Step 8, the interface between Substation/Protection Engineering and the 61850 System Configurator. The file exchanged is an SSD file.

As shown in Figure 2-1, Substation Engineering processing starts with accessing the NMMR to receive the correct as-built model with the correct planning projects added to it as a CIM-PLAN/XML file (information exchange 6). This version of the network model contains actual line parameters, such as impedance values, length, cable characteristics, geometries, line right of way, ratings, etc needed by engineering. Similar parameters are also provided for transformers along with availability and capacity requirements. The substation engineer then, in the process of designing the substation layout and specifying primary equipment, instantiates the existing network model received from the NMMR with new breakers, switches, and bus extensions and assigns names to the lines, transformers, and other equipment. Once the specification of the new network extensions are completed, the system specifications and associated one-line diagrams are exported to the NMMR as a completed CIMPLAN/ XML file (information exchange 7).

The system specification produced by Substation Engineering comprises a single line diagram with an attachment of 61850 LNodes to parts and equipment in the single line diagram to indicate the needed substation automation functionality, such as measurements, data related to a switch controller, and breaker data. The individual phase LNodes are modeled as SubEquipment elements in the SSD. The goal is to reuse the network model from planning (thus avoiding re-entry of this data) and adding to it the LNodes and other 61850 substation model classes.

Once the SCL-SSD file is produced, it is passed to Protection Engineering (information exchange 8) where the additional protection equipment is added to produce a complete SCL-SSD file for the 61850 System Configurator (information exchange 9).

The interface is described in the 61850 standards (see Reference 4) as follows:

"Data exchange from a system specification tool to the system configurator. This file describes the single line diagram and functions of the substation and the required logical nodes. It shall contain a substation description section and may contain the needed data type templates and logical node type definitions. If logical nodes allocated to the Substation section are not already allocated to an IED, the IED name reference (value of iedName attribute of the LNode element) shall be None. If an LN in the substation section is not bound to an IED and also has no logical node type defined, then only the mandatory part of this LN according to IEC 61850-7-4 is specified. If part of the SA system is already known, this might optionally be contained in IED and Communication sections. This is an SSD file."

Data Elements

The specific data elements included in this information exchange include those elements as defined for the Substation Section of the SCL. This is typically what is included in the SSD type file. Appendix A contains the detailed listing of required data elements for this interface.

Use Case 2 – Update EMS Network Model from Imported 61850 SCL File

This use case is to update an EMS load flow model with updated field data imported from a Substation Configuration Database as an SCL-SCD file. This would demonstrate how field changes made by a SS engineer to a 61850-configured SS could be used to automatically update a load flow model without having to re-enter the data manually. This use case would validate that all the necessary harmonization has been done to permit 61850 configuration data to be used to update CIM models.

With the use of SCL offline or the ACSI directory services online, the online properties of each IEC61850 server device can be discovered and used to populate a database in the NMMR. Any changes in the field (i.e., new installations, revisions to existing installations, removal of field equipment, etc.) can be discovered automatically as the changes are made, rather than requiring a separate manual data entry at the control center.

The original intent of SCL was to describe IED configurations and communications systems defined in the 61850-5 and -7xx standards. The main purpose is to allow the exchange of IED and communication system configuration data between an IED configuration tool and a system configuration tool from different vendors. Files created using SCL are also used to transfer the IEC configuration data from the IED configuration tool to IEDs in the switchyard.

So the challenge is to determine if the SCL file can also be used to update an EMS model

Scope

There is some question about whether this needs to be a complete SCD file with all the possible subsections including Substation, IED, Communications, and DataTemplates. The purpose of this interaction is to provide field updates to the NMMR that would be used by planning, operations, and Substation/Protection Engineering.

Interfaces

The interface in view for this use case is defined in Figure 2-1, Step 18 above, the interface between the Substation Configuration Database and the NMMR. The file exchanged is an SCL-SCD file. The assumption is that this needs to be a complete SCD file with all the possible subsections including Substation, IED, Communications, and DataTemplates.

Data Elements

The specific data elements included in this information exchange include those elements as defined for the Substation Section of the SCL (the same as for use case 1) with the addition of the IED, Communications, and DataTemplates subsections. Appendix A contains the detailed listing of required data elements for this interface.

Use Case 3 – SCADA Data Import from 61850 Devices

[TBD]

3 MODEL SEMANTIC UNIFICATION

In order to unify the 61850 and CIM models, the use cases described in the previous chapter were used to identify the interfaces where harmonized information needs to be exchanged. These use cases also give an indication as to what type of information needs to be exchanged. From the CIM perspective, the use cases identify which parts of the CIM need to be supported, leading to the definition of a 61850 Profile Group, similar to the Planning and CPSM profile groups. From the 61850 perspective, the objects that are to be included in the 61850 Profile are based upon what is needed to support the use cases and what is required to create a well formed SSD or SCD SCL file.

The following sections are intended to show from both the CIM and 61850 perspective which objects from their particular domain are being utilized. Table 3-1 provides a few definitions to assist the reader in understanding 61850 terminology and the implied functionality.

Table 3-1
61850 Definitions

Function	Task Performed By An Automation System
LNClass	See Logical Node Class
Logical Node Class	Smallest part of a function that can exchange data. A Logical Node Class (LNClass) represents the automation function. A LNClass is an abstract object defined by its data and methods within the appropriate standards.
Logical Node Instance	Smallest part of a function that exchanges data. A Logical Node Instance (LNInst) represents the function within a specific IED; it performs some operations for that function.
LNInst	See Logical Node Instance
Logical Node (LN)	Smallest part of a function that exchanges data. A Logical Node (LN) represents the function within a physical device; it performs some operations for that function. An LN is an object defined by its data and methods. Logical nodes related to primary equipment are not the primary equipment itself but its intelligent part or image in the secondary system, i.e. local or remote I/Os, intelligent sensors and actuators, etc.

CIM Perspective

Table 3-2 shows which CIM Classes are supported in the Planning and/or CPSM profile groups. There is a column indicating if those classes are to be included within the unified/harmonized profile based upon the use cases. Additionally, there is a Definition column indicating which page the class definition can be found. Within each class definition section, there is the proposed mechanism for allowing the objects to be conveyed within SCL files. The table is "sparse" and blanks indicate that the objects are not included in the specific profile. Whereas a value of "Y" indicates that the object is included within the profile.

Table 3-2
CIM Classes to be Supported in the Unified Model

CIM Class	Supported in Profile Group			Definition (page)
	Planning	CPSM	Unified	
Accumulator		Y	Y	
AccumulatorValue		Y	Y	
ACLineSegment	Y	Y	Y	See page 4-4
ActivePowerLimit		Y		
Analog		Y	Y	
AnalogLimit	Y			
AnalogValue		Y	Y	
ApparentPowerLimit		Y		
BaseVoltage	Y	Y	Y	See page 4-4
Bay		Y	Y	See page 4-6
Breaker		Y	Y	
BusbarSection		Y	Y	
Company	Y			
ConformLoad		Y		
ConformLoadGroup		Y		
ConformLoadSchedule		Y		
ConnectivityNode	Y	Y	Y	See page 4-8
ControlArea		Y		
ControlAreaGeneratingUnit		Y		
CurrentLimit		Y		
CurveData		Y		
DayType		Y		
Disconnector		Y	Y	See page 4-9
Discrete		Y	Y	
DiscreteValue		Y	Y	
EnergyConsumer	Y	Y	Y	See page 4-9
EquipmentRating	Y			
EquivalentBranch		Y		
EquivalentInjection		Y		
EquivalentNetwork		Y		
EquivalentShunt		Y		
FossilFuel		Y		
GeneratingUnit	Y	Y	Y	See page 4-12
GeographicalRegion		Y		
GrossToNetActivePowerCurve		Y		
HydroGeneratingUnit		Y		
HydroPump		Y		

Table 3-2 (continued)
CIM Classes to be Supported in the Unified Model

CIM Class	Supported in Profile Group			Definition (page)
	Planning	CPSM	Unified	
IEC61970CIMVersion		Y		
ImpedanceVariationCurve		Y		
Line		Y		
LoadArea		Y		
LoadBreakSwitch		Y	Y	See page 4-14
LoadResponseCharacteristic		Y		
LossFactor	Y			
MeasurementValueSource		Y		
MutualCoupling	Y	Y		
NonConformLoad		Y		
NonConformLoadGroup		Y		
NonConformLoadSchedule		Y		
NuclearGeneratingUnit		Y		
OperationalLimitSet		Y		
OperationalLimitType		Y		
Ownership	Y			
PhaseTapChanger		Y	Y	See page 4-19
PhaseVariationCurve		Y		
PlanningArea	Y			
PlanningZone	Y			
PowerTransformer	Y	Y	Y	See page 4-15
RatioTapChanger		Y	Y	See page 4-19
RatioVariationCurve		Y		
ReactiveCapabilityCurve		Y		
RegularTimePoint	Y			
RegularTimePoint		Y		
RegulatingControl		Y		
RegulationSchedule	Y			
RegulationSchedule		Y		
Season		Y		
SeriesCompensator	Y	Y	Y	See page 4-17
ShuntCompensator	Y	Y	Y	See page 4-18
StaticVarCompensator		Y	Y	See page 4-18
StationSupply		Y		
SubGeographicalRegion		Y		
SubLoadArea		Y		
Substation		Y	Y	

Table 3-2 (continued)
CIM Classes to be Supported in the Unified Model

CIM Class	Supported in Profile Group			Definition (page)
	Planning	CPSM	Unified	
SVPowerFlow		Y		
SVShuntCompensatorSections		Y		
SvTapStep		Y		
Switch		Y	Y	See page 4-19
SwitchedShunt	Y			
SwitchSchedule		Y		
SynchronousMachine	Y	Y	Y	See page 4-19
TapChanger	Y	Y	Y	See page 4-19
TapSchedule		Y		
Terminal	Y	Y	Y	See page 4-20
ThermalGeneratingUnit		Y		
TieFlow		Y		
TopologicalIsland		Y		
TopologicalNode		Y		
TransformerWinding	Y	Y	Y	See page 4-21
TransformerWinding		Y	Y	
Unit	Y			
Unit		Y		
VoltageLevel	Y			See page 4-21
VoltageLimit				
WindGeneratingUnit		Y	Y	

61850 Perspective

The classes needed in the unified UML model and 61850 profile are identified by analysis of the SCL XML schema, since there is no existing UML model for all objects and properties in 61850.

As shown in Figure 3-1, a normal SCD SCL file has the following sections:

- Substation
- Communication
- IED
- DataTypeTemplates

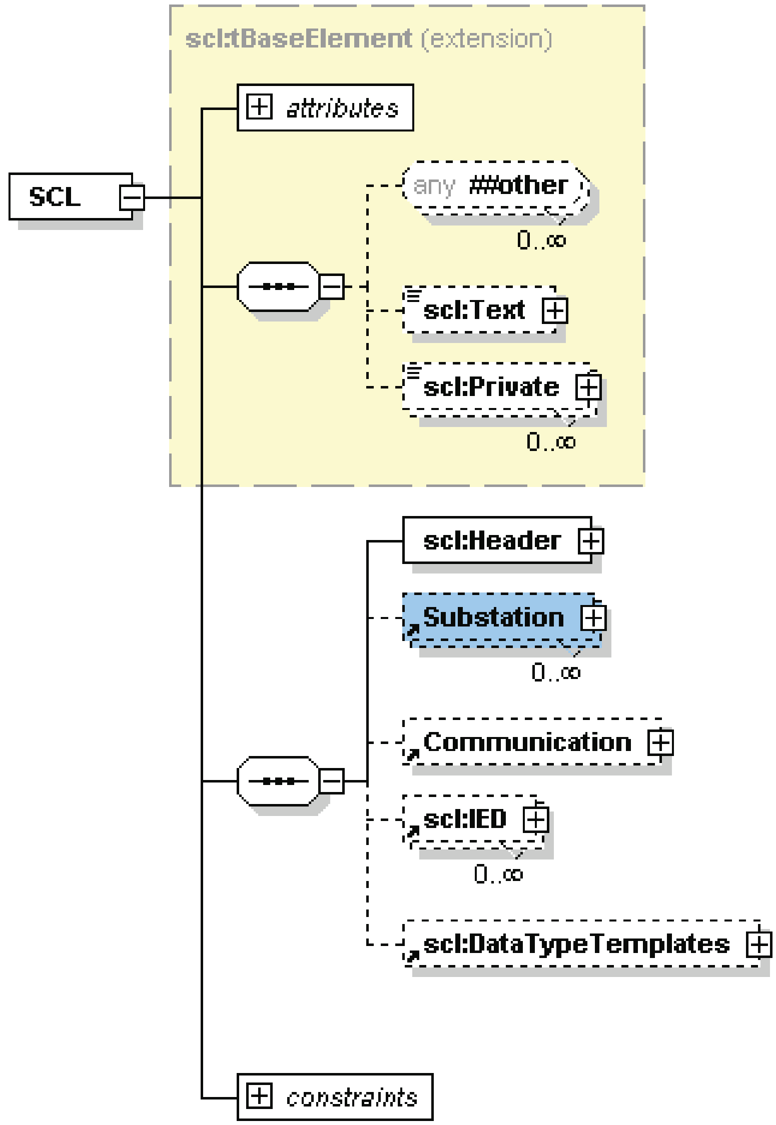


Figure 3-1
Structure of SCL File

Figure 3-1 shows that there may be many Substation sections within a single SCL. In IEC 61850-6, a SCL file that contains the definition of a single substation is a Substation Configuration Definition (SCD) file.

There is a single Communication section in either a SSD or SCD file. However, it is typical that a Communication section must be present in an SCD file where as it is optional in an SSD file.

There may be multiple IED sections in either of the SSD or SCD files.

There is a single DataTypeTemplate section in either file.

Substation

The purpose for the substation SCL can be found in IEC 61850-6:

> *The purpose of the Substation model is to relate a logical node and its function to a substation function (substation part or equipment or subequipment) in order to derive a functional designation for the logical node from the substation structure.*

Relating Logical Nodes to Equipment

Figure 3-2 taken from IEC 61850-6 depicts a simplified model for IEC 61850. The figure shows that functions are associated to substation equipment. What the diagram does not accurately depict is that there is a separation of the specification of a function (e.g. a LNClass) and a runtime/field deployment/instance of that function (e.g. LNode). The support of both of these constructs is needed within the unified model.

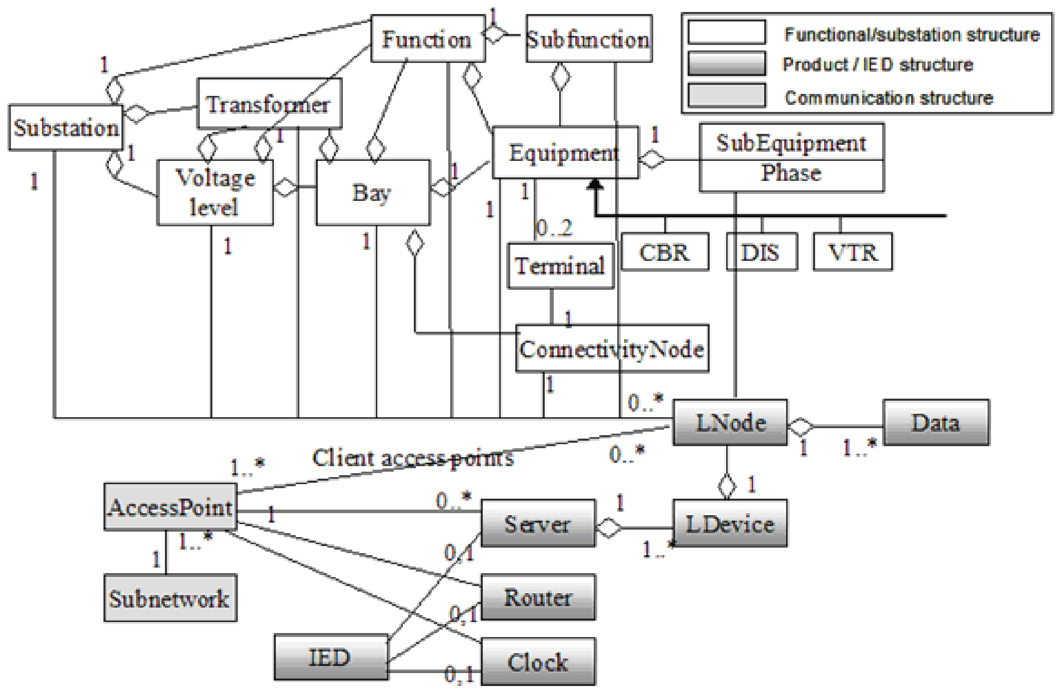


Figure 3-2
Simplified 61850 UML Model

The use cases allow for Functions to be defined as part of the initial SSD sent to the substation engineering configuration system. This allows the planning/protection engineers to specify/request what functions need to be located within a substation.

Based upon this information and the actual implementation of the substation, LNode(s) and the other relevant SCL parts can be added.

However, the CIM does not have the concept of Functions, and this modeling construct needs to be added within the harmonized model. The specific proposal for providing this within UML can be found in the This chapter describes the proposed changes to create a unified UML model which would support both the CIM and 61850 standards. As mentioned previously, this unified model brings us one step closer to having a single semantic model used as the basis for information exchange between systems included in the NIST Smart Grid Interoperability Framework. Specifically it addresses the need to have a single semantic model for information exchanges between CIM-based systems and 61850 field devices.

Ths approach to creating this unified model was to start with the combined 61968/70 CIM UML model which already provides a common semantic model for both the transmission system interfaces (i.e., 61970 standards) and distribution system interfaces (i.e., 61968 standards) and extend it to include support for the 61850 standards, specifically the objects defined in 61850-6 Substation Configuration Languange (SCL). The scope of the proposed changes is to deal with information to be exchanged over the interfaces identified in the use case interfaces defined in Chapter 2 above. However, in the process of dealing with these interfaces, almost all of the objects modeled in SCL have been included.

The complete proposed UML model that includes these recommendations is available in a separate file as an Enterprise Architect .eap model file. Enterprise Architect is the software UML tool used by the IEC and CIM User Group to manage and maintain the CIM UML model.

The following sections address specific modeling issues that arise in harmonizing CIM and 61850 models in UML and recommend solutions, which include both reuse of the existing CIM UML as well as extensions to the CIM UML model,

Relating Logical Nodes to PowerSystemResources section in Chapter 6.

Deriving Logical Nodes from Substation Structure

Figure 3-2 also shows that SCL provides for the definition of the substation topology and connectivity (e.g. very similar to the CIM CPSM profile). To that end, SCL has lists of Equipment and ConductingEquipment that are used to support the creation of substation one-line diagrams.

Table 2-1 shows the list of equipment types defined in IEC 61850-6. The table shows which equipment is to be included as part of the harmonization profile and information exchange as well as where to find their definition and mapping information.

Table 3-3
61850 Equipment Types

Abbreviation	Name	Include in Unified Profile	Definition
AXN	Auxiliary Network		
BAT	Battery	Y	See page 4-5
BSH	Bushing		
CAB	Power cable	Y	See Junction on page 4-13
CAP	Capacitor bank	Y	See page 4-7
CBR	Circuit Breaker	Y	See Breaker on page 4-6
CON	Converter	Y	See RectifierInverter on page 4-16
CTR	Current Transformer	Y	
DIS	Disconnector or earthing switch	Y	See Disconnector on page 4-9
EFN	Earth Fault Neutralizer (Peterson coil)	Y	See Peterson Coil on page 4-14
FAN	Fan	Y	See page 4-10
GEN	Generator	Y	See GeneratingUnit on page 4-11
GIL	Gas Insulated Line	Y	See page 4-10
IFL	Infeeding line; substation limiting object; models a possibly infeeding power network line outside the substation at the single line border		
LIN	Power overhead line or line segment.	Y	See ACLineSegment on page 4-4
LTC	Load Tap Changer	Y	See TapChanger on page 4-19
MOT	Motor	Y	See page 4-14
PSH	Power Shunt	Y	See Shunt Compensator on page 4-18
PTR	Power Transformer	Y	See PowerTransformer on page 4-15
PTW	Power Transformer Winding	Y	See TransformerWinding on page 4-21
REA	Reactor	Y	See page 4-15
RES	Neutral resistor	Y	See Resistor on page 4-16
RRC	Rotating reactive component	Y	See page 4-16

Table 3-3 (continued)
61850 Equipment Types

Abbreviation	Name	Include in Unified Profile	Definition
SAR	Surge arrestor	Y	See page 4-18
SCR	Semiconductor controlled rectifier	Y	See page 4-17
SMC	Synchronous Machine	Y	See page 4-19
TCF	Thyristor controlled frequency converter	Y	See page 4-20
TCR	Thyristor controlled reactive component	Y	See Static Var Compensator on page 4-18
VTR	Voltage Transformer	Y	See page 4-21

4 SUBSTATION RELATED PROFILE MEMBERS

One of the largest issues in matching up semantics is the lack of the ConductingEquipment definitions in 61850-6. One of the activities needed in order to complete harmonization is the full reconciliation of mismatches between 61850 and CIM. In order to accomplish this reconciliation, the intended semantics must be documented within 61850. After the intended semantics are documented, reconciliation of the definitions and appropriate mappings need to occur between CIM and 61850. During this process IEC TC57 WG19 should be involved to evolve a set of definitions that would be utilized throughout TC57.

Since those activities are in the future, the following is a set of recommended semantics and mappings to be used. Since 61850 does not have definitions and therefore CIM , IEC, or IEEE definitions will be used when possible. In general, this section attempts to recommend the best overall definition that provides a definition that is applicable to all of the domains (e.g. CIM and IEC 61850). .

Recommended CIM 61850 Semantic Reconcilation

The following section attempt to correlate and select terminology definitions that are used within the context of the harmonization effort. The surveys include extracting definitions from the IEC Glossary, CIM UML (i.e., Class documentation from UML model), IEEE Dictionary, and the 61850 standards. Table 4-1 lists the possible sources of a definition and the recommended definition to use. This table shows that 61850 does not provide any authoritative definitions for the terms used within the SCL Susbation section/XSD.

Table 4-1
Proposed Eqipment Definitions to Resolve Semantic Differences Between CIM and 61850

Term	IEC	CIM	IEEE	61850	Recommended Definition
ACLineSegment		Y			CIM
AsynchronousMachine	Y		Y		CIM
BaseVoltage		Y			CIM
Battery	Y		Y		CIM
Bay	Y	Y			CIM
Breaker	Y	Y	Y		CIM
BusbarSection	Y	Y			CIM
CurrentTransformer	Y	Y	Y		IEEE
ConductingEquipment		Y			CIM
Conductor	Y	Y	Y		IEEE
ConnectivityNode	Y	Y			CIM
Connector	Y	Y	Y		IEEE
Disconnector	Y	Y	Y		IEEE
EnergyConsumer		Y			CIM
EquipmentContainer		Y			CIM
Fan	Y				IEC
Fuse	Y	Y	Y		IEEE
Gas Insulated Line	Y				
GeneratingUnit		Y			CIM
Ground	Y	Y	Y		IEEE
GroundDisconnector		Y			CIM
HeatExchanger	Y	Y	Y		IEEE
Jumper	Y	Y	Y		IEEE
Junction	Y	Y			CIM
Line	Y	Y			CIM
Load	Y	Y	Y		IEEE
LoadBreakSwitch		Y			CIM
Motor	Y		Y		IEEE
Peterson Coil			Y		IEEE
PotentialTransformer (a.k.a. VT).	Y	Y	Y		CIM
PowerTransformer	Y	Y	Y		CIM
ProtectionEquipment	Y	Y			CIM
Reactor	Y		Y		CIM
RectifierInverter		Y			CIM
RegulatingConductingEq		Y			CIM

Table 4-1 (continued)
Proposed Eqipment Definitions to Resolve Semantic Differences Between CIM and 61850

Term	IEC	CIM	IEEE	61850	Recommended Definition
Resistor	Y	Y	Y		CIM
Rotating Reactive Component					
RectifierInverter		Y			CIM
Semiconductor Controlled Rectifier			Y		IEEE [1]
SynchronousMachine	Y	Y	Y		CIM
Substation	Y	Y	Y		IEEE
Surge Arrestor	Y		Y		IEEE
Switch	Y	Y	Y		CIM
TapChanger	Y	Y	Y		CIM
Terminal	Y	Y	Y		CIM
Thyrisor controlled frequency converter					
Thyristor controlled reactive component					
Transformer Winding		Y			CIM
Voltage Level	Y	Y			CIM
Series Compensator		Y			CIM
Shunt Compensator		Y			CIM
Static Var Compensator		Y			CIM

It is following recommendations are also proposed:

- For those terms that have no authoritative definition, that definitions be created within the auspices of IEC TC57.
- For those terms that are not defined within the IEEE dictionary, IEC TC57 should consider submitting those definitions.
- For those IEEE definitions that are being proposed to be adopted, it is suggested that the appropriate IEC standards reflect those definitions.
- IEC 61850 needs to have a set of definitions documented or IEC TC57 needs to create a common semantic set of terms as a standard.

The following subsections compare the available definitions, document a proposed recommended definition, and discuss how to provide the necessary mapping/changes in UML to accomplish a harmonized/unified model. Note: N/A following a source indicates there is no definition available from that source (e.g., IEC: N/A)

[1] 61850 should update its abbreviation to reflect the IEEE definition.

ACLineSegment

- IEC: N/A
- CIM: A wire or combination of wires, with consistent electrical characteristics, building a single electrical system, used to carry alternating current between points in the power system.
- IEEE: N/A
- Recommended definition: CIM
- Recommended mapping: It is recommended that a CIM ACLineSegment be mapped to a 61850 Line (e.g. LIN).

AsynchronousMachine

- IEC: An alternating current machine in which the speed on load and the frequency of the system to which it is connected are not in a constant ratio.
- CIM: N/A
- IEEE: A machine in which the speed of operation is not proportional to the frequency of the system to which it is connected.

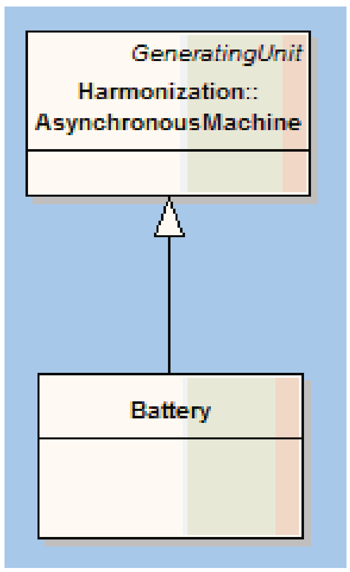


Figure 4-1
Recommended UML for AsynchronousMachine and Battery

- Recommended definition: IEEE
- Recommended mapping: It is recommended that this class be added as shown in Figure 4-1 in order to support the 61850 Battery object.

BaseVoltage

- IEC: N/A
- CIM: Collection of BaseVoltages which is used to verify that the BusbarSection.BaseVoltage and other voltage attributes in the CIM are given a value existing in the collection.
- IEEE: N/A
- Recommended definition: CIM
- Recommended mapping: Based upon the recommendations found in the Element Identification section of this document on page 5-84, the mapping of CIM BaseVoltage would be to an instance of tVoltage within SCL.

Additionally, the units of BaseVoltage are not specified. Therefore, either the naming rule or an association to an instance of Unit needs to occur. It is recommended that the naming convention be used.

Battery

- IEC: One or more cells fitted with devices necessary for use, for example case, terminals, marking and protective devices.
- CIM: N/A
- IEEE: Two or more cells electrically connected for producing electric energy.
- Recommended definition: IEEE
- Recommended mapping: It is recommended that unified model be extended to support the Battery object. In order to accomplish this, it is recommended to use the Dynamics package AsynchronousMachine class The 61850 Battery object would be a sub-type of the AsynchronousMachine class. However, the Dynamics package needs to change since it currently models AsynchronousMachines as RotatingMachines and not all such equipment actually rotate.

Figure 4-2 below shows the recommended change to the existing UML model, which is that Dynamics:

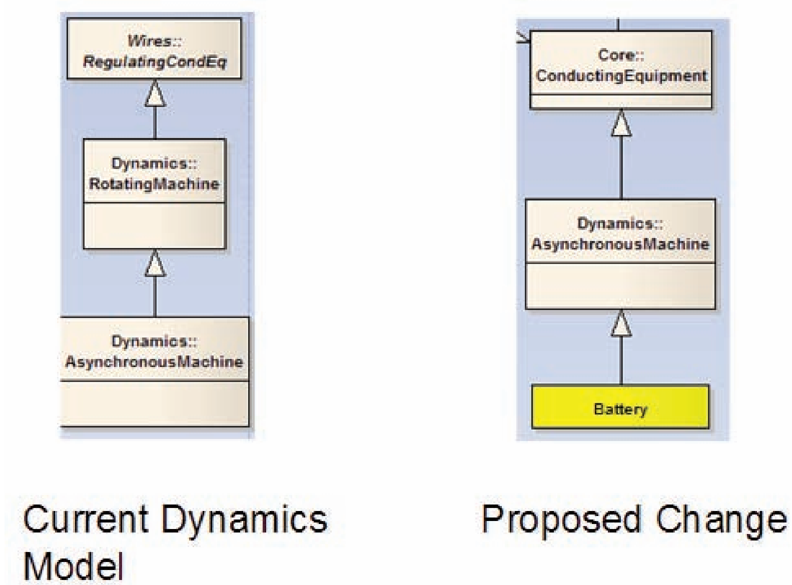


Figure 4-2
Proposed UML to add Battery

AsynchronousMachine class should become a generalization of ConductingEquipment (e.g. instead of RotatingMachine) and that a Battery class be added as a specialization of AsynchrounousMachine.

Bay

- IEC: The part of a substation within which the switchgear and control-gear relating to a given circuit is contained. (NOTE – According to the type of circuit, a substation may include: feeder bays, transformer bays, bus coupler bays, etc.).
- CIM: A collection of power system resources (within a given substation) including conducting equipment, protection relays, measurements, and telemetry.
- IEC-61850: a substation consists of closely connected sub parts with some common functionality. Examples are the switchgear between an incoming or outgoing line, and the busbar, the bus coupler with its circuit breaker and related isolators and earthing switches, the transformer with its related switchgear between the two busbars representing the two voltage levels. The bay concept may be applied to 1½ breaker and ring bus substation arrangements by grouping the primary circuit breakers and associated equipment into a virtual bay. These bays comprise a power system subset to be protected, for example a transformer or a line end, and the control of its switchgear that has some common restrictions such as mutual interlocking or welldefined operation sequences. The identification of such subparts is important for maintenance purposes (what parts may be switched off at the same time with minimum impact on the rest of the substation) or for extension plans (what has to be added if a new line is to be linked in). These subparts are called 'bays' and may be managed by devices with the generic name 'bay controller' and have protection systems called 'bay protection'
- IEEE:
- Recommended definition: CIM
- Recommended mapping: An instance of CIM Bay should be mapped to a 61850 SCL instance of tBay.

Breaker

- IEC: A mechanical switching device, capable of making, carrying and breaking currents under normal circuit conditions and also making, carrying for a specified time and breaking currents under specified abnormal circuit conditions such as those of short circuit.
- CIM: A collection of power system resources (within a given substation) including conducting equipment, protection relays, measurements, and telemetry.
- IEEE: A device that connects and disconnects power circuits, with fault-interrupting capability
- Recommended definition: IEEE
- Recommended mapping: A CIM Breaker should be mapped to a 61850 ConductingEquipment of Type CBR.

BusbarSection

- IEC: The part of a busbar located between two switching devices (or disconnector(s) put in series or between a switching device and the end of the busbar.
- CIM: A conductor, or group of conductors, with negligible impedance, that serve to connect other conducting equipment within a single substation.
- IEEE: N/A
- Recommended definition: CIM
- Recommended mapping: It is recommended that a SCL ConductingEquipment Type be added to represent BusBarSection. It is recommended that the enumerated type be BBS.

CapcitorBank

- CIM: N/A
- IEEE: N/A
- Recommended definition:
- Recommended mapping: It is recommended to add a new class in order to support the 61850 CapacitorBank object (e.g. CAP).   It is recommended that a 61850 primary equipment of CapacitorBank (e.g. CAP) class be made a sub-type of the 61850 Reactor class. This makes a CapicitorBank a sub-type of the CIM RegulatingConductingEquipment.

CompositeSwitch

- IEC: N/A
- CIM: A model of a set of individual Switches normally enclosed within the same cabinet and possibly with interlocks that restrict the combination of switch positions. These are typically found in medium voltage distribution networks.
- A CompositeSwitch could represent a Ring-Main-Unit (RMU), or pad-mounted switchgear, with primitive internal devices such as an internal bus-bar plus 3 or 4 internal switches each of which may individually be open or closed. A CompositeSwitch and a set of contained Switches can also be used to represent a multi-position switch e.g. a switch that can connect a circuit to Ground, Open or Busbar.
- IEEE: N/A
- Recommended definition: CIM
- Recommended mapping: None
- It is recommended that CompositeSwitches be outside of the scope of the harmonized profile. It is recommended that only individual switches, and sub-classes, of switches be used within the profile. In past use cases, the issue of opening/closing a composite switch was not detailed. To operate a CompositeSwitch (e.g. Open or Close) the actual internal switches need to be know and controlled.
- In order to perform the control function, the existing association between CompositeSwitch and Switch is included in the profile.

ConductingEquipment

- IEC: N/A
- CIM: The parts of the power system that are designed to carry current or that are conductively connected therewith. ConductingEquipment is contained within an EquipmentContainer that may be a Substation, or a VoltageLevel or a Bay within a Substation.
- IEEE: N/A
- Recommended definition: CIM
- Recommended mapping: The CIM Class of ConductingEquipment does not need to be concretely mapped since it is not typically instantiated although its sub-classes are instantiated. As such, it needs to be included in the harmonized profile, and should be considered to be equivalent to the 61850 ConductingEquipment construct.

Conductor

- IEC: A medium in which a time-varying electric field produces an electric current density the component vector of which in a given direction has a magnitude large compared with that of the component vector of the displacement current density in this direction, in a particular frequency band.
- CIM: Combination of conducting material with consistent electrical characteristics, building a single electrical system, used to carry current between points in the power system.
- IEEE: A wire or combination of wires stranded together not insulated from one another, suit-

able for carrying an electric current. However, it may be bare or insulated.

- Recommended definition: IEEE
- Recommended mapping: It is recommended that an enumeration of "CND" be added to the ConductingEquipment types within 61850.

ConnectivityNode

- IEC: An identifiable, named, common connection point between terminals of primary devices whose only function is to connect them electrically with minimum resistance; for example a bus bar as a connectivity node connects bus bar disconnectors. The connection to a device is done at a device terminal. A connectivity node can connect an arbitrary number of terminals (devices).
- CIM: Connectivity nodes are points where terminals of conducting equipment are connected together with zero impedance.
- IEEE: N/A
- Recommended definition:
- Recommended mapping: The recommended mapping depends on the implementation of the SCL changes detailed in the Element Identification, on page 5-84, section of this document. This change allows both the Terminal and ConnectivityNode to contain persistent IDs (e.g. rdf:IDs) and still allows for the "pathname" attribute to be utilized within the SCL file to associate between the two entities.
- Based upon the recommended change, a CIM ConnectivityNode can be mapped to a 61850 ConnectivityNode whose "grounded" attribute has a "false" value (see the discussion regarding Ground on page 4-43).

Connector

- IEC: A component which terminates conductors for the purpose of providing connection and disconnection to a suitable mating component.
- CIM: A conductor, or group of conductors, with negligible impedance, that serve to connect other conducting equipment within a single substation and are modeled with a single logical terminal.
- IEEE: A current-carrying mechanical device used to join two or more conductors or a conductor to conductor hardware.
- Recommended definition: IEEE
- Recommended mapping: It is recommended that a CON type be added to the ConductingEquipement enumeration and that this be used for the purposes of mapping.

Current Transformer

- IEC: An instrument transformer in which the secondary current, in normal conditions of use, is substantially proportional to the primary current and differs in phase from it by an angle which is approximately zero for an appropriate direction of the connections.
- CIM: Instrument transformer used to measure electrical qualities of the circuit that is being protected and/or monitored. Typically used as current transducer for the purpose of metering or protection. A typical secondary current rating would be 5A.
- IEEE: An instrument transformer intended to have its primary winding connected in series with the conductor carrying the current to be measured or controlled. [From IEEE Std 1159-1995 IEEE Recommended Practice for Monitoring Electric Power Quality]
- Recommended definition: IEEE
- Recommended mapping: As shown in Figure 4-3, currently the CurrentTransformer class is a generalization of Equipment. However, IEC 61850 explicitly models it as

ConductingEquipment so that the terminal relationships can be detailed. Therefore, it is recommended that the inheritance of CurrentTransformer be changed from Equipment to ConductingEquipment. The same recommendation applies to PotentialTransformer.

Disconnector

- IEC: A mechanical switching device which provides, in the open position, an isolating distance in accordance with specified requirements (NOTE – A disconnector is capable of opening and closing a circuit when either negligible current is broken or made, or when no significant change in the voltage across the terminals of each of the poles of the disconnector occurs. It is also capable of carrying currents under normal circuit conditions and carrying for a specified time currents under abnormal conditions such as those of short circuit).
- CIM: A manually operated or motor operated mechanical switching device used for changing the connections in a circuit, or for isolating a circuit or equipment from a source of power. It is required to open or close circuits when negligible current is broken or made.

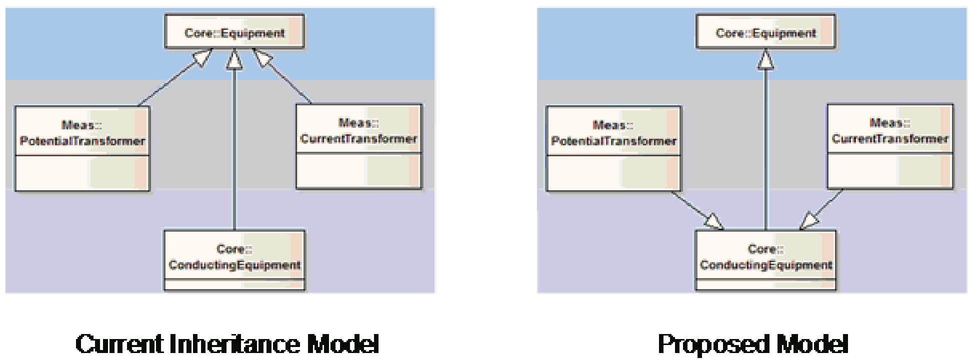


Figure 4-3
Proposed Inheritance Change for CTs and PTs

- IEEE: A mechanical switching device used for changing the connections in a circuit, or for isolating a circuit or equipment from the source of power.
- Recommended definition: IEEE
- Recommended mapping: A general solution for mapping sub-classes of the CIM Switch class can be found on page 4-63. Based upon the methodology proposed in that section, the mapping of a CIM Disconnector would be to a type DIS of a SCL Switch.

EnergyConsumer

- IEC: N/A
- CIM: Generic user of energy - a point of consumption on the power system model
- IEEE: N/A
- Recommended definition: CIM
- Recommended mapping:
  It is suggested that a rework of the CIM and SCL schemas is needed in order to differentiate between loads and conducting equipment. Within 61850 SCL there are several types of conducting equipment (e.g. fans and motors) that really represent loads. See the Modeling of Loads section on page 4-69 to see the specific proposal.
  Based upon the acceptance of the modeling of loads, it is suggested that an EnergyConsumer be mapped to an SCL Load of type EnergyConsumer. If the suggestion for modeling

loads is not accepted, then it would be suggested that an EnergyConsumer type be added to the SCL enumeration for ConductingEquipment.

EquipmentContainer

- IEC: N/A
- CIM: A modeling construct to provide a root class for all Equipment classes
- IEEE: N/A
- Recommended definition: CIM
- Recommended mapping: Although both CIM and 61850 SCL has the concept of EquipmentContainer(s), the alignment is not 100%. This alignment needs to be corrected and is detailed on page 5-75.

Fan

- IEC: A machine designed to increase the pressure or kinetic energy of cooling air for a motor, transformer, etc.
- CIM: N/A
- IEEE: N/A
- Recommended definition:
- Recommended mapping: See Modeling of Loads on page 4-69. Besides the recommendation regarding the modeling of loads, it is also recommended that 61850 change the non-load (e.g. Equipment enumeration of FAN) to be another enumerated value. It is suggested that the new value be FANA indicating a fan asset. The Asset version of FAN is not in scope of the proposed unification profile based upon the current use cases.

Fuse

- IEC: A device that by the fusing of one or more of its specially designed and proportioned components, opens the circuit in which it is inserted by breaking the current when this exceeds a given value for a sufficient time. The fuse comprises all the parts that form the complete device.
- CIM: An overcurrent protective device with a circuit opening fusible part that is heated and severed by the passage of overcurrent through it. A fuse is considered a switching device because it breaks current.
- IEEE: A device that protects a circuit by melting open its current-carrying element when an overcurrent or short-circuit current passes through it.
- Recommended definition: IEEE
- Recommended mapping: A general solution for mapping sub-classes of the CIM Switch class can be found on page 4-63. Based upon the methodology proposed in that section, the mapping of a CIM Fuse would be to a type FUSE of a SCL Switch.

Gas Insulated Line

- IEC: An electric line whose conductors are contained in a enclosure and insulated with a compressed gas.
- CIM: N/A
- IEEE: N/A
- Recommended definition:
- Recommended mapping: As shown in Figure 4-4, it is recommended that an attribute be added to the CIM Conductor class to represent the insulation type of a conductor. The attribute values would be based upon an enumeration consisting of at least the values of Air and Gas. This would permit a 61850 Gas Insulated Line to be mapped to a CIM ACLineSegment whose InsulationType value is equal to “Gas”.

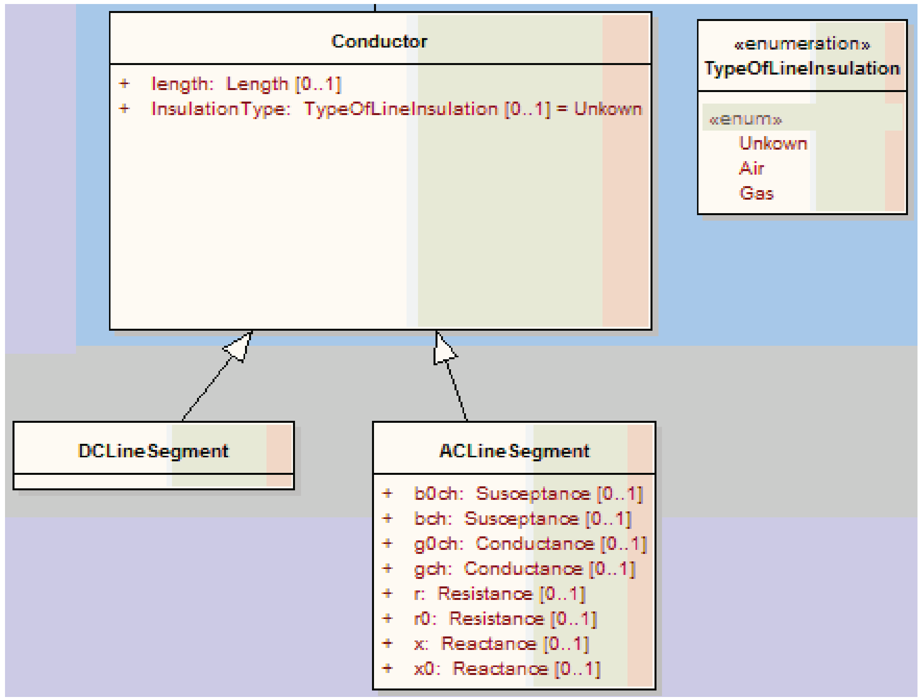


Figure 4-4
Recommended Model Changes to Support Gas Insulated Lines

GeneratingUnit

- IEC: N/A
- CIM: A single or set of synchronous machines for converting mechanical power into alternating-current power. For example, individual machines within a set may be defined for scheduling purposes while a single control signal is derived for the set. In this case there would be a GeneratingUnit for each member of the set and an additional GeneratingUnit corresponding to the set.
- IEEE: N/A
- Recommended definition: CIM
- Recommended mapping: It is recommended to add a GEN type to the SCL tPredefined-GeneralEquipmentEnum for the purposes of this mapping. However, within CIM there is also a need to associate one or more SynchronousMachines to a GeneratingUnit instance.

Ground

- IEC: A flat conductive surface whose potential is used as a common reference.
- CIM: A common point for connecting grounded conducting equipment such as shunt capacitors. The power system model can have more than one ground.
- IEEE: The single point at which an ac power system has its common or neutral terminal connected to the power system ground reference.
- Recommended definition: IEEE
- Recommended mapping: Currently 61850 does not have an object that represents Ground in a normative XSD manner. The text of 61850 specifies that Ground should be a reserved name for a ConnectivityNode that is grounded. However, it is suggested that the XSD of the tConnectivityNode be enhanced to allow this information to be conveyed without using a pre-defined name. The following is the existing XSD:

```
<xs:complexType name="tConnectivityNode">
        <xs:complexContent>
                <xs:extension base="tLNodeContainer">
                        <xs:attribute name="pathName" type="tRef" use="required"/>
                </xs:extension>
        </xs:complexContent>
</xs:complexType>
```

It is recommended that a new attribute "grounded" be added to SCL. The resulting XSD would look like the following:

```
<xs:complexType name="tConnectivityNode">
    <xs:complexContent>
            <xs:extension base="tLNodeContainer">
                <xs:attribute name="pathName" type="tRef" use="required"/>
                <xs:attribute name="grounded"  type="xs:boolean" use="optional" default="false"/>
            </xs:extension>

        </xs:complexContent>
</xs:complexType>
```

In this example, the attribute "grounded" with a default value of FALSE indicates that the ConnectivityNode is not grounded.

Based upon this recommended change, a CIM Ground Class would map to an instance of a 61850 ConnectivityNode that has the grounded attribute set to "true".

GroundDisconnector

- IEC: N/A
- CIM: A manually operated or motor operated mechanical switching device used for isolating a circuit or equipment from Ground.
- IEEE: N/A
- Recommended definition: CIM
- Recommended mapping: A general solution for mapping sub-classes of the CIM Switch class can be found on page 4-63. Based upon the methodology proposed in that section, the mapping of a CIM GroundDisconnector would be to a type GNDDIS of a SCL Switch.

HeatExchanger

- IEC: A component intended to transfer heat from one coolant to another while keeping the two coolants separate.
- CIM: Equipment for the cooling of electrical equipment and the extraction of heat.
- There are two ways to view the utilization of a HeatExchanger. One is as an electrical load. The other would be an Asset that is located in the substation, but having no electrical load. Since the HeatExchanger is Associated to only PowerTransformer, within CIM, it is clear that this is not an electrical load usage, but rather an Asset utilization.
- IEEE: An oil-to-air, or oil-to-water, heat exchanging device attached to an oil-filled transformer for the purpose of exchanging heat from the transformer oil to the ambient media, typically requiring pumps for oil circulation and fans for circulation of the ambient air across the heat exchanging surfaces.
- Recommended definition: IEEE
- Recommended mapping: It is recommended to exclude HeatExchanger from the profile since there is no electrical load characteristics.

Jumper

- IEC: A short length of conductor, not under mechanical tension, making an electrical connection between two separate sections of a line.
- CIM: A manually operated or motor operated mechanical switching device used for isolating a circuit or equipment from Ground.
- IEEE: A conductive tool used to maintain electrical continuity across equipment, or a conductor that shall be opened mechanically to enable various operations of live-line work to be performed.
- Recommended definition: IEEE
- Recommended mapping: A general solution for mapping sub-classes of the CIM Switch class can be found on page 4-63. Based upon the methodology proposed in that section, the mapping of a CIM GroundDisconnector would be to a type JMP of a SCL Switch.

Junction

- IEC: A connection between two or more conductor ends.
- CIM: A point where one or more conducting equipments are connected with zero resistance.
- IEEE: N/A
- Recommended definition: CIM
- Recommended mapping: It is recommended to map the CIM Junction class to the CAB type of SCL ConductingEquipment.

Line

- IEC: A device connecting two points for the purpose of conveying electromagnetic energy between them.
- CIM: A component part of a system extending between adjacent substations or from a substation to an adjacent interconnection point.
- IEEE: N/A
- Recommended definition: CIM
- Recommended mapping: No specific mapping is required for the use case(s) under discussion. However, for future use in Distribution, please see the discussion regarding Other Types of Equipment Containers on page 4-61.

Load

- IEC: A device intended to absorb power supplied by another device or an electric power system.
- CIM: A generic equivalent for an energy consumer on a transmission or distribution voltage level. It may be under load management and also has cold load pick up characteristics.
- IEEE: A device to which power (watts) is delivered or consumed. [From IEEE Std C37.106™-2003 IEEE Guide for Abnormal Frequency Protection for Power Generating Plants]
- Recommended definition: IEEE
- Recommended mapping: This is an abstract class that is being added to clarify the model constructs. Note: There is a Load class defined in a normative section of IEC 61968 and this will need to be reconciled as well.

LoadBreakSwitch

- IEC: N/A
- CIM: A mechanical switching device capable of making, carrying, and breaking currents under normal operating conditions.
- IEEE: N/A
- Recommended definition: CIM
- Recommended mapping: A general solution for mapping sub-classes of the CIM Switch class can be found on page 4-63. Based upon the methodology proposed in that section, the mapping of a CIM GroundDisconnector would be to a type LBS of a SCL Switch.

Motor

- IEC: A machine which converts electrical energy into mechanical energy.
- CIM: N/A
- IEEE: A rotating machine that converts electrical energy into mechanical energy. As used in this recommended practice, the term can also be used to mean a generator.
- Recommended definition: IEEE
- Recommended mapping: See Modeling of Loads on page 4-69. Besides the recommendation regarding the modeling of loads, it is also recommended that 61850 change the non-load (e.g. Equipment enumeration of MOT) to be another enumerated value. It is suggested that the new value be MOTA indicating a motor asset. The Asset version of FAN is not in scope of the proposed unification profile based upon the current use cases.

Peterson Coil

- IEC: N/A
- CIM: N/A
- IEEE: A tunable reactor used for impedance grounding a distribution or transmission system that is usually tuned to the resonance of the system.
- Recommended definition: IEEE

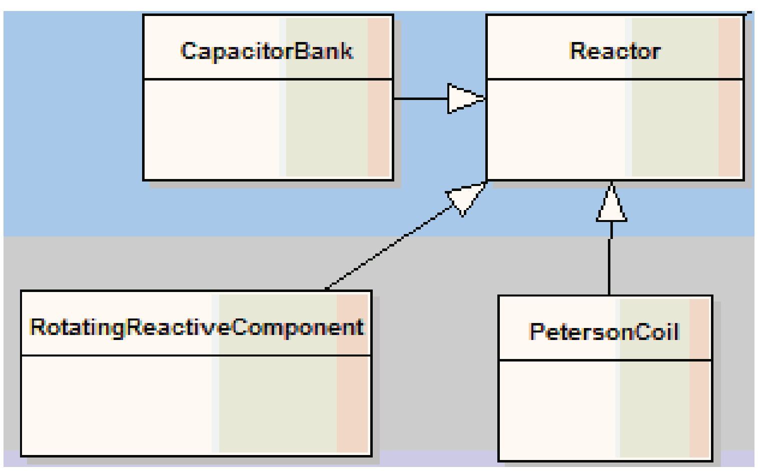


Figure 4-5
Recommended UML Modification to Support Peterson Coils

- Recommended mapping: As shown in Figure 4-5, the recommended proposal is to add a new class representing Rotating Reactive Components (RRC) modeled as sub-type of the Reactor Class. This proposed UML allows the 61850 EFN to be mapped to the Peterson Coil class.

However, there are two additional options that should be closely evaluated:

1. It is also possible that the added Reactor class could have an attribute indicating the type of Reactor (e.g. rotating ,non-rotating, peterson coil, etc..) and thereby removing the need for an addition PetersonCoil class in the model.
2. The design principle of 61850 that most LogicalNodes should have a corresponding primary equipment could be changed. Such a change would allow a 61850 EFN to be removed from SCL and a 61850 Reactor (REA) could be used instead.

PowerTransformer

- IEC: A static piece of apparatus with two or more windings which, by electromagnetic induction, transforms a system of alternating voltage and current into another system of voltage and current usually of different values and at the same frequency for the purpose of transmitting electrical power.
- CIM: An electrical device consisting of two or more coupled windings, with or without a magnetic core, for introducing mutual coupling between electric circuits. Transformers can be used to control voltage and phase shift (active power flow).
- IEEE: A transformer that transfers electric energy in any part of the circuit between the generator and the distribution primary circuits.
- Recommended definition: IEEE
- Recommended mapping: The CIM PowerTransformer class should be mapped to the Type PTR or the SCL PowerTransformer.

ProtectionEquipment

- IEC: Equipment incorporating one or more protection relays and, if necessary, logic elements intended to perform one or more specified protection functions.
- CIM: An electrical device designed to respond to input conditions in a prescribed manner and after specified conditions are met to cause contact operation or similar abrupt change in associated electric control circuits, or simply to display the detected condition. Protection equipment is associated with conducting equipment and usually operate circuit breakers.
- IEEE: N/A
- Recommended definition: CIM
- Recommended mapping: It is recommended to map the CIM ProtecttionEquipment class to the 61850 tPredefinedGeneralEquipmentEnum using a Type of PROT. However, it is not required for the current use case(s).

Reactor

- IEC: A device used because of its inductance.
- CIM: N/A
- IEEE: A device with the primary purpose of introducing reactance into an electric circuit for purposes such as motor starting, paralleling transformers, and control of current.
- Recommended definition: IEEE
- Recommended mapping: It is recommended to add a class of Reactor to the unified UML that can be used to represent the 61850 Reactor (REA). This class should be a sub-type of the CIM RegulatingConductingEq class.

RectifierInverter

- IEC: N/A
- CIM: Bi-directional AC-DC conversion equipment that can be used to control DC current, DC voltage, DC power flow, or firing angle.
- IEEE: N/A
- Recommended definition: CIM
- Recommended mapping: It is recommended that 61850 add a ConductingEquipment type of RINV to provide the 1:1 mapping capability.

RegulatingConductingEq

- IEC: N/A
- CIM: RegulatingCondEq is a type of ConductingEquipment that can regulate Measurements and have a RegulationSchedule.
- IEEE: N/A
- Recommended definition: CIM
- Recommended mapping: It is recommended that CIM mark the RegulatingConductingEq class as being Abstract and that the profile only allow instance of the sub-classes of it. As such, it can be included in the profile, but no mapping to 61850 is required. However, mapping of its sub-classes will be required.

Resistor

- IEC: A two-terminal device characterized essentially by its resistance.
- CIM: Resistor, typically used in filter configurations or as earthing resistor for transformers. Used for electrical model of distribution networks.
- IEEE: A device with the primary purpose of introducing resistance into an electric circuit. (A resistor as used in electric circuits for purposes of operation, protection, or control, commonly consists of an aggregation of units. Resistors, as commonly supplied, consist of wire, metal, ribbon, cast metal, or carbon compounds supported by or embedded in an insulating medium. The insulating medium may enclose and support the resistance material as in the case of the porcelain tube type, or the insulation may be provided only at the points of support, as in the case of heavy duty ribbon or cast iron grids mounted in metal frames.
- Recommended definition: CIM
- Recommended mapping: It is recommended that the 61850 RES object be mapped to the CIM Resistor class.

RectifierInverter

- IEC: N/A
- CIM: Bi-directional AC-DC conversion equipment that can be used to control DC current, DC voltage, DC power flow, or firing angle.
- IEEE: N/A
- Recommended definition: CIM
- Recommended mapping: It is recommended that an enumeration of "RECTINVERT" be added to the ConductingEquipment types within 61850. Additionally, it is recommended that CIM change the definition of the DataType OperatingMode (currently just a string) to be a concretely specified enumeration.

Rotating Reactive Component

- IEC: N/A
- CIM: N/A
- IEEE: N/A

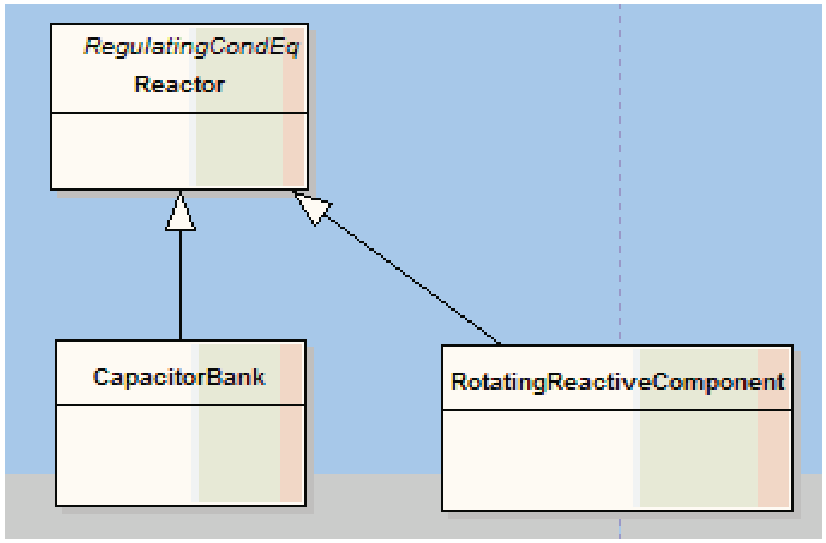


Figure 4-6
Recommended UML Modification to Support Rotating Reactive Components

- Recommended definition: N/A
- Recommended mapping: It is recommended to extend the unified model as shown in Figure 4-6 to include a class representing Rotating Reactive Components (RRC). This class should be a sub-type of the Reactor Class.

However, there are two additional options that should be closely evaluated:

1. It is also possible that the added Reactor class could have an attribute indicating the type of Reactor (e.g. rotating or non-rotating), thereby removing the need for an addition RotatingReactiveComponent class in the model.
2. The design principle of 61850 that most LogicalNodes should have a corresponding primary equipment could be changed. Such a change would allow a 61850 RRC to be removed from SCL and a 61850 Reactor (REA) could be used instead.

Semiconductor Controlled Rectifier

- IEC: N/A
- CIM: N/A
- 61850: None
- IEEE: Silicon controlled rectifier
- Recommended definition: IEEE
- Recommended mapping: It is recommended that a sub-type of the CIM RectifierInverter class be added to allow the mapping of the 61850 SCR Object.

Series Compensator

- IEC: N/A
- CIM: For a series capacitor or reactor, this is the physical asset performing the SeriesCompensator role (PSR).
- IEEE: N/A
- Recommended definition: CIM
- Recommended mapping: It is recommended to add a type of SCMP to the tPredefinedCommonConductingEquipmentEnum enumeration to allow the mapping to occur.

Shunt Compensator

- IEC: N/A
- CIM: A shunt capacitor or reactor or switchable bank of shunt capacitors or reactors. A section of a shunt compensator is an individual capacitor or reactor. A negative value for reactivePerSection indicates that the compensator is a reactor. ShuntCompensator is a single terminal device. Ground is implied.
- IEEE: N/A
- Recommended definition: CIM
- Recommended mapping: It is recommended that the CIM ShuntCompensator be mapped to the IEC 61850 PSH type.

Static Var Compensator

- IEC: N/A
- CIM: A facility for providing variable and controllable shunt reactive power. The SVC typically consists of a stepdown transformer, filter, thyristor-controlled reactor, and thyristor-switched capacitor arms.
- The SVC may operate in fixed MVar output mode or in voltage control mode. When in voltage control mode, the output of the SVC will be proportional to the deviation of voltage at the controlled bus from the voltage setpoint. The SVC characteristic slope defines the proportion. If the voltage at the controlled bus is equal to the voltage setpoint, the SVC MVar output is zero.
- IEEE: N/A
- Recommended definition: CIM
- Recommended mapping: It is recommended that the CIM Static Var Compensator be mapped to the 61850 Thyristor Controlled Reactor (TCR) object.

Substation

- IEC: A part of an electrical system, con-fined to a given area, mainly including ends of transmission or distribution lines, electrical switchgear and controlgear, buildings and transformers. A substation generally includes safety or control devices (for example protection).
- NOTE – The substation can be qualified according to the designation of the system of which it forms a part. Examples: transmission, substation (transmission system), distribution substation, 400 kV or 20 kV substation.
- CIM: A collection of equipment for purposes other than generation or utilization, through which electric energy in bulk is passed for the purposes of switching or modifying its characteristics.
- IEEE: An assemblage of equipment for purposes other than generation or utilization, through which electric energy in bulk is passed for the purpose of switching or modifying its characteristics (definition excerpted from ANSI/IEEE 100-1988).
- Recommended definition: IEEE
- Recommended mapping: It is recommended that a CIM substation be mapped to the SCL Element Substation.

Surge Arrestor

- IEC: A device intended to protect the electrical apparatus from high transient overvoltages and to limit the duration and frequently the amplitude of the follow-on current.
- CIM: N/A
- IEEE: A protective device for limiting surge voltages on equipment by discharging or bypassing surge current; it prevents continued flow of follow current to ground, and is capable of

repeating these functions as specified.

- Recommended definition: IEEE
- Recommended mapping: It is recommended to add a sub-type of RegulatingConductingEq called SurgeArrest to allow a 1:1 mapping to the 61850 SAR object.

Switch

- IEC: A device for changing the electric connections among its terminals.
- CIM: A generic device designed to close, or open, or both, one or more electric circuits.
- IEEE: A device designed to close or open, or both, one or more electric circuits.
- Recommended definition: IEEE
- Recommended mapping: A general solution for mapping sub-classes of the CIM Switch class can be found on page 4-63. Based upon the methodology proposed in that section, the mapping of a CIM Fuse would be to a type GEN (e.g. General) of a SCL Switch.

SynchronousMachine

- IEC: An alternating current machine in which the frequency of the generated voltages and the speed of the machine are in a constant ratio.
- CIM: An electromechanical device that operates synchronously with the network. It is a single machine operating either as a generator or synchronous condenser or pump.
- IEEE: "A machine in which the average speed of normal operation is exactly proportional to the frequency of the system to which it is connected." [From IEEE Std 45™-2002 IEEE Recommended Practice for Electrical Installations on Shipboard]
- Recommended definition: CIM
- Recommended mapping: A CIM class of SynchronousMachine should be mapped to a 61850 SMC object.

TapChanger, PhaseTapChanger, and RatioTapChanger

- IEC: Part of the converter unit control for controlling the converter transformer tap changers.
- CIM: Mechanism for changing transformer winding tap positions.
- IEEE: A selector switch device, which may include current interrupting contactors, used to change transformer taps with the transformer energized and carrying full load. [From Load Tap Changer]

```
<xs:complexType name="tTapChanger">
    <xs:complexContent>
        <xs:extension base="tPowerSystemResource">
            <xs:attribute name="type" type="xs:Name" use="required" fixed="LTC"/>
            <xs:attribute name="TypeOfLTC" type="tPredefinedLTCTypes"/>
            <xs:attributeGroup ref="agVirtual"/>
        </xs:extension>
    </xs:complexContent>
</xs:complexType>
```

```
<xs:simpleType name="tPredefinedLTCTypes">
    <xs:restriction base="xs:Name">
        <xs:enumeration value="General"/>
        <xs:enumeration value="PHASE"/>
        <xs:enumeration value="RATIO"/>
    </xs:restriction>
</xs:simpleType>
```

Figure 4-7
Suggested SCL Changes to Support CIM TapChanger Types

- Recommended definition: CIM
- Recommended mapping: The CIM TapChanger is a parent for both the PhaseTapChanger and RatioTypeChanger. Howerver, the current SCL definition only allows a single Tap-Changer type. Therefore, it is recommended to extend the SCL TapChanger definition to allow three different types of TapChangers (e.g. General, Phase, and Ratio).

In order to accomplish this, the XSD modifications shown in Figure 4-7 are suggested:

Terminal

- IEC: A point of interconnection of an electric circuit element, an electric circuit or a network with other electric circuit elements, electric circuits or networks.
- CIM: An electrical connection point to a piece of conducting equipment. Terminals are connected at physical connection points called “connectivity nodes”.
- IEEE: A connector for attaching a conductor to electrical apparatus.
- Recommended definition: CIM
- Recommended mapping: The recommended mapping depends on the implementation of the SCL changes detailed in the Element Identification, on page 5-84, section of this document. This change allows both the Terminal and ConnectivityNode to contain persistent IDs (e.g. rdf:IDs) and still allows for the “pathname” attribute to be utilized within the SCL file to associate between the two entities.
- Based upon the recommendations in Element Identification, it is also required that Bays be made optional due to the change in the SCL EquipmentContainership model being proposed. The resulting Terminal definition, in SCL would be:

```
<xs:complexType name="tTerminal">
        <xs:complexContent>
                <xs:extension base="tUnNaming">
                        <xs:attribute name="name" type="tAnyName" use="optional" default=""/>
                        <xs:attribute name="connectivityNode" type="tRef" use="required"/>
                        <xs:attribute name="substationName" type="tName" use="required"/>
                        <xs:attribute name="voltageLevelName" type="tName" use="required"/>
                        <xs:attribute name="bayName" type="tName" use="optional"/>
                        <xs:attribute name="cNodeName" type="tName" use="required"/>
                        <xs:attribute name="connectivityNodeRef" type="tRDFIDREF" use="optional"/>
                        <xs:attribute name="substationRef" type="tRDFIDREF" use="optional"/>
                        <xs:attribute name="voltageLevelRef" type="tRDFIDREF" use="optional"/>

                        <xs:attribute name="bayRef" type="tRDFIDREF" use="optional"/>
                </xs:extension>
        </xs:complexContent>
</xs:complexType>
```

Based upon the recommended change, a CIM Terminal can be mapped to a 61850 Terminal.

Thyristor controlled frequency converter

- IEC: N/A
- CIM: N/A
- IEEE: N/A
- Recommended definition: N/A
- Recommended mapping: It is recommended that a sub-type of the CIM FrequencyConverter class be added. This sub-class should be used for the mapping of the 61850 TCF objct.

TransformerWinding

- IEC: N/A
- CIM: An electrical connection point to a piece of conducting equipment. Terminals are connected at physical connection points called "connectivity nodes".
- IEEE: N/A
- Recommended definition: CIM
- Recommended mapping: It is recommended that a CIM TransformerWinding be mapped to an SCL PTW (e.g. the tTransformerWinding type).

VoltageLevel

- IEC: One of the nominal voltage values used in a given system.
- CIM: A collection of equipment at one common system voltage forming a switchgear. The equipment typically consist of breakers, busbars, instrumentation, control, regulation and protection devices as well as assemblies of all these.
- IEEE: N/A
- Recommended definition: CIM
- Recommended mapping: It is recommended that a CIM VoltageLevel be mapped to an SCL VoltageLevel.

Voltage/PotentialTransformer

- IEC: An instrument transformer in which the secondary voltage, in normal conditions of use, is substantially proportional to the primary voltage and differs in phase from it by an angle which is approximately zero for an appropriate direction of the connections.
- CIM: Instrument transformer (also known as Voltage Transformer) used to measure electrical qualities of the circuit that is being protected and/or monitored. Typically used as voltage transducer for the purpose of metering, protection, or sometimes auxiliary substation supply. A typical secondary voltage rating would be 120V.
- IEEE: An instrument transformer intended to have its primary winding connected in shunt with the voltage to be measured or controlled. [From IEEE Std C57.13-1993 IEEE Standard Requirements for Instrument Transformers]
- Recommended definition: CIM
- Recommended mapping: As shown in Figure 4-8, the present model of PotentialTransformer has it being a generalization of Equipment. However, IEC 61850 explicitly models it as

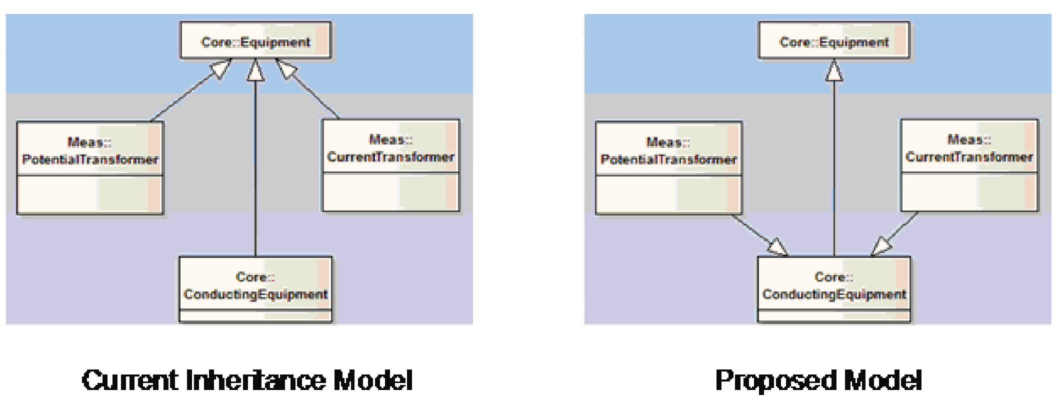


Figure 4-8
Proposed Inheritance Change for CTs and PTs

ConductingEquipment so that the terminal relationships can be detailed. Therefore, it is recommended to change the inheritance of CurrentTransformer from Equipment to ConductingEquipment.

- Note: The same recommendation applies for CurrentTransformer.

Other CIM 61850 Model Differences and Recommendations

There are a number of additional differences in the CIM and 61850 models that need to be addressed. This section describes these differences and offers recommendations for resolution.

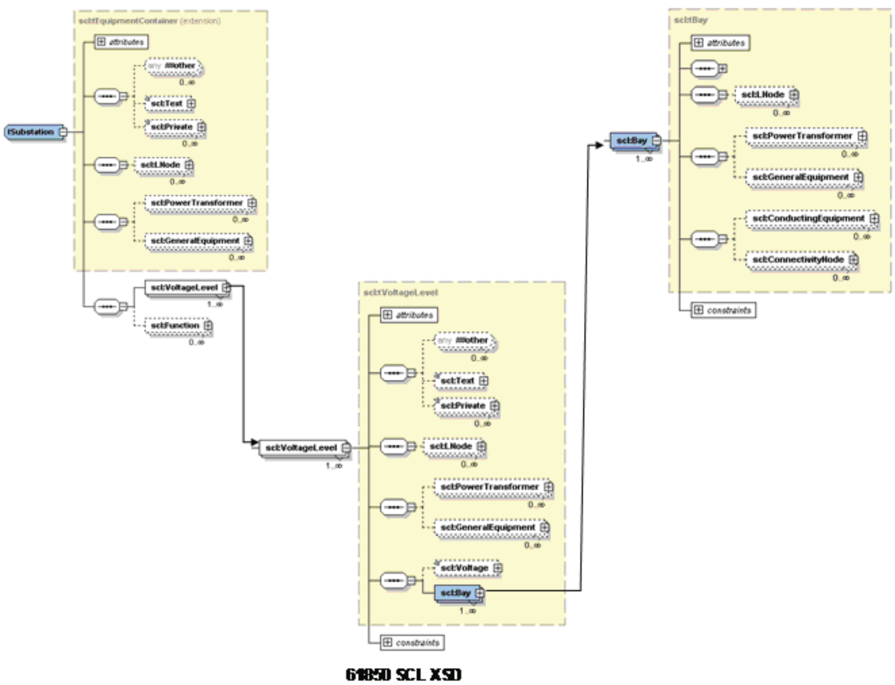


Figure 4-9
Current SCL Equipment Containership in SCL XSD

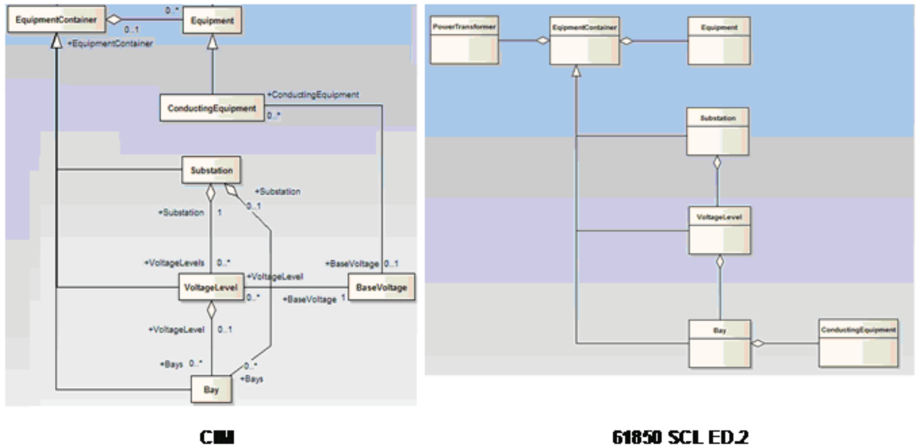


Figure 4-10
Comparison of CIM and 61850 Equipment Containership for Substations

Equipment Containership

The current 61850 XSD representation of equipment containership is shown in Figure 4-9. Figure 4-10 compares the equipment containership UML models for CIM and 61850.

It is noteworthy that 61850 does not allow ConductingEquipment at the VoltageLevel or Substation whereas CIM does allow this. In order to allow a planned model to be received and more detail added (e.g. by the System Configuration Tool), the CIM relationships need to be accommodated within SCL. In order to accomplish this, there are two changes needed to SCL:

1. The tEquipmentContainer needs to be extended to allow ConductingEquipment.
2. The Substation Element, in SCL, needs to extended to allow a Bay to allowed.

The proposed revisions to the SCL XSD are shown in Figure 4-11 below.

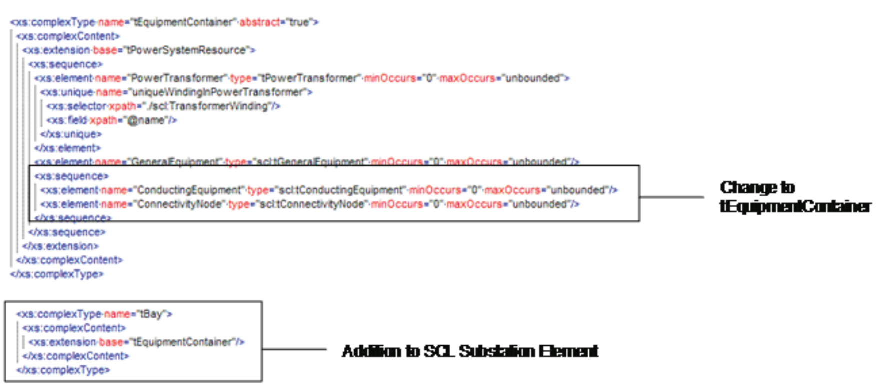


Figure 4-11
Proposed SCL Modifications to Correct Mismatch in Equipment Containership Models

The resulting SCL XSD is shown in Figure 4-12.

Other Types of Equipment Containers in the CIM

Originally, a CIM and 61850 Line were categories/classes of ConductingEquipment. However, CIM has changed Line from ConductingEquipment to a sub-class of EquipmentContainer. 61850 has not made such a change, although a 61850 LIN could be considered a Line Segment. It is suggested that SCL make such a change so that substations do not have to be modeled for Equipment/functions that

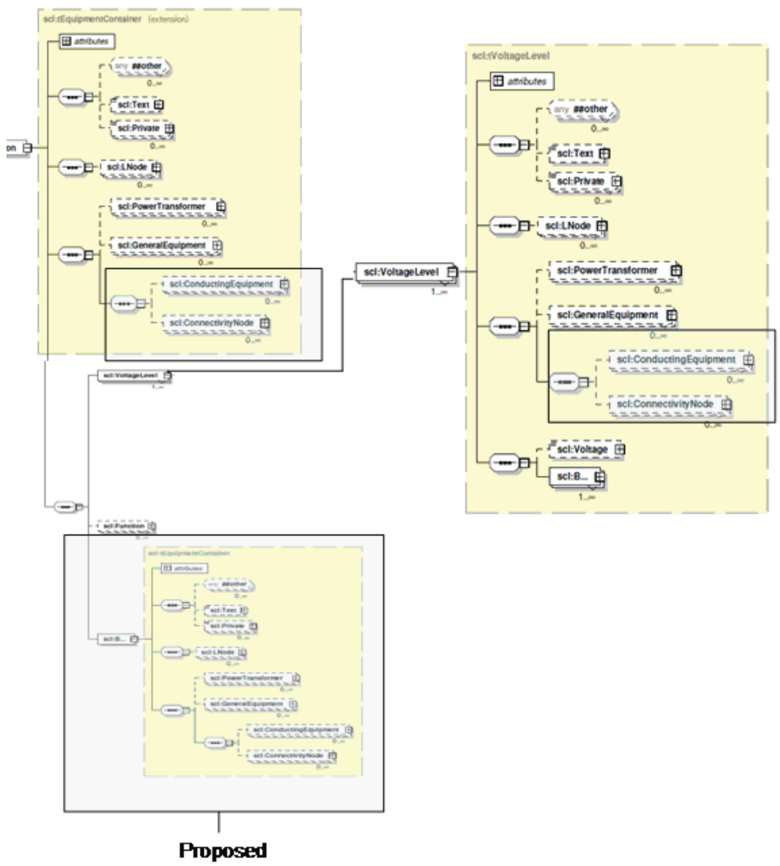


Figure 4-12
Graphical Representation of Containership changes for SCL

are on Transmission lines (e.g. outside a normal substation fence) or on distribution circuits (e.g. the new Circuit class).

In the future, more SCL Elements similar to substation will need to be added to embrace these new CIM EquipmentContainers containers. In order to accomplish this, the following Elements would need to be added:

<xs:element name="Line" type="tEquipmentContainer"/>

A similar element could be defined in order to represent Plants in SCL. However, in order to allow SCL Plants to align with the number and types of CIM plants, it is further recommended that a "typeOfPlant" parameter to be added. Additionally, Plants can contain other equipment containers. As an example, a WindPower Plant (e.g. Windfarm) can contain multiple WindTurbines (e.g. Generators). Based upon this analysis, it is recommended that a Plant element be added to SCL with something similar to the following declaration:

```
<xs:complexType name="tPlant">
    <xs:complexContent>
        <xs:extension base="tEquipmentContainer">
            <xs:sequence>
                <xs:element name="Substation" type="scl:tSubstation" minOccurs="0"
                    maxOccurs="unbounded"/>
<xs:element name="Generator" type="scl:tEquipmentContainer" minOccurs="0"
    maxOccurs="unbounded"/>
            </xs:sequence>
            <xs:attribute name="typeOfPlant" type="tPredefinedTypeOfPlantEnum"
            use="required"/>
        </xs:extension>
    </xs:complexContent>
</xs:complexType>

<xs:simpleType name="tPredefinedTypeOfPlantEnum">
    <xs:restriction base="xs:Name">
        <xs:enumeration value="unknown"/>
        <xs:enumeration value="HydroElectric"/>
        <xs:enumeration value="CHP"/>
        <xs:enumeration value="Windfarm"/>
        <xs:enumeration value="WindTurbine"/>
    </xs:restriction>
</xs:simpleType>
```

Note: The actual enumerated values will need further specification.

Table 4-2 shows which containers are to be included in the 61850 Profile.

Table 4-2
Equipment Containers to be Included in 61850 Profile

CIM	61850	In scope of profile
Line	Line	Y
Plant	Plant	
Bay	Bay	Y
VoltageLevel	VoltageLevel	Y
Substation	Substation	Y

Switches

There are several categories of CIM Switches (e.g. sub-classes of the CIM Switch class) that are not directly supported by 61850. In order to achieve the 1:1 correspondence required by the use case, additional enumerations need to be added to the 61850 SCL. Through the use of an XSD <xs:choice>, it is possible to create a Switch element within SCL (e.g. in a similar fashion to Load). Such a change will make determining the correspondence between SCL and CIM easier. Figure 4-13 shows how the modified SCL XSD would appear.

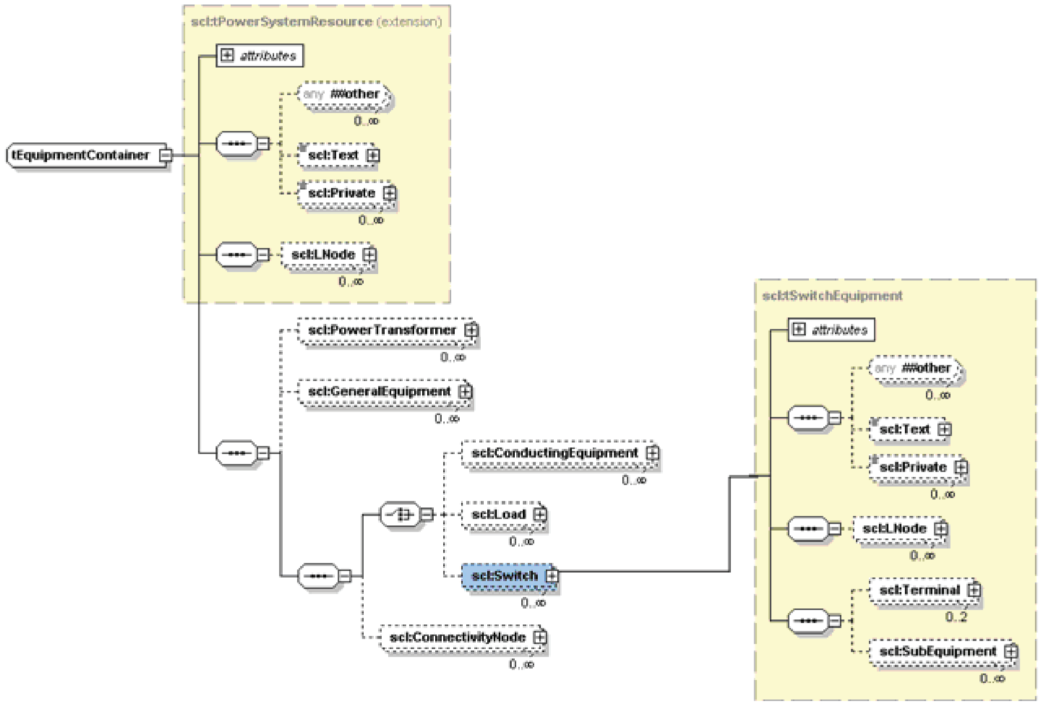


Figure 4-13
Proposed SCL Extension for Switches

The set of enumerated values for Switch should include at least the values shown in Table 4-3 below.

Table 4-3
Proposed Enumerated Values for Switches in SCL

Enumerated Value	Description
GEN	In some cases, CIM instantiates the abstract class of Switch. This value is reserved to allow mapping should such an instantiation occur. However, the CIM Switch class should be considered an abstract class and therefore should not be instanciated.
DIS	Disconnector
FUSE	Fuse
JMP	Jumper
GNDDIS	Grounded Disconnector
CBR	Breaker
LBS	Load Break Switch

Planning Elements

In order to satisfy the use cases, certain aspects of the CIM Planning Profile also need to be included within the scope of harmonization. The required additional element is BusNameMarker.. The inclusion of this element, and its relationship to ConnectivityNodes will allow a planned model to be exchanged, thus allowing the substation engineering process to add the appropriate equipment associations (e.g. through Terminals to ConnectivityNodes). This ability will enable (along with the other recommendations in this document) a completed connectivity model of a particular substation to be exchanged via an SCL file within the constraints of the unified model.

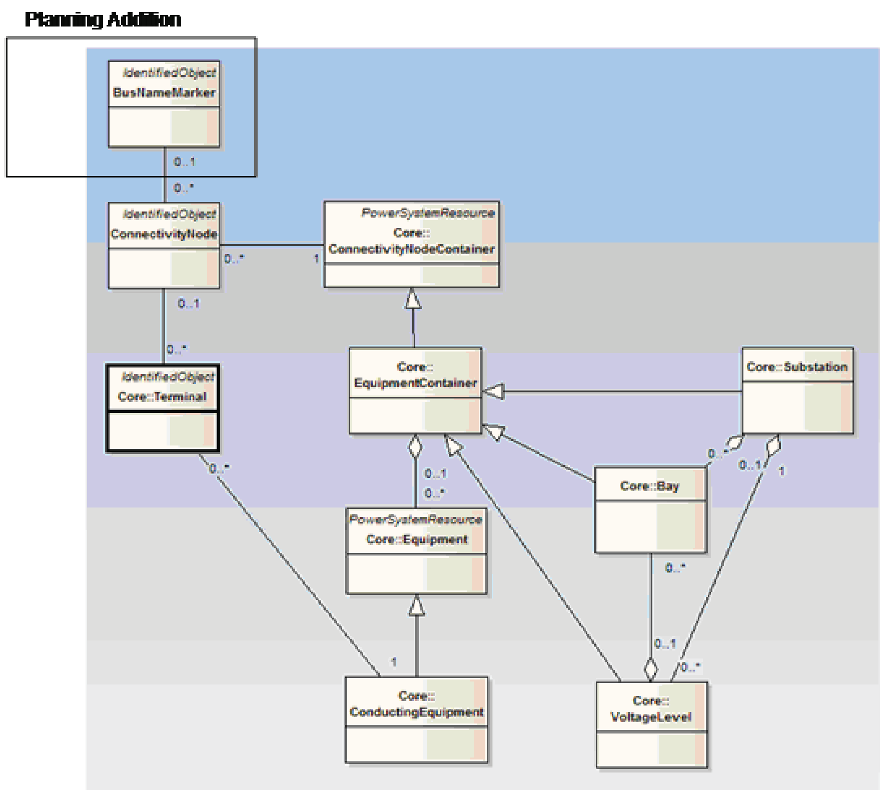


Figure 4-14
CIM Planning Model

Since 61850 was not designed with a planning model in mind, the concept of a "planned" model must be introduced into SCL. Additionally, there is no equivalent to BusNameMarker within SCL. In order to know how to extend SCL to support this, the existing CIM UML model is provided in Figure 4-14.

There are two possible approaches to add the planning information into SCL:

1. Add a planning section to SCL that allows the specification of instances of BusNameMarkers and their relationship to ConnectivityNodes that are specified in the Substation section.
2. Introduce the concept of a BusNameMarker within the Substation section.

It is recommended that a separate SCL section be added for the purposes of conveying the additional planning information. Such a section would be optional.

It is also recommended that a separate XSD be created for the Planning information. The proposed construction for this XSD is shown in Figure 4-15.

The text view of Figure 4-15 is shown below:

```
<xs:complexType name="tBusNameMarker">
    <xs:complexContent>
        <xs:extension base="tNaming">
            <xs:sequence>
                <xs:element ref="ConnectivityNode" type="tRDFIDREF"/>
```

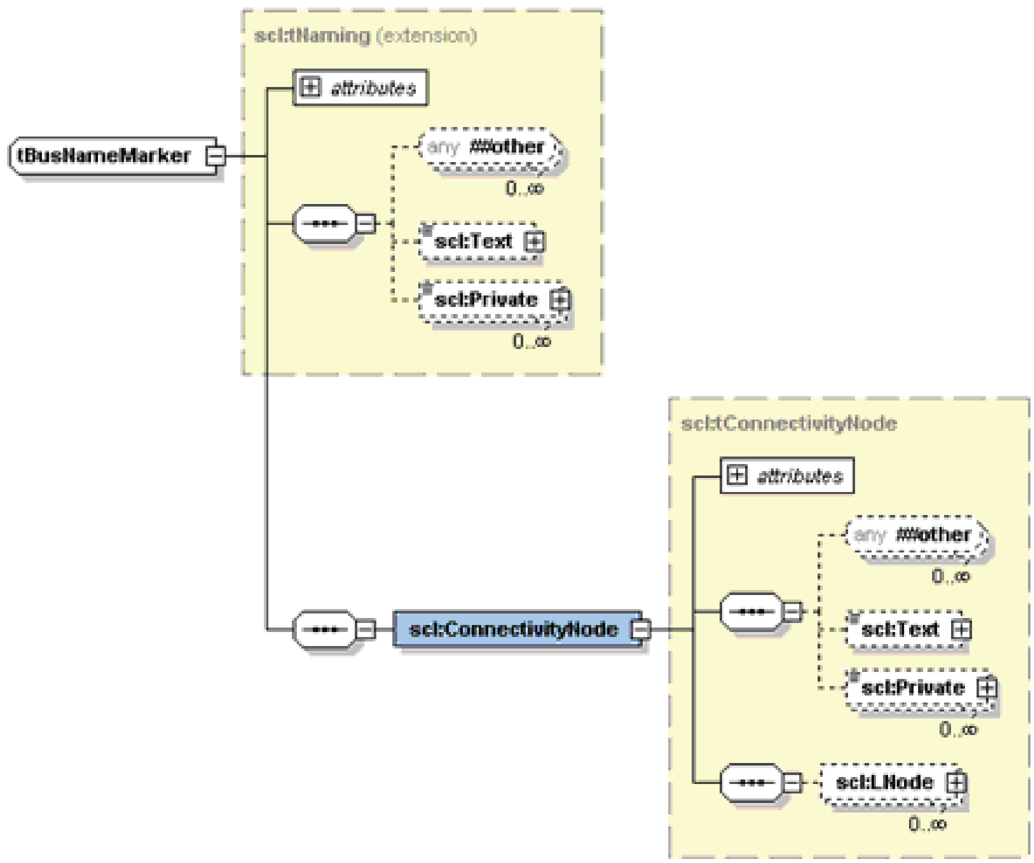


Figure 4-15
Proposed Planning Model Extension: Introduction of BusNameMarker

```
            </xs:sequence>
        </xs:extension>
    </xs:complexContent>
</xs:complexType>
```

The proposal for adding the Planning section to the SCL XSD is shown in Figure 4-16.

This extension to the SCL XSD will permit, through the normal Substation section, Planning and or Substation Engineering to specify what type of Functions (e.g. LNodes) need to be associated to a

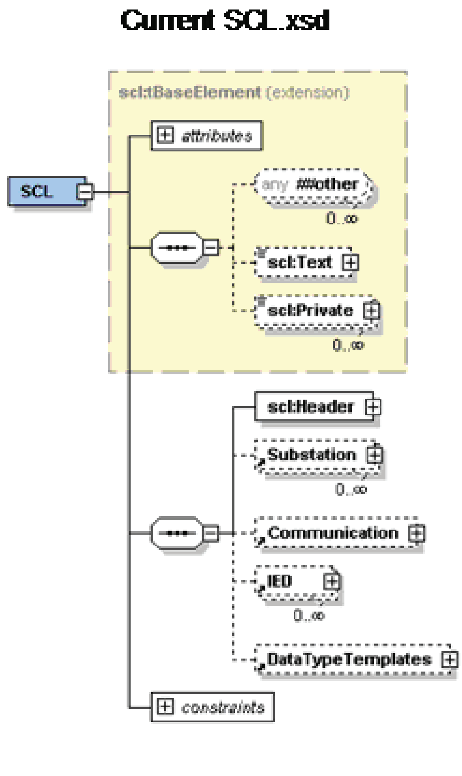


Figure 4-16
Addition of Planning Section to SCL XSD

particular ConnectivityNode, Terminal, or other substation equipment. In order to allow the linkage from the Planning section to the Substation section, the same ConnectivityNode needs to be duplicated in both sections (with the same name and id).

Modeling of Loads

The current model in the 61970 package of CIM does not model the concept of loads directly, nor does IEC 61850. However, there is a CIM Dynamics package under development that does. For purposes of clarity, it is recommended that the unified model explicitly model the concept of loads based upon the proposed Dynamics package.

Within the context of IEC 61850, there are two "loads" that need to be modeled. These are the primary equipment of Motor and Fan. Figure 4-17 shows the recommended approach of (1) mapping the 61850 Motor to the LoadMotor class defined in the Dynamics package and (2) creating a new Fan class as a sub-type of LoadMotor class.

In regards to the 61850 SCL, a similar change would be needed to differentiate Loads from ConductingEquipment. The Load concept would need to be added into the EquipmentContainer XSD production, and then the appropriate supplementing productions and enumerations would need to be provided, as shown in Figure 4-18.

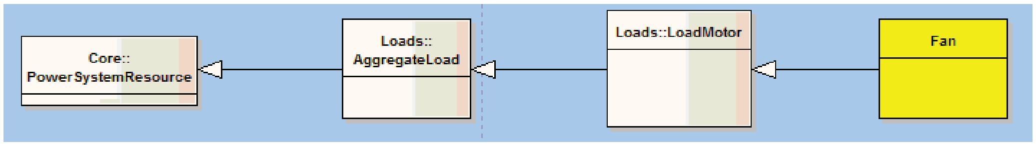


Figure 4-17
Proposed Modeling of IEC 61850 Motor and Fan

Figure 4-18 shows one possible solution to adding Load in an extensible fashion using a <xs:choice> that allows a choice of ConductingEquipment or Load. This option is recommended so that it will be possible to follow the sub-classing of CIM ConductingEquipment when needed (e.g. for Switches).

Summary of Unified Model Reconciliation Recommendations

In order to assist both CIM and 61850 experts understand the recommendations for harmonization, the following sections attempt to summarize the recommended changes and mappings from the perspective of each group indicating. As will be seen, changes to both the existing CIM UML model and the 61850 SCL are required to implement these recommendations.

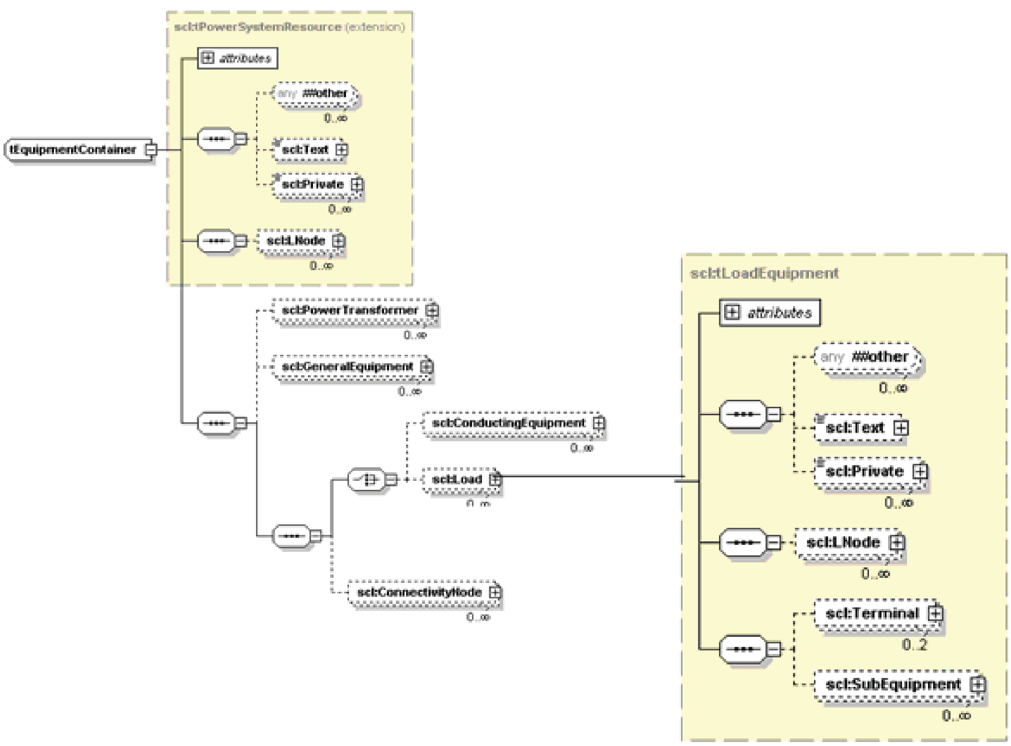


Figure 4-18
Proposal for Adding Loads to SCL

UML Changes

Figure 4-19 shows the inheritance hierarchy that contains the proposed class additions to the UML (shown in yellow). Besides the new classes added, an attribute was added to the Conductor class. The attribute InsulationType was added to allow the expression of the type of insulation used by the Conductor. A proposed enumeration was also added to support the values of this attribute (e.g. TypeOfLineInsulation).

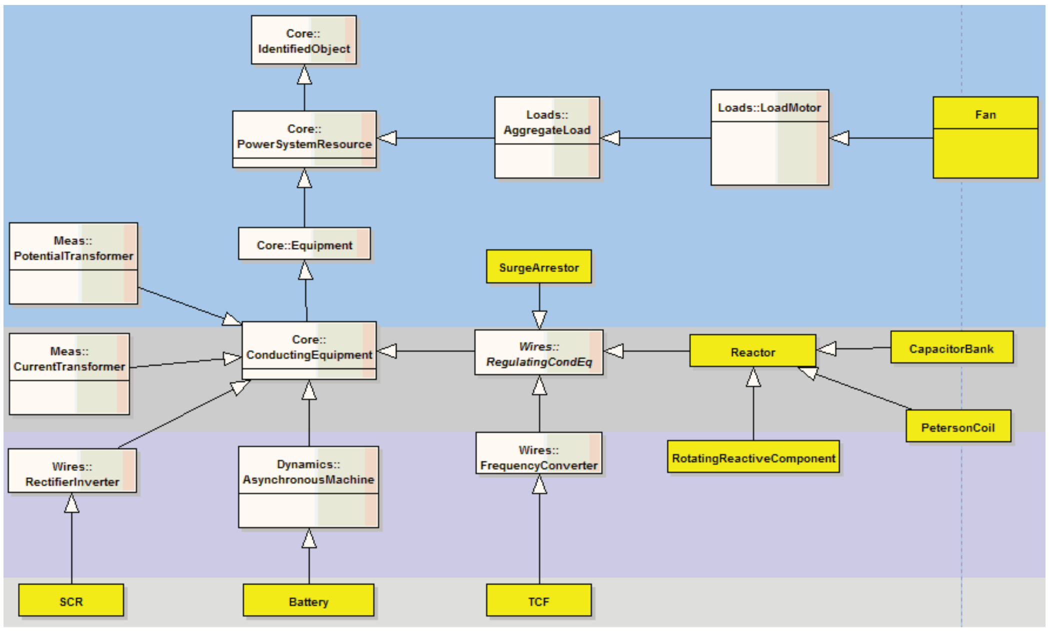


Figure 4-19
Proposed Changes to Substation Equipment UML Model

SCL Changes

This section summarizes the proposals for addition of enumerated values to the following XSD Types:

- To tPredefinedCommonConductingEquipmentEnum, the following enumeration values are proposed to be added:
  BBS – BusBarSection
  CND – Conductor
  CON – Connector
  EnergyConsumer
  RINV – RectifierInverter
  SCMP – Series Compensator
- To tPredefinedGeneralEquipmentEnum, the following enumeration values are proposed to be added:
  GEN – GeneratingUnit
  PROT – Protection Equipment
- An attribute was added to tConnectivityNode to indicate if the node was grounded or not.
- A tSwitch production was added to allow a closer alignment to CIM Switches. The enumerated values proposed for this type are:

DIS – Disconnector
FUSE
GNDDIS – Ground Disconnector
JMP – Jumper
GEN – General Switch
CBR – Breaker (was removed from tPredefinedCommonConductingEquipmentEnum)

- The production of tTapChanger was enhanced to allow a "TypeOfLTC" parameter so that there could be differentiation between regular, phase, and ratio tap changers.
- Changes to the Equipment Container relationship were made in order to align with CIM and allow other equipment containers besides Substations, Bays, and VoltageLevels.
- Additionally, a new section type has been added to support planning information.

Mapping Recommendations

In order to relate the UML model classes for equipment to the 61850 SCL representation of equipment, it is necessary to unambiguously map one to the other. Table 4-4 summarizes the recommended mappings.

Table 4-4
Recommended Mappings of UML and SCL Equipment Types

UML		SCL	
Class	**Attribute**	**Abbreviation**	**Type**
ACLineSegment		LIN	tPredefinedCommonConductingEquipmentEnum
BaseVoltage			tVoltage
Battery		BAT	tPredefinedCommonConductingEquipmentEnum
Bay			tBay
Breaker		CBR	tSwitch
BusBarSection		BBS	tPredefinedCommonConductingEquipmentEnum
CapacitorBank		CAP	tPredefinedCommonConductingEquipmentEnum
Conductor		CND	tPredefinedCommonConductingEquipmentEnum
Conductor	InsulationType= Gas	GIL	tPredefinedCommonConductingEquipmentEnum
ConnectivityNode			tConnectivityNode
Connector		CON	tPredefinedCommonConductingEquipmentEnum
CurrentTransformer		CTR	tPredefinedCommonConductingEquipmentEnum

Table 4-4 (continued)
Recommended Mappings of UML and SCL Equipment Types

UML Class	Attribute	SCL Abbreviation	Type
Disconnector		DIS	tSwitch
EnergyConsumer		EnergyConsumer	tPredefinedCommonConductingEquipmentEnum
Fan		FAN	tPredefinedCommonConductingEquipmentEnum
Fuse		FUSE	tSwitch
GeneratingUnit		GEN	tPredefinedGeneralEquipmentEnum
Ground			tConnectivityNode with grounded=True
GroundDisconnector		GNDDIS	tSwitch
Jumper		JMP	tSwitch
Junction		CAB	tPredefinedCommonConductingEquipmentEnum
Line			tLine
LoadBreakSwitch		LBS	tSwitch
Motor		MOT	tPredefinedCommonConductingEquipmentEnum
Peterson Coil		EFN	tPredefinedCommonConductingEquipmentEnum
PowerTransformer			tPowerTransformer
ProtectionEquipment		PROT	tPredefinedGeneralEquipmentEnum
Reactor		REA	tPredefinedCommonConductingEquipmentEnum
RectifierInverter		RINV	tPredefinedCommonConductingEquipmentEnum
Resistor		RES	tPredefinedCommonConductingEquipmentEnum
RotatingReactiveComponent		RRC	tPredefinedCommonConductingEquipmentEnum
SCR		SCR	tPredefinedCommonConductingEquipmentEnum
SeriesCompensator		SCMP	tPredefinedCommonConductingEquipmentEnum
ShuntCompensator		PSH	tPredefinedCommonConductingEquipmentEnum
StaticVarCompensator		TCR	tPredefinedCommonConductingEquipmentEnum
Substation			tSubstation
SurgeArrestor		SAR	tPredefinedCommonConductingEquipmentEnum

Table 4-4 (continued)
Recommended Mappings of UML and SCL Equipment Types

UML		SCL	
Class	**Attribute**	**Abbreviation**	**Type**
Switch		GEN	tSwitch
SynchronousMachine		SMC	tPredefinedCommonConductingEquipmentEnum
TapChanger		General	tTapChanger
PhaseTapChanger		Phase	tTapChanger
RatioTapChanger		Ratio	tTapChanger
Terminal			tTerminal
TCF		TCF	tPredefinedCommonConductingEquipmentEnum
TopologicalIsland			tTopologicalIsland
TopologicalNode			tTopologicalNode
TransformerWinding			tTransformerWinding
VoltageLevel			tVoltageLevel
PotentialTransformer		VTR	tPredefinedCommonConductingEquipmentEnum

5 GENERAL SCL DESIGN CHANGES

This chapter addresses recommended changes to the SCL to reconcile differences in naming and identification of specific instances of equipment and equipment containment.

Addition of Persistent IDs

The CIM XML instance file format makes use of the construct of rdf:id in order to specify persistent identifications of object instances. Without this form of instance identification that persists beyond identification assigned when a file is created, instance names for the same object would be different for each file exchange.

Currently, SCL makes use of inter-object references through a type called tRef which is name based. However, in Edition 2, for some objects, an attribute of Master Resource Identifier (mrid) was recently added and therefore indicating an acknowledgment for the need of persistent identification besides the use of names.

It is important that the use of mrid/rdf:id be expanded to all instances within an SCL file. This is needed so that changes in the linkage (e.g. associations) and name changes can be detected within the exchanges specified in the use cases.

RDF:ID Definition

From W3C, the following trail of definitions is relevant for the proposed changes to SCL:

> *The rdf:ID attribute on a node element (not property element, that has another meaning) can be used instead of rdf:about and gives a relative RDF URI reference equivalent to # concatenated with the rdf:ID attribute value. So for example if rdf:ID="name", that would be equivalent to rdf:about="#name". rdf:ID provides an additional check since the same name can only appear once in the scope of an xml:base value (or document, if none is given), so is useful for defining a set of distinct, related terms relative to the same RDF URI reference.*
>
> [From http://www.w3.org/TR/2004/REC-rdf-concepts-20040210/#dfn-URI-reference]
>
> *An attribute string-value matching any legal [XML-NS] token NCName*
>
> [From http://www.w3.org/TR/rdf-syntax-grammar/#rdf-id]
>
> *Attribute Names for Namespace Declaration…*
>
> *[4] NCName ::= NCNameStartChar NCNameChar* /* An XML Name, minus the ":" */*
> *[5] NCNameChar ::= NameChar – ':'*
> *[6] NCNameStartChar ::= Letter | '_'*
>
> *The attribute's normalized value MUST be either a URI reference — the namespace name identifying the namespace — or an empty string. The namespace name, to serve its intended purpose, SHOULD have the characteristics of uniqueness and persistence. It is not a goal that it be directly usable for retrieval of a schema (if any exists). Uniform Resource Names [RFC2141] is an example of a syntax that is designed with these goals in mind. However, it should be noted that ordinary URLs can be managed in such a way as to achieve these same goals.*
>
> [From http://www.w3.org/TR/REC-xml-names/#NT-NCName]

Based upon the definitions from W3C, it is possible to represent either arbitrary identifiers or Globally

Unique Identifiers (GUIDs) as an RDF:ID. The movement of the industry is towards GUID usage and should be what is used for the purposes of information exchange within the scope of harmonization.

In order to accomplish this, a SCL XSD Type of tRDFID needs to be created. The type would be something similar to:

```
<xs:simpleType name="tRDFID">
        <xs:restriction base="xs:Name">
                <xs:pattern value="[0-9_]*"/>
        </xs:restriction>
</xs:simpleType>
```

The tRDFID declaration insures that the first character of the ID is numeric or an "_".

The introduction of an RDF:ID construct also means that there needs to be a mechanism to allow associations between instances object instances in SCL based upon RDF:ID (e.g. similar to the rdf:resource construct used in CIM XML). It is proposed that a tRDFIDREF be added to SCL with the following definition:

```
<xs:simpleType name="tRDFIDREF">
        <xs:restriction base="xs:Name">
                <xs:pattern value="[#][0-9_]*"/>
        </xs:restriction>
</xs:simpleType>
```

The tRDFIDREF must have a first character of "#". The following characters then have the same restriction as required by tRDFID.

In order to insure that the RDFID is propagated throughout SCL, the tUnNaming , tNaming, and tIDNaming types need to be changed. If other naming types have been overlooked, these will also have to be modified in a similar manner. Figure 5-1 compares the current definitions with the proposed definitions for these types.

The RDFID attribute is being proposed as "optional" to allow some backward compatibility during the transition period. However, long term, it should be a "required" attribute.

Additionally, reference extensions need to be added to:

Current Definitions

```xml
<xs:complexType name="tUnNaming" abstract="true">
  <xs:complexContent>
    <xs:extension base="tBaseElement">
      <xs:attributeGroup ref="agDesc"/>
    </xs:extension>
  </xs:complexContent>
</xs:complexType>
```

```xml
<xs:complexType name="tNaming" abstract="true">
  <xs:complexContent>
    <xs:extension base="tBaseElement">
      <xs:attribute name="name" type="tName" use="required"/>
      <xs:attributeGroup ref="agDesc"/>
    </xs:extension>
  </xs:complexContent>
</xs:complexType>
```

```xml
<xs:complexType name="tIDNaming" abstract="true">
  <xs:complexContent>
    <xs:extension base="tBaseElement">
      <xs:attribute name="id" type="tName" use="required"/>
      <xs:attributeGroup ref="agDesc"/>
    </xs:extension>
  </xs:complexContent>
</xs:complexType>
```

Proposed Definitions

```xml
<xs:complexType name="tUnNaming" abstract="true">
  <xs:complexContent>
    <xs:extension base="tBaseElement">
      <xs:attributeGroup ref="agDesc"/>
      <xs:attribute name="RDFID" type="tRDFID" use="optional"/>
    </xs:extension>
  </xs:complexContent>
</xs:complexType>
```

```xml
<xs:complexType name="tNaming" abstract="true">
  <xs:complexContent>
    <xs:extension base="tBaseElement">
      <xs:attribute name="name" type="tName" use="required"/>
      <xs:attributeGroup ref="agDesc"/>
      <xs:attribute name="RDFID" type="tRDFID" use="optional"/>
    </xs:extension>
  </xs:complexContent>
</xs:complexType>
```

```xml
<xs:complexType name="tIDNaming" abstract="true">
  <xs:complexContent>
    <xs:extension base="tBaseElement">
      <xs:attribute name="id" type="tName" use="required"/>
      <xs:attributeGroup ref="agDesc"/>
      <xs:attribute name="RDFID" type="tRDFID" use="optional"/>
    </xs:extension>
  </xs:complexContent>
</xs:complexType>
```

Figure 5-1
Proposed SCL Type Extensions for Inclusion of RDF:IDs

- tLN0: to allow referencing to lnType (lnTypeRef attribute) and lnClass (lnClassRef attribute).
- tFCDA: to allow referencing to lnClass (lnClassRef attribute).

Standardized Objects and GUIDs

IEC 61850's use of GUIDs is slightly different the way CIM uses them. In order to actually create a usable exchange, certain GUIDs need to be pre-assigned and standardized. This is particularly true for the standardized definitions of LNClass(s) and standardized Common Data Classes (CDCs). These IDs will need to be consistently used by all exporters of information so that model consistency is maintained.

Therefore, there is a requirement to pre-assign, document, and standardize the GUID rdf:id(s) that are to be used for LNClass and CDC definitions. The use of standardized GUIDs protects the exchange from future name changes of these objects. Such assignment will prevent ambiguity within the harmonized model.

As an example, the following table Table 5-1 show possible assignments to some of the LNClass and CDC definitions that are part of IEC 61850.

Table 5-1
Proposed Assignment of GUIDs to IEC 61850-7-4 LNClass Names

LNClass(s) from IEC 61850-6

LNClass Name	Standardized GUID[2]
ANCR	15170fea-6753-415e-93e2-7c709282e3e3
ARCO	5644a53a-3bc1-4549-8fea-d2a76c7ddb10
ATCC	25620f31-1932-4439-85b7-6109bb7cba13
AVCO	776f8874-3cc8-4c6f-b8c0-dd859b0c0622
CILO	d845c42b-3ff6-477f-a1f4-000ac4d8c27f
CSWI	ffcb887a-25e5-43e0-9164-38c3eeebc729
CALH	ffcb887a-25e5-43e0-9164-38c3eeebc729
CCGR	0df97505-8e41-4fc0-826f-ef2453bba36b
CPOW	48300dae-b0b8-419a-b79a-08de9ee8ae38
GAPC	6e8617c2-c263-4c54-adff-f24be6db4a12
GGIO	8db2ac10-e95d-42e6-8ed5-6217a1e77657
GSAL	77769087-bc5d-4e7c-bb7f-f1305b18459c
IHMI	5c16dc1b-3600-4f0e-8bf3-0d6219692cb6
IARC	c711e36a-2a07-478e-ae80-a519ce512a9b
ITCI	01f2b27b-ca81-4369-936b-379da959ae92
ITMI	5edeb2b7-5ad6-4135-ba47-0eeb4fd02bbe
MMXU	8435f48a-9fd7-4563-82a8-9dff30cb26d6
MDIF	d62a5f6c-7a4d-40a9-b3c3-db876d2c7f08
MHAI	14549cb3-98dc-43f3-9a62-b964f662db39
HMAN	ad6eb214-0d4d-46ba-a40f-8fcbd589265f
MMTR	5a03b031-edd5-40e8-83ea-0582451411c3
MMXN	1adb7c01-78ec-4f38-acf1-5a6d419a4fce
NSQU	1adb7c01-78ec-4f38-acf1-5a6d419a4fce
MSTA	8140e68f-f4c4-4973-aabf-4ce94e705ee6
PDIF	75195da5-4d6d-4ab5-8f74-08dd99035c52
PDIS	5cae7efd-2916-4c80-9701-8d7e8d22520c
PDIR	df9997e5-f86b-4a7c-8b06-c110ef2fa2da
PDOP	aaf82a78-74fc-47be-8ab2-651e2578510a
PDUP	d00628f7-9f70-4947-82dd-53a476bda1c2
PFRC	3ac5b63b-82d9-4fbe-a6cf-59fda8cdb662
PHAR	65499a01-4261-46e7-b4d7-0698822432e9
PHIZ	c3b40683-a751-4496-916f-182204c69d3a
PIOC	92d10c8c-7ddb-49aa-9dec-8cd730b7f7b1
PMRI	0569d620-c0c1-4cbb-b951-42ea66c838e6
PMSS	c1bb3117-4558-4ec0-a20e-861bad0bf20d
POPF	c2060d3c-50bf-4981-b428-02a630eac7ab
PPAM	0333e0a6-b2d1-421a-ba08-a70ebfa2d845

Table 5-1 (continued)
Proposed Assignment of GUIDs to IEC 61850-7-4 LNClass Names

LNClass(s) from IEC 61850-6

LNClass Name	Standardized GUID[2]
PSCH	22519dfe-69d5-4fa3-befa-acef040087ce
PSDE	9db1c7f5-a230-4b42-b523-9ad878077576
PTEF	ee87ee01-fb61-4cf2-a879-30cbce8f6444
PTOC	826a9a69-d1c2-44ab-a403-35050ffc5c93
PTOV	63baa547-22b6-4448-a54c-43335f1234ac
PTRC	e1b80498-1b7d-402f-9310-1b4aca6148ad
PTTR	929aea70-366c-4feb-a07f-2e52aab93ac7
PTUC	03718c6f-4a28-4b8c-8b8e-7c4b43e573aa
PTUV	af751c4a-4cfb-41fc-b110-a32b37c191e7
PUPF	90f89f55-08cf-4f35-a0c1-2eb3b39fdfb4
PTUF	5cbf1bad-649d-46e2-b4a8-43e41724a0a5
PVOC	0841acf0-81f3-47b7-a7af-34d47fa0da7b
PVPH	423f6e7f-d3d4-42fe-8eb1-60285c96397a
PZSU	750ed7e1-4a5d-4fb6-80c0-7db2f1e915b4
RSYN	c4a41f37-4162-4a53-903f-0dfb3c0ec2a3
RDRE	95626d5c-cb72-4621-b932-47ae2ec6c110
RADR	0181e5ca-4d6d-423c-ac1f-06314cbf1330
RBDR	216a2bc1-a005-4d96-a80f-367a5f262a27
RDRS	389e501f-1c12-4a46-aeff-9841d64ffdab
RBRF	50fef061-5d51-4651-9435-d45ac252c965
RDIR	009633a4-d25d-4e75-8cbf-2471438dbccd
RFLO	40a328c7-d75a-4ce6-8c8c-b2e0dc3a0fb7
RPSB	a864ac4b-0d9f-448d-8bf4-2d18537f8d71
RREC	2d5ceb7b-a155-4ddb-b03f-683c3916e2e4
SARC	22685109-e3fa-4991-a78a-92bccacb691e
SIMG	067d33c9-bc40-487f-bd01-120c410a62a3
SIML	b31f9f09-337c-45d4-9270-5f38be72c293
SPDC	96d123c4-2f9d-493c-8085-9773ef351dba
TCTR	b6beefb6-d10b-4e20-b0a3-54ab501161f8
TVTR	0337e0a0-06af-40df-b5bc-43d097b3e198
XCBR	ed8574c8-7f02-48b4-b124-cde1868d2c1b
XSWI	1f9aef0a-9b3c-4d45-8867-0e8dcc5fe89f
YPTR	c1aa5622-35b9-481a-aba8-c40aca9b63df
YEFN	2765cf83-9e7d-4a27-a848-8e06c8940243
YLTC	95fd6b34-b18e-4f61-b316-25bde84aa0ec
YPSH	b04b9e59-e954-40ff-9189-c9bcabd83699
ZAXN	31495f7e-1ba6-4594-826f-205759626ae0

Table 5-1 (continued)
Proposed Assignment of GUIDs to IEC 61850-7-4 LNClass Names

LNClass(s) from IEC 61850-6	
LNClass Name	**Standardized GUID[2]**
ZBAT	a3f8205a-368d-4764-adeb-487572a0657e
ZBSH	fd7beb20-482e-476d-9ae7-12e98fb11a3a
ZCAB	4fee1862-19c4-46a2-bf85-bdc23cf8d919
ZCAP	9a077104-1e04-403c-9dec-9cf3751fbaf5
ZCON	cf1ec06c-d8d5-41ee-8fe1-1a9209dbe9f5
ZGEN	8cf74605-abd9-4289-aee8-445bd233ffb4
ZGIL	5cb29f83-dc34-4e21-915c-3657e2b92682
ZLIN	fc5663a1-28fb-4a9b-9659-6d548089e182
ZMOT	64daabb8-d366-4bef-a866-4832350f99c5
ZREA	18c1930c-f71e-4776-912e-03dd0401fd6b
ZRRC	e54cd2d6-61fd-4e31-b401-da64503560f0
ZSAR	67350318-8681-41a5-83e6-b0cca58947ae
ZTCF	654e9509-6bf0-4ea8-b894-05a2d26335a0
ZTCR	78cd8fa3-9e2d-4d90-87f1-0517e8828e53
LLN0	d0886865-913a-4fe1-95dd-fa7911fdc198
LPHD	965b6c44-b538-4d8d-a36b-d80dd0169539

[2] GUIDs generated through: http://www.guidgenerator.com/online-guid-generator.aspx

In order to allow referencing of these standardized GUIDs/RDF:IDs, the tLNode and tFCDA class of SCL needs to be extended to allow a lnClassRef as shown in Figure 5-2 below. Table 5-2 provides proposed assignments of GUIDs to IEC 61850-7-3 Base CDC Names.

```
<xs:complexType name="tLNode">
    <xs:complexContent>
        <xs:extension base="tUnNaming">
            <xs:attribute name="lnInst" type="tAnyName" use="optional" default=""/>
            <xs:attribute name="lnClass" type="tLNClassEnum" use="required"/>
            <xs:attribute name="iedName" type="tName" use="optional" default="None"/>
            <xs:attribute name="ldInst" type="tAnyName" use="optional" default=""/>
            <xs:attribute name="prefix" type="tAnyName" use="optional" default=""/>
            <xs:attribute name="lnType" type="tName" use="optional"/>
            <xs:attribute  name= "lnClassRef" type="tRDFIDREF" use="optional"/>
        </xs:extension>
    </xs:complexContent>
</xs:complexType>

<xs:complexType name="tFCDA">
    <xs:attribute name="ldInst" type="tName" use="optional"/>
    <xs:attribute name="prefix" type="tAnyName" use="optional"/>
    <xs:attribute name="lnClass" type="tLNClassEnum" use="optional"/>
    <xs:attribute name="lnInst" type="tName" use="optional"/>
    <xs:attribute name="doName" type="tName" use="optional"/>
    <xs:attribute name="daName" type="tName" use="optional"/>
    <xs:attribute name="fc" type="tFCEnum" use="required"/>
    <xs:attribute name="lnClassRef" type="tRDFIDREF" use="optional"/>
</xs:complexType>
```

Figure 5-2
Proposed SCL Extension of tLNode and tFCDA to Include an LNClass Reference

Table 5-2
Proposed Assignment of GUIDs to IEC 61850-7-3 Base CDC Names

CDC Base Names from IEC 61850-6[3]	
CDC Base Name	**Standardized GUID**
SPS	e5a34eb7-a945-4c78-9dc0-8e7890b78bf1
DPS	52213393-e174-4959-a653-0c03ea0719a6
INS	ff111ab8-2f71-47ba-9217-ecb168b6a235
ACT	6b70c9d3-144f-4d29-80cf-1340e987e6b6
ACD	628ee7d8-b2e6-4f2a-a2ea-aab8f466e5b5
SEC	1c5d0133-a5d0-42e4-95bb-d24fdb4fb1e8
BCR	c3763807-832c-403a-ad1c-dd0780b92bcb
MV	2ceea2bc-ca2b-425d-a151-7b7e69127aed
CMV	6373c908-7862-42f4-bc22-d5fa5e1fb9d4
SAV	362d7146-5ede-4d47-a940-b0ba1abb9f29
WYE	54cdfbcb-9cdf-4da0-916e-c9eab1abe119
DEL	7e0b5427-c0f4-4e5b-a4fd-e31f201a3d1a
SEQ	0eba4bac-b864-4dc3-9d09-e30b747e57b3
HMV	925a07a4-450f-4dc1-8afb-9e53d3236fe1
HWYE	2761f798-6c95-4430-8dc9-0f7ebf66c54e
HDEL	e78f5a35-6e3d-40a9-be8f-4f79e45cfbbf
SPC	95bde53e-9083-4575-9460-ae3e1e37f55d
DPC	fd0d93be-9834-4de6-bda1-d617536fe12f
INC	6e5c268b-fd9e-4139-a8fb-c9fd69e4a03b
BSC	d1e63612-e89d-4a6d-9eb7-3c53f76d9feb
ISC	2a4f263d-08b3-4254-90b6-d08e4c21f2b7
APC	d2a88c53-73a3-493f-82f7-1f71ab1118c9
SPG	3bf17878-8f4f-42a5-8aa8-868a55f10de5
ING	e57be893-b32a-4094-aad3-a4c454ecb1cc
ASG	80c3d40b-04f0-49d2-b053-f31d52c89339
CURVE	53f6674a-18ad-4a00-8f81-18ccf2f17081
DPL	a2791e35-bbf1-4e78-8ee9-347c4647184a
LPL	75e325bd-df9e-4f1e-830d-e7ced66d6cf4
CSD	f6da088e-c589-4a00-b268-613da2ccab40

In a similar manner to tLNode, the tDOType needs to be extended to allow the standardized GUIDs to be referenced (see Figure 5-3).

[3] GUIDs generated through: http://www.guidgenerator.com/online-guid-generator.aspx

```
<xs:complexType name="tDOType">
	<xs:complexContent>
		<xs:extension base="tIDNaming">
			<xs:choice minOccurs="0" maxOccurs="unbounded">
				<xs:element name="SDO" type="tSDO"/>
				<xs:element name="DA" type="tDA"/>
			</xs:choice>
			<xs:attribute name="iedType" type="tAnyName" use="optional" default=""/>
			<xs:attribute name="cdc" type="tCDCEnum" use="required"/>
			<xs:attribute name="cdcRef" type="tRDFIDREF" use="optional"/>
		</xs:extension>
	</xs:complexContent>
</xs:complexType>
```

Figure 5-3
Proposed SCL extension of tDOType to allow use of standardized GUIDs

As shown in Table 5-3 below, standardized enumerations should also be assigned standardized GUIDs. Note that this table contains only those enumerations that are associated in order to determine a value of an attribute in the unified model. It is a future activity to decide if these should also be represented as a kind of ValueAliasSet.

Any LNClass, CDC, or Enumeration that does not have an assigned Standardized ID shall be considered a private definition.

Note: The same process needs to be performed for IEC 61400-25-2, IEC 61850-7-410, and IEC 61850-7-420 LNClasses, CDCs, and Enumerations in order to have a complete mapping.

Table 5-3
Proposed Standardized GUID Assignments for SCL Enumerations

Standardized Enumerations from IEC 61850-6[4]	
Enumeration	**Standardized GUID**
tPredefinedPTypeEnum	e5a34eb7-a945-4c78-9dc0-8e7890b78bf1
tServiceSettingsEnum	52213393-e174-4959-a653-0c03ea0719a6
tPhaseEnum	ff111ab8-2f71-47ba-9217-ecb168b6a235
tAuthenticationEnum	6b70c9d3-144f-4d29-80cf-1340e987e6b6
tAssociationKindEnum	628ee7d8-b2e6-4f2a-a2ea-aab8f466e5b5
tTrgOptEnum	1c5d0133-a5d0-42e4-95bb-d24fdb4fb1e8
tTrgOptControlEnum	c3763807-832c-403a-ad1c-dd0780b92bcb
tServiceFCEnum	2ceea2bc-ca2b-425d-a151-7b7e69127aed
tValKindEnum	6373c908-7862-42f4-bc22-d5fa5e1fb9d4
tGSEControlTypeEnum	362d7146-5ede-4d47-a940-b0ba1abb9f29
tSIUnitEnum	54cdfbcb-9cdf-4da0-916e-c9eab1abe119
tUnitMultiplierEnum	7e0b5427-c0f4-4e5b-a4fd-e31f201a3d1a
tRangeEnum	ecbee66c-63bd-4987-a669-0b575e83fa25
tAngRef	e9dabe6b-e47a-4db5-a4c1-bbc7ec86f67a

[4] This list is not all inclusive.

Element Identification

Within the IEC 61970-552 document, the CIM XML file format definition explicitly defines the use of rdf:id. However, within IEC 61850-6 Edition 2, this concept has not been introduced. Therefore, an attribute needs to be added within the SCL file format definition that allows the definition of the persistent ID.

It is recommended that the attribute tag of rdf:id be utilized within the SCL XSD. This attribute shall eventually need to be mandatory in order to achieve the use case. The rdf:id attribute will need to be added to all type definitions within the SCL XSD(s). Additionally, there needs to be a restriction on the characters allowed for the actual attribute value so that it conforms to the allowed syntax for rdf:id(s) when using GUIDs. Currently, the tName type can be used for this purpose although a more prescriptive type might be desirable.

As an example, the tPowerSystemResource is defined to be:

```
<xs:complexType name="tPowerSystemResource" abstract="true">
        <xs:complexContent>
                <xs:extension base="tLNodeContainer"/>
        </xs:complexContent>
</xs:complexType>
```

To incorporate the recommended rdf:id attribute, the following XSD could be used:

```
<xs:complexType name="tPowerSystemResource" abstract="true">
        <xs:complexContent>
                <xs:extension base="tLNodeContainer">
                        <xs:attribute name="rdf:id" type="tName" use="required"
                </xs:extension>
        </xs:complexContent>
</xs:complexType>
```

Similar changes would be needed for other object types as well.

Additionally, there are some objects that reference other objects. As an example, the IEC 61850 tTerminal type is defined as:

```
<xs:complexType name="tTerminal">
        <xs:complexContent>
                <xs:extension base="tUnNaming">
                        <xs:attribute name="name" type="tAnyName" use="optional" default=""/>
                        <xs:attribute name="connectivityNode" type="tRef" use="required"/>
                        <xs:attribute name="substationName" type="tName" use="required"/>
                        <xs:attribute name="voltageLevelName" type="tName" use="required"/>
                        <xs:attribute name="bayName" type="tName" use="required"/>
                        <xs:attribute name="cNodeName" type="tName" use="required"/>
                </xs:extension>
        </xs:complexContent>
</xs:complexType>
```

It is clear that the attributes connectivityNode is a reference to a particular instance. However, the reference is by Name and not persistent ID. There are two (2) options to solve this particular issue:

- Make any "attribute" that is of type tRef, an explicit attribute of the encapsulating type. The replacement attribute would be a complex type that has both a name attribute and a ID attribute (e.g. that can store the persistent IDs) as shown below:

```
<xs:complexType name="tTerminal">
    <xs:complexContent>
        <xs:extension base="tUnNaming">
            <xs:attribute name="name" type="tAnyName" use="optional" default=""/>
            <xs:attribute name="connectivityNode" type="tRef" use="required"/>
            <xs:attribute name="substationName" type="tName" use="required"/>
            <xs:attribute name="voltageLevelName" type="tName" use="required"/>
            <xs:attribute name="bayName" type="tName" use="required"/>
            <xs:attribute name="cNodeName" type="tName" use="required"/>
        </xs:extension>
      <xs:attribute name="connectivityNode" type="tComplexRef" use="required"/>
    </xs:complexContent>
</xs:complexType>

<xs:complexType name="tComplexRef" mixed="true">
    <xs:complexContent mixed="true">
        <xs:extension base="tAnyContentFromOtherNamespace">
            <xs:attribute name="name" type="xs:normalizedString" use="required"/>
            <xs:attribute name="RDFIDREF" type="tRDFIDREF" use="required"/>
        </xs:extension>
    </xs:complexContent>
</xs:complexType>
```

Make an extension attribute that contains only the ID that is being referenced.

```
<xs:complexType name="tTerminal">
    <xs:complexContent>
        <xs:extension base="tUnNaming">
            <xs:attribute name="name" type="tAnyName" use="optional" default=""/>
            <xs:attribute name="connectivityNode" type="tRef" use="required"/>
            <xs:attribute name="substationName" type="tName" use="required"/>
            <xs:attribute name="voltageLevelName" type="tName" use="required"/>
            <xs:attribute name="bayName" type="tName" use="required"/>
            <xs:attribute name="cNodeName" type="tName" use="required"/>
<xs:attribute name="connectivityNodeRef" type="tRDFIDREF" use="optional"/>
            <xs:attribute name="substationRef" type="tRDFIDREF" use="optional"/>
            <xs:attribute name="voltageLevelRef" type="tRDFIDREF" use="optional"/>
            <xs:attribute name="bayRef" type="tName" use="required"/>
        </xs:extension>
    </xs:complexContent>
</xs:complexType>
```

It is recommended that the latter be utilized for any attributes that were providing concrete references to other objects. This design pattern needs to be implemented throughout the SCL XSD definitions. Some of the impacted type specifications are:

- tLN
- tLN0
- tLNodeType
- tDOType

Equipment Containership

Please see page 4-23 for the discussion of alignment of CIM and IEC 61850 Equipment Containership. The referred section addresses several issues including:

- Bay and VoltageLevel alignment as EquipmentContainers.
- The extension of SCL EquipmentContainers to include Plants. Not only does this align with IEC 61970, but IEC 61850-7-410 needs this type of container so that SCL can express the connectivity/equipment within a plant (e.g. Hydro Electric generation plant).

- The extension of SCL EquipmentContainers to include Lines. This is needed in order to allow IEC 61850-7-420 to align with the containership models of IEC TC57 WG14 (e.g. IEC 61968). Such an alignment allows a placeholder for the IEC 61850-7-420 equipment and connectivity in SCL.
- An extension to SCL that allows Plants to contain other equipment containers (e.g. Substations and Generators).

6 UNIFIED UML MODEL

This chapter describes the proposed changes to create a unified UML model which would support both the CIM and 61850 standards. As mentioned previously, this unified model brings us one step closer to having a single semantic model used as the basis for information exchange between systems included in the NIST Smart Grid Interoperability Framework. Specifically it addresses the need to have a single semantic model for information exchanges between CIM-based systems and 61850 field devices.

Ths approach to creating this unified model was to start with the combined 61968/70 CIM UML model which already provides a common semantic model for both the transmission system interfaces (i.e., 61970 standards) and distribution system interfaces (i.e., 61968 standards) and extend it to include support for the 61850 standards, specifically the objects defined in 61850-6 Substation Configuration Languange (SCL). The scope of the proposed changes is to deal with information to be exchanged over the interfaces identified in the use case interfaces defined in Chapter 2 above. However, in the process of dealing with these interfaces, almost all of the objects modeled in SCL have been included.

The complete proposed UML model that includes these recommendations is available in a separate file as an Enterprise Architect .eap model file. Enterprise Architect is the software UML tool used by the IEC and CIM User Group to manage and maintain the CIM UML model.

The following sections address specific modeling issues that arise in harmonizing CIM and 61850 models in UML and recommend solutions, which include both reuse of the existing CIM UML as well as extensions to the CIM UML model,

Relating Logical Nodes to PowerSystemResources

There are actually two uses for a relationship of substation functions (e.g. IEC 61850 Logical Nodes) to the CIM PowerSystem Resources (PSR) (see Chapter 4, Substation Related Profile Members):

1. The first use, based upon the Use Case 1 described in Chapter 2, is to allow the planning activity to specify what type of substation functions need to be associated with a PSR. Such a specification allows the abstract requested "function" to be related to the actual PSR upon which the function is requested.
2. The second use is to relate the actual instance of the function to the PSR that is providing the requested function. Additionally, this second type of relationship allows for the substation engineer to assign actual "functions" and instances to PSRs even if the planned model did not explicitly define a particular need (e.g. determined during some other process or substation commissioning).

Figure 6-1 depicts the proposed UML to allow both the abstract function and Logical Nodes to be related to PSRs.

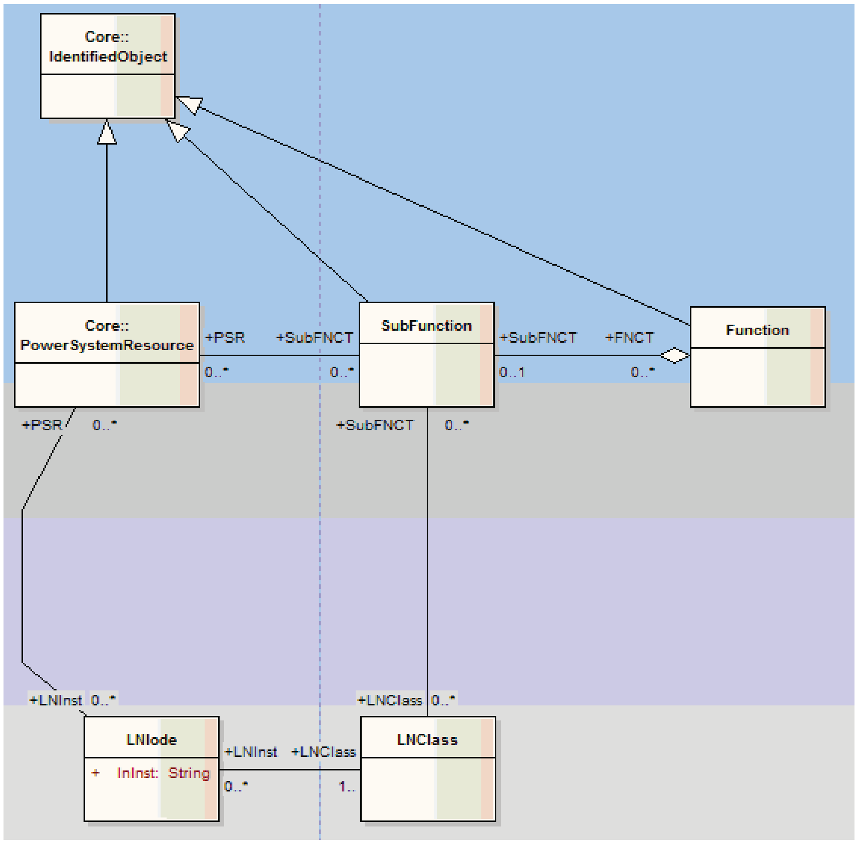


Figure 6-1
PSR to Function and Logical Node Relationships

For the purposes of abstraction, and possibly future expansion, a Function class has been added in the UML. There are two candidate definitions for this class:

1. IEC 61850: task which is performed by the substation automation system. Generally, a function consists of subparts called logical nodes, which exchange data with each other. By definition, only logical nodes exchange data and, therefore, a function that exchanges data with other functions must have at least one logical node. As a consequence, only data contained in logical nodes can be exchanged in the context of the IEC 61850 series.
2. IEEE: A task, action, or activity that must be accomplished to achieve a desired outcome. [From IEEE Std 1233, 1998 and 1233-1996 a IEEE Guide for Developing System Requirements Specifications]

Recommended definition: IEEE

Functions consist of sub-functions to which Logical Node Classes can be associated. The LNClass class allows the association of a specific 61850 or 61400 function; however, it does not include the data of the actual Logical Node. It only specifies the type of Logical Node.

This UML allows the support for the use case where it will be possible for a designer to specify a set of functions/sub-functions associated to a particular PSR. The UML allows for other sub-functions to eventually be added to the model besides IEC 61850 functions, thus the association between SubFunction and LNClass. The UML further allows the specific Logical Nodes to be associated to the LNClass/

Subfunction and to the PSR, thereby allowing the deployment/runtime to be associated to the design time requirements.

Equipment Mechanical Connectivity and Logical Nodes

The current CIM model is PowerSystemResource-centric. However, IEC 61400-25-2 has non-PSR types of Equipment (e.g. Rotors, transmissions, etc.). It will be future work to model these relationships and the mechanical connectivity between such components.

There is a well recognized standard for accomplishing this: ISO 15926. Figure 6-2 shows the proposed modeling approach which makes use of the ISO15926 concepts of Node/Point connectivity. This is a similar set of relationships as CIM ConnectivityNode and Terminals. The full definition of this package, including the modeling of relationships and the mechanical connectivity between such components, is a matter for future work.

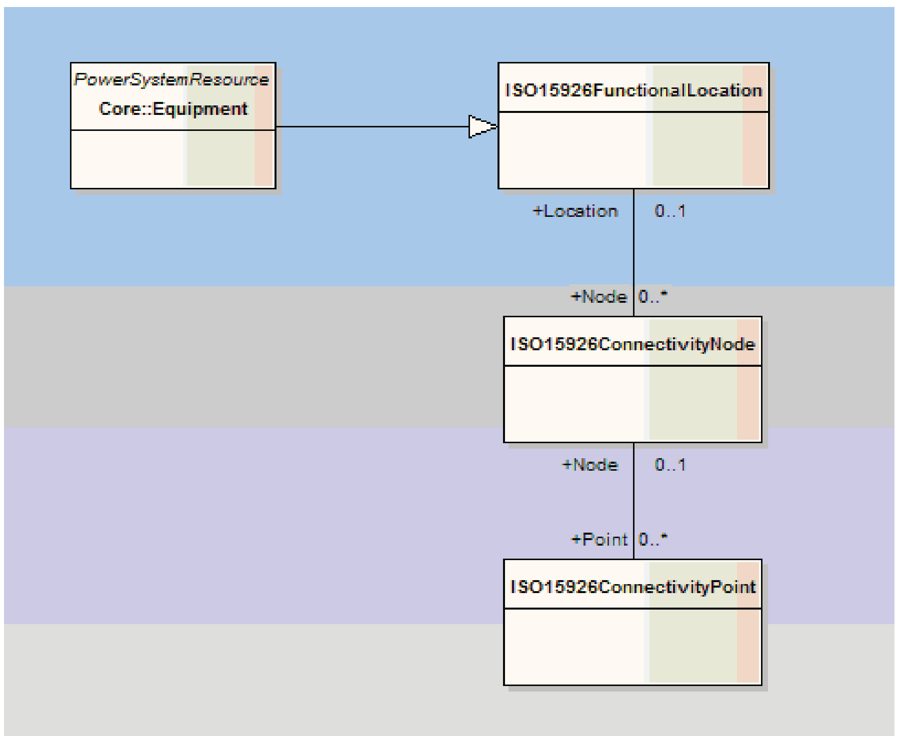


Figure 6-2
Proposed Draft for Mechanical Connectivity

Logical Nodes

In general, the proposed harmonized UML attempts to separate the design time functions from the runtime/deployed instantiations of those functions/Logical Nodes. The difference between the design and runtime can best be summed up as:

- Design time: This allows the specification of what is needed based upon the definitions found in the standard(s).
- Runtime: What is actually deployed in the field, within a communicating IED, that provides the actual communication of Logical Node data/information.

Design Time Definitions (LNClass)

Within the 61850 suite of standards (e.g. IEC 61850-7-4, IEC 61850-7-410, IEC 61850-7-420, and IEC 61400-25-2) that specify functions as Logical Nodes, the following relationships as represented in UML have been established.

First, in order to properly show the dependencies between the various standards, the common logical node information from IEC 61850-7-4 has been placed into a Common package since the other standards have dependencies on the common definitions (see Figure 6-3).

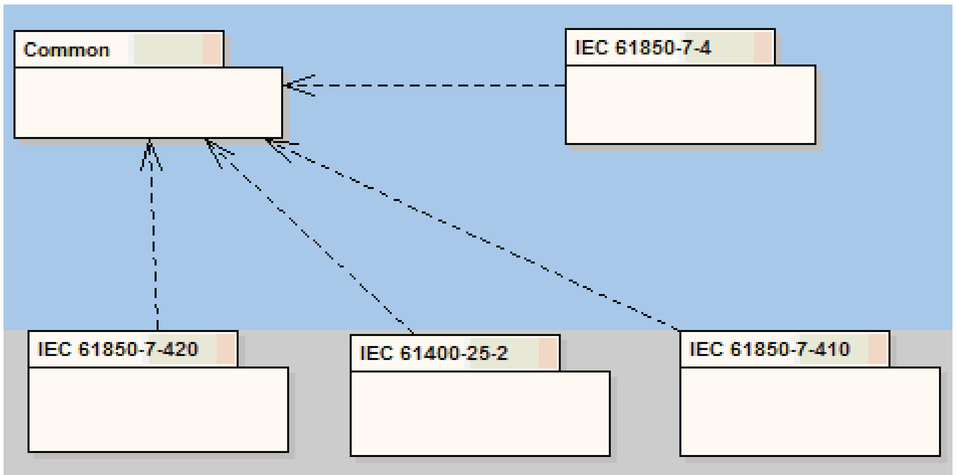


Figure 6-3
IEC 61850 Standard Definitions for Logical Nodes

Next, as shown in Figure 6-4 and Figure 6-5, the general LNClass has several specialized classes. First as shown in Figure 6-4, is the CommonLNClass, with a single attribute specifying the type of Logical Node via enumeration, and associations to the Standard_LPHD_Definition and Standards_LLNO_Definition classes. Other specializations are shown in Figure 6-5.

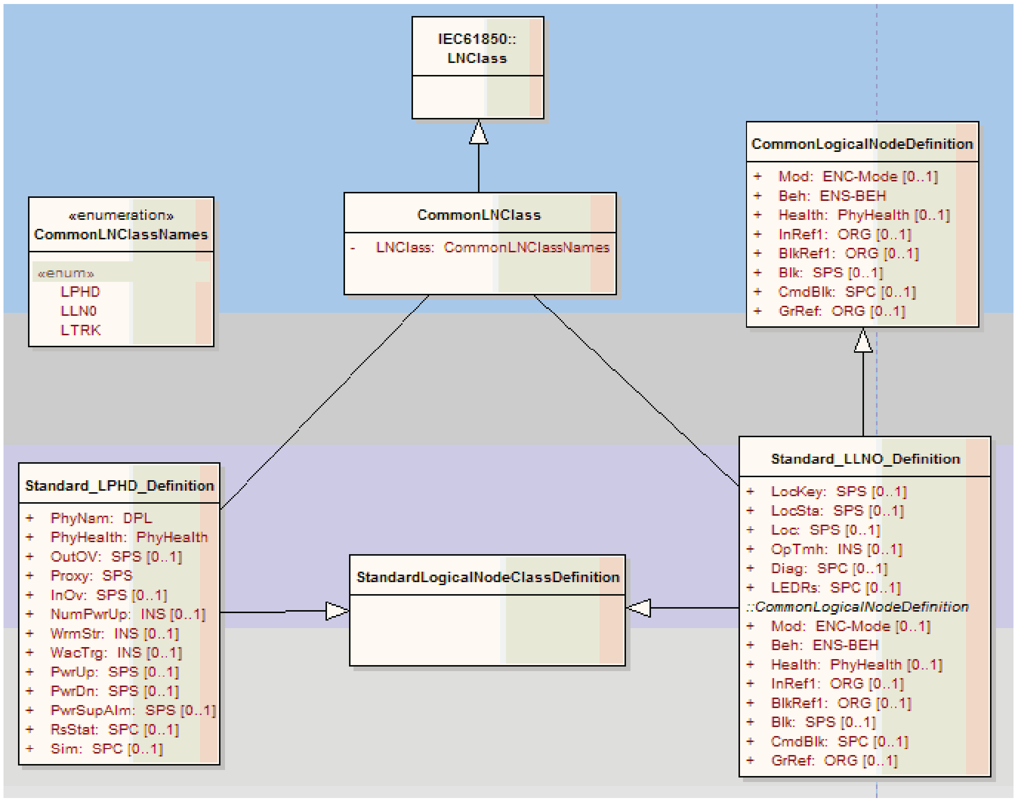


Figure 6-4
Common Logical Node Definitions

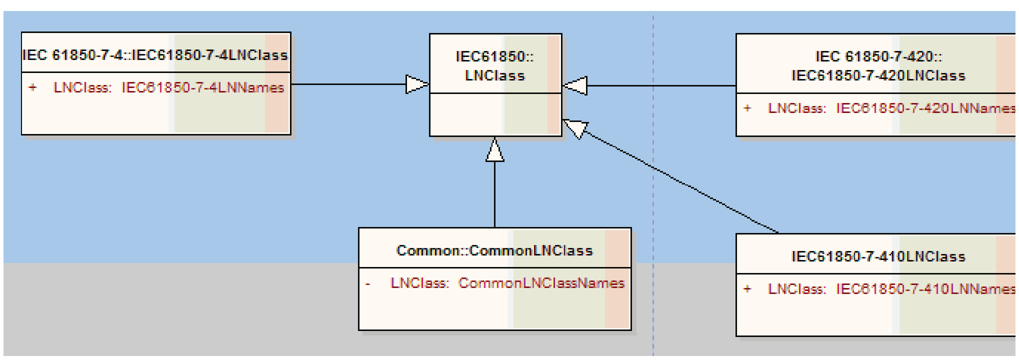


Figure 6-5
Specializations of LNClass

Through this type of UML design template, ease of expansion and maintenance is allowed. This includes the possibility of additions of custom Logical Nodes that are defined by a vendor or a 61850 user.

Note: All the LNClass classes, including the specializations need to be included within the harmonized profile in order to satisfy the use cases.

The actual definitions/structure of specific Logical Nodes is not within the scope of the current set of use cases/harmonization. There are several issues involved with creating an appropriate profile that allows the runtime to be validated against what is specified in the standard (e.g. the relationship of the definition of LLNO to the CommonLNClass class):

- Of primary concern is that the tooling provided for creating a profile does not allow for classes to be constructed from other classes or datatypes. Therefore, prior to the inclusion of validation, within the scope of the harmonized profile, the tooling needs to be updated.
- The RDFS format, specified by IEC 61970-501 needs to be reviewed to determine if the syntax can support this construct.

Reconciling the CIM SCADA Package

In order to more easily understand the reconciliation of the CIM SCADA package with IEC 61850, a redrawing of the diagram in the SCADA package will aid in the discussion. The obvious change to the CIM SCADA UML, shown in Figure 6-6, is that an IED has been declared as a sub-class of RemoteUnit. There are several other "touch" points that need to be reconciled as well:

- The CommunicationLink needs to be reconciled with the IEC 61850 Communication information (see page 6-96).
- The ability to automatically create RemoteControl points needs to be able to be supported in order to fulfill the SCADA use case.

The ability to automatically create RemoteSource points needs to be able to be supported in order to fulfill the SCADA use case.

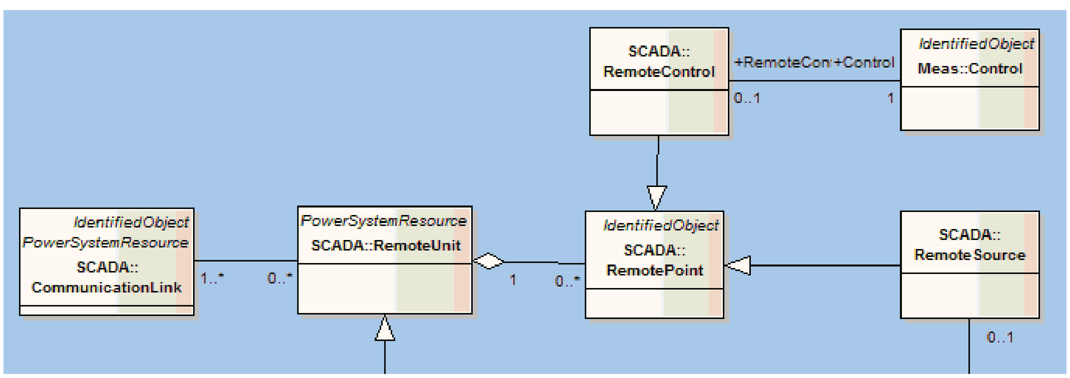


Figure 6-6
Proposed Overview UML for CIM SCADA Package

The obvious change to the CIM SCADA UML, shown in Figure 6-6, is that an IED has been declared as a sub-class of RemoteUnit. There are several other "touch" points that need to be reconciled:

- The CommunicationLink needs to be reconciled with the IEC 61850 Communication information (see page 6-96).
- The ability to automatically create RemoteControl points needs to be able to be supported in order to fulfill the SCADA use case.
- The ability to automatically create RemoteSource points needs to be able to be supported in order to fulfill the SCADA use case.

Additionally, the existing IEC61970 SCADA package needs to be modified.

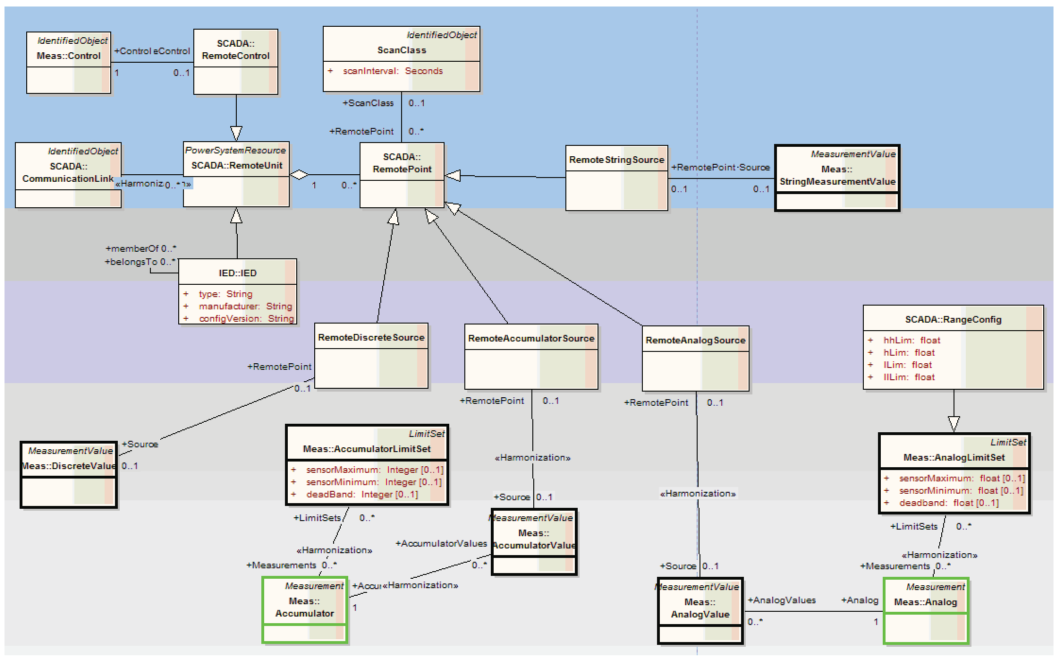


Figure 6-7
Proposed revision to SCADA package

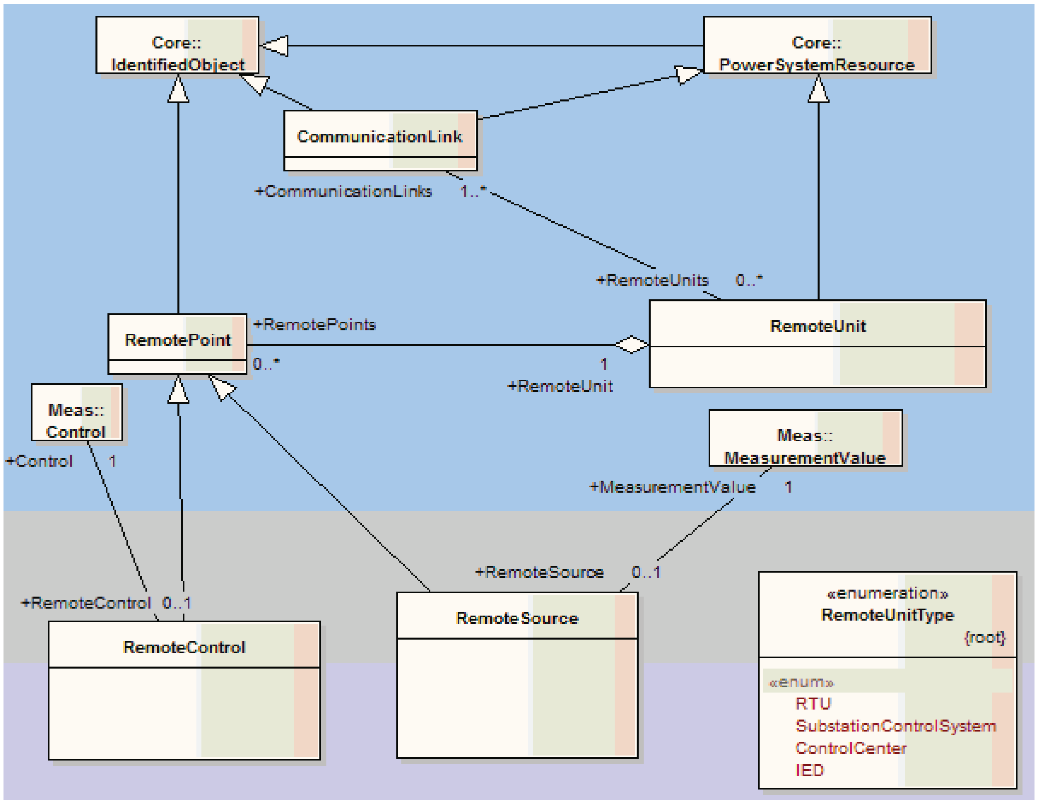


Figure 6-8
IEC 61970 SCADA Package

The proposed revisions allow the SCADA package to take advantage of other parts of the unified model. In particular the IED, Control, and Communication modeling enhancements.

Reconciling Communication Information

The current CIM model only contains a single reference to anything relating to communications. This is the ComunicationLink class found within the 61970 SCADA Package.

The actual CIM CommunicationLink class has no attributes currently defined.

IEC 61850-6 specifies a comprehensive model for communications.

One of the use harmonization use cases involves the ability to auto-configure a SCADA system so that it can perform SCADA functions/communicate with IEC 61850 devices. Therefore, the SCADA package must be reconciled as part of the harmonized model (see page 6-94 . As part of that reconciliation, the communication model must also be reconciled (see page 6-96).

In order to perform the appropriate reconciliation for the documented set of use cases, it is clear that the CIM CommunicationLink class needs to be reconciled/harmonized with the IEC 61850-6 communication model.

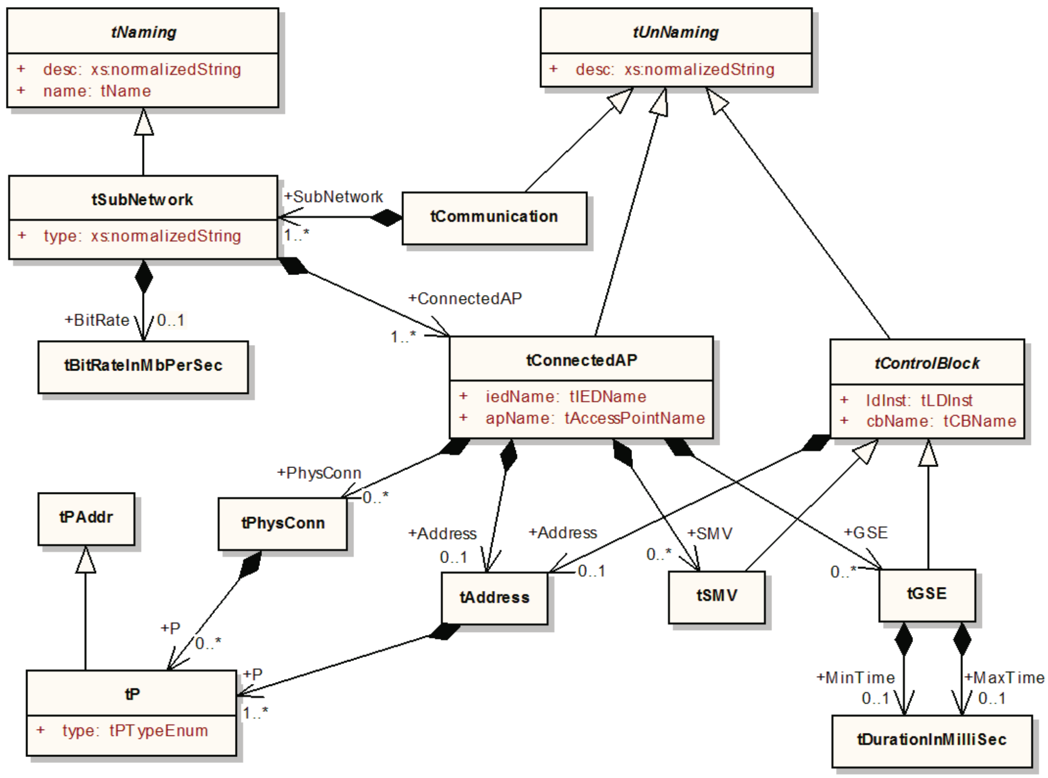


Figure 6-9
IEC 61850-6 Communication Model

However, such reconciliation needs to be done in a manner consistent with the use cases and with an eye for future extension use. Within the scope of IEC TC57, there are at least two (2) other standards that should be taken into account: IEC 60870-5-104 and IEC 60870-6 TASE.2. Both of these standards make use of TCP/IP addressing/communications.

Additionally, it is fairly clear that SampledValues will not be streamed between substations (e.g. IEC 61850-90-1) or between substations and control centers (e.g. IEC 61850-90-2). However, what is not clear is the effect of sub-SCADA masters within a substation. Such sub-masters could be capable of receiving SampledValues and GSE messages. Therefore, the following UML is proposed to support the SCADA use case, including sub-masters within a substation.

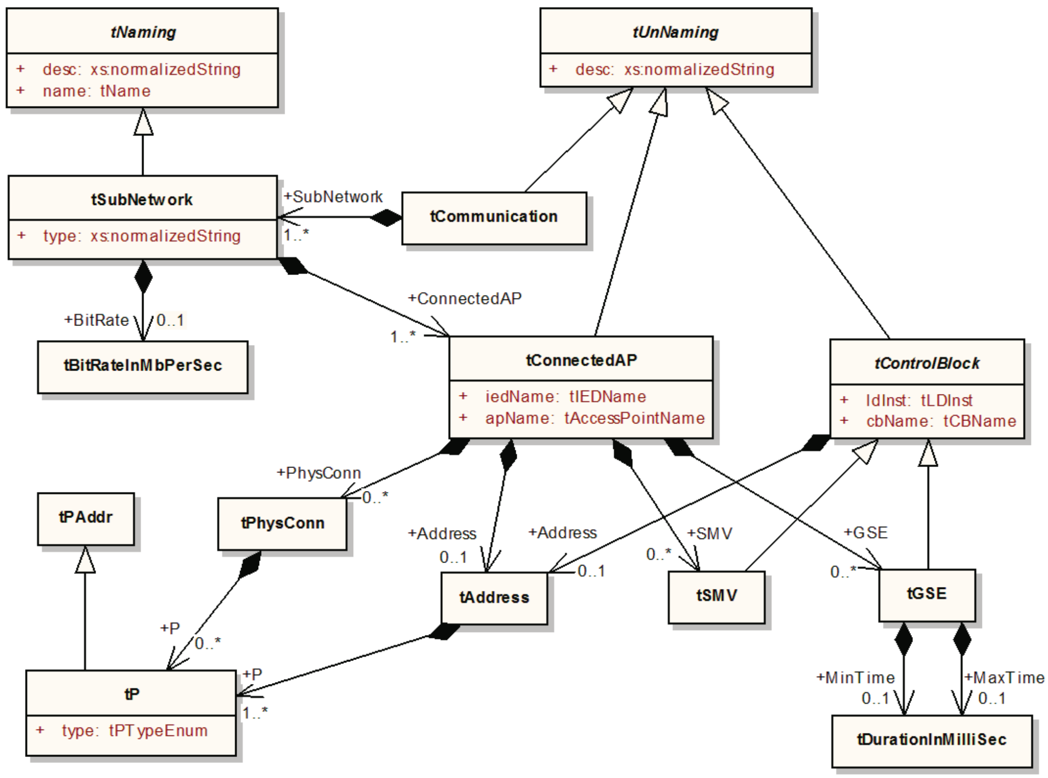


Figure 6-10
IEC 61850-6 Communication Model

There are obvious similarities between Figure 6-10 and Figure 6-11. However, Figure 6-11 is constructed so that the other TCP/IP based IEC TC57 protocols can make use of the TCP_AccessPoint. Additionally, the proposed UML model also supports the possibility of UDP access points.

The CommunicationLink.ProtocolinUse attribute is currently with a data type of string. This could eventually be converted to an Enumeration if an appropriate set of values can be agreed upon. In lieu of such an agreement, the standardization of specific string values is required. For the purposes of this document, the following string values have been identified:

- IEC61850_8_1_ISO9506 – The ISO 9506 (e.g. MMS) profile
- IEC61850_8_1_GOOSE
- IEC61850_9_2_SV
- IEC60870-6-TASE2
- IEC60870-5
- DNP3

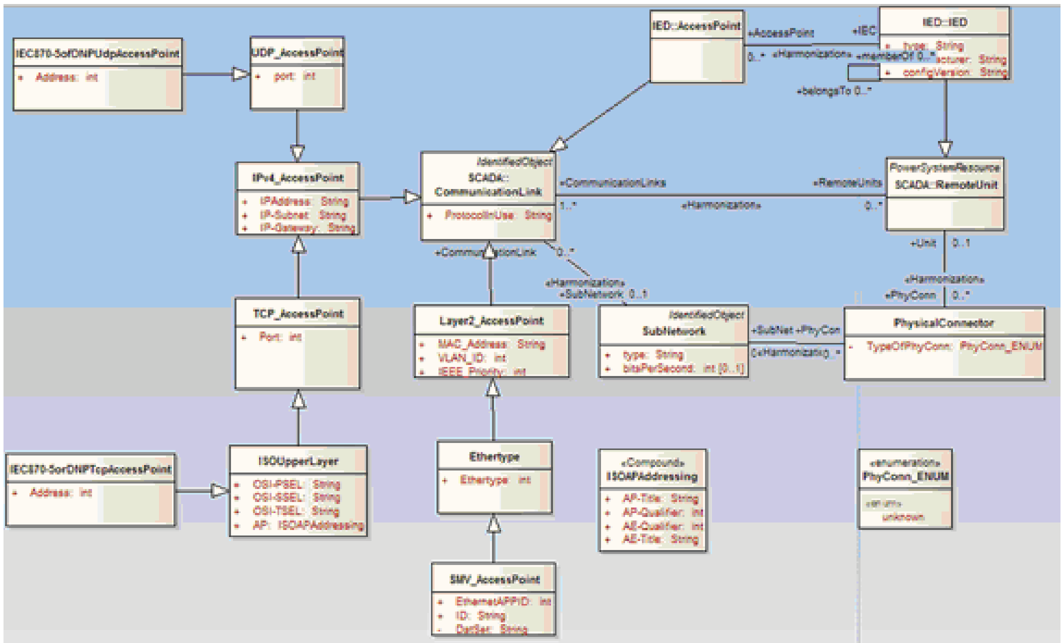


Figure 6-11
Proposed Communication Harmonized UML

Reconciling Measurements and IEC 61850

Figure 6-12 shows the current IEC 61970 Measurement Model versus a simplified view of the equivalent model in IEC 61850. There are some immediate differences that can be seen:

- IEC 61970 allows for only simple data types (e.g. AnalogValue) and does not allow for structure or arrays of data (e.g. the IEC 61850 ComplexData).
- IEC 61970 assumes that all instances MeasurementValues, associated to an instance of a Measurement, represents the value for the same measurement except from potentially different MeasurementValue sources.

Therefore, IEC 61970 Measurements should not be used to group different MeasurementValues from the same source that represent different entities.

Besides the aforementioned, there are other harmonization/mapping issues that need to be resolved:

- There is a design pattern within IEC 61970 and IEC 61968 that needs to be rectified.
- The base data types of the MeasurementValues and IEC 61850 do not align in a manner that allows the re-generation of SCL files.
- There are issues regarding the precision of the timestamp in CIM versus what is specified in IEC 61850.
- There are issues in allowing the reconstruction of the SCL/IEC 61850 hierarchies.
- How to map names and descriptions needs to be determined.

IEC 61970 and IEC 61968 Design Pattern Issue

One of the major areas where there is a significant harmonization linkage, between IEC 61850 and CIM, is the Measurement/MeasurementValue classes. In order to provide a stable point of harmoniza-

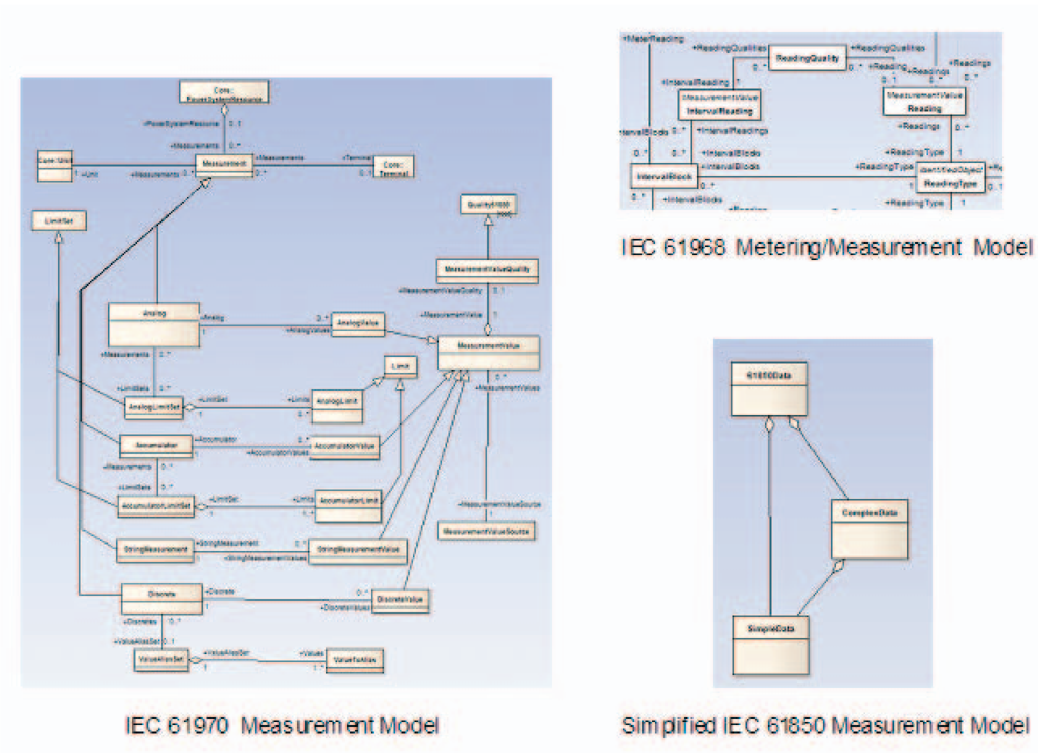


Figure 6-12
Comparison of IEC 61850 and CIM Measurement Model

tion, the current design pattern of each CIM information domain creating further specializations must come to an end and be corrected within the unified model.

Figure 6-13 shows that the MeasurementValue class has been specialized beyond its normal Discrete-Value, StringMeasurementValue, AnalogValue, and AccumulatorValue. In order to not overly complicate the class mappings (e.g. between IEC 61850 and CIM), each specialization of Measurements/MeasurementValues needs to be investigated. In general, these classes do not appear to require specialization for anything that is a tele-metered or calculated value. Extreme care, regarding specialization, needs to be exercised in areas where both CIM and IEC 61850 are intended to be used. Such is the case with the Metering package of CIM where both Interval Reading and Reading are defined.

Figure 6-14 shows the IEC 61970 Measurement model and a portion of the IEC 61968 Metering Model. In general, it is recommended that IEC 61970 MeasurementValues be used in an non-specialized form for any modeling that is being performed as extensions to CIM or for harmonization.

It is clear in IEC 61968 that the Reading class is a specialization of MeasurementValue (e.g. from IEC 61970). Although it is not immediately obvious why IEC 61968 decided to specialize Measurement-Value, this pattern is indicative of a thought pattern that each information domain is "special" and that Measurements/MeasurementValues are different depending upon the information domain. The desire to be "special" is based upon human nature and possible lack of coherent definitions and an understanding of applying the concept of profiling.

In order to allow IEC 61850 to be used to provide readings, within the IEC 61968 domain, the IEC 61968 model must be changed to align with IEC 61970. The Reading.value attribute type is a floating point. There are two options to accomplish this alignment:

- Replace the Reading class with AnalogValue explicitly. This mechanism would be more consistent with the use of profiles.
- Replace the inheritance of Reading so that it inherits from AnalogValue. This mechanism provides less disruption to the metering model.

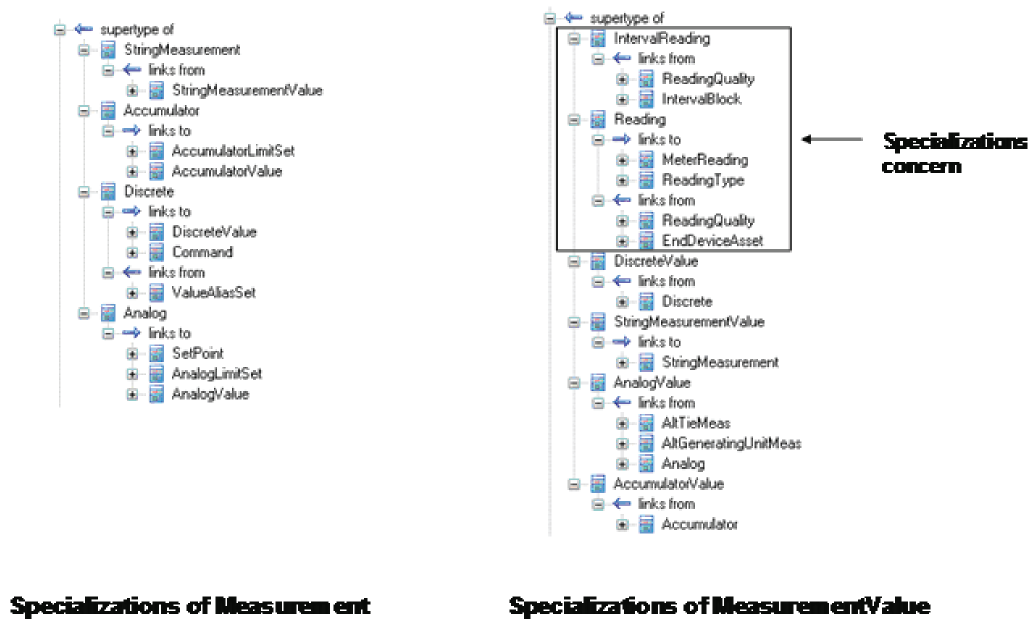
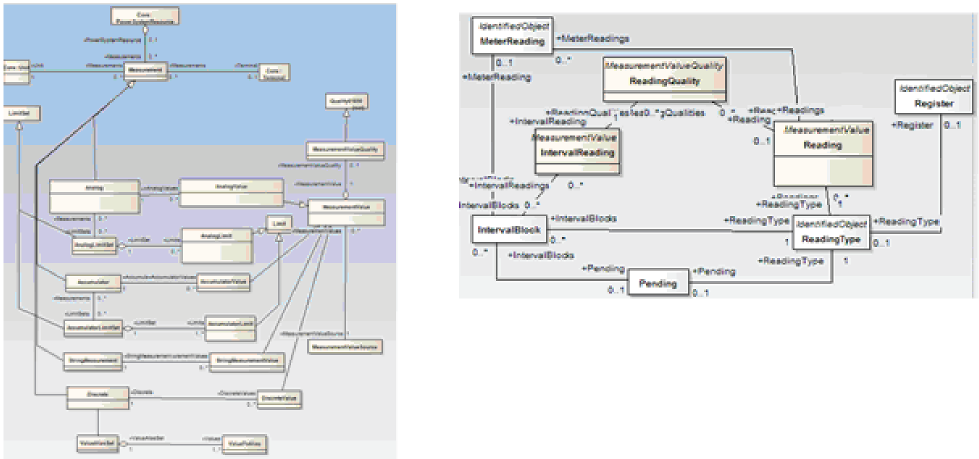


Figure 6-13
Current CIM Specializations of Measurements and MeasurementValues



61970

61968

Figure 6-14
61970 and 61968 Metering Measurement Model

Therefore, there should be no Reading class, but instead an IEC 61970 AnalogValue class should be utilized. In order to reconcile this, the following changes to the UML is recommended:

Additionally, IEC 61970 and IEC 61850 have well defined quality values whereas IEC 61968's ReadingQuality.value attribute is of type string (e.g. not well typed in the UML). It is clear, that within the unified model, only one set of standardized quality should be used. The reconciliation of qualities within the unified model needs to be an issue for IEC TC57 WG19 and future work.

Additionally, the details of the ReadingType class include unit type and scaling information. The issue between the IEC 61970 and IEC 61968 model, regarding units, is that IEC 61970 associates units (e.g. the Unit class) to Measurements, whereas IEC 61968 has chosen to associate units with a MeasurementValue. In order to keep IEC 61970, IEC 61968, and IEC 61970, it is important that these be aligned per the changes recommended on page 6-138.

This results in the UML shown in Figure 6-16 below.

An association to a standardized Unit class was added and the unit information was removed from within the ReadingType class.

The other specialization, that needs to be addressed is the IntervalReading class. The definition of this class is currently:

> *Data captured at regular intervals of time. Interval data could be captured as incremental data, absolute data, or relative data. The source for the data is usually a tariff quantity or an engineering quantity. Data is typically captured in time-tagged, uniform, fixed-length intervals of 5, 10, 15, 30, or 60 minutes.*
>
> *Note: Interval Data is sometimes also called "Interval Data Readings" (IDR).*

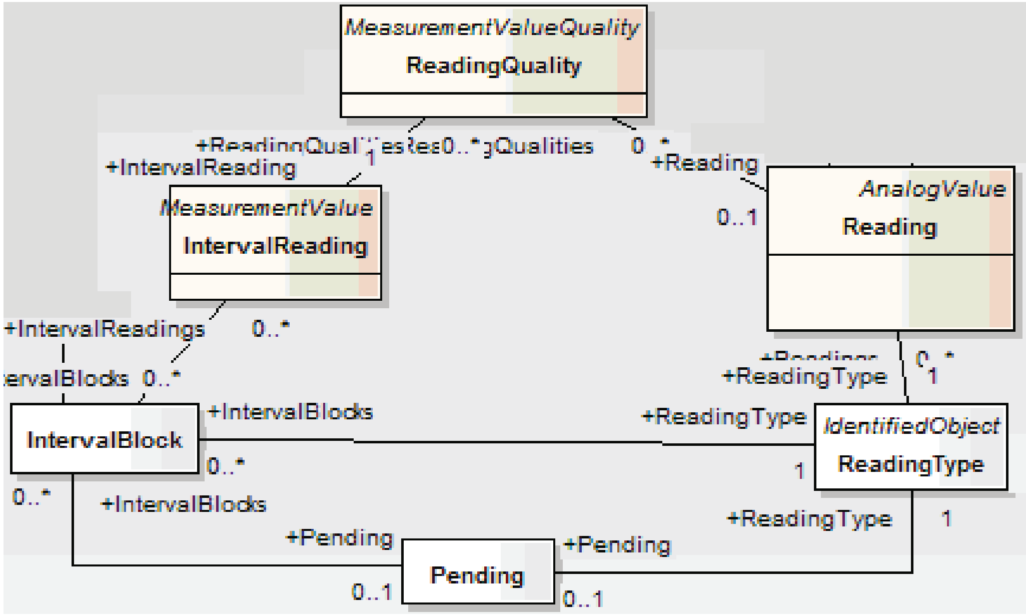


Figure 6-15
Change of Reading to Inherit from AnalogValue

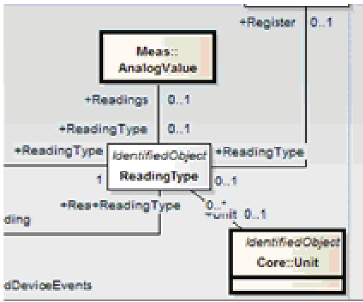
The difference between the Reading and IntervalReading class is the association to IntervalBlock. Such an association should be enough to differentiate between what was formerly and Reading and Interval-Reading. Additionally, such a change allows the same standardized quality to be utilized throughout the unified model.

It is important that all editors of the relevant standards that are within a harmonized/unified model do not make specializations that are not consistent with other parts of the model. In the past, it was IEC 61970 and IEC 61968 only. However, the reconciliation just performed indicates that rules needed to be in place. With the introduction of IEC 61850 into the model, rules and consistent design patterns become even more important.

In general the following rules should be fairly non-controversial:

- Standardized Unit definitions should be used via association (e.g. make use of the Unit class) as shown in Figure 6-18 below.

  Note: This rule may impact the IEC 61970 Curve class. At a minimum, the revised enumerations should be used. Another solution would be to change the attributes to be based upon the actual Unit class. Another solution is to have Curve be composed of three instances of Unit.
- No specializations of Measurement/MeasurementValues should occur unless such special-ization are unique within the domain being modeled. However, for telemetered values, it is difficult to see where such specializations would be needed.
- Standardization of well defined quality representations is mandatory and all packages, within the model, should use the same class definition or specialize it further for its domain purpose.



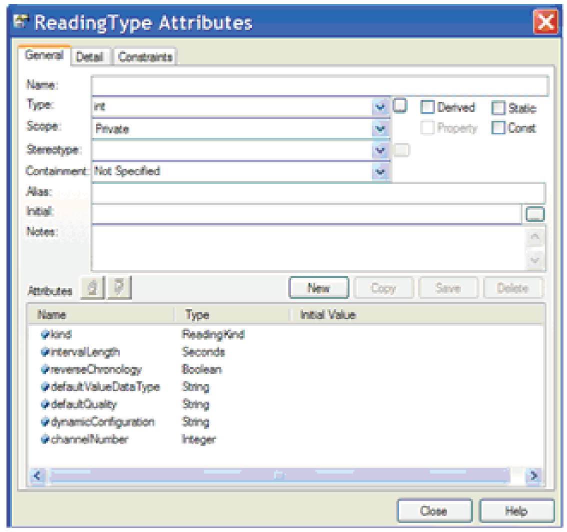


Figure 6-16
Proposed Model to Reconcile 61968 and 61970 Difference in ReadingType

Alignment of BasicTypes

Figure 6-19 shows the CIM Measurement model versus the IEC 61850 Basic Types from IEC 61850-7-2. Only some of the basic types can be found in IEC 61850 attributes that would be typically mapped to instances considered within the CIM Measurement model. Within IEC 61850, such attributes would typically have a functional constraint of MX (e.g. Measurement) or ST (e.g. Status).

The IEC 61850 basic types of concern are the Integer, Floating Point, Enumerated, and boolean types.

This section deals with the UML changes and mapping definitions required to allow such IEC 61850 attributes to be properly represented within the CIM Measurement model. Additionally, the design pattern of mapping/modification is intended to allow the unified model-to-SCL interface to be able to form a well constructed SCL file.

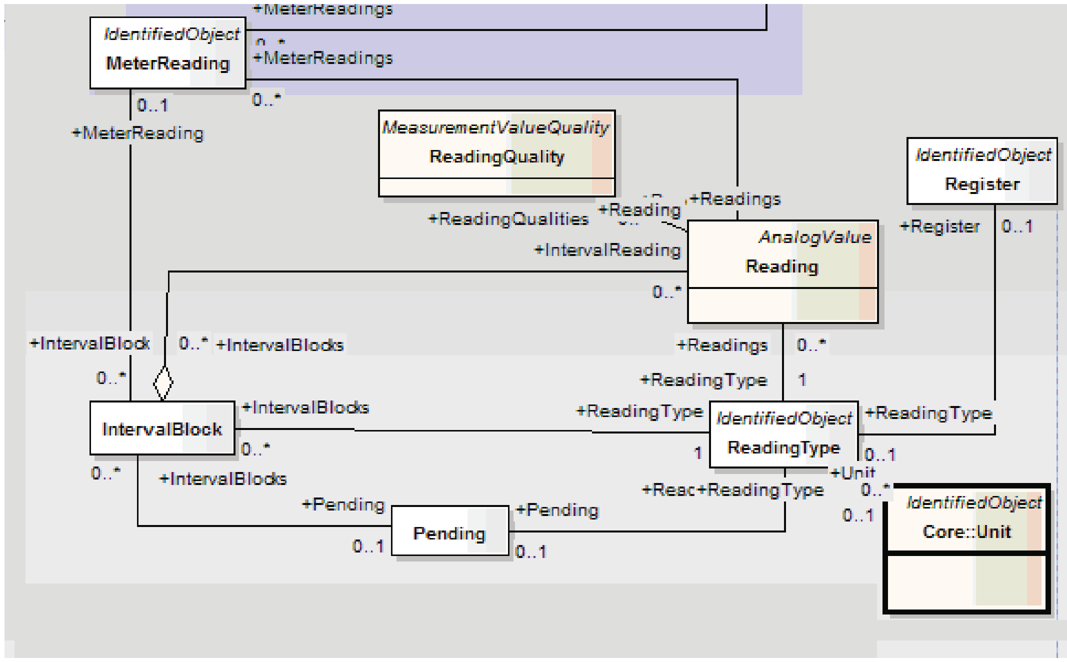


Figure 6-17
Proposed removal of IntervalReading Class

AccumulatorValue

In IEC 61850 there are seven(7) different precisions of Integer values that can be specified in SCL. However, CIM only has a single AccumlatorValue class in which to represent all Integer values. In order to be able to reconstruct, and properly specify SCL, the precision of the value needs to somehow be specified.

Where the value of the precision attribute determines the maximum ranges of values that could be represented.

It is worthwhile to note that IEC 61850-7-4 FNCT Logical Node specifies the use of a 64-Bit integer.[5] With this acknowledgment, CIM implementations must be capable of interpreting the Accumulator-Value.value attribute as possible a value that could require 64-bits. It is not clear in the UML that this is precisely defined.

[5] The actual specification indicates INT128. However, in IEC 61850-7-2, INT128 is specified to have a range consistent with INT64.

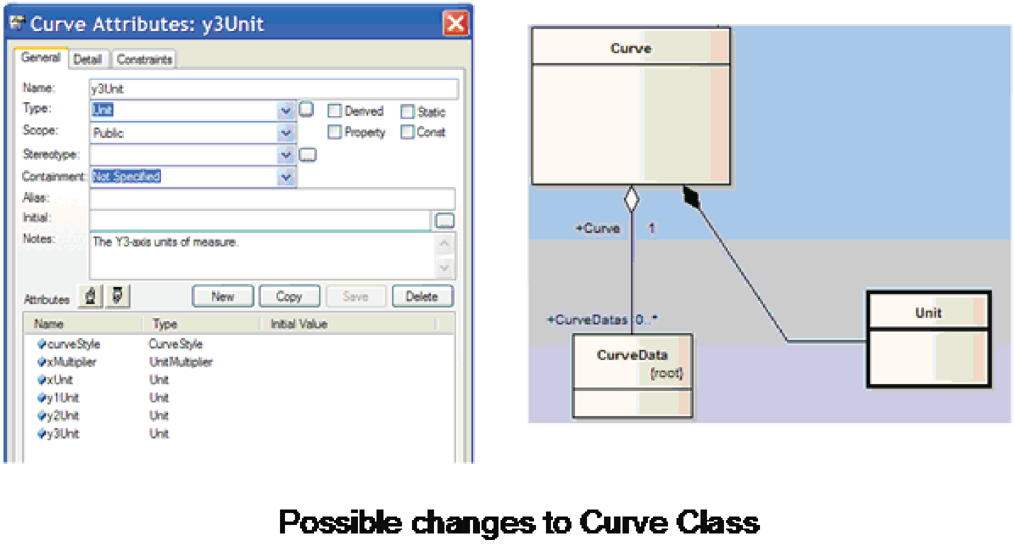


Figure 6-18
Possible Changes to Curve Class

With these modifications, any IEC 61850-x attribute that has a functional constraint of FC=ST or FC=MX should be mapped to an instance of the CIM AccumaltorValue class.

AnalogValue

There are other IEC 61850 attributes, of FC=MX or FC=ST, that are Integer values. For those attributes that do not represent enumerated values, these attributes should be mapped to an instance of the AnalogValue class. However, due to the need to reconstruct SCL, the actual data type/precision needs to be specified in a similar manner to what was recommended for the modification to AccumulatorValue.

Where the value of the precision attribute determines the maximum ranges of values that could be represented.

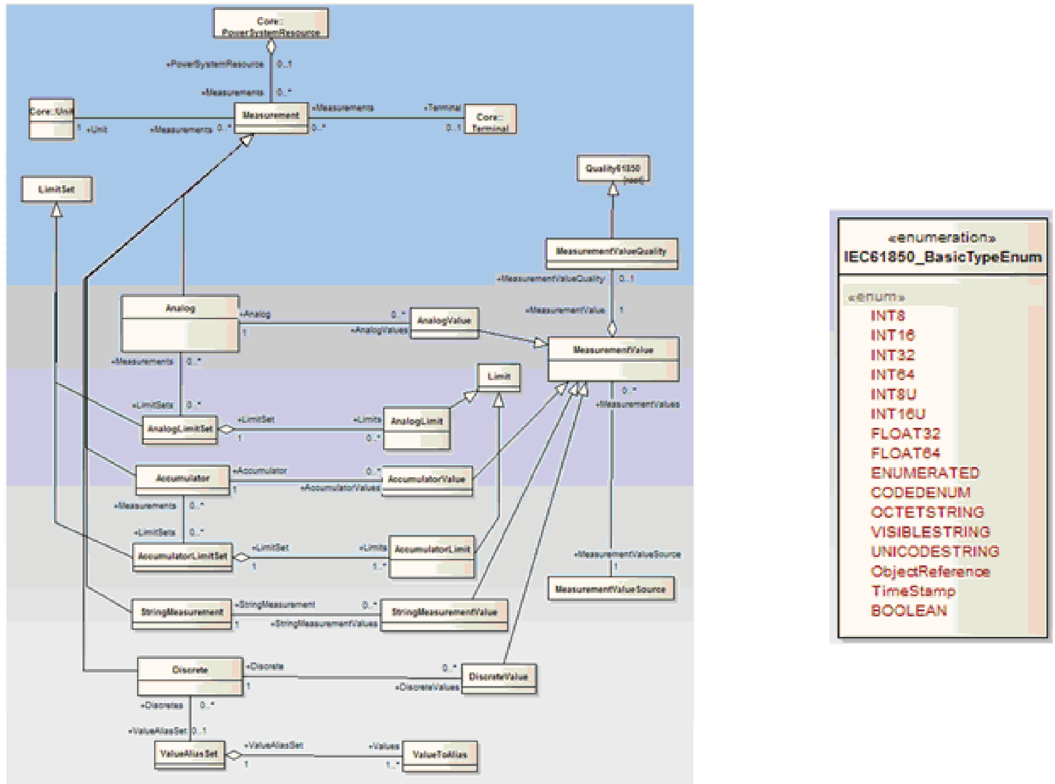


Figure 6-19
Comparison of CIM Measurement Model and IEC 61850 Basic Types

DiscreteValue

Both the IEC 61850 ENUMERATED and BOOLEAN types can be represented by an instance of the CIM DiscreteValue class. It is possible to follow the same pattern proposed for the previous MeasurementValues, however, since there are only two(2) types to be reconciled, an additional class is proposed to be added instead.

Where a value of TRUE shall be a non-zero value. The value of FALSE shall be indicated by a value of zero (0).

Through this specialization, and the ability to therefore make use of the ValueAliasSet, more optimal values can be displayed besides TRUE and FALSE. Coincidently, IEC 61850-7-4 specifies the meaning of TRUE for interesting status points.

As Figure 6-23 shows, a TRUE value is really represented by “synchronized”. Thus, using the proposed modifications, an ValueAliasSet could be instantiated within the unified mode, but the enumerations would not be transferred into SCL via the interface.

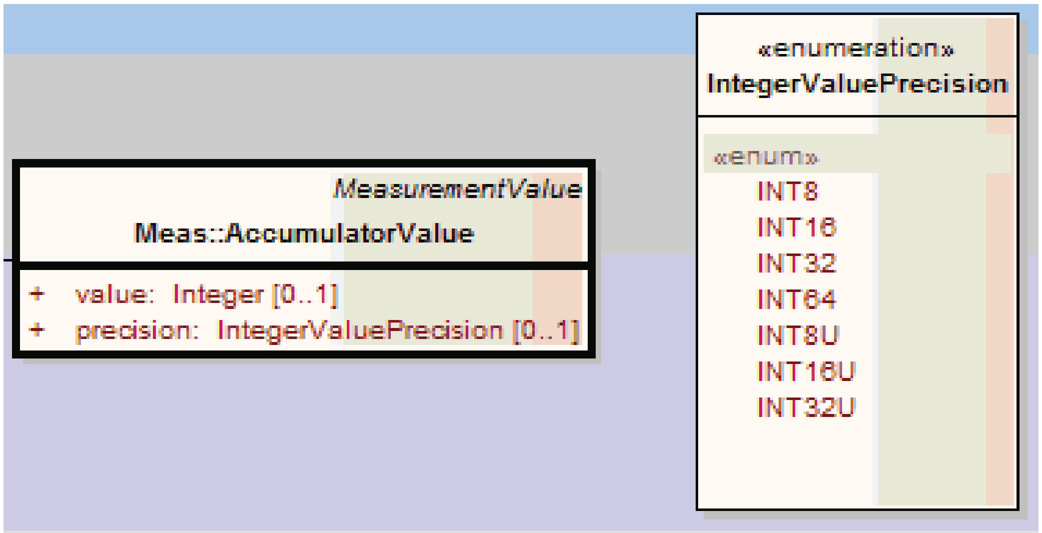


Figure 6-20
Proposed UML Modification to add Integer precision to AccumalatorValue

Timestamp

The timestamp representation, for MeasurementValues, is specified as AbsoluteDate Time and has a precision of milli-seconds (msec). However, IEC 61850 and IEEE C37.118 (Synchrophasor standard) specify timestamp resolutions beyond the msec level. Additionally, IEC 61850, and other standards, specify the fractional portion as fractions of a second instead of absolute msec, usec, or nsec.

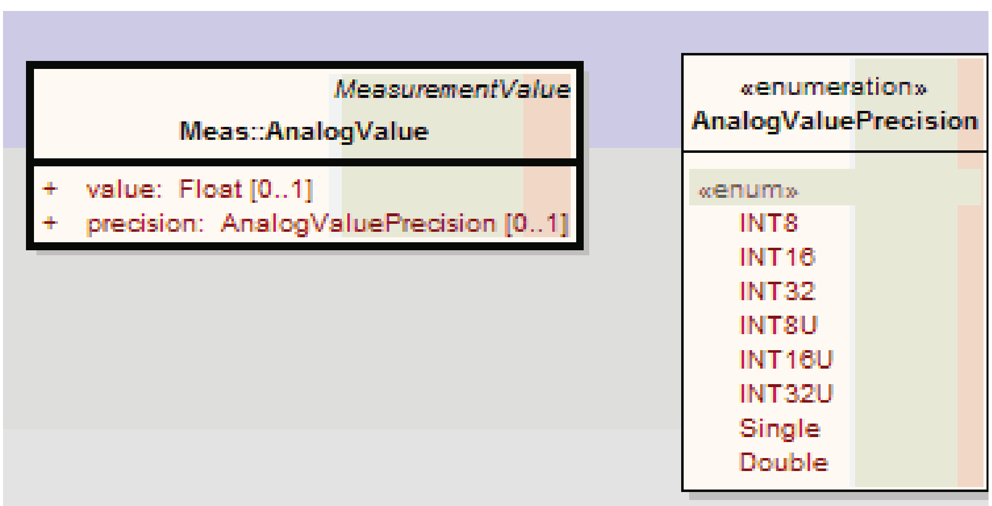


Figure 6-21
Proposed UML Modification to add Integer precision to AnalogValue

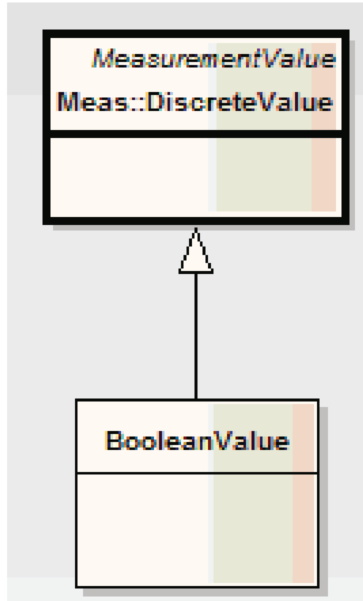


Figure 6-22
Proposed Specialization of DiscreteValue

There are two possible techniques to reconcile the differences in Timestamps:

- The definition of the CIM AbsoluteDateTime data type could be extended to allow at least micro-second resolution. Since the data type is defined as a string value, there is no true impact on the model except for documentation and specifying an extensible format. However, due to the representation of IEC 61850, there will be a residual error in the timestamp since it is not possible to represent a single msec. The residual error could be approximately 60 nsec (best case).
- Another DateTime format could be defined that is consistent with IEC 61850 and SNTP. This data type would then replace the AbsoluteDateTime timestamp for MeasurementValues.

It is recommended that the current AbsoluteDateTime data type be extended.

MDIF class				
Data Object Name	**Common Data Class**	**Explanation**	**T**	**M/O/C**
LNName		The name shall be composed of the class name, the LN-Prefix and LN-Instance-ID according to IEC 61850-7-2 clause 19		
Data Objects				
Measured Values				
OpARem	WYE	Operate Current (phasor) of the local current measurement		C
Amp	SAV	Operate Current (Sampled value) of the local current measurement		C
SynSt	SPS	Synchronization status (TRUE: synchronized, FALSE: not synchronized)		O

Figure 6-23
IEC 61850-7-4 MDIF Definition

IEC 61850 Data Hierarchy

Consider the way CIM and 61850 would represent a 3-phase voltage measurement:

Figure 6-24 shows how a CIM Measurement/MeasurementValue combination is typically used to represent the hierarchy of a WYE connected voltage measurement. The CIM representation typically embeds a user defined hierarchy into the value of the IdentifiedObject.name attribute. In many cases, the hierarchy includes the substation name and potentially other identifying characteristics. Although it is not possible to prescribe the behavior of users, CIM itself recommends following IEC 61850 naming conventions in order to have standardized names that are exchanged. Additionally, most CIM

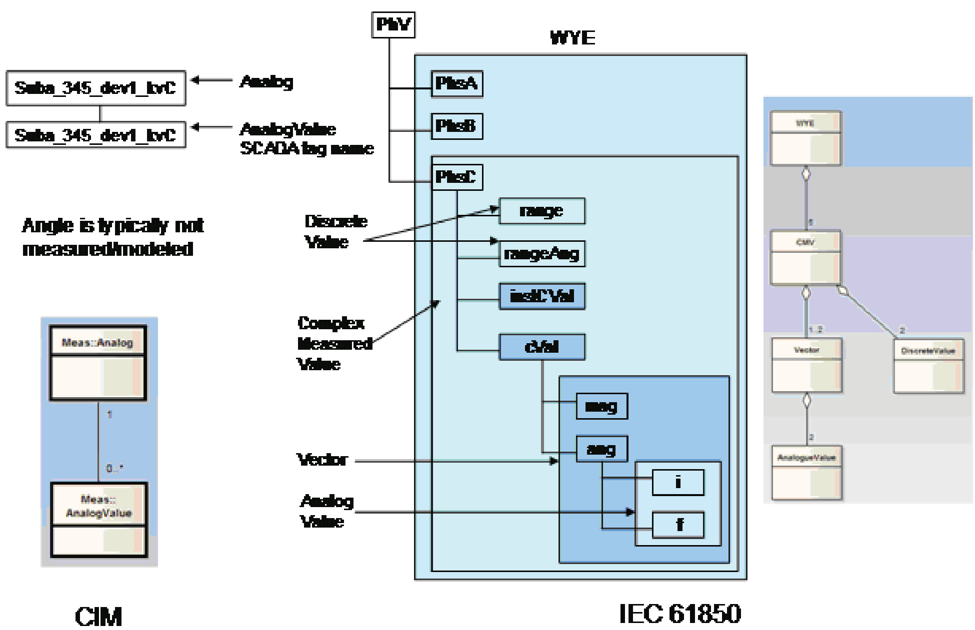


Figure 6-24
Specific Comparison of 3-phase Voltage Measurement

models/users assume that only the field dead-banded value is of interest/provided and therefore the <cVal> differentiation is typically not part of the current naming hierarchy. Therefore, any reconciliation approach must allow the user the flexibility that they currently enjoy while promoting the methodology of IEC 61850 naming.

The figure also shows that IEC 61850 has a very well defined structure and naming convention. This arises from a runtime type definition structure (shown in Figure 6-25). The runtime definition mechanism is recursive and creates grouping of information.

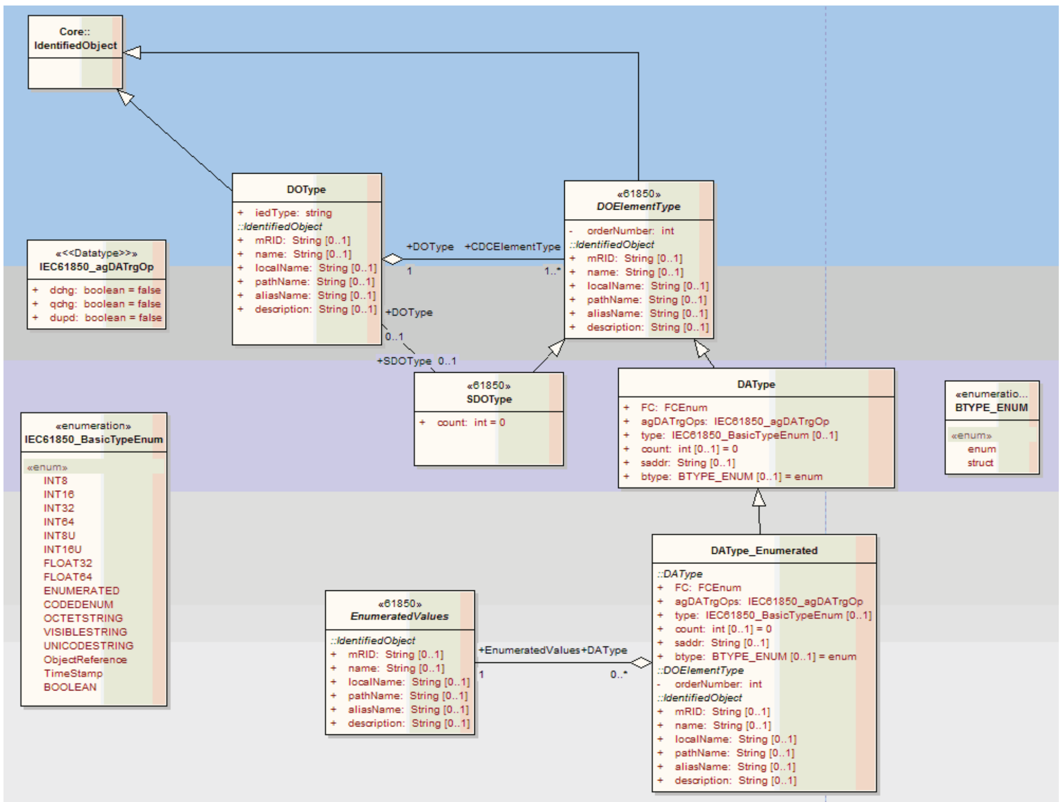


Figure 6-25
UML Representation of SCL CDC Construction

The basic levels can best be described as:

- **Basic Data Types:** These are "simple" or leaf data types such as INT16. Each attribute has a name and is assigned to a functional constraint. It is this level that would typically be mapped to a MeasurementValue.
- **Data Object Element Types:** These are more complex type definitions and that typically represent structures of data (e.g. Vector and CMV). Note: The DOElementType is not defined in IEC 61850, but provides some clarification.
- **Data Object Types:** These aggregate DOElementTypes and therefore can represent both structures and arrays of data.

The complexity can be seen in Figure 6-26.

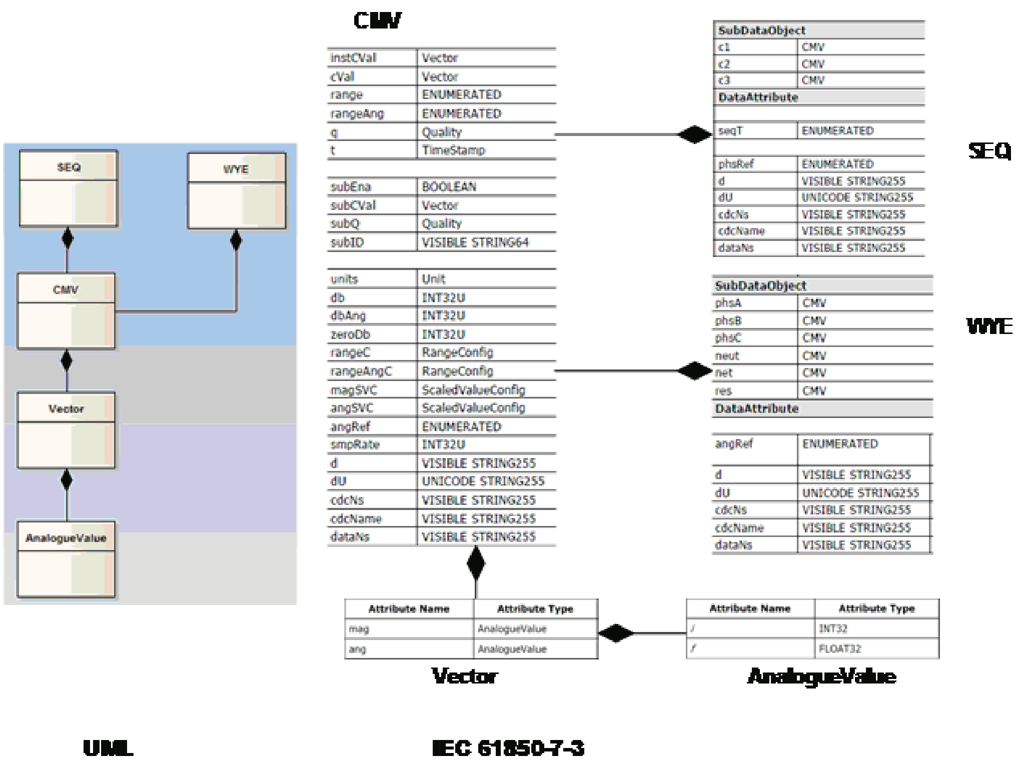


Figure 6-26
UML Representation of SEQ and WYE CDC Types

The figure shows that data types can be used to create more complicated objects and that data types can be shared between different objects/types.

```
<DOType id="myWYE" cdc="WYE">
        <SDO name="phsA" type="myCMV"/>
        <SDO name="phsB" type="myCMV"/>
        <SDO name="phsC" type="myCMV"/>
        <SDO name="neut" type="myCMV"/>
</DOType>
<DOType id="mySEQ" cdc="SEQ">
        <SDO name="c1" type="myCMV"/>
        <SDO name="c2" type="myCMV"/>
        <SDO name="c3" type="myCMV"/>
        <DA name="seqT" fc="MX" bType="Enum" type="seqT"/>
</DOType>
<DOType id="myCMV" cdc="CMV">
        <DA name="cVal" fc="MX" bType="Struct" type="myVector" dchg="true"/>
        <DA name="q" fc="MX" bType="Quality" qchg="true"/>
        <DA name="t" fc="MX" bType="Timestamp"/>
</DOType>
<DAType id="myVector">
        <BDA name="mag" bType="Struct" type="myAnalogValue"/>
        <BDA name="ang" bType="Struct" type="myAnalogValue"/>
</DAType>
<DAType id="myAnalogValue">
        <BDA name="f" bType="FLOAT32"/>
</DAType>
```

Figure 6-27
Sample SCL for IEC 61850-7-3 SEQ and WYE CDC

```
<DOType id="myWYE" cdc="WYE">
        <SDO name="phsA" type="myCMV"/>
        <SDO name="phsB" type="myCMV"/>
        <SDO name="phsC" type="myCMV"/>
        <SDO name="neut" type="myCMV"/>
</DOType>
<DOType id="mySEQ" cdc="SEQ">
        <SDO name="c1" type="myCMV"/>
        <SDO name="c2" type="myCMV"/>
        <SDO name="c3" type="myCMV"/>
        <DA name="seqT" fc="MX" bType="Enum" type="seqT"/>
</DOType>
<DOType id="myCMV" cdc="CMV">
        <DA name="cVal" fc="MX" bType="Struct" type="myVector" dchg="true"/>
        <DA name="q" fc="MX" bType="Quality" qchg="true"/>
        <DA name="t" fc="MX" bType="Timestamp"/>
</DOType>
<DAType id="myVector">
        <BDA name="mag" bType="Struct" type="myAnalogValue"/>
        <BDA name="ang" bType="Struct" type="myAnalogValue"/>
</DAType>
<DAType id="myAnalogValue">
        <BDA name="f" bType="FLOAT32"/>
</DAType>
```

The partial contents of an SCL file, Figure 6-27, shows that not all of the optional attributes are typically included within a runtime definition. What is not shown, is that the types can actually be extended. It is this extension capability and the requirement to recreate the specified SCL type definitions (e.g. for lossless round-tripping of information) that must also be addressed as part of the reconciliation solution. This means that the actual runtime type specification must be available at the appropriate point in the hierarchy.

It is also noteworthy that at the DAType level, in SCL, there is no reference to the "standard" type. This referencing is provided in all levels of SCL except for the DAType and EnumType production (see Figure 6-28). The LNodeType and DOType both have references to the standardized types (e.g. lnClass and cdc respectively), whereas DAType and EnumType do not.

Therefore, it is suggested that the DAType and EnumType XSD be expanded to mandate a reference to the "standard" type definition. Such references to standardized classes would have pre-assigned and standardized IDs as shown in the "This chapter addresses recommended changes to the SCL to reconcile differences in naming and identification of specific instances of equipment and equipment containment in the Addition of Persistent IDs" section.

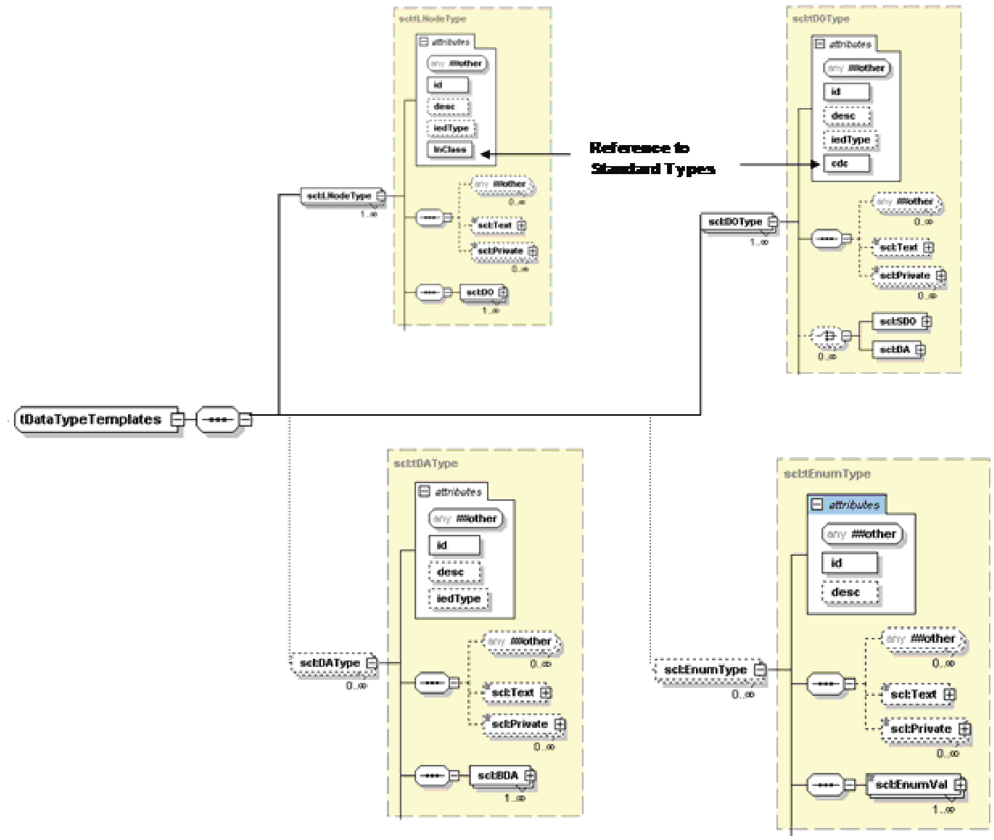


Figure 6-28
DAType Template SCL Productions

The suggested SCL XSD extension are shown in Figure 6-29.

Figure 6-29
Proposed SCL XSD changes for DAType and EnumType

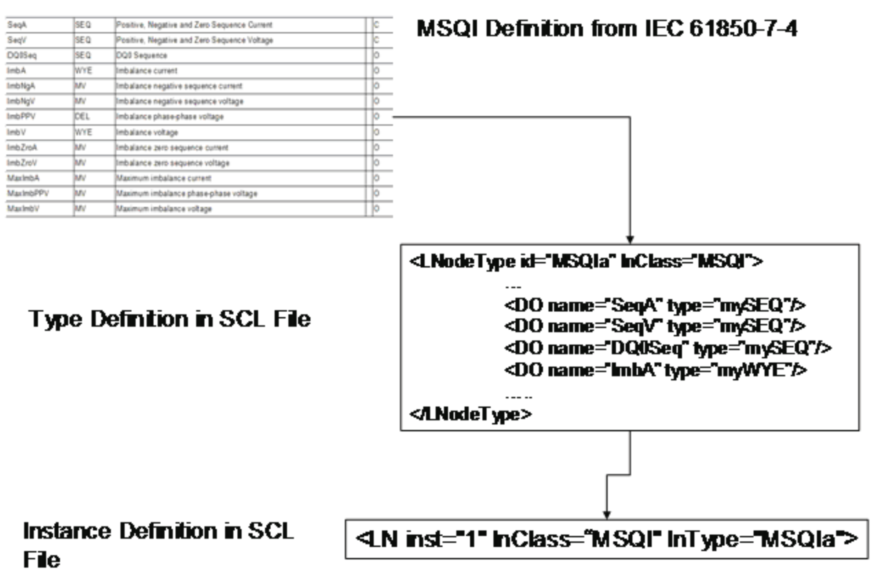


Figure 6-30
IEC 61850-7-4 Definition of MQSI Logical Node

Although there is a strong runtime type definition mechanism in SCL, the instantiation of all of the data comes when a Logical Node is instantiated (see Figure 6-30). In the figure, it is the <LN… line that actually causes a logical node to be created. When this is created, all the data types are instantiated and can be assigned values.

The solution for allowing the unified model to appropriate represent the IEC 61850 hierarchy, while allowing SCADA tag naming (e.g. CIM) is based upon the following constructs:

- The runtime type definitions need to be maintained.
- There needs to be a mechanism to create an instance hierarchy.
- The "touch" points need to be at the MeasurementValue/Measurement level.

A general solution might be best explained by the following diagram:

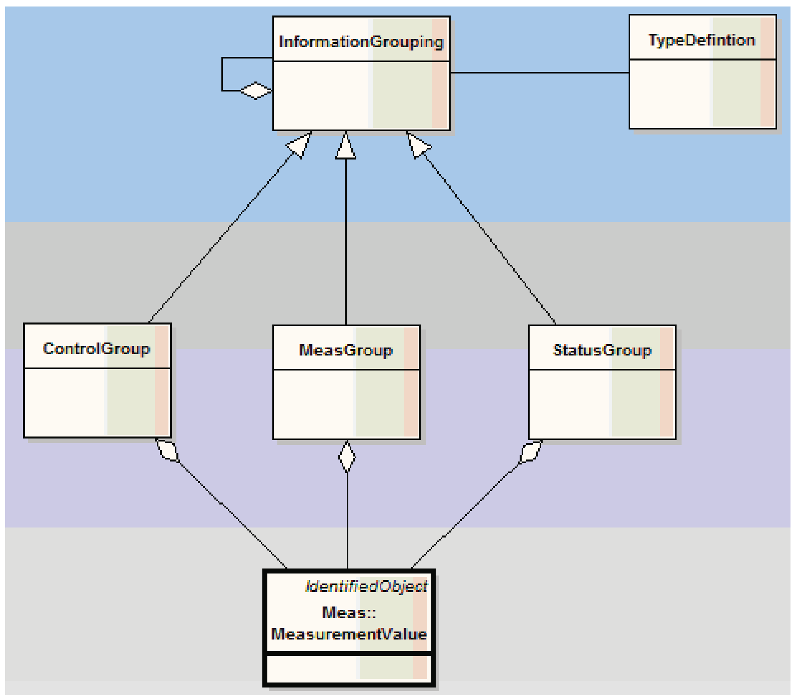


Figure 6-31
General Grouping Concept

Where the ability to create recursive aggregations would allow for the full IEC 61850 hierarchy to be fully expressed. The TypeDefinition would allow structural information to be maintained (e.g. for IEC 61850 the declarative SCL XML string). In the case shown in Figure 6-24, the following diagram would show the different levels of Information Grouping:

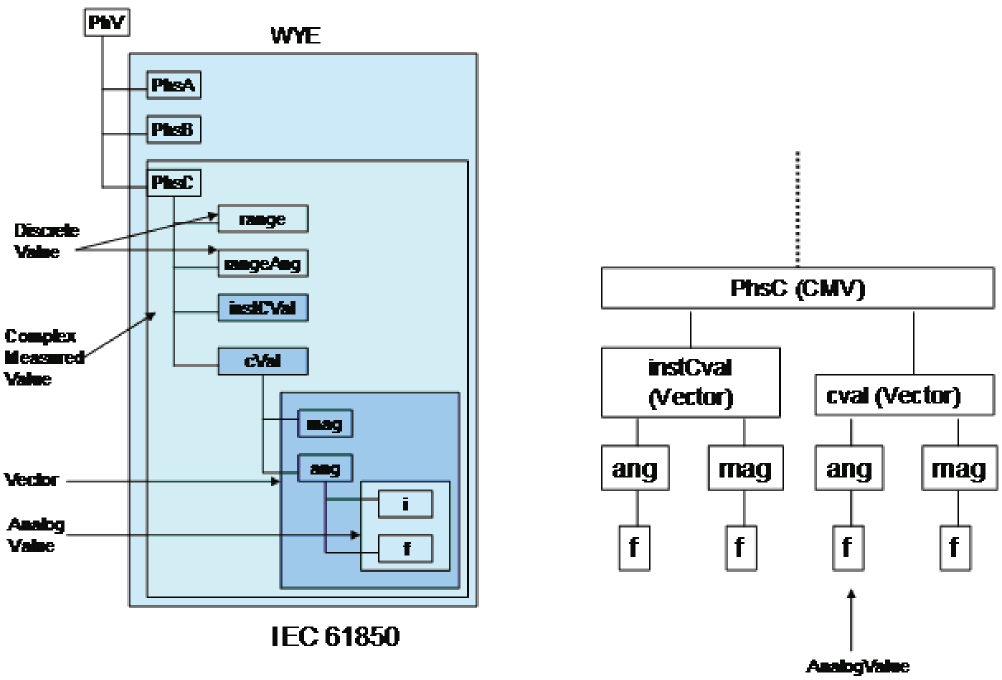


Figure 6-32
Grouping concept and IEC 61850

However, a look at the CIM Control Model shows that CIM Controls are currently specified via Measurements and not MeasurementValues:

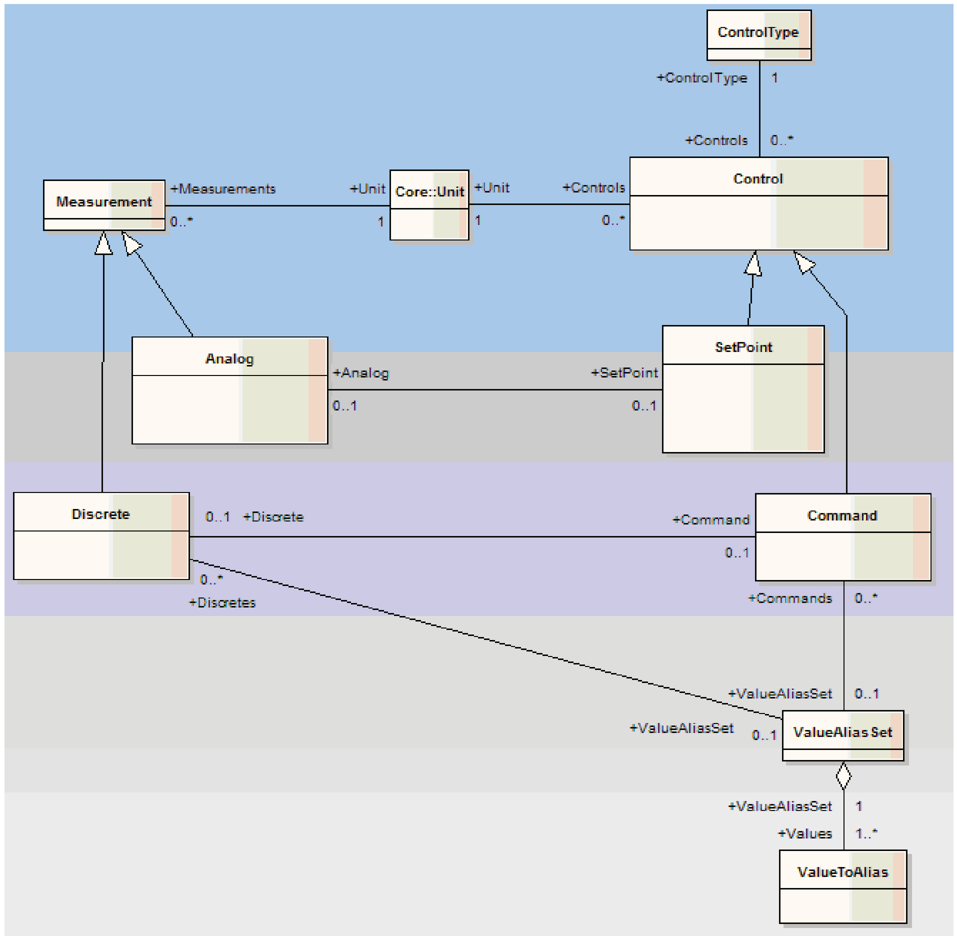


Figure 6-33
Current IEC 61970 Control Model

This means that a re-thought of how to create the hierarchy, using Measurements and Measurement-Values will be needed.

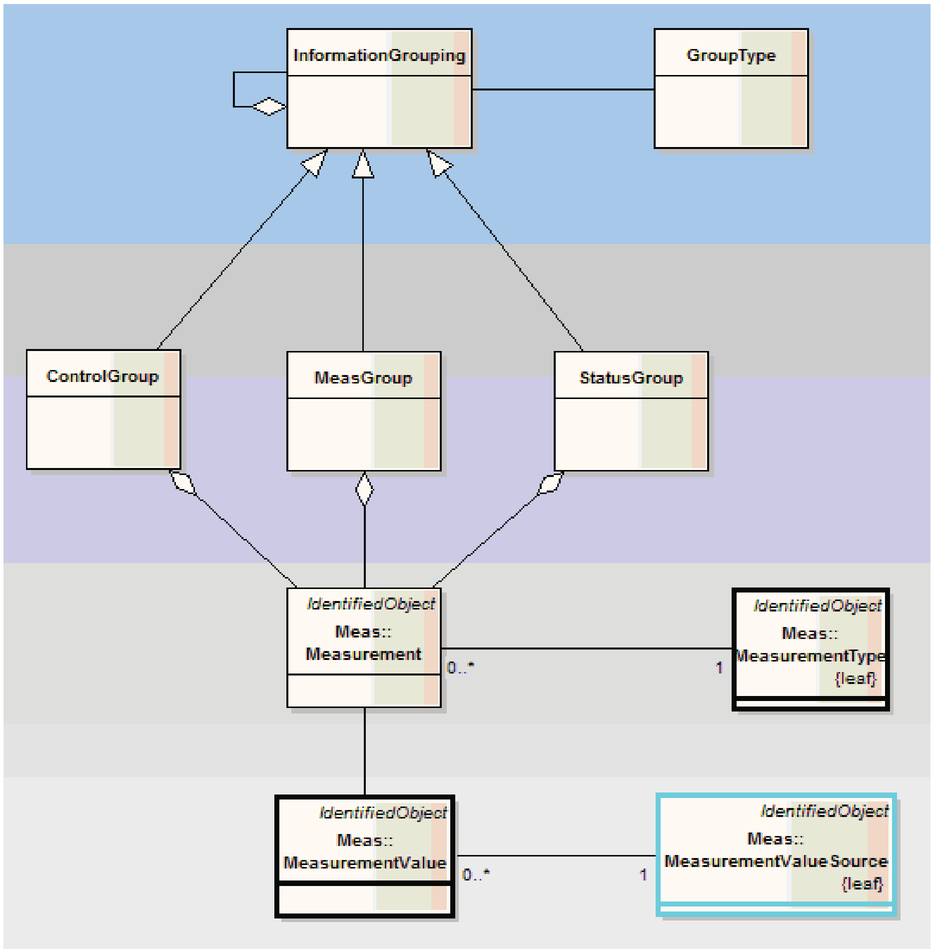


Figure 6-34
General Concept of Measurement Grouping

The revised figure allows for Measurements to be aggregated into groups with an associated MeasurementType. The "TypeDefinition" name was changed to GroupType to mirror the terminology of MeaurementType. In order to actually instantiate these objects, certain rules would need to be applied in the case of IEC 61850 groupings:

- The MeasurementValueSource, for IEC 61850 sourced MeasurementValues, must have a standard definition that is unambiguous and clearly indicates that this is a 61850 MeasurementValue. In order to accomplish this, the following should be similar to how ICCP data exchange is specified in IEC 61970-452 Revision 6.06. However, with the extension some of the proposed unified model extensions (e.g. the Server class), the recommendations are no longer valid and need to be revised for ICCP as well.
- Since CIM Measurements only represent simple or leaf level data, the values of MeasurementType does not need to be used by IEC 61850. However, interfaces should populate instances of the type. However, the allowed values in IEC 61970-452 Revision 6.06 are not inclusive enough for IEC 61850.

Measurement Subclass	MeasurementType
Analog	ThreePhasePower
	ThreePhaseActivePower
	ThreePhaseReactivePower
	LineCurrent
	PhaseVoltage
	LineToLineVoltage
	Angle
	TapPosition
Discrete	SwitchPosition

Figure 6-35
Allowed MeaurementTypes in the CPSM Profile (IEC 61970-452 Revision 6.06)

In order to be more flexible, it is recommended that either the list be expanded to include all possible IEC 61850 values, or that a specialization of MeasurementType is provided (preferred approach). The CIM13 and CIM14 UML have removed the MeasurementType class and therefore, such a table should be removed in IEC 61970-452.

The GroupType class should be able to be used by other protocols. Therefore, it is recommended that it be specialized and that the specialization have associations to the actual standards based definition that the actual type is derived from.

The concept can be extended to include DataObjects, SDOs, and DataSets, and others.

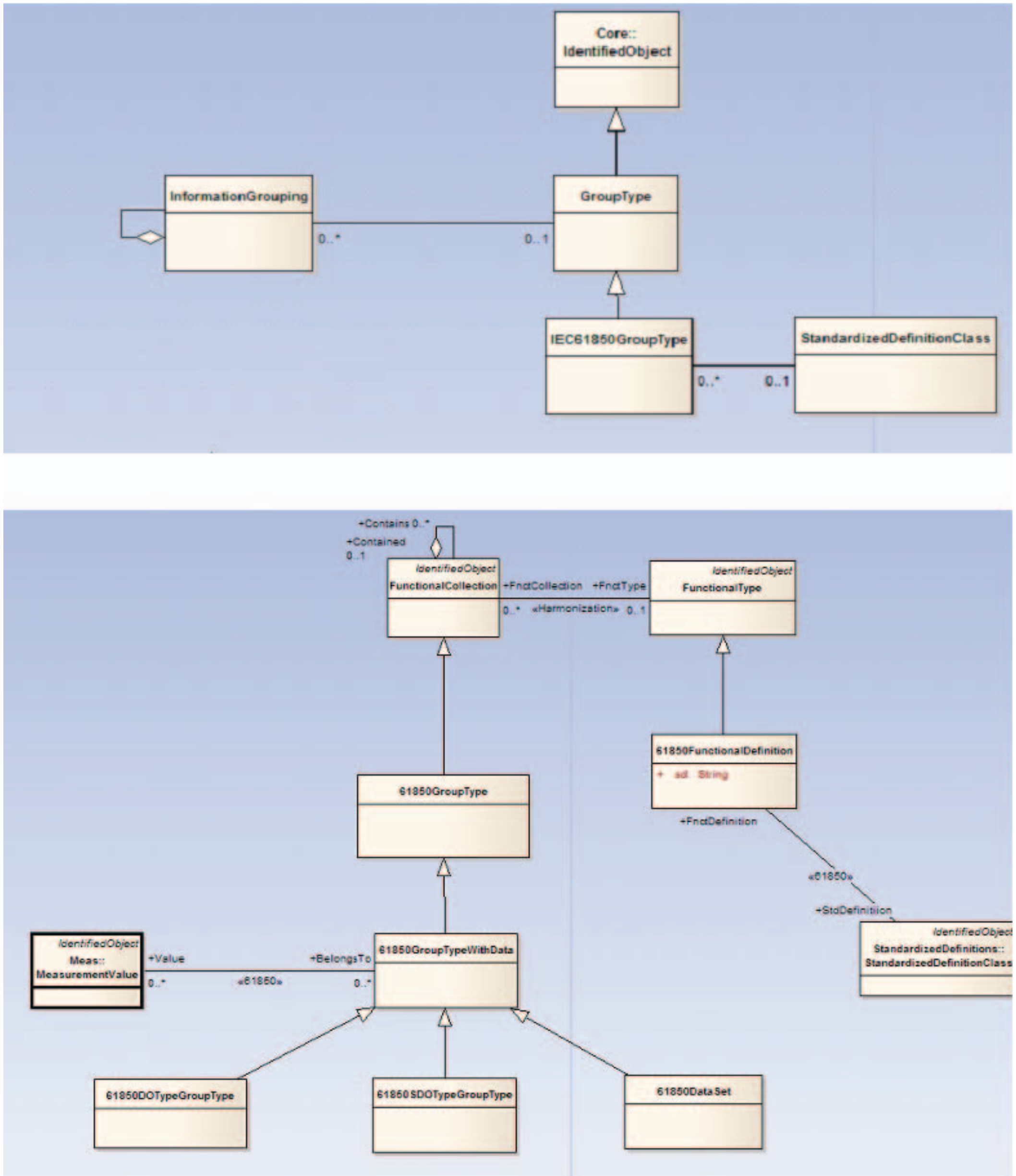


Figure 6-36
Grouping Model

Figure 6-36 shows a model that has two branches. One branch (e.g. GroupTypes and DataSets) will be used to represent the instances of particular objects within SCL. However, there is a required structure of information within IEC 61850 and that structure is determined by the SCL XML information stored in the 61850FunctionalDefinition class instance. In order to be able to reconstruct the correct structure, the IdentifiedObject.name attributes of the GroupType instance shall need to match the attribute names in the SCL string.

In order to reconstruct structure information with MeasurementValues, there has been a set of additional attributes added to the MeasurementValue class (see page 6-158).

The introduced classes have the following descriptions:

- FunctionalCollection: Used to group Measurements and other objects based upon a type of function.

  In the case of IEC 61850, FunctionalGrouping would correspond to Functional Contraints (e.g. at the CDC level), Data Objects (e.g. at the Logical Node Level), and others.

  The general construct is available for users to create their own groupings as their application need.

  There are pre-defined, standardized, specialization of the FunctionalCollection class:
  (1) 61850GroupType: This class is a predefined collection that allows grouping of of IEC 61850 DOs, SDOs, and DataSets. In the terms of IEC 61850, this would typically be a Logical Node instance.
  (2) 61850GroupTypewithData: This class is an abstract collection that allows grouping for MeasurementValue instances to be associated into a particular functional group.
  (3) 61850DOGroupType: The class is a collection that represents an SCL DO object.
  (4) 61850SDOGroupType: The class is a collection that represents an SCL SDO object.
  (5) 61850DataSet: The class is a collection that allows the representation of an IEC 61850 DataSet.

- FunctionalType: Used to describe the functional collection. It has been intentionally modeled as a separate object so that a user can define a single type of functional collection have multiple collections that satisfy that purpose.
- 61850GroupType: Used by IEC 61850 collections to hold the SCL definition of the 61850 grouping.
- StandardizedDefinitionClass: Used to specify the standardized class that the GroupType represents.

The StandardizedDefinitionClass is specialized into three different common classes that allows the appropriate IEC 61850 expansions to be used.

The UML depicts that there are specializations to allow IEC 61850 Common Data Classes (CDCs),

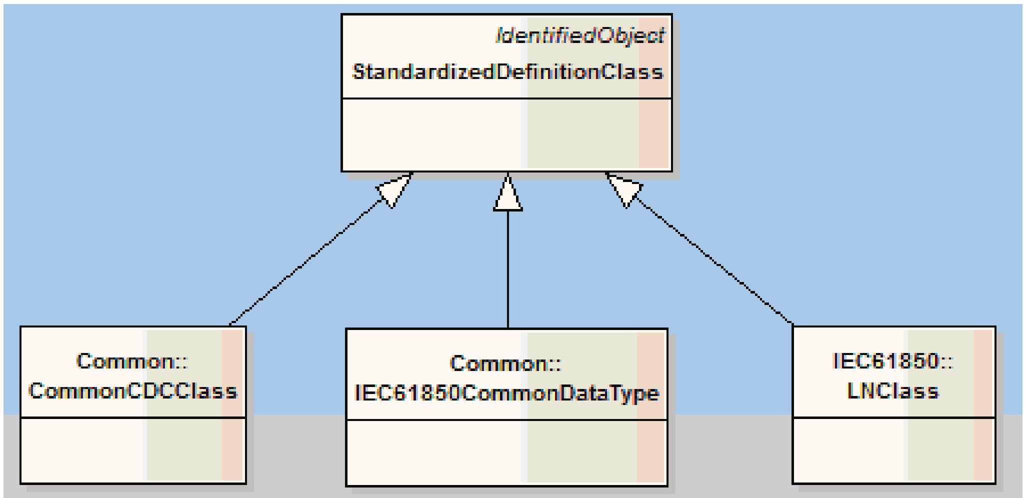


Figure 6-37
Overview of IEC 61850 StandardizedDefinitionClasses

Common Data Types, and Logical Node Classes to be appropriately defined. Each of the specializations are expanded further to support the various IEC 61850 standards.

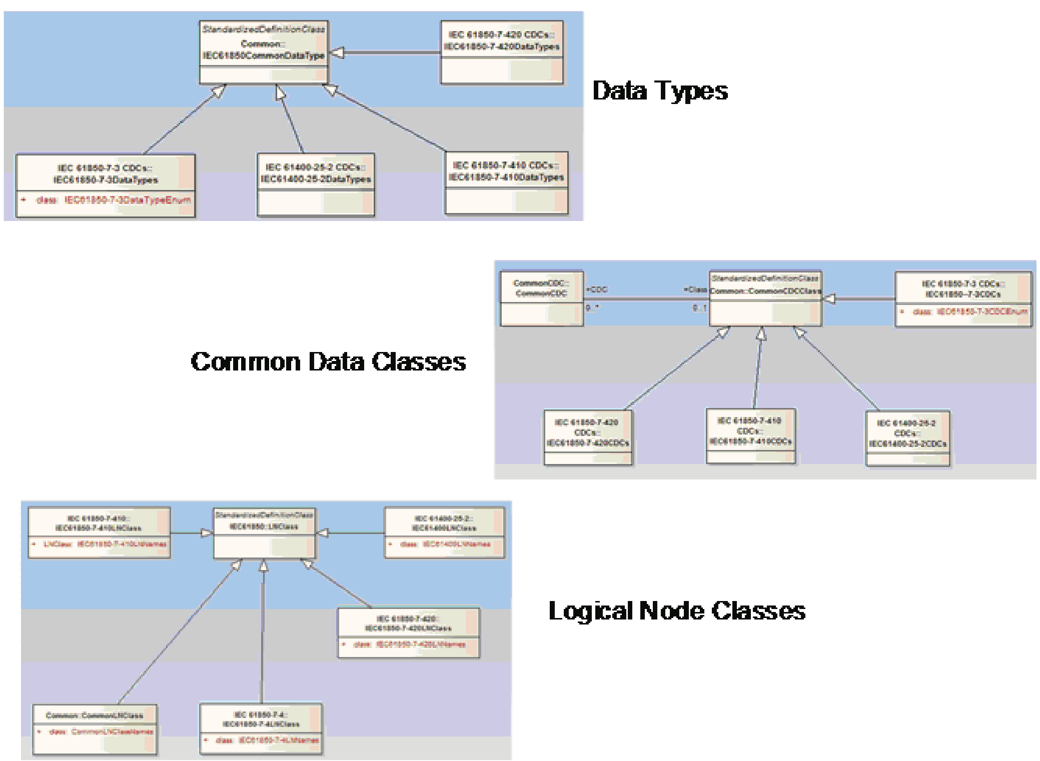


Figure 6-38
Expansion of StandarrdizedStandardDefinitions for IEC 61850

Through the collection construct, IEC 61850 complex objects can be properly represented while allowing users the capability of creating contextual significant groups/collections.

The FunctionalCollection concept is also used to allow multiple Logical Nodes to be used to define complex functions (e.g. protection functions that require more than one Logical Node). The FunctionClass is a specialization of FunctionalCollection.

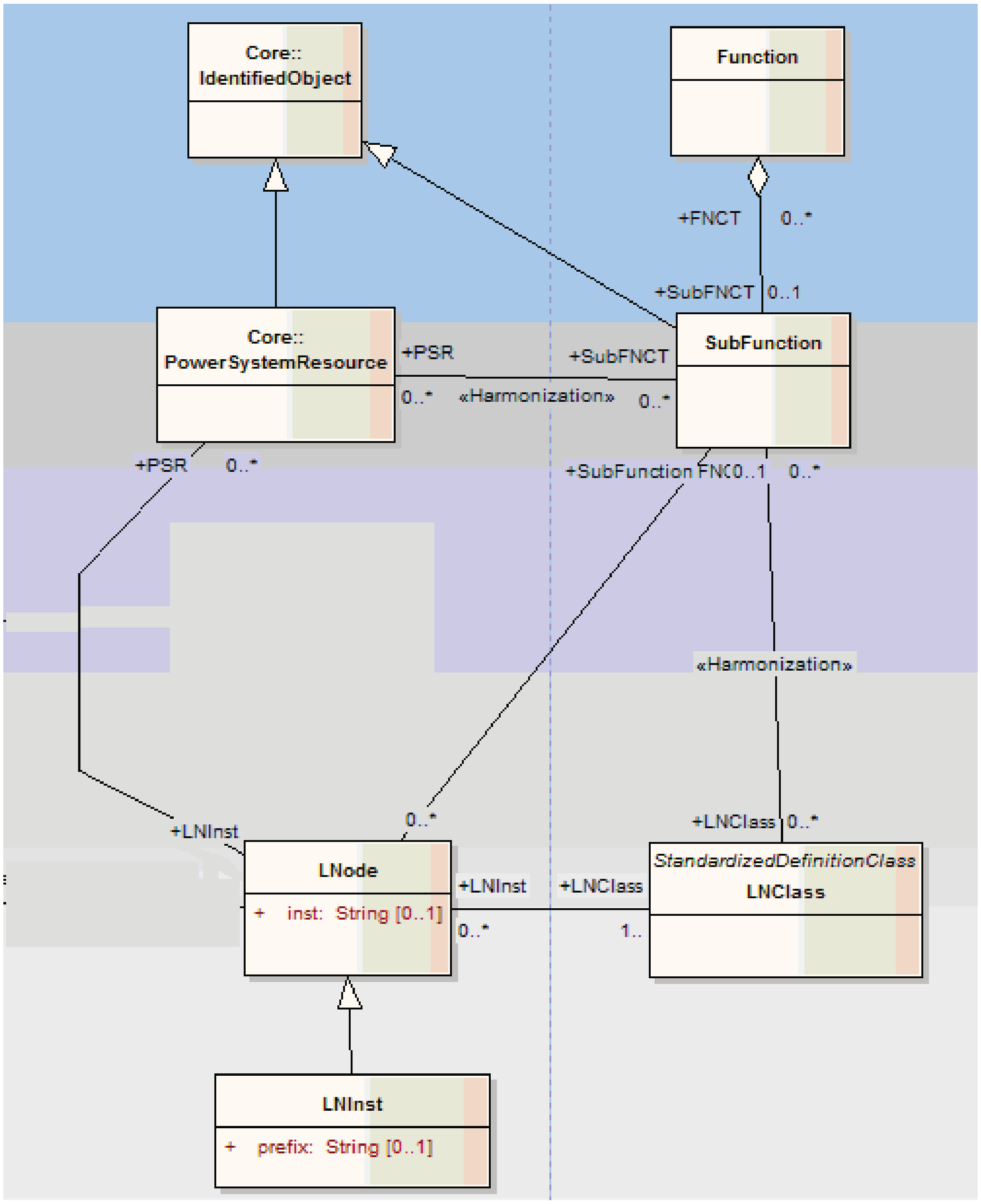


Figure 6-39
Complex Substation Functions and Functional Collections

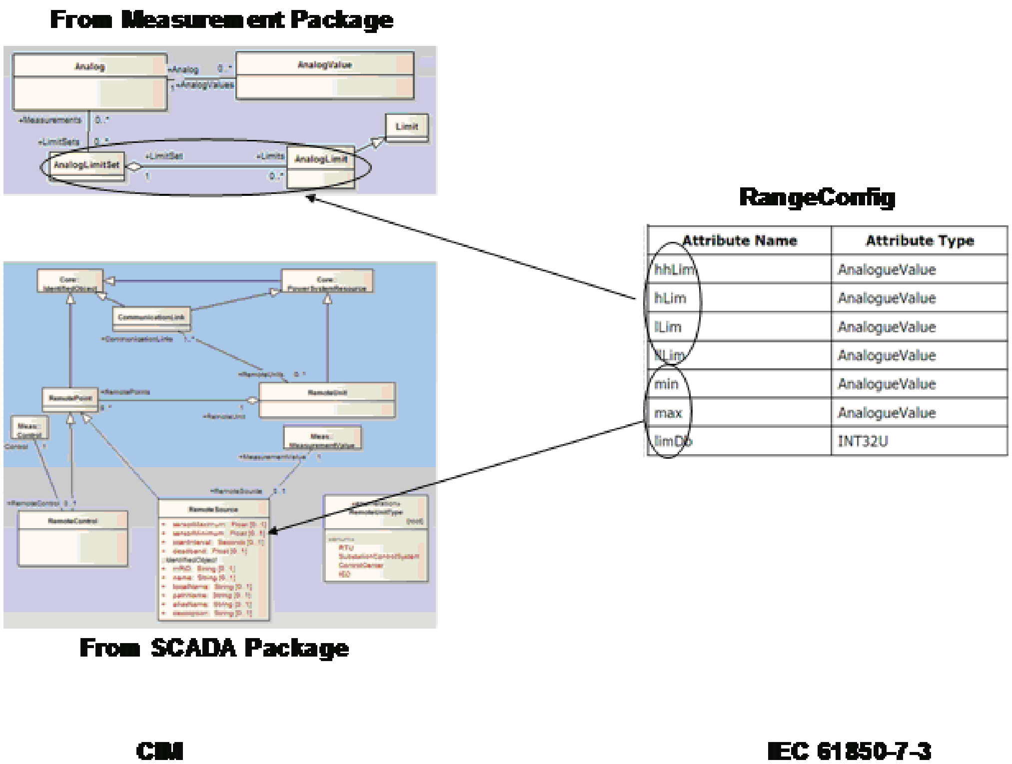


Figure 6-40
Comparison of CIM and IEC 61850 Analog Limits

Reconciling Limits

IEC 61850 has a concrete definition for defining AnalogLimits. The standard type definition is found in IEC 61850-7-3 and is the RangeConfig type. In IEC 61970, there are two(2) modeling constructs of interest: RemoteSource and AnalogLimitSet. Additionally, in CIM the same RemoteSource definition is used for Analogs and Discrete values. It is suggested to modify the unified model UML to accurately reflect the true relationships and to embrace the concrete RangeConfig definition from IEC 61850. Figure 6-41 shows the recommended changes needed to reconcile the CIM LimitSet(s) with IEC 61850 analog limits (e.g. RangeConfig). In order to keep one of the designs, within the CIM SCADA package, the proposed RemoteSource class inherits from both RemotePoint and LimitSet. An alternative would be to have RemoteUnit(s) aggregate RemoteSources. It should be left to IEC TC57 WG13 to make that choice.

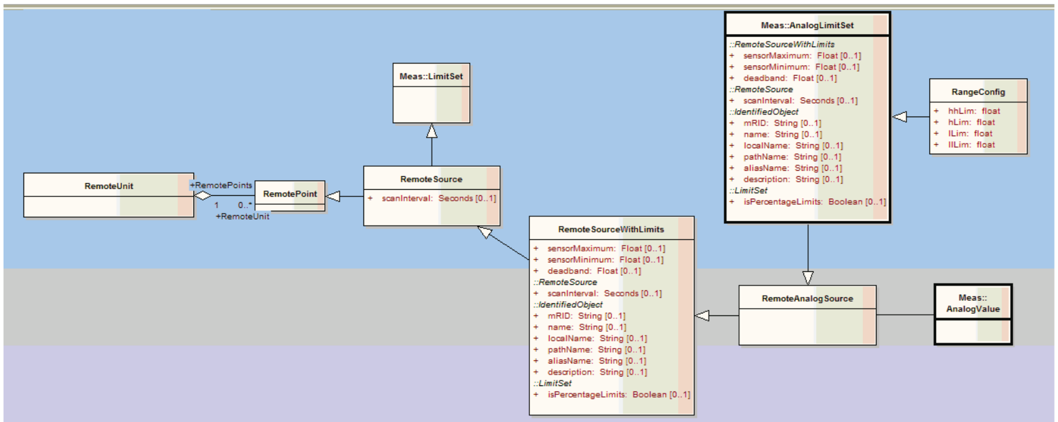


Figure 6-41
Recommended UML Reconiliation for Analog Limits

However, by adding the analog detail into the SCADA package, this requires that a similar amount of detail be added for Discrete, Accumulator, and String Measurements/MeasurementValues.

Figure 6-42 shows the proposed UML that would allow the appropriate remote point and limit set definition. The minimum and maximum values, for accumulators should not be floating point representations as the range of values/accuracy is lost especially in the case of 64-bit Integer values (needed for metering applications). However, IEC 61850 does not provide information concerning such limits. Therefore, the need for such limits/deadbanding needs to be discussed. If such limits are not required, then the RemoteAccumulatorSource class should become a specialization of the RemoteSourceWithoutLimits class.

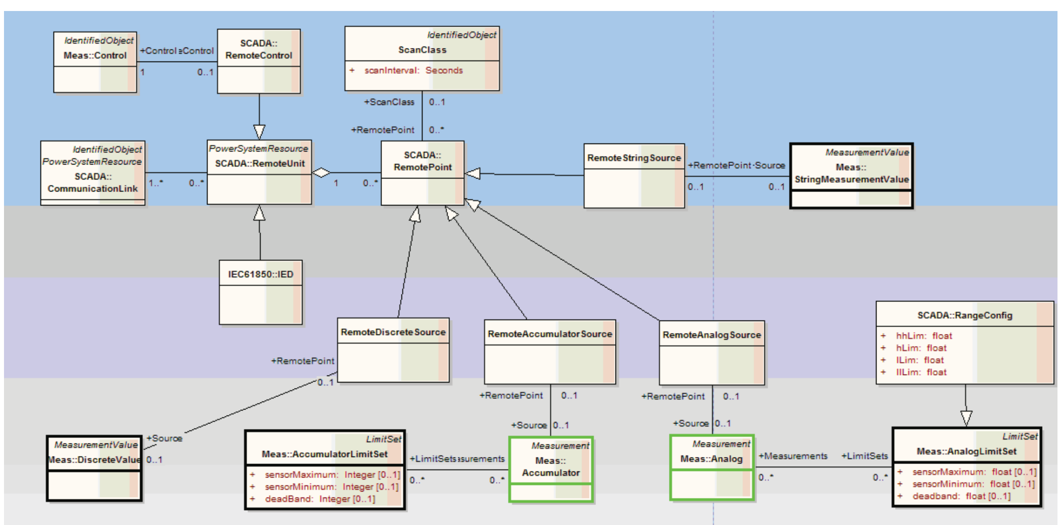


Figure 6-42
CIM SCADA RemotePoint and LimitSet reconciliation

Discretes would be assumed to not require minimum/maximums or deadbanding. However, if Discretes did require deadbanding, they would require integer style values.

Additionally, the figure depicts how StringMeasurementValues would be accommodated.

Reconciling Control Models

Figure 6-43 shows the UML for the current IEC 61970 control model. This section discusses the various aspects of harmonization/reconciliation that are necessary to be able to use a control model and IEC 61850. The control specific definitions for the various aspects of the model are:

- **ControlType:** Specifies the type of Control, e.g. BreakerOn/Off, GeneratorVoltageSetPoint, TieLineFlow etc. The ControlType.name shall be unique among all specified types and describe the type. The ControlType.aliasName is meant to be used for localization.
- **Control:** Control is used for supervisory/device control. It represents control outputs that are used to change the state in a process, e.g. close or open breaker, a set point value or a raise lower command.
- **SetPoint:** A SetPoint is an analog control used for supervisory control.
- **Command:** A Command is a discrete control used for supervisory control.

There are several aspects of the model, that need to be changed, irrespective of the harmonization with IEC 61850. The current IEC 61970 control model does not acknowledge and Accumulators/counters may have control associated with them (e.g. to be able to reset the count). Additionally, Accumulators may be key for future SmartGrid related activities, and these need to be able to be commanded to be frozen (e.g. a freeze command). Therefore, Accumulators need to be added into the model.

Note: It is unclear if string values need to be added to the model. Since IEC TC57 WG13 has not added them previously, the addition will be deferred to WG13.

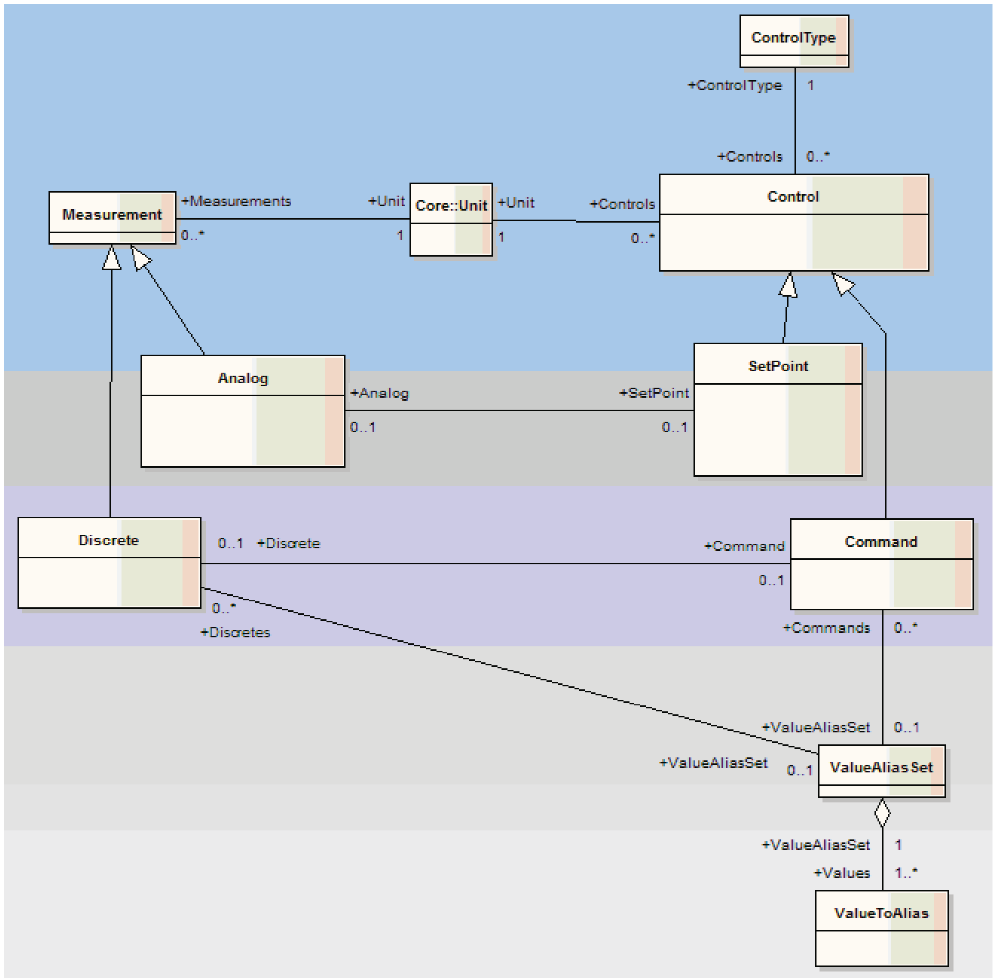


Figure 6-43
Current IEC 61970 Control Model

The current control model attempts to depict that controls are separate from the measured values/statuses associated with the control. However, the fact that Control is associated to Unit and Unit is associated to Measurement (which it is) allows for the Control to have a different set of Units than are being measured by the Measurement. Clearly, this can lead for confusion and can easily be remedied by mandating that Control shall use the same Units as are associated to the Measurement.

Based upon these "fix-ups", the revised UML begins to look as follows:

In Figure 6-44, it is now possible to perform Resets/Freezes on accumulators. The actual Reset/Freeze would be determined by the ValueAliasSet. However, the model still appears to be static in nature (e.g. it shows what can happen but does not allow the dynamic to actually issue the control). In order to be more explicit, a UML method should be added to the model. However, methods have typically not been added previously. Therefore, the "value" attributes will be used instead of using a method.

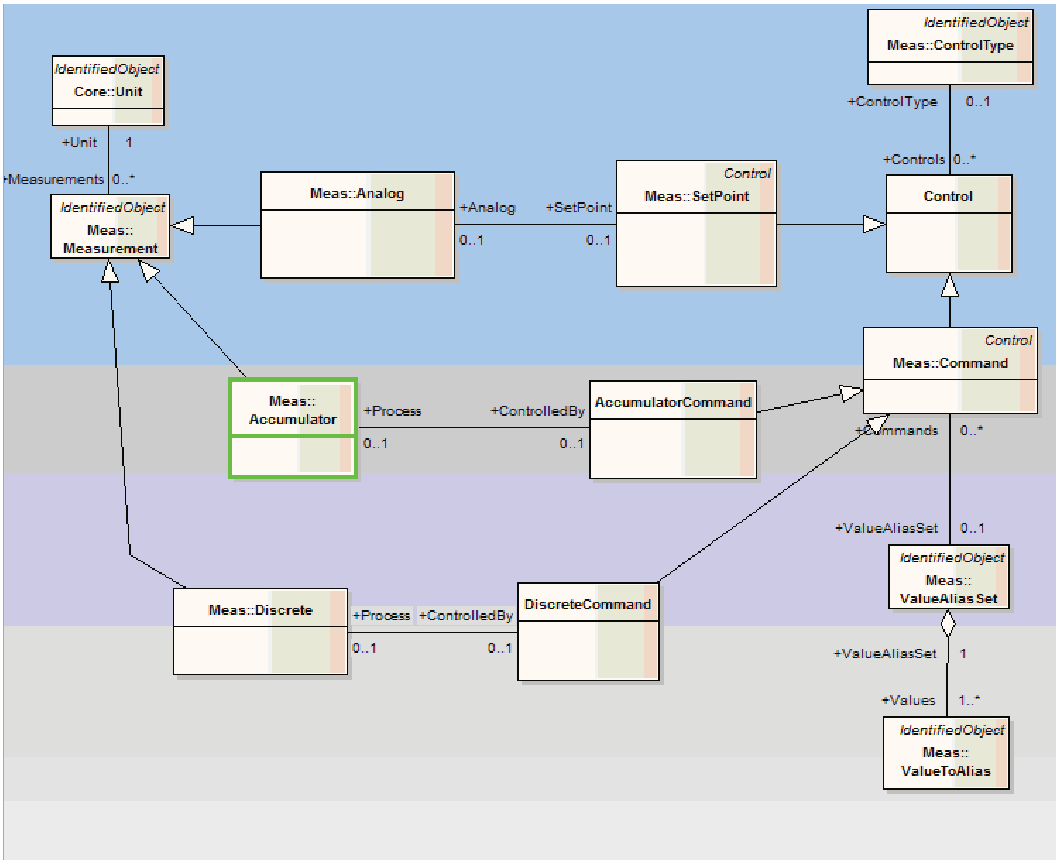


Figure 6-44
First general revision of Control Model revision

The expansion of the attributes, shown in Figure 6-45, shows that the Setpoint class contains limit information. The actual limits should be determined by the limits of the Analog/AnalogValue. Therefore, the limits in Setpoint should be removed.

With the completion of the general revision, the impact of IEC 61850 needs to be analyzed. In IEC 61850 the allowed control values (e.g. the definition of the ValueAliasSet) are defined as enumerated values within various parts of the standard. Additionally, IEC 61850 has strong Unit definition. The reconciliation of Enumerations and Units can be found in the following sections.

The current CIM Control model does not recognize the industry "types" of control (e.g. Direct, SBO, etc.). These are well standardized within IEC 61850 and IEC 870-5/DNP. Therefore, the recommended changes to the control model includes the ability to specify the type of control as well.

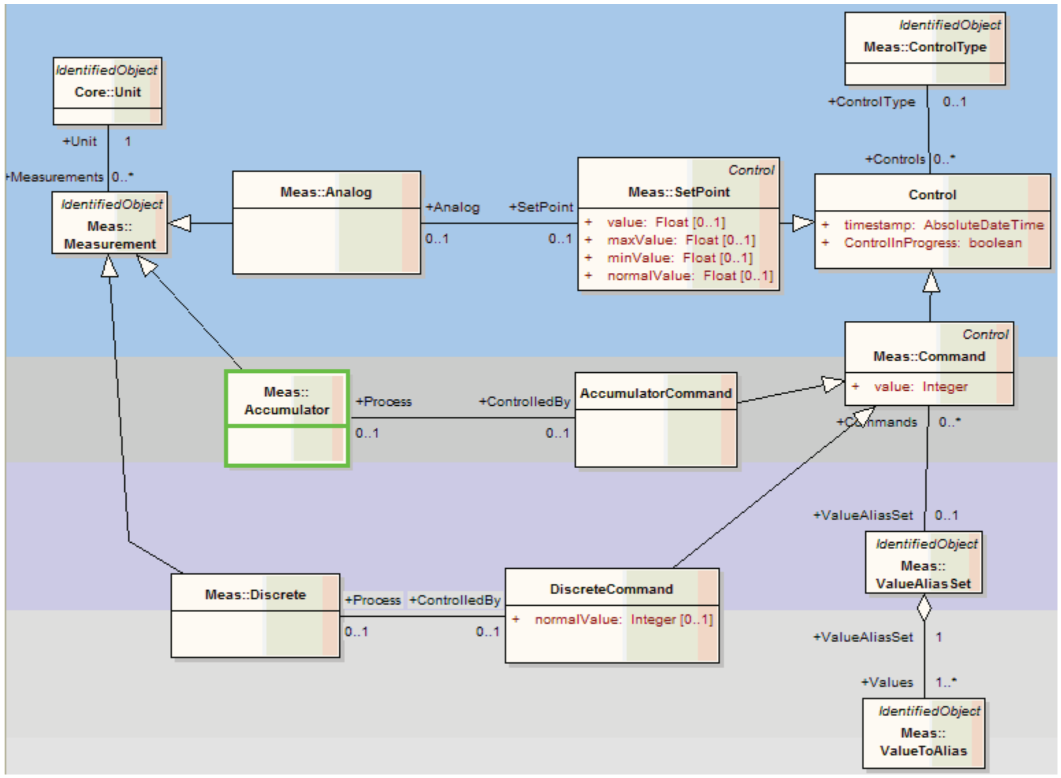


Figure 6-45
Second general revision of Control Model revision

IEC 61850 Enumeration Reconciliation

In general, IEC 61850 Enumerations should be mapped to the IEC 61970 construct of the ValueAliasSet. However, it is suggested that the following UML be added to the unified model in order to allow easier mapping for IEC 61850.

The proposed UML, in Figure 6-48, allows the enumeration information in an SCL file to be fully expressed and provides the ability to have the SCL reconstructed.

It is also proposed, that for any 61850 enumeration that is standardized, that the ValueAliasSet and the ValuetoAlias instances be assigned standardized IDs.

Based upon the recommendations, 61850 Standardized Enumerations (e.g. from any of the 61850 documents) need to have standardized IDs assigned.

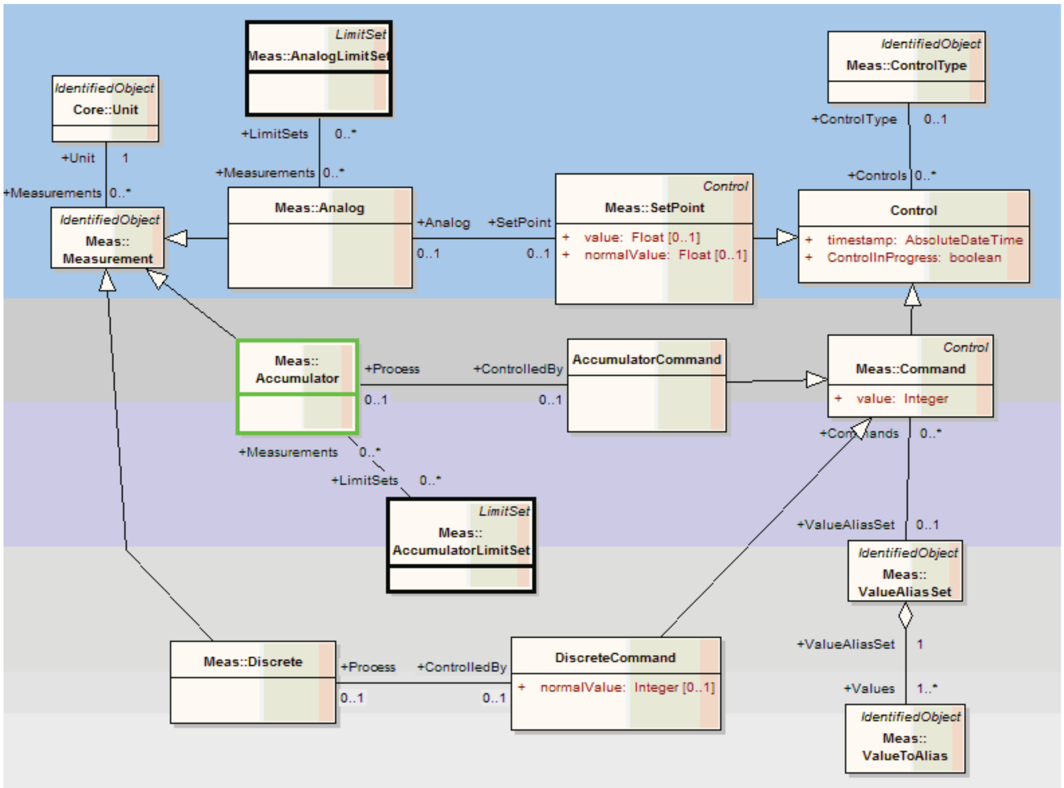


Figure 6-46
Third general revision of Control Model

As an example, the following table shows a proposal for some of the Enumerations found in IEC 61850-7-4.

Table 6-1
Partial list of proposed Standardized IDs for 61850-7-4 Enumerations

Enumeration	Proposed ID
AdjSt	2925fc57-ab8c-457b-89ca-bdba56392e2d
AutoRecSt	2110c985-27f7-486d-aedd-936a42a57c31
Beh	318b23bd-bd6b-4aca-90df-cd95ad0397d3
ClcIntvTyp	97d1b52e-0dc2-4670-9bcc-79a541a6dc31
ClcMth	865697a3-de8d-4a47-89cd-8f7c36eb22c9
ClcMod	fe31d91f-fe09-4cd3-b7f1-3617cfe35ad9
ClcRfTyp	0ccb50b6-6f78-4b42-9dc0-487cf253284d
DirMod	9a1607c6-61f5-4056-bc96-6b19c5ba9037
FltLoop	c8b69759-b1ab-4ab8-ab34-f7c08a0b8b38
GnSt	2c25d754-9372-4631-b7ec-37f348fdc216
Health	48a034fc-46d4-43dc-9866-952fab361efd
IntrDetMt	c7d76eca-cc33-4e3f-92fe-ea03b8c1a0e4
LevMod	99d0df66-2811-4224-87f3-fe81e2013877
LivDeaMod	95def0bf-f045-4760-abd5-b26e08480551
MechHealth	a414f9b9-626e-4106-b3cf-3e17da3bba64
Mod	4aea27d1-574c-46d2-be8d-a61fdc2f2b87
TrMod	87543521-07bd-460e-9c02-f4733cc5e7df

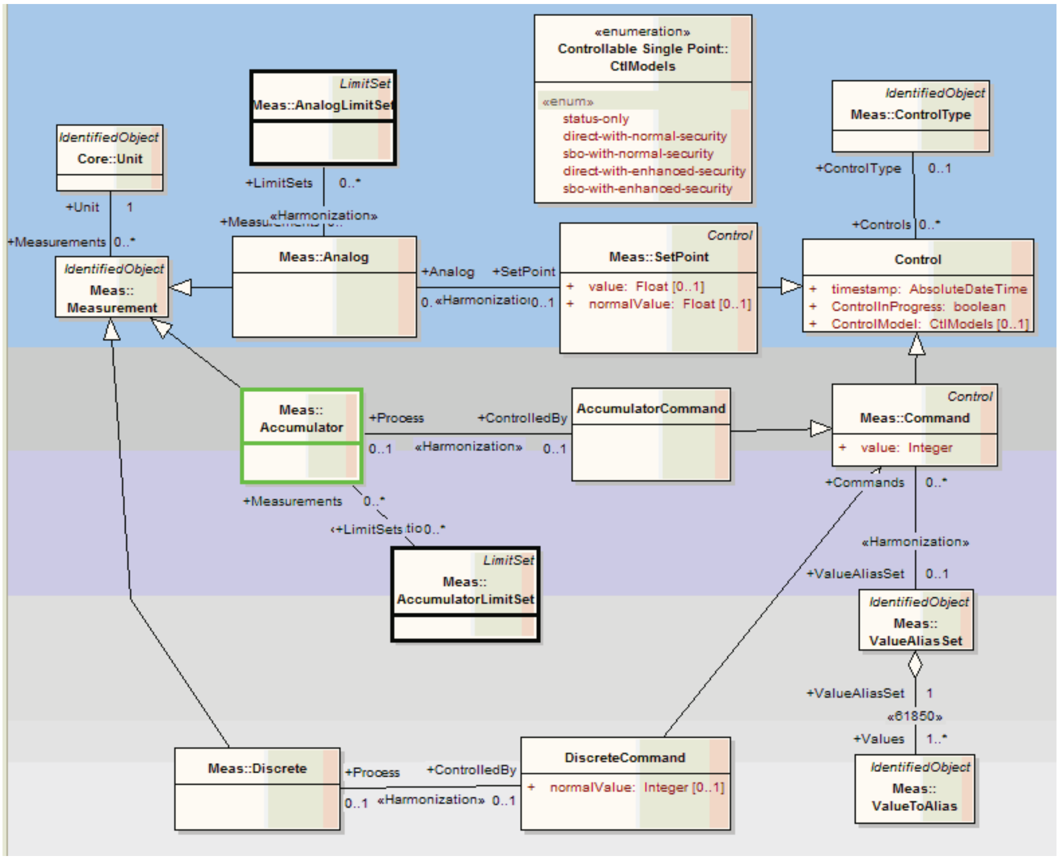


Figure 6-47
Recommended Revised Control Model

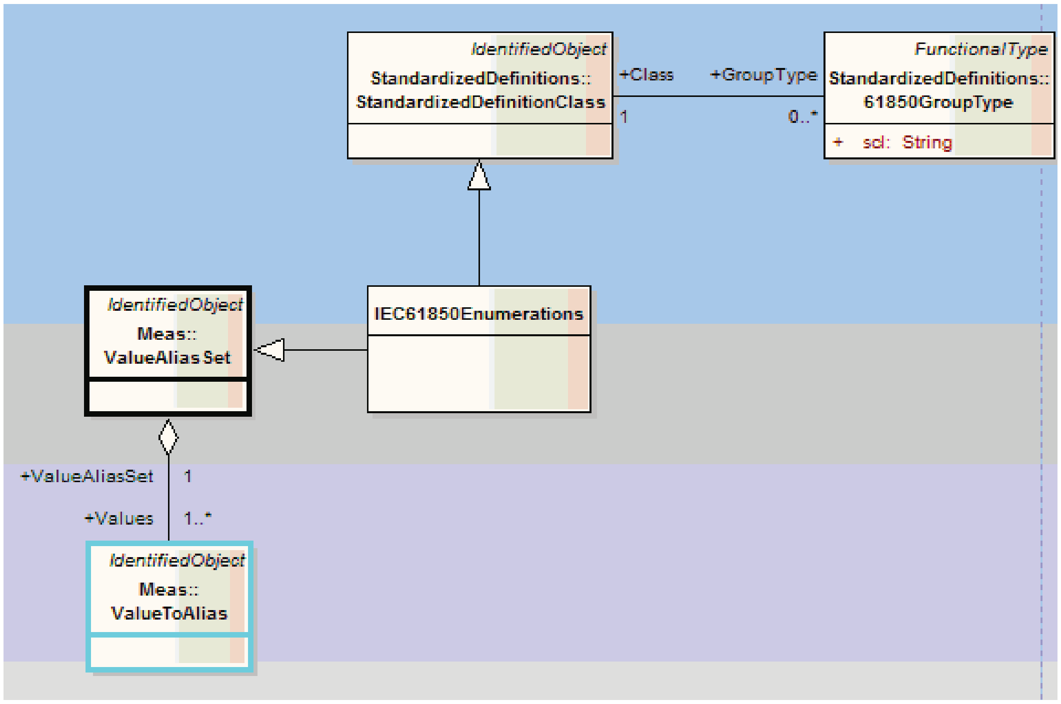


Figure 6-48
Proposed Enumeration Reconciliation UML

Additionally, the names the instances representing the ValueAliasSet(s) need standardization. It is recommended that the instance name be the Enumeration Name appended by the string Enum.

As an example, consider the enumeration for Mode:

- The instance name, in the unified model, would be: ModeEnum.
- Its standardized ID would be: 4aea27d1-574c-46d2-be8d-a61fdc2f2b87

Furthermore, the values in Figure 6-49 need to be converted to standardized IDs for instances of ValueToAlias.

Table A.1 – Values of mode and behavior

Value	Mode	
1	on	The application represented by the LN works. All communication services work and get updated values
2	on-blocked	The application represented by the LN works. No output data (digital by relays or analog setting) will be issued to the process. All communication services work and get updated values. Data objects will be transmitted with quality "operatorBlocked". Control commands will be rejected. See note below the table.
3	test	The application represented by the LN works. All communication services work and get updated values. Data objects will be transmitted with quality "test". Control commands with quality test will be accepted only by LNs in "test" or "test-blocked" mode. "Processed as valid" means that the application should react in the manner what is foreseen for "test".
4	test/blocked	The application represented by the LN works. No output data (digital by relays or analog setting) will be issued to the process. All communication services work and get updated values. Data objects will be transmitted with quality "test". Control commands with quality test will be accepted only by LNs in TEST or TEST-Blocked mode.
5	off	The application represented by the LN doesn't work. No process output is possible. No control command should be acknowledged (negative response). Only the data object Mod and Beh should be accessible by the services.
NOTE	The Mod ="blocked" from edition 1 is changed in edition 2 to "on-blocked".	

Figure 6-49
Definition of Mode enumeration from IEC 61850-7-4 ED.2 FDIS

The end result, in sample CIM XML, would be:

```
<cim:ValueAliasSet rdf:ID="_318b23bd-bd6b-4aca-90df-cd95ad0397d3">  –ID needs to be standardized
  <cim:IdentifiedObject.name>BehEnum</cim:IdentifiedObject.name>
</cim:ValueAliasSet>

<cim:ValuetoAlias rdf:ID="_ae97bc6b-eb99-450b-9fc5-e224b9e2bb76>  –should be standardized
  <cim:IdentifiedObject.name>on</cim:IdentifiedObject.name>>
  <cim:ValuetoAlias.value>1</cim:ValuetoAlias.value>
  <cim:ValuetoAlias.ValueAliasSet rdf:resource="#_318b23bd-bd6b-4aca-90df-cd95ad0397d3"/>
</cim:ValuetoAlias>

<cim:ValuetoAlias rdf:ID="_b24ae657-9951-453f-8cac-04bfe26a8096>  –should be standardized
  <cim:IdentifiedObject.name>on-blocked</cim:IdentifiedObject.name>>
  <cim:ValuetoAlias.value>2</cim:ValuetoAlias.value>
  <cim:ValuetoAlias.ValueAliasSet rdf:resource="#_318b23bd-bd6b-4aca-90df-cd95ad0397d3"/>
</cim:ValuetoAlias>

<cim:ValuetoAlias rdf:ID="_7ada2f16-2c7c-4c8b-9194-54eb2035f21a>  –should be standardized
  <cim:IdentifiedObject.name>test</cim:IdentifiedObject.name>>
  <cim:ValuetoAlias.value>3</cim:ValuetoAlias.value>
  <cim:ValuetoAlias.ValueAliasSet rdf:resource="#_318b23bd-bd6b-4aca-90df-cd95ad0397d3"/>
</cim:ValuetoAlias>

<cim:ValuetoAlias rdf:ID="_11499f4c-079f-4058-ba72-5e8bea244dbe>  –should be standardized
  <cim:IdentifiedObject.name>test/blocked</cim:IdentifiedObject.name>>
  <cim:ValuetoAlias.value>4</cim:ValuetoAlias.value>
  <cim:ValuetoAlias.ValueAliasSet rdf:resource="#_318b23bd-bd6b-4aca-90df-cd95ad0397d3"/>
</cim:ValuetoAlias>
```

```
<cim:ValuetoAlias rdf:ID="_7ca2b46e-d5cf-408a-93ab-331e35dce3e8>  –should be standardized
  <cim:IdentifiedObject.name>off</cim:IdentifiedObject.name>>
  <cim:ValuetoAlias.value>5</cim:ValuetoAlias.value>
  <cim:ValuetoAlias.ValueAliasSet rdf:resource="#_318b23bd-bd6b-4aca-90df-cd95ad0397d3"/>
</cim:ValuetoAlias>
```

Unit Reconciliation

As part of reconciling the Control models, there is an issue of Units/UnitsofMeasure. Figure 6-50 shows the Unit class in the CIM UML.

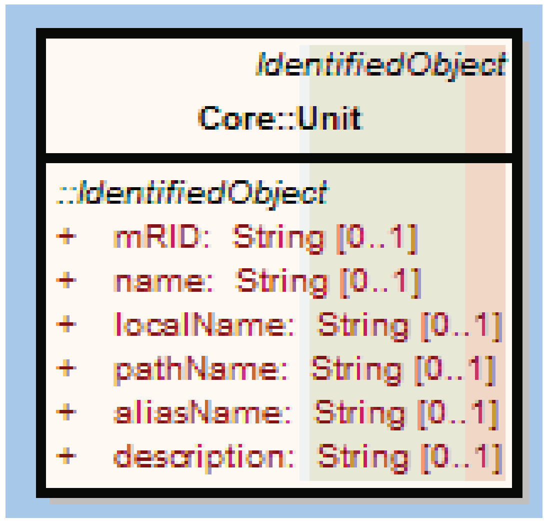


Figure 6-50
IdentifiedObject Class in 61970

IEC 61970 defines the Unit class as follows:

"Quantity being measured. The Unit.name shall be unique among all specified quantities and describe the quantity. The Unit.aliasName is meant to be used for localization." However, the documentation is incorrect since there is no Unit.aliasName. The UML documentation needs to be corrected to read "IdentifiedObject.aliasName".

In IEC 61968, there is no particular "unit" class. However, there are unitOfMeasure attributes that have been added to the appropriate classes.

Both in IEC 61970 and IEC 61968, the value of the Unit is a string value. Additionally, these standards sometimes specify the use of an enumeration named UnitSymbol.

The first issue with this enumeration is that it only contains typical transmission/distribution unit symbols. With the advent of Distributed Energy Resources, additional unit symbols are required to support solar, hydroelectric, biomass, and others. To accommodate this and future, potential expansion, IEC 61850 actually enumerates all base SI units (found in IEC 61850-7-3). Therefore, there needs to be an enumeration for all base SI units added to the unified model.

The second issue, with UnitSymbol, is that it is unclear if this enumeration is to be used to detail what units are being utilized, or the symbol for the units to be utilized. One could infer that since both IEC 61970 and IEC 61968 have Units Of Measure attributes that are strings, that the intent is the latter. In order to be precise, it is important to separate the Unit selection from the presentation issue (e.g. UnitSymbol).

It is recommended that the UML models of both IEC 61970 and IEC 61968 be modified to embrace the concept of base SI units as an enumeration. IEC 61850 follows the recommendations of ISO 1000: SI units and recommendations for the use of their multipliers and of certain other units.

From IEC 61850-7-3

Unit Type Definition		
Attribute Name	**Attribute Type**	**Value/Value Range**
SIUnit	ENUMERATED	According to Tables A.1 to A.4 in Annex A
multiplier	ENUMERATED	According to Table A.5 in Annex A

Table A.5 – Multiplier

Value	Multiplier value	Name	Symbol
–24	10^{-24}	Yocto	y
–21	10^{-21}	Zepto	z
–18	10^{-18}	Atto	a
–15	10^{-15}	Femto	f
–12	10^{-12}	Pico	p
–9	10^{-9}	Nano	n
–6	10^{-6}	Micro	µ
–3	10^{-3}	Milli	m
–2	10^{-2}	Centi	c
–1	10^{-1}	Deci	d
0	1		
1	10^{1}	Deca	da
2	10^{2}	Hecto	h
3	10^{3}	Kilo	k
6	10^{6}	Mega	M
9	10^{9}	Giga	G
12	10^{12}	Tera	T
15	10^{15}	Peta	P
18	10^{18}	Exa	E
21	10^{21}	Zetta	Z
24	10^{24}	Yotta	Y

```
<xs:simpleType name="tUnitMultiplierEnum">
        <xs:restriction base="xs:normalizedString">
                <xs:enumeration value=""/>
                <xs:enumeration value="m"/>
                <xs:enumeration value="k"/>
                <xs:enumeration value="M"/>
                <xs:enumeration value="mu"/>
                <xs:enumeration value="y"/>
                <xs:enumeration value="z"/>
                <xs:enumeration value="a"/>
                <xs:enumeration value="f"/>
                <xs:enumeration value="p"/>
                <xs:enumeration value="n"/>
                <xs:enumeration value="c"/>
                <xs:enumeration value="d"/>
                <xs:enumeration value="da"/>
                <xs:enumeration value="h"/>
                <xs:enumeration value="G"/>
                <xs:enumeration value="T"/>
                <xs:enumeration value="P"/>
                <xs:enumeration value="E"/>
                <xs:enumeration value="Z"/>
                <xs:enumeration value="Y"/>
        </xs:restriction>
</xs:simpleType>
```

SCL Enumeration

Figure 6-51
IEC 61850 Unit Type definition and Enumeration

It is recommended that the strong definition style of IEC 61850 be adopted by both IEC 61970 and IEC 61968. In order to accomplish this, the current UnitMultiplier enumeration in IEC 61970 needs to be changed to align with IEC 61850 and ISO 1000. As can be seen in Figure 6-52, the number of enumerated values in the current "Domain" enumeration does not match that being proposed. Therefore, the current UnitMultipler should be deleted from the model.

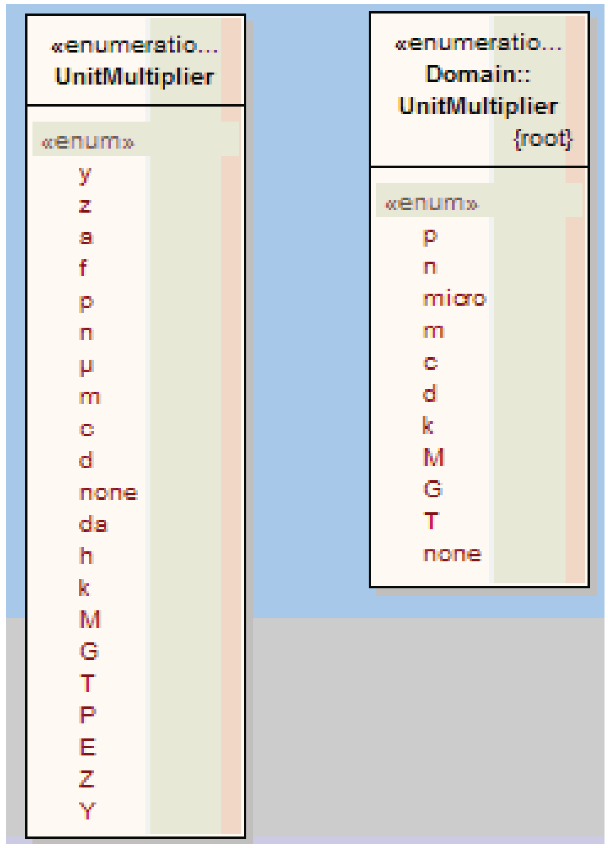


Figure 6-52
Current CIM UnitMultiplier and UnitMultiplier Data Type

It is then suggested that the current IEC 61970 Unit class be extended to include SIUnits and multipliers in a similar fashion as is specified in IEC. This requires that an SIUnits enumeration be added into the UML. The resulting UML appears something similar to Figure 6-53 shown below.

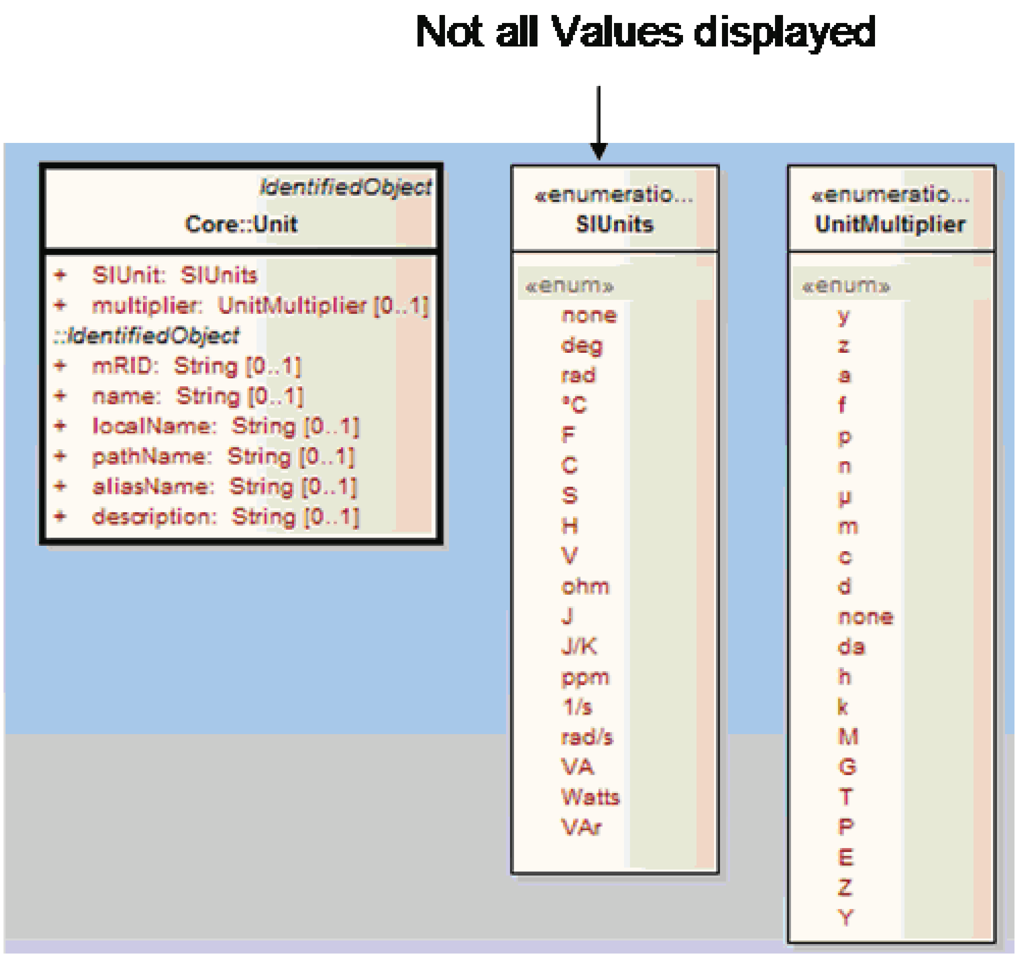


Figure 6-53
Proposed IEC 61970 Unit UML

tUnitMultiplierEnum enumeration as specified in IEC 61850-6 should be changed to replace the "" (e.g. blank value) with the word "none" as shown in Figure 6-53 in order to allow easier mapping/ interface creation.

It should be noted that if UnitSymbol is supposed to be used to specify the units in use, it should be deleted and the appropriate model updates should be made to reflect the use of SIUnit. However, if the UnitSymbol enumeration is supposed to define the actual symbol displayed, its value set needs to be expanded to align with SIUnits and an additional attribute should be added to the Unit class.

Additionally, rules for the value of the IdentifiedObject.name value need to be created based upon the concatenation of UnitMultiplier and UnitSymbol in order to create well defined strings. In most best practices, the actual unit name is the multiplier concatenated with the unit/unit symbol (e.g. k+Va = kVA). It is that practice that should be specified as a concrete rule. Additionally, it is clear that the string is case sensitive and therefore the case needs to be preservedc.

The same rules should apply for the UnitOfMeasure string of IEC 61968. It is interesting that IEC 61850 also defined an enumerated set named UnitSymbol and also defined a generic (e.g. string UnitofMeasure. However, the contents of UnitSymbol are a subset of the full SIUnits defined in IEC 61850, therefore it should be replaced by the SIUnits enumeration defined in this section.

IEC 61850 Mappings

Mapping of Names and Descriptions

In general, within the unified model, named objects/classes, should inherit from the IdentifiedObject class. This class has two(2) important attributes that need to be discussed as part of this section:

- IdentifiedObject.name: The current definition, from CIM, is the following:

  "The name is a free text human readable name of the object. It may be non unique and may not correlate to a naming hierarchy."

  For the purposes of the unified model, and the interfaces to be developed, the SCL object name values shall be used to set the value of the IdentifiedObject.name attribute in the appropriate unified model class.
- IdentifiedObject.description: The current definition, from CIM, is the following:

  "The description is a free human readable text describing or naming the object. It may be non unique and may not correlate to a naming hierarchy."

  It is clear that the IdentifiedObject.description field should be used to hold descriptions in the unified model. However, IEC 61850 has some classes that expose two(2) descriptions. One is a Unicode description (designated by the "dU" attribute) and one is an ASCII description (designated by the "d" attribute). Therefore, an analysis of where both descriptions needing to be supported needs to be performed as well as mapping rules for the various SCL objects need to be developed.

The tNaming definition in the SCL XSD is shown in Figure 6-54 below as an expansion of the tIED.

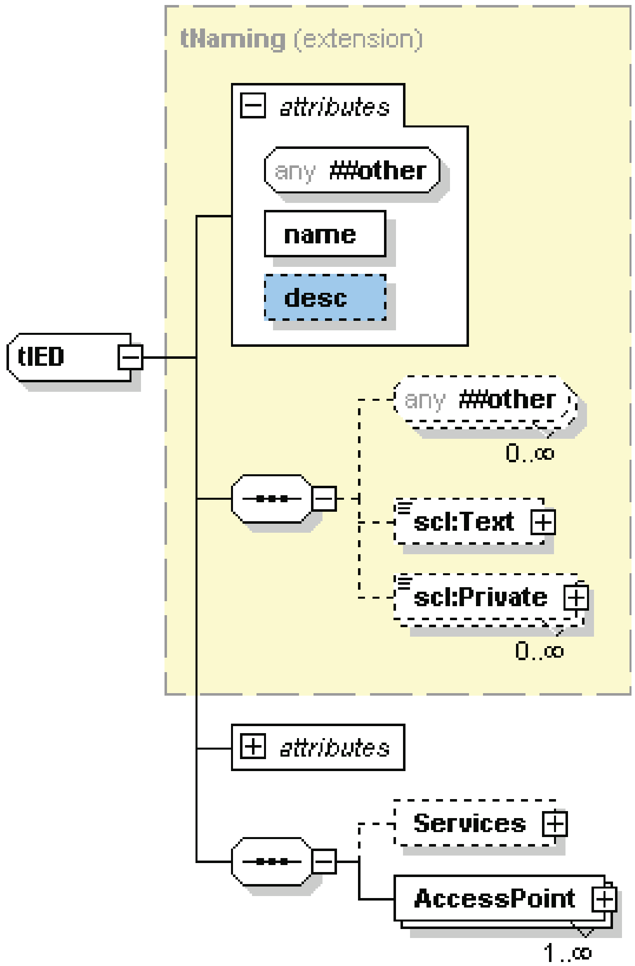


Figure 6-54
tIED and tNaming SCL Definitions

As a general rule, the value of the SCL "name" attribute shall be mapped to IdentifiedObject.name attribute value. The value of the "desc" attribute shall be mapped to the IdentifiedObject.description attribute value.

The general mapping rule is valid for instances of the following SCL types:

- tIED (e.g. IED instances)
- tAccessPoint (AccessPoint): Mapped to an instance of CommunicationLink
- tServer (Server Object)
- tLDevice (Logical Device)

The general mapping rule shall also apply to the following types that are mapped to instances of FunctionalCollections:

- tDOI (Data Object Instance)
- tDAI (Data Attribute Instance)
- tSDI (Sub Data Instance)

The major IEC 61850 type that is not covered by the general rule is the Logical Node or Logical Node Instance. The mapping rule is defined in the following section.

IED Mappings

This section deals with the mapping recommendations for the IED and Server information found within the SCL information.

Figure 6-55 represents the proposed model for IED and Server relationships. In the proposed model a single physical IED can contain multiple Servers. Each Server allows the communication capability regarding a particular communication endpoint/server to be declared. This allows a single physical entity to expose endpoints for 61850, DNP (out of scope of this document and shown for example purposes only), and other protocols.

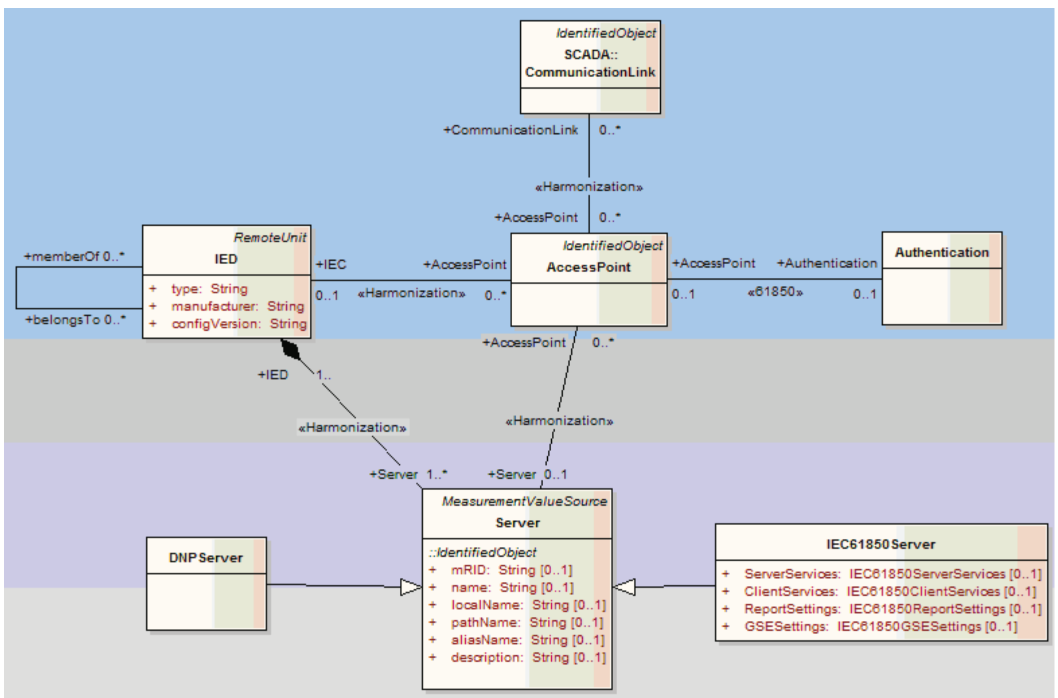


Figure 6-55
Proposed IED Model

In the case of a 61850Server, the server/IED capabilities from the SCL file (e.g. ServerServices, ClientServices, etc..) are exposed as attributes of the Server specialization "IEC61850Server".

In order to appropriately declare the capability of an IEC 61850 Server, an instance of the IEC-61850Server class must be created. This class contains the IED Client and Server service support that is declared in SCL. The details can be found in Figure 6-56 below.

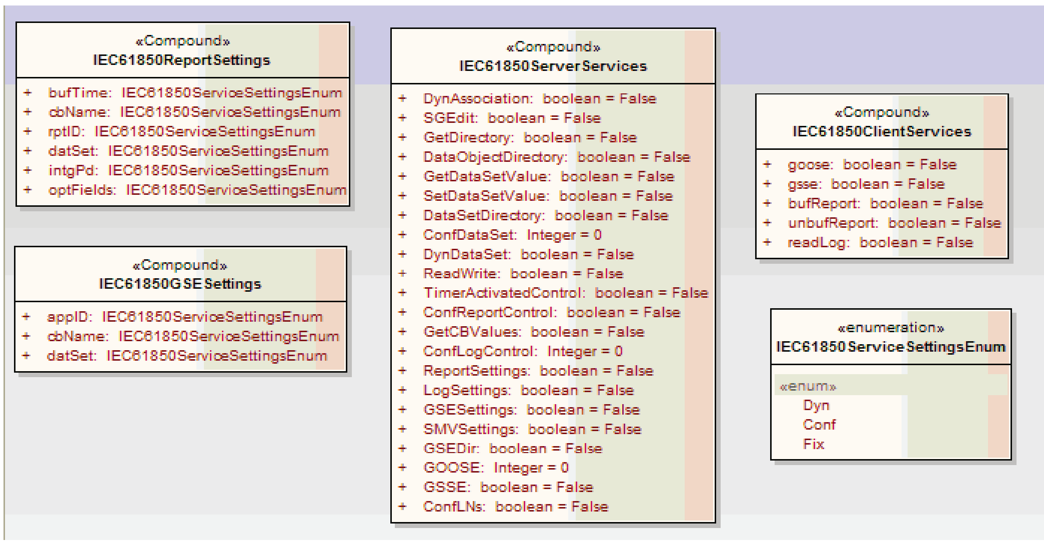


Figure 6-56
61850 IED Capability Definitions

AccessPoint Mapping

The SCL AccessPoint is replaced/mapped to the unified model's AccessPoint object. It is recommended that the SCL name of the access point be stored in the IdentifiedObject.pathName attribute value of an instance of a AccessPoint. Furthermore, it is recommended that if there is no value in the IdentifiedObject.name attribute, the SCL name should also be placed in that attribute value as well. If there is a previous value in the IdentifiedObject.name attribute, it should not be overwritten.

The SCL "desc" field contents should be mapped into the IdentifiedObject.description attribute value.

The purpose is to allow the SCL AccessPoint information to be stored/retrieved independently of a SCADA (or other) assigned name (e.g. by the Communication Configuration group). Such assigned name should be stored in the IdentifiedObject.name attribute value.

ConnectedAP

Upon applying the previous recommendations, the SCL definition of a ConnectedAP appears as shown in Figure 6-57 below. As shown the Address and PhysConn types did not inherit from either tNaming or tUnaming and therefore would not support the persistent ID concept unless their definitions are modified. It is suggested that both should be based upon tUnaming as are the SMV and GSE types

However, there is another issue with the definition of ConnectedAP and the Address information. The issue is that only a single primary set of addressing information is allowed. In the future, the support

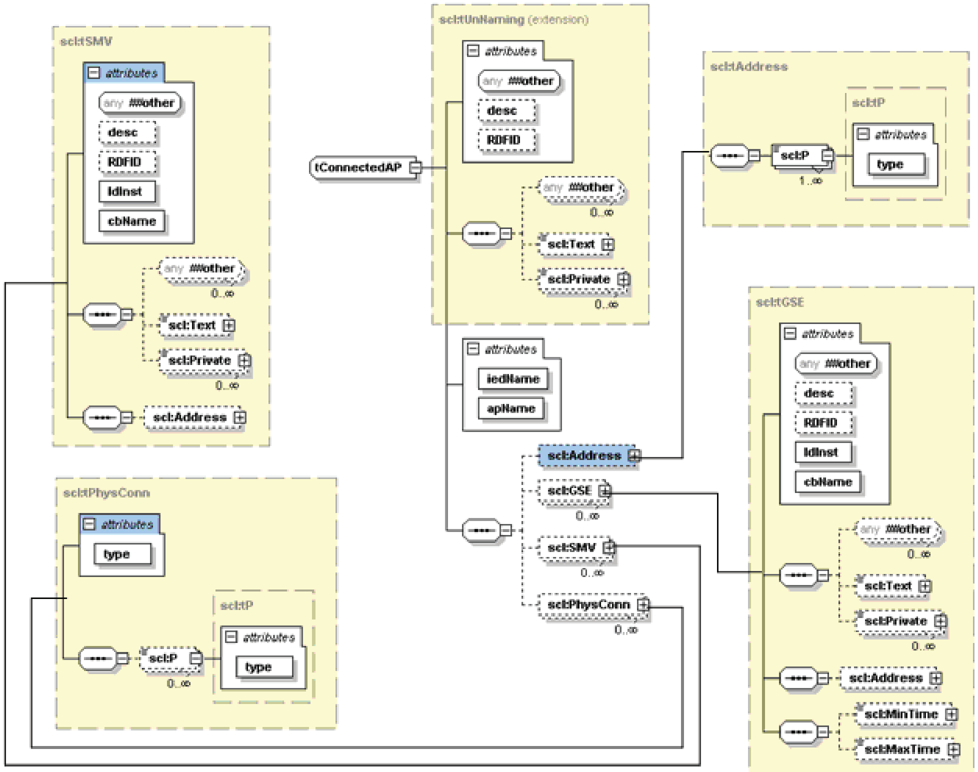


Figure 6-57
SCL for ConnectedAP Type with Naming/Unamed Extensions

for multiple addresses will be needed. Therefore, it is suggested to change the multiplicity of the Address information as well.

Based upon these recommendations, the XSDs for Address and PhysConn should be changed to the following:

```
<xs:complexType name="tAddress">
        <xs:complexContent>
                <xs:extension base="tUnNaming">
                        <xs:sequence>
                                <xs:element name="P" type="tP" maxOccurs="unbounded"/>
                        </xs:sequence>
                </xs:extension>
        </xs:complexContent>
</xs:complexType>

<xs:complexType name="tPhysConn">
        <xs:complexContent>
                <xs:extension base="tUnNaming">
                        <xs:sequence>
                                <xs:element name="P" type="tP" minOccurs="0"
                                maxOccurs="unbounded"/>
                        </xs:sequence>
                        <xs:attribute name="type" type="xs:normalizedString" use="required"/>
                </xs:extension>
        </xs:complexContent>
</xs:complexType>
```

Upon changing the multiplicity of the Address within tConnectedAP, the resultant type definition should appear as shown in Figure 6-58 below.

Logical Device Mapping

Figure 6-59 shows that a Logical Device is a specialization of FunctionalCollection. This means that a hierarchy of LogicalDevices can be represented in the unified model. This is a future requirement of IEC 61850 that is being taken into account in advance.

Logical Device instances can contain instances of LNode(s) or LNInst(s).

In order to allow for mappings of other non-SCL based implementations of 61850 mappings (e.g. DNP, etc..), the LogicalDevice is contained in a Server. For most 61850 implementations the actual instance should be an instance of an IEC61850Server class.

Logical Node Mapping

IEC 61850 Logical Nodes does not utilize the tNaming type. Figure 6-60 below shows the production utilized for Logical Nodes.

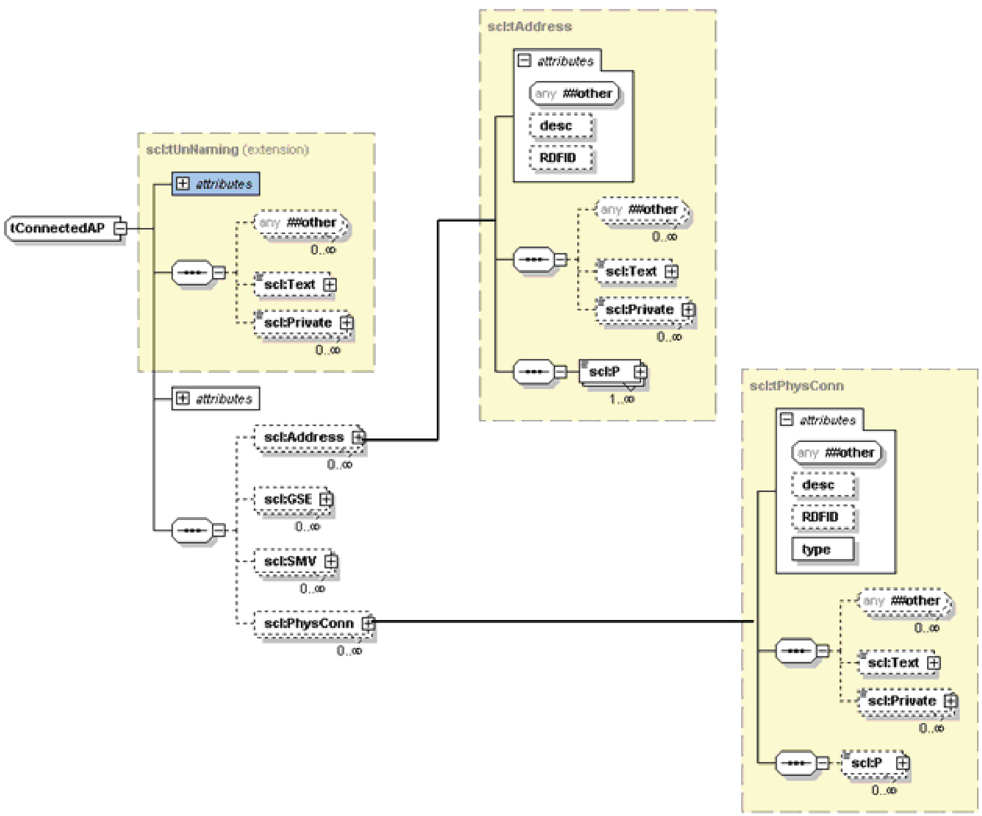


Figure 6-58
Updated tConnected SCL XSD

An IEC 61850 Logical Node name (LNode or LNIsnt) is specified to be a concatenation of:

<prefix><LnClass><inst>

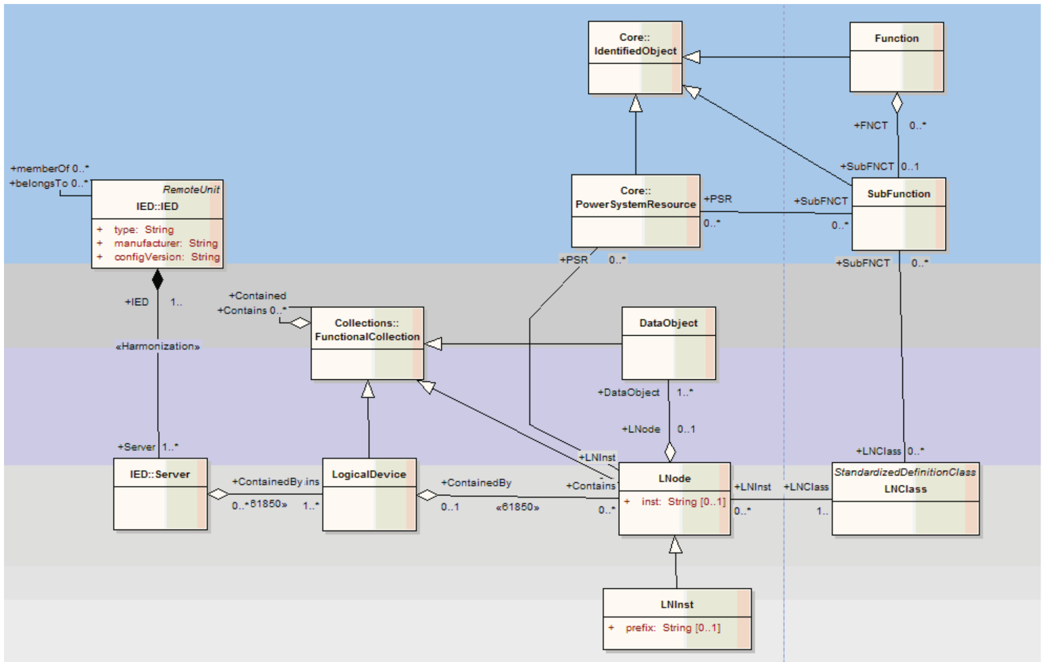


Figure 6-59
Mapping of Logical Devices

The concatenation shall be the value of the appropriate IdentifiedObject.name attribute.

The value of the "desc" attribute shall be the value of the IdentifiedObject.description attribute.

Figure 6-61 shows the UML classes that should be created when an interface imports an SCL file. An LNode or LNInst instance would be created with naming assigning the IdentifiedObject.name attribute as specified. It shall also associate to the appropriate LNClass using the standardized IDs assigned previously in this document. The association shall replace the use of an attribute to represent the LN-Class value. The name of the associated LNClass instance shall be the Enumerated value selected.

Use of Measurement Classes for 61850 and other Protocol Data Exchange

Use of the CIM Measurement classes (Analog, Accumulator, and Discrete) is frequently misunderstood. In addition to the use representing points in the system where telemetry is available, the classes have been defined to be used in situations where telemetry is not available. For the purposes of data exchange, a Measurement may be used to define a point for voltage regulation, to associate Limits with a piece of Equipment, or to facilitate exchange of 61850 data.

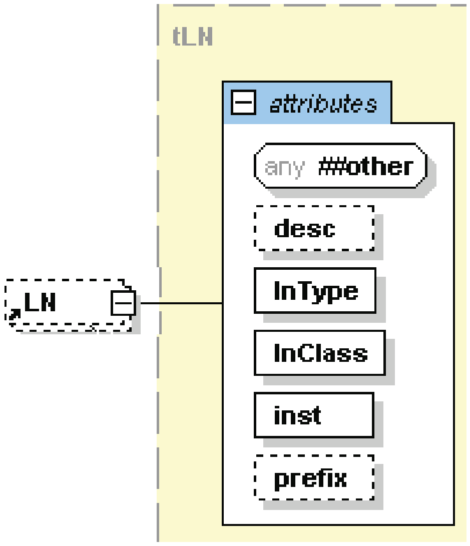


Figure 6-60
tLN Name Related Attributes

In the case of 61850, a Measurement must be associated with a PowerSystemResource to convey containment information for the Measurement. The PowerSystemResource, to which the Measurement is associated should be the same PowerSystemResource to which the 61850 Logical Node Instance, from which the Measurement is derived , is associated to. However, some 61850 data objects need not be associated to a PSR (e.g. Beh which is logical node related only).

61850 data is exchanged using the Measurement classes (Analog, Discrete, Accumulator, etc), the MeasurementValue classes (AnalogValue, DiscreteValue, AccumulatorValue, etc.), and the MeasurementValueSource class. Unlike the mapping of ICCP information, the MeasurementValueSource class/instance is used to indicate that the MeasurementValue is being sourced via IEC 61850 protocol. For an instance of a MeasurementValueSource class, the standardized attributes/IDs for this instance should be:

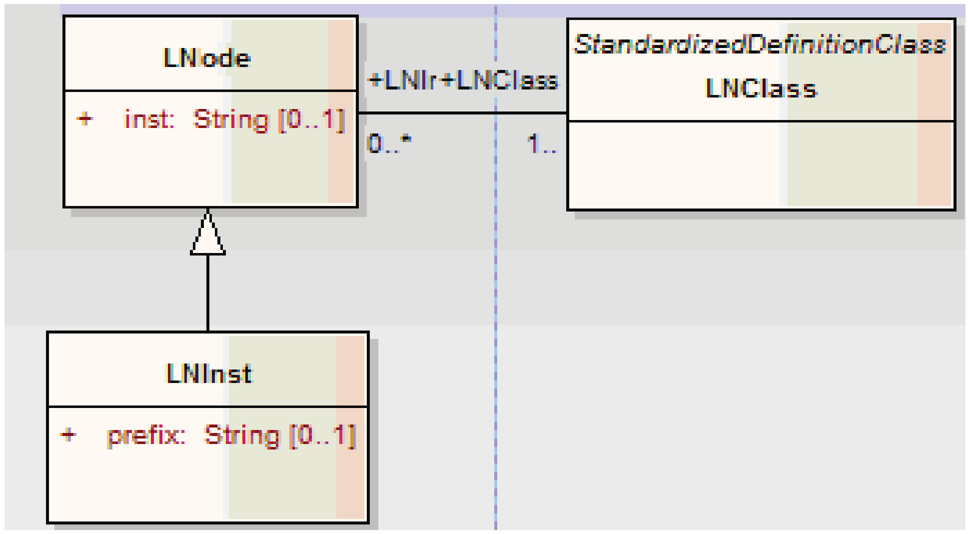


Figure 6-61
UML LNode-related Classes Created for an Imported SCL File

Standardized ID:	d0852b37-d4e2-4bf9-96bd-2de92b0c96e4
IdentifiedObject.name:	IEC61850
IdentifiedObject.pathName:	61850

However, it is recommended that an instance of MeasurementValueSource not be utilized for this purpose, rather an instance of the unified model's Server class should be used. In which case, there would be no standardized ID. Additionally, the IdentifiedObject.name attribute should be set to IEC61850 only if the attribute value was NULL or empty. In the case of an instance of the Server class, the IdentifiedObject.name attribute is reserved for a user assigned (e.g. SCADA or other) value.

The resulting CIM XML would appear as follows:

```
<cim:MeasurementValueSource rdf:ID="_d0852b37-d4e2-4bf9-96bd-2de92b0c96e4">
  <cim:IdentifiedObject.name>IEC61850</cim:IndentifiedObject.name>
  <cim:IdentifiedObject.pathName>61850</cim:IdentifiedObject.pathName>
</cim:MeasurementValueSource>
```

The MeasurementValue class attributes are used to specify the:

- MeasurementValue.pathName: Will contain the 61850 ACSI expression of the addressing of the leaf, including Logical Device information. As an example:
  S1/MMXU1.Beh.stval[ST] where the Functional Constraint is included in the "[ ]".
  It is the pathName attribute value that should be used in order to acquire.
- MeasurementValue.name: Attribute holds the SCADA point name.
- Harmonization/61850 attributes:
  MeasurementValue.simpleName: Contains the 61850 leaf name of the 61850 item (e.g. stval for Beh).
  MeasurementValue. functionOfMV: Contains the 61850 Functional Constraint of the leaf (e.g. ST for Beh.Stval).

It is suggested that the IdentifiedObject.name attribute value, of an associated Measurement instance, should be similar to the pathName value of the MeasurementValue. It should not include Logical Device, Logical Node, Leaf or Functional constraint.

As examples:

Path	Measurment name attribute
S1/MMXU1.Beh.stval[ST]	Beh
S1/MMXU1.TotW.mag.f[MX]	TotW.mag

Note: Since the MeasurementValue object has implied quality and timestamps, such 61850 items do not require individual MeasurementValue instances to represent their values.

Each MeasurementValue being supplied via IEC 61850 must also have an association to a MeasurementValueSource. However, through the unified model, a MeasurementValueSource can be a Server object that can have communication addressing information associated to it. Thereby allowing SCADA packages to take advantage of this capability.

The ability to use a Server, and its associated communication information, has long term advantages to other protocols as well. The current proposed model allows for DNP, ICCP, IEC 870-5, and 61850 Servers to be supported. In the case of the current mapping of ICCP data exchange, the fact that a Server class is an extension of the MeasurementValueSource class would allow model backwards capability while allowing the communication relationship functionality to be used in the future.

DataTypeTemplates

Figure 6-62 shows the proposed UML model for the DataTypeTemplate section of the SCL.

In general, the DataTypeTemplate section allows the definitions of the following types:

- Enumerations (tEnumType): These types are typically referenced by Data Attribute types (tDAType).
- DataAttribute Types (tDAType): These types are usually used within Sub Data Object (tSDO) or Data Object (tDO) types.
- Sub Data Object Types (tSDO) are only able to be referenced as part of Data Object Types.
- Data Object Types (tDOType) are used to compose Logical Node Types (tLNodeType).
- Logical Node Types (tLNNodeType) are used to instanciate Logical Node Instances within the IED section of the SCL file.

Control Blocks and DataSets

Figure 6-63 shows the proposed UML model for Control Blocks and DataSets. Control Blocks are uniqueto IEC 61850. Each Control Block can have a single association to a set of information/objects known as a DataSet (the class is IEC61850DataSet).

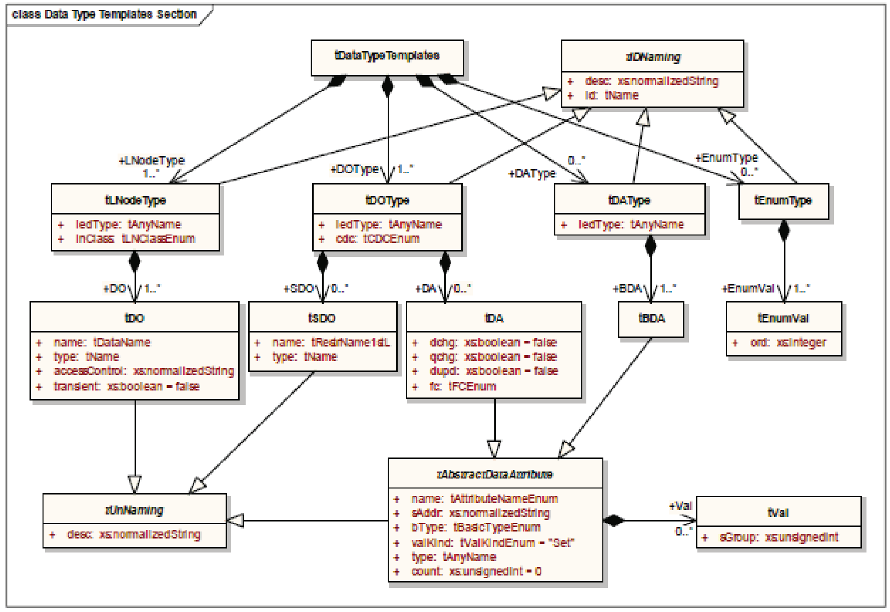


Figure 6-62
DataTypeTemplate Section Definition from IEC 61850-6

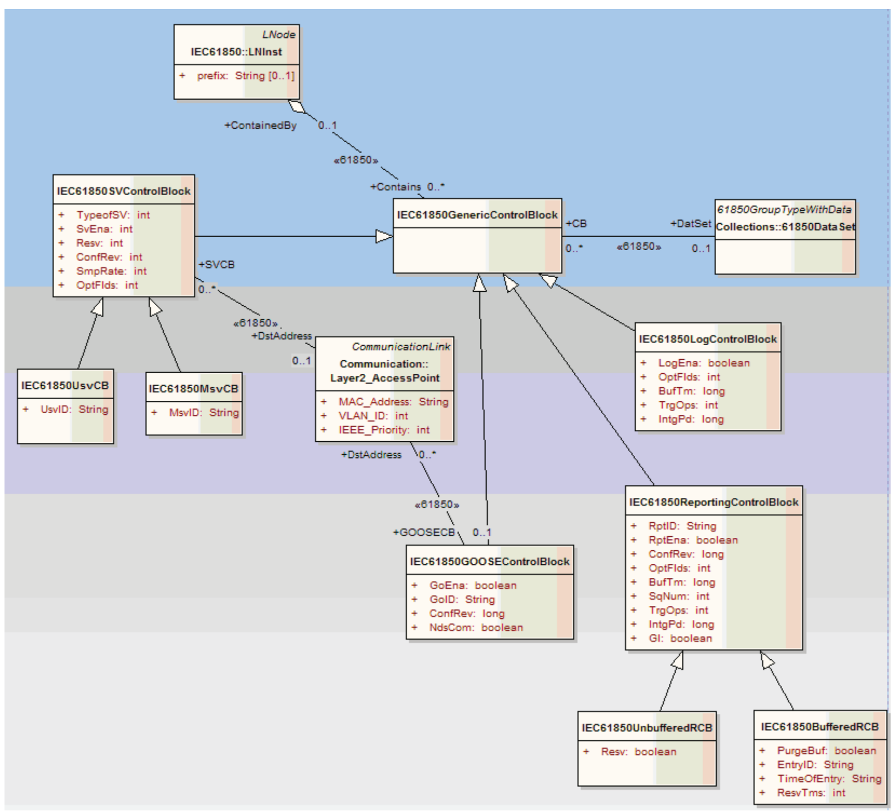


Figure 6-63
Proposed Control Block and DataSet UML Model

7 FUTURE HARMONIZATION ACTIVITIES NEEDED

The following is a list of activities that need to be undertaken in the future to complete harmonization between CIM and 61850. The following clauses indicate the activities and the experts (e.g. CIM or 61850) whose task it would be to perform the activity. The listed activities are beyond the review and comment on the recommendations in this report.

IEC TC57 WG10, WG16, WG17 and IEC TC88

- There is a need for the 61850 and Substation Experts to add semantic definitions to the Equipment and ConductingEquipment types used in 61850-6.
- IEC TC57 WG10, WG16, WG17 and experts from IEC TC88 need to develop the appropriate SCL extensions within the containers specified in this document.

IEC TC57 WG13

- Since the MeasurementType class has been removed, the declaration of the allowed values/names for the class needs to be removed from IEC 61970-452.

IEC TC57 WG10, WG13, and WG14

- The involved standards committees need to discuss the use of Enumerations versus ValueAliasSets.
- The relevant committee experts need to meet to determine the modeling of ConductionEquipment. As an example, there is a dispute between the two committees regarding if a CT is ConductingEquipment.
- The relevant committee experts, including TC88, need to analyze the mechanical connectivity modeling required. This document recommends ISO 15926 for this purpose.

IEC TC57 WG19

- WG19 should consider undertaking an activity to define, or reference to an existing set of definitions, for the PowerSystem resources found in CIM and 61850. These definitions/semantics should be used across all activities within TC57.
  Besides adopting a set of definitions, for use within TC57, definitions need to be created for the following terms that have no identified standardized definitions.
- The continuation of standardization of Quality value definitions is needed.

A USE CASE DATA ELEMENTS

This appendix contains a list of data elements identified for each use case interface that need to be included in the profile for that interface. Refer to the diagram in Figure 2-1 to identify each of these system interaction points.

Use Case 1 – SCL File Generation from Unified UML Model

Interface 1 - Substation/Protection Engineering to System Configurator

The primary interface in view for this use case is Substation/Protection Engineering to 61850 System Configurator.

The specific SCL elements that are included in this SSD file are as follows:

Substation Section

- VoltageLevel
- PowerTransformer
- TransformerWinding
- TapChanger
- Voltage
- Bay
- ConductingEquipment
  - This includes all primary equipment including breakers and switches as needed for an operational model
- SubEquipment
  - This adds the detail needed for representing 3 phases
- Terminal
- ConnectivityNode
  - cNodeName (relative to Bay) added by SS engineer
- Lnode

SCL xsd types that need to be supported in the UML model include:

- tNaming
- tLNodeContainer
- tUnNaming
- tPowerSystemResource
- tEquipmentContainer
- tFunction
- tSubFunction
- tEquipment

Interface 2 - 61850 System Configurator to Communications Engineering

The specific SCL elements that are included in this SCD file are as follows:

Substation section from Interface 1

IED Section (new)

- Services
  - List of services (i.e., capabilities) supported
- AccessPoint
- Server
- LDevice
- LNode (or LN)
  - List of possible class/types of LNodes, such as CSWI
    Example of lnClass = CSWI attributes
    - Local operation: SPS
    - Remote control blocked: SPC
    - Local control behavior: SPS
    - Resetable operation counter: INC
    - General switch control: DPC
    - Phase A switch control: DPC
    - Phase B switch control: DPC
    - Phase C switch control: DPC
    - Operation "Open Switch" status: ACT
    - Operation "Close Switch" status: ACT

For LN0

- DataSet
- ReportControl
- LogControl
- GSEControl
- SampledValueControl

DataTypeTemplates (unclear if these need to be included for this interface)

Interface 3 - Communications Engineering to Substation Configuration Database (SCL-SCD files) - (Step 13)

The specific SCL elements included in this SCD file are as follows:

Substation and IED sections from Interface 2

Communication Section (new)

- Subnetwork
- Text (readable name (e.g., Station bus)
- BitRate
- ConnectedAP
- Address
- GSE
- PhysConn
- SMV
- P

Content of model handed to SS engineering contain EQ and CONNECTIVITY and Measurement (i.e., Analog, Discrete, etc.) associated to Terminals, but no MeasurementValue. Also will pass MRIDs.

Return path then is either:

- ctvalues are used to create MeasurementValues and their association to Measurements, or
- MRID is persisted in 61850 and used to automatically associate these points.

Use Case 2 – EMS Model Update from Imported SCL File

Interface 1 – Substation Configuration Database to Network Model Manager and Repository

This data elements are a complete SCD SCL file with the same elements as contained in Use Case 2, Interface 3 – the Substation, IEC, and Communications sections.

B EXAMPLE APPLICATION OF UNIFIED MODEL CONCEPTS TO SCADA DATA EXCHANGE

The CIM Small Model, used at the various EPRI Interoperability (IOP) tests, will be used to demonstrate the concepts/solutions proposed in this document. The CIM Small Model consists of two (2) substations: Airport and River. This document will focus on the workflow/transformations for the Airport substation only.

Generation of the Planning Model

Assume that the Airport Substation is being planned. This means that a planning model will be generated that is a bus/branch model. Such a model can be graphically represented as:

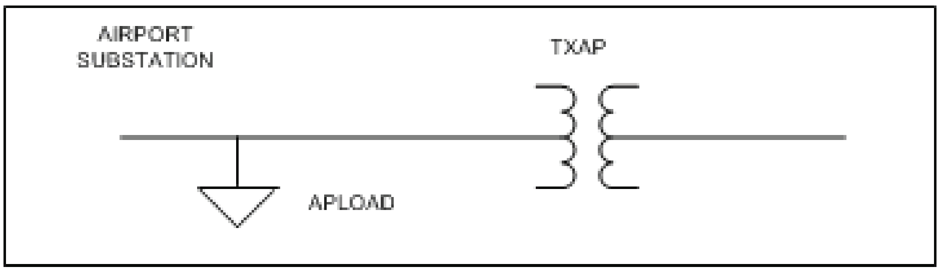


Figure B-1
Planning Model for Airport Substation

The planned model shows one PowerTransformer (TXAP) with one EnergyConsumer/Load (APLOAD). The AC Line that is to come into the transformer is to be named AIRP_RIVER.

In order to build a bus/branch model, in CIM, BusNameMarkers must be added. Additionally, the appropriate Terminals and ConnectivityNodes need to be added. In order to accomplish this, the appropriate TransformerWindings need to be added (e.g. TXAPH and TXAPX).

Based upon this model, the following diagram represents the bus/branch model that would typically be translated into CIM XML.

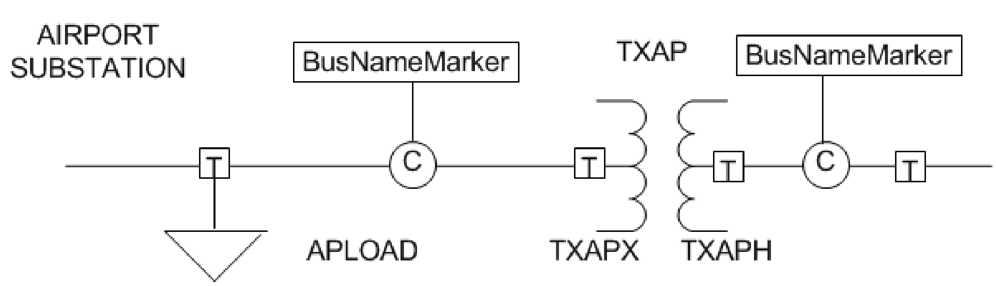


Figure B-2
CIM Planning Model Details

Figure B-2 shows that at least four (4) Terminals, two (2) ConnectivityNodes, and two (2) BusNameMarkers and needed to fully define the planning model.

A simplified CIM XML representation of the model could be:


```xml
<cim:Substation rdf:ID="_2">
        <cim:IdentifiedObject.name>AIRPORT</cim:IdentifiedObject.name>
</cim:Substation>
<cim:PowerTransformer rdf:ID="_9">
        <cim:IdentifiedObject.name>TXAP</cim:IdentifiedObject.name>
        <cim:Equipment.MemberOf_EquipmentContainer rdf:resource="#_2"/>
</cim:PowerTransformer>
<cim:TransformerWinding rdf:ID="_10">
        <cim:IdentifiedObject.name>TXAPH</cim:IdentifiedObject.name>
        <cim:TransformerWinding.MemberOf_PowerTransformer
rdf:resource="#_9"/>
        <cim:Equipment.MemberOf_EquipmentContainer rdf:resource="#_3"/>
</cim:TransformerWinding>
<cim:TransformerWinding rdf:ID="_11">
        <cim:IdentifiedObject.name>TXAPX</cim:IdentifiedObject.name>
        <cim:TransformerWinding.MemberOf_PowerTransformer
rdf:resource="#_9"/>
        <cim:Equipment.MemberOf_EquipmentContainer rdf:resource="#_5"/>
</cim:TransformerWinding>
<cim:VoltageLevel rdf:ID="_3">
      <cim:IdentifiedObject.name>VL_AIRP_345</cim:IdentifiedObject.name>
      <cim:VoltageLevel.MemberOf_Substation rdf:resource="#_2"/>
      <cim:VoltageLevel.BaseVoltage rdf:resource="#_4"/>
</cim:VoltageLevel>
<cim:BaseVoltage rdf:ID="_4">
      <cim:BaseVoltage.nominalVoltage>345kV
                  </cim:BaseVoltage.nominalVoltage>
      <cim:BaseVoltage.BasePower rdf:resource="#_13"/>
</cim:BaseVoltage>
<cim:VoltageLevel rdf:ID="_5">
        <cim:IdentifiedObject.name>VL_AIRP_22</cim:IdentifiedObject.name>
        <cim:VoltageLevel.MemberOf_Substation rdf:resource="#_2"/>
        <cim:VoltageLevel.BaseVoltage rdf:resource="#_6"/>
</cim:VoltageLevel>
<cim:BaseVoltage rdf:ID="_6">
      <cim:BaseVoltage.nominalVoltage>22kV
                        </cim:BaseVoltage.nominalVoltage>
      <cim:BaseVoltage.BasePower rdf:resource="#_13"/>
</cim:BaseVoltage>
<cim:BasePower rdf:ID="_13">
        <cim:BasePower.basePower>100</cim:BasePower.basePower>
</cim:BasePower>
<cim:EnergyConsumer rdf:ID="_8">
        <cim:IdentifiedObject.name>APLOAD</cim:IdentifiedObject.name>
        <cim:Equipment.MemberOf_EquipmentContainer rdf:resource="#_5"/>
</cim:EnergyConsumer>
<cim:Terminal rdf:ID="_30">
        <cim:IdentifiedObject.name>AIR_CN11_APLOAD</cim:IdentifiedObjec
t.name>
        <cim:Terminal.ConductingEquipment rdf:resource="#_8"/>
        <cim:Terminal.ConnectivityNode rdf:resource="#_60"/>
</cim:Terminal>
<cim:ConnectivityNode rdf:ID="_60">
    <cim:IdentifiedObject.name>CN11</cim:IdentifiedObject.name>
    <cim:ConnectivityNode.MemberOf_EquipmentContainer rdf:resource="#_5"/>
</cim:ConnectivityNode>
<cim:BusNameMarker rdf:ID="_BusMarker1">
        <cim:IdentifiedObject.name>HighSide
                Airport</cim:IdentifiedObject.name>
        <cim:BusNameMarker.ConnectivityNode rdf:resource="#_60"/>
</cim:BusNameMarker>
<cim:Terminal rdf:ID="_33">
      <cim:IdentifiedObject.name>AIR_CN12_TXAPX</cim:IdentifiedObject.name>
        <cim:Terminal.ConductingEquipment rdf:resource="#_11"/>
        <cim:Terminal.ConnectivityNode rdf:resource="#_60"/>
</cim:Terminal>
<cim:Terminal rdf:ID="_34">
        <cim:IdentifiedObject.name>AIR_CN13_
TXAPH</cim:IdentifiedObject.name>
        <cim:Terminal.ConductingEquipment rdf:resource="#_10"/>
        <cim:Terminal.ConnectivityNode rdf:resource="#_61"/>
</cim:Terminal>
<cim:BusNameMarker rdf:ID="_BusMarker2">
        <cim:IdentifiedObject.name>LoadSide
                Airport</cim:IdentifiedObject.name>
        <cim:BusNameMarker.ConnectivityNode rdf:resource="#_61"/>
</cim:BusNameMarker>
<cim:ConnectivityNode rdf:ID="_61">
   <cim:IdentifiedObject.name>CN12</cim:IdentifiedObject.name>
   <cim:ConnectivityNode.MemberOf_EquipmentContainer rdf:resource="#_5"/>
</cim:ConnectivityNode>
```


It is interesting to note that the BaseVoltage.nominalVoltage must include the actual units and multipliers in order to be properly translated into SCL. In the original small model, the value of BaseVoltage.nominalVoltage might be 22. However, in order to allow the interface to appropriately map, the value should be 22kV.

Important harmonization recommendations

It should be noted that the current SCL definitions do not provide the ability to represent a planning model. Thus, one of the recommendations was to add a separate section in SCL for this purpose.

Another key feature of the harmonization recommendations is to provide lossless transformation into/out of the unified model. One of the key requirements, in order to achieve this, is that SCL objects have persistent identifiers associated with them (a.l.a. CIM RDF identifiers). The current SCL only uses naming to provide instance information which makes it difficult to determine if name changes represent new instances or modifications to old instances. These types of issues are resolved with the recommendation to enhance SCL to include instance (RDFID) and association references (RDFREF and others) that use persistent identifiers as opposed to names.

The equivalent SCL would appear as follows:

```
<Substation name="AIRPORT" RDFID="_2">
    <PowerTransformer name="TXAP" type="PTR" RDFID="_9">
        <TransformerWinding name="TXAPH" type="PTW" RDFID="_10" >
            <Terminal RDFID="_34" substationName="AIRPORT" voltageLevelName="VL_AIRP_345" cNodeName="CN12"
                      connectivityNodeRef="#_61" substationRef="#_2" voltageLevelRef="#_3"/>
        </TransformerWinding>
        <TransformerWinding name="TXAPX" type="PTW" RDFID="_11">
            <Terminal RDFID="_33" connectivityNode="AIRPORT/VL_AIRP_22/CN11" substationName="AIRPORT" voltageLevelName="VL_AIRP_22" cNodeName="CN11"
                      connectivityNodeRef="#_60" substationRef="#_2" voltageLevelRef="#_5"/>
        </TransformerWinding>
    </PowerTransformer>
    <ConnectivityNode name="CN11" RDFID="_60" pathName="AIRPORT/VL_AIRP_345/CN11"/>
    <ConnectivityNode name="CN12" RDFID="_61" pathName="AIRPORT/345/CN12"/>
    <ConductingEquipment name="APLOAD" RDFID="_8" type="EnergyConsumer" >
        <Terminal RDFID="30" connectivityNode="AIRPORT/VL_AIRP_22/CN11" substationName="AIRPORT" voltageLevelName="VL_AIRP_22" cNodeName="C11"
                  connectivityNodeRef="#_60" substationRef="#_2" voltageLevelRef="#_5"/>
    </ConductingEquipment>
    <VoltageLevel name="VL_AIRP_345" RDFID="_3">
        <Voltage RDFID="_4" multiplier="k" unit="V">345</Voltage>
    </VoltageLevel>
    <VoltageLevel name="VL_AIRP_22" RDFID="_3">
        <Voltage RDFID="_6" multiplier="k" unit="V">22</Voltage>
    </VoltageLevel>
</Substation>
<Planning>
  <BusNameMarker RDFID="_BusMarker1" name="HighSide Aiport">
      <ConnectivityNode="#_61">
  </BusNameMarker>
  <BusNameMarker RDFID="_BusMarker2" name="LoadSide Aiport >
      <ConnectivityNode="#_60">
  </BusNameMarker>
<Planning>
```


Note that BasePower is not translated into SCL. If this is needed, the addition/mapping of this into SCL would be a future work item.

Substation and Protection Engineering

The next step in the use case is for Protection and Substation Engineering to specify what Switches (including Breakers) and Functions (either protection or other) into the model.

In the CIM Small model, there is one (1) LoadBreakSwitch (LBS) that needs to be added into the model:

In order to accomplish this, two (2) additional Terminals and one additional ConnectivityNode must be added to the CIM model. Additionally, the Terminal associations from APLOAD need to be changed to associate to CN13.

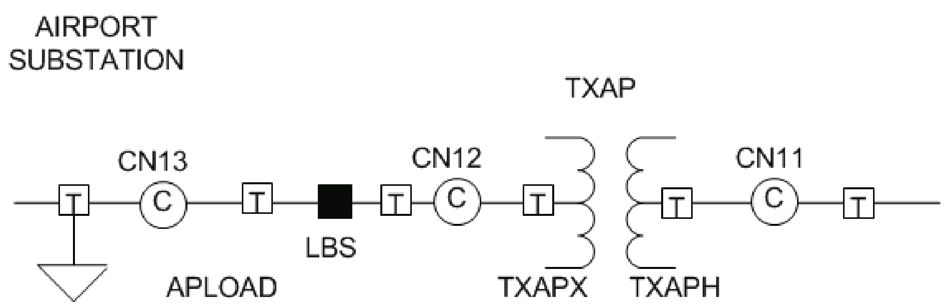


Figure B-3
Connectivity/Topology Model for Airport Substation

The changes to the CIM XML file might look something like:

Then the Substation/Protection engineers decide that they need to have measurement monitoring on the high-side transformer winding (TXAPH) and a Controllable Switch function associated with the LBS. This means that they would add LNodes/LNInst of MMXU and CWSI to the appropriate points in the topology.


```
<cim:LoadBreakSwitch rdf:ID="_0081">
        <cim:IdentifiedObject.name>LBS</cim:IdentifiedObject.name>
</cim:LoadBreakSwitch>
<cim:ConnectivityNode rdf:ID="_6113">
        <cim:IdentifiedObject.name>CN13</cim:IdentifiedObject.name>
        <cim:ConnectivityNode.MemberOf_EquipmentContainer rdf:resource="#_6"/>
</cim:ConnectivityNode>
<cim:Terminal rdf:ID="_30">
        <cim:IdentifiedObject.name>AIR_CN11_APLOAD</cim:IdentifiedObject.name>
        <cim:Terminal.ConductingEquipment rdf:resource="#_8"/>
        <cim:Terminal.ConnectivityNode rdf:resource="#_60"/>
</cim:Terminal>
<cim:Terminal rdf:ID="_3013">
        <cim:IdentifiedObject.name>LBS_CN13_APLOAD</cim:IdentifiedObject.name>
        <cim:Terminal.ConductingEquipment rdf:resource="#_0081"/>
        <cim:Terminal.ConnectivityNode rdf:resource="#_6113"/>
</cim:Terminal>
<cim:Terminal rdf:ID="_3014">
        <cim:IdentifiedObject.name>LBS_CN12_TXAPX</cim:IdentifiedObject.name>
        <cim:Terminal.ConductingEquipment rdf:resource="#_0081"/>
        <cim:Terminal.ConnectivityNode rdf:resource="#_61"/>
</cim:Terminal>
```


Important harmonization recommendations

Currently, CIM has no concept of Logical Nodes or other such IEC 61850 constructs. Besides adding such classes to the unified model UML, there needed to be defined an association between the CIM PowerSystemResource and IEC 61850 Logical Nodes. The following UML shows the relevant model that will allow a CIM XML/SCL representation of the unified model to reflect the PSR to Logical Node relationships:

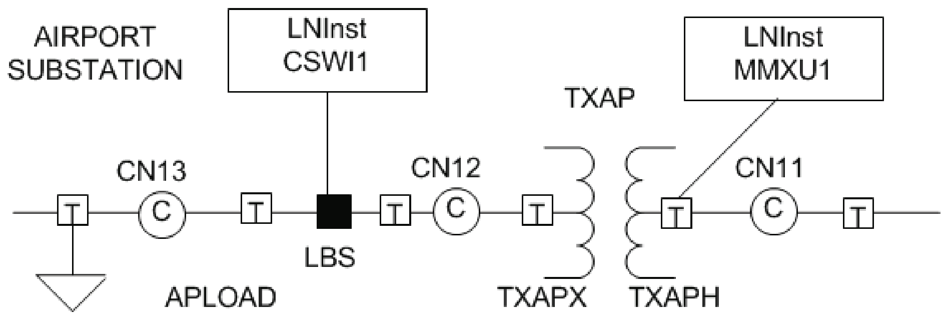


Figure B-4
Connecitivy of Substation including Logical Node Instances

UML models represent the meta-data for a model. Instances of the defined classes are given unique identifiers. However, there is an issue regarding what persistent identifier should be given to a instance that must be standardized across all model instances. As an example, consider the LNClass of MMXU. This definition is found in IEC 61850-7-4. In order to be un-ambiguous about what the LNClass represents, the same persistent identifier needs to be used to represent that class across all models globally. Therefore, the standards need to define the standardized persistent identifier for such instances.

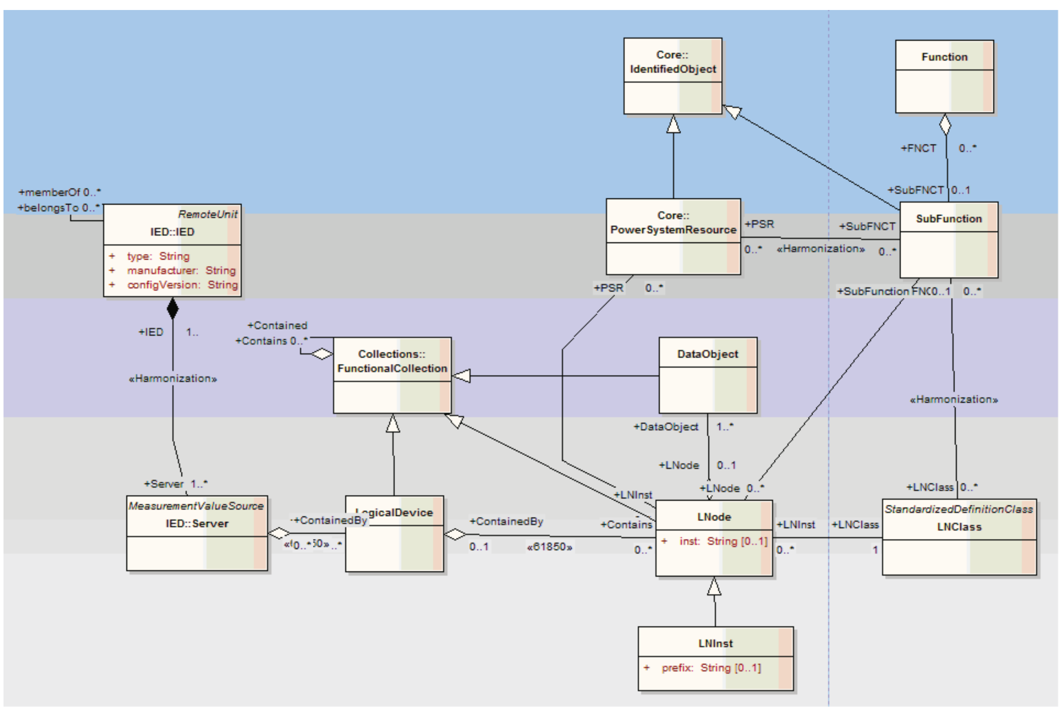


Figure B-5
PowerSystemResource to LogicalNode Relationship

This means that the rdf:id for the LNClass objects are standardized and can be found assigned as part of the harmonization proposal and not by model managers.

With these recommendations, the following CIM XML represents the diagram:

```
<cim:LNode rdf:id="_MMXU">
        <cim:IdentifiedObject.name>MMXU</cim:IdentifiedObject.name>
        <cim:LNode.LNClass rdf:resource="#_8435f48a-9fd7-4563-82a8-9dff30cb26d6"/>
        <cim:LNode.PSR rdf:resource="#_34"/>
</cim:LNode>
<cim:LNode rdf:id="_CSWI">
        <cim:IdentifiedObject.name>CSWI</cim:IdentifiedObject.name>
        <cim:LNode.LNClass rdf:resource="#_ffcb887a-25e5-43e0-9164-38c3eeebc729"
        <cim:LNode.PSR rdf:resource="#_0081"/>
</cim:LNode>
<cim:IEC61850-7-4LNClass rdf:id="_ffcb887a-25e5-43e0-9164-38c3eeebc729">
        <cim:LNClass.class>CSWI</cim:LNClass.class>
</cim:IEC61850-7-4LNClass>
<cim:IEC61850-7-4LNClass rdf:id="_8435f48a-9fd7-4563-82a8-9dff30cb26d6">
        <cim:LNClass.class>MMXU</cim:LNClass.class>
</cim:IEC61850-7-4LNClass>
```

It is also probably that the BusMarkers would be removed during this engineering process.

The equivalent SSD that would be sent to the Substation Configurator would be similar to the following:

```
<Substation name="AIRPORT" RDFID="_2">
    <PowerTransformer name="TXAP" type="PTR" RDFID="_9">
        <TransformerWinding name="TXAPH" type="PTW" RDFID="_10" >
            <Terminal RDFID="_34" substationName="AIRPORT" voltageLevelName="VL_AIRP_345" cNodeName="CN12"
                                  connectivityNodeRef="#_61" substationRef="#_2" voltageLevelRef="#_3"/>
            <LNode name="MMXU" lnclass="MMXU"/>
        </TransformerWinding>
        <TransformerWinding name="TXAPX" type="PTW" RDFID="_11">
            <Terminal RDFID="_33" connectivityNode="AIRPORT/VL_AIRP_22/CN11" substationName="AIRPORT" voltageLevelName="VL_AI
                                  connectivityNodeRef="#_60" substationRef="#_2" voltageLevelRef="#_5"/>
        <LNode name="MMXU" lnclass="MMXU" lnClassRef="#__8435f48a-9fd7-4563-82a8-9dff30cb26d6"/>
        </TransformerWinding>
    </PowerTransformer>
    <ConnectivityNode name="CN11" RDFID="_60" pathName="AIRPORT/VL_AIRP_345/CN11"/>
    <ConnectivityNode name="CN12" RDFID="_61" pathName="AIRPORT/345/CN12"/>
    <ConnectivityNode name="CN13" RDFID="_6113" pathName="AIRPORT/345/CN12"/>
    <ConductingEquipment name="APLOAD" RDFID="_8" type="EnergyConsumer" >
        <Terminal RDFID="30" connectivityNode="AIRPORT/VL_AIRP_22/CN13" substationName="AIRPORT" voltageLevelName="VL_AIRP_22
                        connectivityNodeRef="#_6113" substationRef="#_2" voltageLevelRef="#_5"/>
    </ConductingEquipment>
    <ConductingEquipment name="LBS" RDFID="_0081" type="EnergyConsumer" >
        <Terminal RDFID="_3013" connectivityNode="AIRPORT/VL_AIRP_22/CN13" substationName="AIRPORT" voltageLevelName="VL_AIRP_
                        connectivityNodeRef="#_6113" substationRef="#_2" voltageLevelRef="#_5"/>
        <Terminal RDFID="_3014" connectivityNode="AIRPORT/VL_AIRP_22/CN12" substationName="AIRPORT" voltageLevelName="VL_AIRP_
                        connectivityNodeRef="#_61" substationRef="#_2" voltageLevelRef="#_5"/>
        <LNode name="CSWI" lnclass="CSWI" lnClassRef="#_ffcb887a-25e5-43e0-9164-38c3eeebc729"/>
    </ConductingEquipment>
    <VoltageLevel RDFID="_3" name="VL_AIRP_345">
        <Voltage RDFID="_4" multiplier="k" unit="V">345</Voltage>
    </VoltageLevel>
    <VoltageLevel RDFID="_5" name="VL_AIRP_22" RDFID="_3">
        <Voltage RDFID="_6" multiplier="k" unit="V">22</Voltage>
    </VoltageLevel>
</Substation>
```

☐ - **Recommended Extensions and Standa GUIDs**

Substation Configuration

In the Substation configuration activity, the IED section of the SCL file is created. This engineering task allows the Logical Nodes to be assigned to IEDs and Logical Devices.

In order to insure that the proposed recommendations are appropriate, this section will detail the resulting CIM XML that would result from certain sections of the SCL file.

DataObjects

Important harmonization recommendations

The following UML is the basis of the unified model's decomposition of the hierarchy of IEC 61850 Logical Nodes, DataObjects, etc.

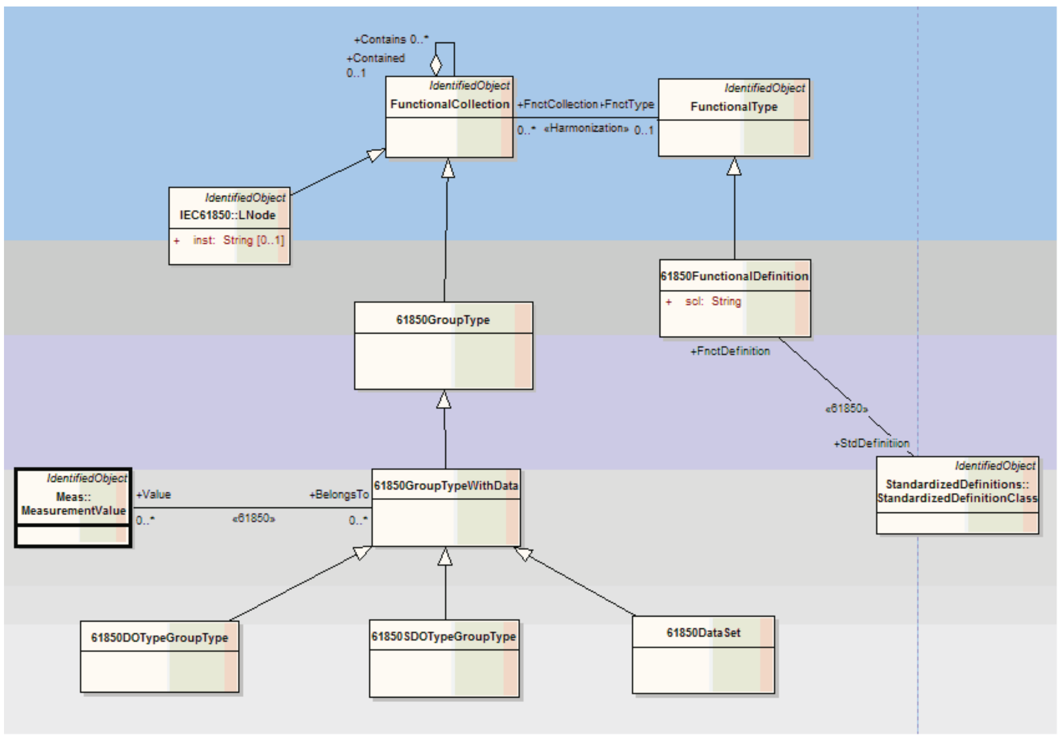
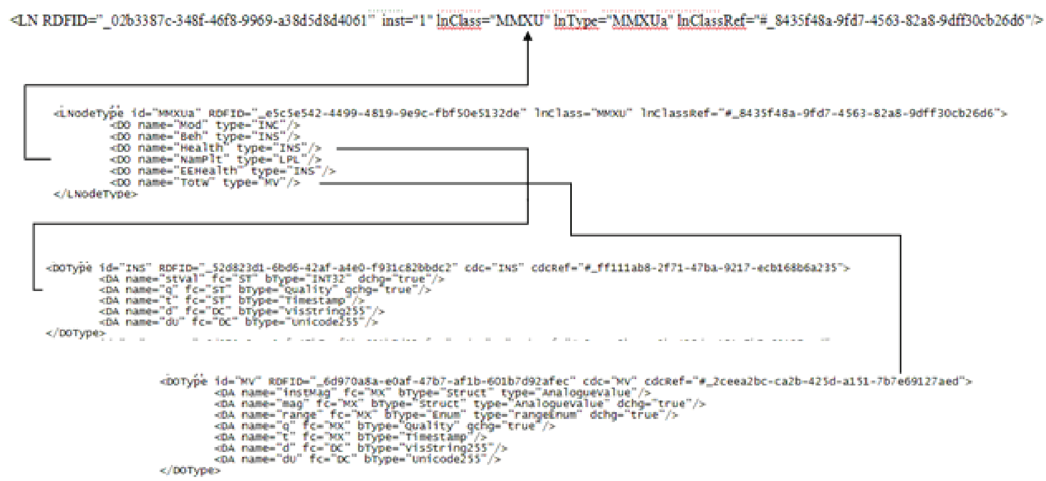


Figure B-6
Decomposition of LogicalNode Instances into MeasurementValues

The UML separates the Type information from the hierarchy of actual data. In SCL, the two are the same.

Based upon the recommendations, the DOs would be translated by an interface, to the appropriate sets of unified model classes using the functional collection DataObject class.

As an example, only a portion of the SCL will be used to illustrate the mapping/transformation.



This figure shows that SCL has defined a Logical Node which is an MMXU (instance 1) which has a LNodeType of MMXUa. MMXUa consists of multiple DataObjects (e.g. Mod, Beh, NamPlt, etc..). The figure also shows that the MMXUa DO "Health" is a "INS" DOType wheras the TotW DO is of a "MV" type. The figure further shows the definition of two of the DataObject types used in defining MMXUa (e.g. INS and MV).

Based upon the harmonization recommendations, the equivalent CIM XML for the Logical Node Instance of of the SCL would be converted into an instance of an LNInst class, DataObject Grouping objects, and one 61850FunctionalDefinition Object. For the example, only the DataObject Grouping objects for the Logical Node (e.g. MMXUa), and two(2) DataObject Groupings (e.g. Beh and TotW) are shown. Each of the DataObject Groupings have their own 61850FunctionalDefinition.

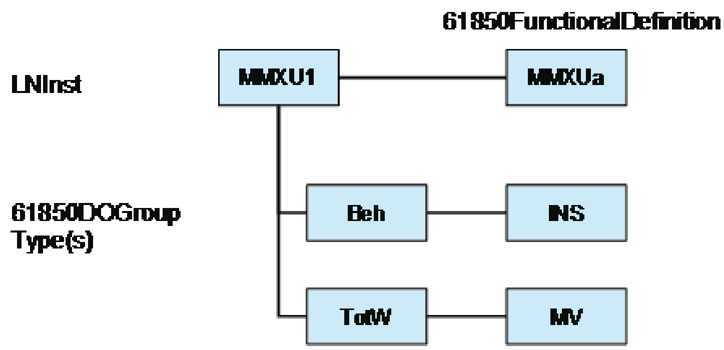


Figure B-7
UML to Generate CIM XML

The above figure attempts to graphically represent the resulting unified model relationships that result in the following CIM XML:

Logical Node Instance that has one FunctionType and contains two(2) other groupings.


```
<cim:LNinst rdf:id="_02b3387c-348f-46f8-9969-a38d5d8d4061">
  <cim:IdentifiedObject.name>MMXU</cim:IdentifiedObject.name>
  <cim:LNode.inst>1</cim:LNode.inst>
  <cim:FunctionalCollection.FnctType rdf:resource="#_e5c5e542-4499-4819-9e9c-fbf50e5132de"/>
  <cim:FunctionalCollection.contains rdf:resource="#_9549fec2-5f18-4dfc-a018-7c5f7eb79157"/>
  <cim:FunctionalCollection.contains rdf:resource="#_52f71f57-3cf6-4ebf-873d-48b6c83767ba"/>
</cim:LNinst>

<cim:61850FunctionalDefinition rdf:ID="_e5c5e542-4499-4819-9e9c-fbf50e5132de">
  <cim:IdentifiedObject.name>MMXUa</cim:IdentifiedObject.name>
  <cim:61850FunctionalDefinition.StdDefinition rdf:resource="#_8435f48a-9fd7-4563-82a8-9dff30cb26d6"/>
  <cim:scl>
                    <DO name="Mod" type="INC" />
                    <DO name="Beh" type="INS" />
                    <DO name="Health" type="INS"/>
                    <DO name="NamPlt"  type="LPL"/>
                    <DO name="EEHealth"  type="INS" />
                    <DO name="TotW"  type="MV"/>
   </cim:scl>
</cim:61850FunctionalDefinition>

<cim:61850DOTypeGroupType rdf:ID="_e5c5e542-4499-4819-9e9c-fbf50e5132de">
   <cim:IdentifiedObject.name>Beh</cim:IdentifiedObject.name>
   <cim:FunctionalCollection.FnctType rdf:resource="#_52d823d1-6bd6-42af-a4e0-f931c82bbdc2"/>
   <cim:61850GroupTypeWithData.Value rdf:resource="#__d0852b37-d4e2-4bf9-96bd-2de92b0c96e4"/>
</cim:61850DOTypeGroupType>

<cim:61850DOTypeGroupType rdf:ID="_52d823d1-6bd6-42af-a4e0-f931c82bbdc2">
  <cim:IdentifiedObject.name>TotW</cim:IdentifiedObject.name>
  <cim:FunctionalCollection.FnctType rdf:resource="#_6d970a8a-e0af-47b7-af1b-601b7d92afec"/>
  <cim:MeasurementValue.Status rdf:resource="#_12e9c007-9ee8-427b-a9b2-cc8c232dc1e6"/>
</cim:61850DOTypeGroupType>
```

The associated Functional Types would be (e.g. MMXUa, INS, and MV):


```
<cim:61850FunctionalDefinition rdf:ID=”_e5c5e542-4499-4819-9e9c-fbf50e5132de”>
  <cim:IdentifiedObject.name>MMXUa</cim:IdentifiedObject.name>
  <cim:61850FunctionalDefinition.StdDefinition rdf:resource=”#_8435f48a-9fd7-4563-82a8-9dff30cb26d6”/>
  <cim:scl>
                <DO name=”Mod” type=”INC” />
                <DO name=”Beh” type=”INS” />
                <DO name=”Health” type=”INS”/>
                <DO name=”NamPlt”  type=”LPL”/>
                <DO name=”EEHealth”  type=”INS” />
                <DO name=”TotW”  type=”MV”/>
   </cim:scl>
</cim:61850FunctionalDefinition>

<cim:61850FunctionalDefinition rdf:ID=”_52d823d1-6bd6-42af-a4e0-f931c82bbdc2”>
  <cim:IdentifiedObject.name>INS</cim:IdentifiedObject.name>
  <cim:61850FunctionalDefinition.StdDefinition rdf:resource=”#_ff111ab8-2f71-47ba-9217-ecb168b6a235”/>
  <cim:scl>
                <DA name=”stVal” fc=”ST” bType=”INT32” dchg=”true”/>
                <DA name=”q” fc=”ST” bType=”Quality” qchg=”true”/>
                <DA name=”t” fc=”ST” bType=”Timestamp”/>
                <DA name=”d” fc=”DC” bType=”VisString255”/>
                <DA name=”dU” fc=”DC” bType=”Unicode255”/>
  </cim:scl>
</cim:61850FunctionalDefinition>

<cim:61850FunctionalDefinition rdf:ID=”_6d970a8a-e0af-47b7-af1b-601b7d92afec”>
  <cim:IdentifiedObject.name>MV</cim:IdentifiedObject.name>
  <cim:61850FunctionalDefinition.StdDefinition rdf:resource=”#_2ceea2bc-ca2b-425d-a151-7b7e69127aed”/>
  <cim:scl>
                <DA name=”instMag” fc=”MX” bType=”Struct” type=”AnalogueValue”/>
                <DA name=”mag” fc=”MX” bType=”Struct” type=”AnalogueValue” dchg=”true”/>
                <DA name=”range” fc=”MX” bType=”Enum” type=”rangeEnum” dchg=”true”/>
                <DA name=”q” fc=”MX” bType=”Quality” qchg=”true”/>
                <DA name=”t” fc=”MX” bType=”Timestamp”/>
                <DA name=”d” fc=”DC” bType=”VisString255”/>
                <DA name=”dU” fc=”DC” bType=”Unicode255”/>
  </cim:scl>
</cim:61850FunctionalDefinition>
```


For the Beh and TotW DataObject Group Types, each has a single MeasurementValue associated to them (e.g. for Beh status value and TotW magnitude). This restriction is to make the example simpler. The resulting CIM XML, following the recommended MeasurementValue mappings to 61850, would be:


```
<cim:DiscreteValue rdf:ID=”_d0852b37-d4e2-4bf9-96bd-2de92b0c96e4”>
  <cim:MeasurementValue.pathName>S1/MMXU1.Beh.stval[ST]</cim:MeasurementValue.pathName>
  <cim:MeasurementValue.functionOfMV>ST</cim:MeasurementValue.functionOfMV>
  <cim:MeasurementValue.simpleName>stVal</cim:MeasurementValue.simpleName>
  <cim:MeasurementValue.MeasurementValueSource rdf:resource=”#_31d6f2de-6ec9-4270-ba1c-a90174eb6b7c “/>
  <cim:DiscreteValue.Discrete rdf:resource=”#_61249c22-33d4-4260-b892-9c841dd33aeb”/>
</cim:DiscreteValue>

<cim:AnalogValue rdf:ID=”_87543521-07bd-460e-9c02-f4733cc5e7df”>
  <cim:MeasurementValue.pathName>S1/MMXU1.TotW.mag.f[MX]</cim:MeasurementValue.pathName>
  <cim:MeasurementValue.functionOfMV>MX</cim:MeasurementValue.functionOfMV>
  <cim:MeasurementValue.simpleName>f</cim:MeasurementValue.simpleName>
  <cim:MeasurementValue.MeasurementValueSource rdf:resource=”#_31d6f2de-6ec9-4270-ba1c-a90174eb6b7c “/>
  <cim:AnalogValue.Analog rdf:resource=”#_87543521-07bd-460e-9c02-f4733cc5e7df”/>
</cim:AnalogValue>
```

Each of the MeasurementValue instances associates to a single 61850 Server that acts as the MeasurementValueSource. The CIM XML declaration of the Server can be found in the Communications section of this part.

Each MeasurementValue has an associated Measurement instance:

```
<cim:Discrete rdf:ID="_61249c22-33d4-4260-b892-9c841dd33aeb">
  <cim:IdentifiedObject.name>Beh</cim:IdentifiedObject.name>
</cim:Discrete>

<cim:Analog rdf:ID="_87543521-07bd-460e-9c02-f4733cc5e7df">
  <cim:IdentifiedObject.name>TotW.mag</cim:IdentifiedObject.name>
  <cim:Measurement.PowerSystemResource rdf:resource="#_34"/>
</cim:Discrete>
```

An analysis of the Measurement instances shows that Beh is not associated to a PowerSystemResource due to it being Logical Node related only. The Measurement instance representing TotW.mag follows the recommendation to be associated to the same PowerSystemResource as the Logical Node Instance.

The Discrete Measurement has an enumeration set that is defined in the SCL. Based upon the harmonization recommendations, the resulting CIM XML is:

```
<cim:ValueAliasSet rdf:ID="_318b23bd-bd6b-4aca-90df-cd95ad0397d3">
  <cim:IdentifiedObject.name>BehEnum</cim:IdentifiedObject.name>
  <cim.ValueAliasSet.Discrete rdf:resource="#_61249c22-33d4-4260-b892-9c841dd33aeb"/>
</cim:ValueAliasSet>

<cim:ValuetoAlias rdf:ID="_ae97bc6b-eb99-450b-9fc5-e224b9e2bb76">
  <cim:IdentifiedObject.name>on</cim:IdentifiedObject.name>>
  <cim:ValuetoAlias.value>1</cim:ValuetoAlias.value>
  <cim:ValuetoAlias.ValueAliasSet rdf:resource="#_318b23bd-bd6b-4aca-90df-cd95ad0397d3"/>
</cim:ValuetoAlias>

<cim:ValuetoAlias rdf:ID="_b24ae657-9951-453f-8cac-04bfe26a8096">
  <cim:IdentifiedObject.name>on-blocked</cim:IdentifiedObject.name>>
  <cim:ValuetoAlias.value>2</cim:ValuetoAlias.value>
  <cim:ValuetoAlias.ValueAliasSet rdf:resource="#_318b23bd-bd6b-4aca-90df-cd95ad0397d3"/>
</cim:ValuetoAlias>

<cim:ValuetoAlias rdf:ID="_7ada2f16-2c7c-4c8b-9194-54eb2035f21a">
  <cim:IdentifiedObject.name>test</cim:IdentifiedObject.name>>
  <cim:ValuetoAlias.value>3</cim:ValuetoAlias.value>
  <cim:ValuetoAlias.ValueAliasSet rdf:resource="#_318b23bd-bd6b-4aca-90df-cd95ad0397d3"/>
</cim:ValuetoAlias>

<cim:ValuetoAlias rdf:ID="_11499f4c-079f-4058-ba72-5e8bea244dbe">
  <cim:IdentifiedObject.name>test/blocked</cim:IdentifiedObject.name>>
  <cim:ValuetoAlias.value>4</cim:ValuetoAlias.value>
  <cim:ValuetoAlias.ValueAliasSet rdf:resource="#_318b23bd-bd6b-4aca-90df-cd95ad0397d3"/>
</cim:ValuetoAlias>

<cim:ValuetoAlias rdf:ID="_7ca2b46e-d5cf-408a-93ab-331e35dce3e8">
  <cim:IdentifiedObject.name>off</cim:IdentifiedObject.name>>
  <cim:ValuetoAlias.value>5</cim:ValuetoAlias.value>
  <cim:ValuetoAlias.ValueAliasSet rdf:resource="#_318b23bd-bd6b-4aca-90df-cd95ad0397d3"/>
</cim:ValuetoAlias>
```

The creation of a Logical Node Instance, within the Substation configuration tool, requires that the instance be contained in a Logical Device, Server, AccessPoint, and IED. In SCL, this would appear as follows:

```
<IED name="D1Q1SB4" RDFID="_D1Q1SB4">
        <Services>
                <DynAssociation/>
                <GetDirectory/>
                <GetDataObjectDefinition/>
                <GetDataSetValue/>
                <DataSetDirectory/>
                <ReadWrite/>
                <FileHandling/>
                <ConfDataSet max="4"/>
                <ConfReportControl max="12"/>
                <ReportSettings bufTime="Dyn" cbName="Conf" rptID="Dyn" datSet="Conf" intgPd="Dyn" optFields="Conf"/>
                <ConfLogControl max="1"/>
                <GetCBValues/>
                <GOOSE max="2"/>
                <GSESettings appID="Conf" cbName="Conf" datSet="Conf"/>
        </Services>
        <AccessPoint name="S1" RDFID="_47f106df-5815-496d-9d0b-e5f10d0995cd">
                <Server RDFID="_31d6f2de-6ec9-4270-ba1c-a90174eb6b7c">
                        <Authentication/>
                        <LDevice inst="C1" RDFID="_f3025769-7aef-4d9b-a71d-db1d4716d649">
                                <LN0 RDFID="_91d50a5d-ee81-4e7c-8608-66b078d001f8 " lnType="LN0" lnClass="LLN0"
                                        inst="" lnClassRef="#_d0886865-913a-4fe1-95dd-fa7911fdc198"/>
                                <LN RDFID="_dda51a5e-1bd7-4484-8525-ae0f68357e1b " lnType="LPHDa" lnClass="LPHD"
                                        inst="1" lnClassRef="#_965b6c44-b538-4d8d-a36b-d80dd0169539"/>
                                <LN RDFID="_339a393d-43ad-4ac2-b9be-c3a609ae2586"  inst="1" lnClass="CSWI"
                                        lnType="CSWIa" lnClassRef="#_ffcb887a-25e5-43e0-9164-38c3eeebc729"/>
                                <LN RDFID="_02b3387c-348f-46f8-9969-a38d5d8d4061"  inst="1" lnClass="MMXU"
                          lnType="MMXUa" lnClassRef="#_8435f48a-9fd7-4563-82a8-9dff30cb26d6"/>
                        </LDevice>
                </Server>
        </AccessPoint>
</IED>
```

The Logical Device information would be represented by the following CIM XML:

```
<cim:LogicalDevice rdf:ID="_f3025769-7aef-4d9b-a71d-db1d4716d649">
  <cim:IdentifiedObject.name>C1</IdentifiedObject.name>
  <cim:LogicalDevice.ContainedBy rdf:resource="#_31d6f2de-6ec9-4270-ba1c-a90174eb6b7c"/>
  <cim:LogicalDevice.Contains rdf:resource="#_91d50a5d-ee81-4e7c-8608-66b078d001f8"/>
  <cim:LogicalDevice.Contains rdf:resource="#_dda51a5e-1bd7-4484-8525-ae0f68357e1b"/>
  <cim:LogicalDevice.Contains rdf:resource="#_339a393d-43ad-4ac2-b9be-c3a609ae2586"/>
  <cim:LogicalDevice.Contains rdf:resource="#_02b3387c-348f-46f8-9969-a38d5d8d4061"/>
</cim:LogicalDevice>
```

Note that there are four (4) LogicalDevice.Contains associations (e.g. one for each of the Logical Nodes contained by the Logical device in the SCL file.

The AccessPoint information is mapped into the unified model.CIM XML by an instance of CommunicationLink:

```
<cim:AccessPoint rdf:ID="_47f106df-5815-496d-9d0b-e5f10d0995cd">
  <cim:IdentifiedObject.name>S1</IdentifiedObject.name>
  <cim:IdentifiedObject.pathName>S1</IdentifiedObject.pathName>
  <cim:AccessPoint.IED rdf:resource="#_D1Q1SB4"/>
</cim:AccessPoint>
```

The Server information, that contains the AccessPoint is represented in CIM XML by an instance of a IEC61850Server class:

```
<cim:IEC61850Server rdf:ID="_31d6f2de-6ec9-4270-ba1c-a90174eb6b7c">
  <cim:IdentifiedObject.name>IEC61850</cim:IndentifiedObject.name>
  <cim:IdentifiedObject.pathName>61850</cim:IdentifiedObject.pathName>
  <cim:IEC61850Server.ServerServices.DynAssociation>True</cim:IEC61850Server.ServerServices.DynAssociation>
  <cim:IEC61850Server.ServerServices.GetDirectory>True</cim:ServerServices.GetDirectory>
  <cim:ServerServices.GetDataObjectDefinition>True</cim:IEC61850Server.ServerServices.GetDataObjectDefinition>
  <cim:IEC61850Server.ServerServices.GetDataSetValue>True</cim:ServerServices.GetDataSetValue>
  <cim:ServerServices.DataSetDirectory>True</cim:IEC61850Server.ServerServices.DataSetDirectory>
  <cim:IEC61850Server.ServerServices.ReadWrite>True</cim:IEC61850Server.ServerServices.ReadWrite>
  <cim:IEC61850Server.ServerServices.FileHandling>True</cim:IEC61850Server.ServerServices.FileHandling>
  <cim:IEC61850Server.ServerServices.GetCBValues>True</cim:IEC61850Server.ServerServices.GetCBValues>
  <cim:IEC61850Server.ServerServices.ConfDataSet>4</cim:IEC61850Server.ServerServices.ConfDataSet>
  <cim:IEC61850Server.ServerServices.ConfLogControl>1</cim:IEC61850Server.ServerServices.ConfLogControl>
  <cim:IEC61850Server.ServerServices.GOOSE>2</cim:IEC61850Server.ServerServices.GOOSE>
  <cim:IEC61850Server.ReportSettings.bufTime>Dyn</cim:IEC61850Server.ReportSettings.bufTime>
  <cim:IEC61850Server.ReportSettings.cbName>Conf</cim:IEC61850Server.ReportSettings.cbName>
  <cim:IEC61850Server.ReportSettings.rptID>Dyn</cim:IEC61850Server.ReportSettings.rptID>
  <cim:IEC61850Server.ReportSettings.datSet>Conf</cim:IEC61850Server.ReportSettings.datSet>
  <cim:IEC61850Server.ReportSettings.intgPd>Dyn</cim:IEC61850Server.ReportSettings.intgPD>
  <cim:IEC61850Server.ReportSettings.optFields>Conf</cim:IEC61850Server.ReportSettings.optFields>
  <cim:IEC61850Server.GSESettings.appIDe>Conf</cim:IEC61850Server.GSESettings.appID>
  <cim:IEC61850Server.GSESettings.cbName>Conf</cim:IEC61850Server.GSESettings.cbName>
  <cim:IEC61850Server.GSESettings.datSet>Conf</cim:IEC61850Server.GSESettings.datSet>
  <cim:Server.IED rdf:resource="#_D1Q1SB4"/>
</cim:IEC61850Server>
```

Note: Based upon the harmonization recommendations, the server contains the service capabilities instead of the SCL representation within an IED. Additionally, through the recommendations, the Server instance also acts as the MeasurementValueSource.

The actual IED information is represented by an instance of an IED class:

```
<cim:IED rdf:ID="_D1Q1SB4">
  <cim:IdentifiedObject.name>D1Q1SB4</cim:IdentifiedObject.name>
</cim:IED>
```

Communications

Once the Substation configuration is complete, that configuration would be further "flushed" out through the addition of Communication information. This information would typically be configured/ assigned.

The SCL for such configuration would appear in the Communication section of the file(s) and would have contents similar to the following:

```
<Communication>
  <SubNetwork name="NONE">
    <ConnectedAP RDFID="_77b82466-090d-4912-be3e-89cd902b3df5" iedName="D1Q1SB4" apName="S1">
      <Address RDFID="_6e4cdd9a-e459-40e4-817c-57b85c295ed4">
        <P type="IP">192.168.1.7</P>
        <P type="IP-SUBNET">255.255.255.0</P>
        <P type="OSI-AP-Title">1,3,9999,23</P>
        <P type="OSI-PSEL">00000001</P>
        <P type="OSI-SSEL">0001</P>
        <P type="OSI-TSEL">0001</P>
        <P type="OSI-AE-Qualifier">1</P>
      </Address>
    </ConnectedAP>
  </SubNetwork>
</Communication>
```

Important harmonization recommendations

The current CIM model only has the concept of a CommunicationLink. The CommunicationLink definition does not contain any communication addressing information as would be found in SCL. Therefore, the unified model needed to be able to contain the addressing information found in SCL. Additionally, it was identified that other protocols (e.g. DNP, IEC 870-5, and ICCP) should also be accommodated within the unified model. The following UML represents the recommended unified model enhancements needed to accomplish this objective.

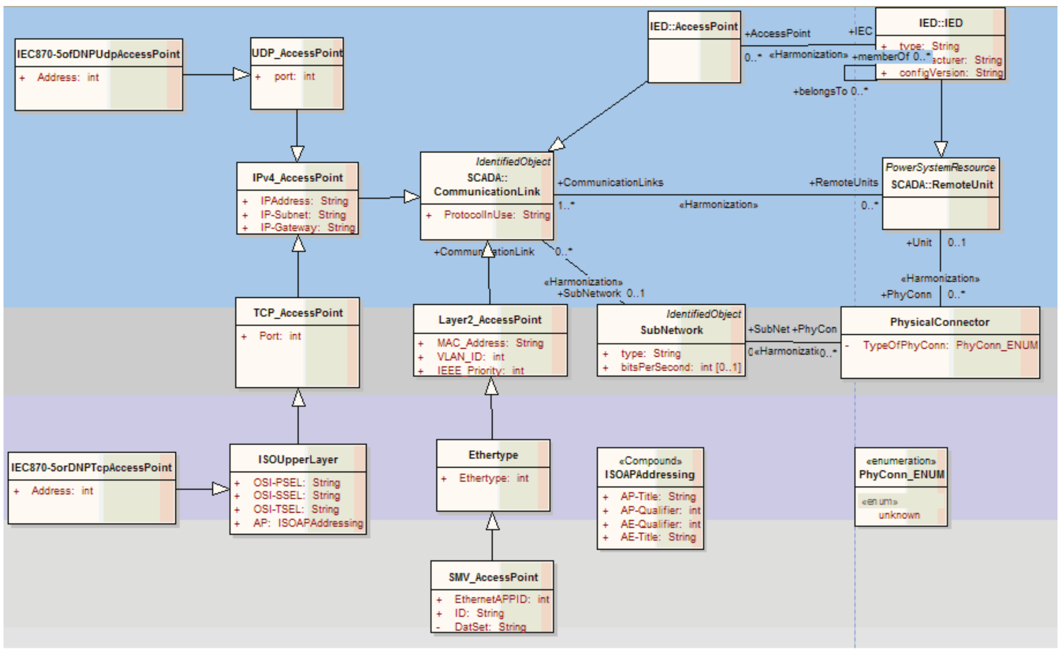


Figure B-8
AccessPoint and CommunicationLink Model

The equivalent CIM XML, based upon the recommendations would be:[6]

```
<cim:AccessPoint rdf:ID="_47f106df-5815-496d-9d0b-e5f10d0995cd">
  <cim:IdentifiedObject.name>S1</IdentifiedObject.name>
  <cim:IdentifiedObject.pathName>S1</IdentifiedObject.pathName>
  <cim:AccessPoint.IED rdf:resource="#_D1Q1SB4"/>
</cim:AccessPoint>

<cim:SubNetwork rdf:ID="_33f759c4-59a5-46c3-9ab4-43ccaaed3160">
  <cim:IdentifiedObject.name>NONE</cim:IdentifiedObject.name>
</cim:SubNetwork>

<cim:ISOUpperLayer rdf:ID="_6e4cdd9a-e459-40e4-817c-57b85c295ed4">
  <cim:CommunicationLink.ProtocolinUse>IEC61850-8-1-ISO9506</cim:CommunicationLink.ProtocolinUse>
  <cim:TCP_AccessPoint.port>102</<cim:TCP_AccessPoint.port>
  <cim:IPv4_AccessPoint.IPAddress>192.168.1.7</cim:IPv4_AccessPoint.IPAddress>
  <cim:IPv4_AccessPoint.IP-Subnet>255.255.255.0</cim:IPv4_AccessPoint.IP-Subnet>
  <cim:ISOUpperLayer.OSI-PSEL>00000001<cim:ISOUpperLayer.OSI-PSEL>
  <cim:ISOUpperLayer.OSI-SSEL>0001<cim:ISOUpperLayer.OSI-SSEL>
  <cim:ISOUpperLayer.OSI-TSEL>0001<cim:ISOUpperLayer.OSI-TSEL>
  <cim:ISOUpperLayer.AP.AE-Qualifier>1<cim:ISOUpperLayer.AP.AE-Qualifier>
  <cim:CommunicationLink.SubNetwork rdf:resource="#_33f759c4-59a5-46c3-9ab4-43ccaaed3160"/>
  <cim:CommunicationLink.AccessPoint rdf:resource="#__47f106df-5815-496d-9d0b-e5f10d0995cd"/>
<cim:ISOUpperLayer>
```

[6] Note that the AccessPoint information is replicated for ease of reading, but was defined previously by the substation design process.

It is worthy to note that the example is intentionally simple and does not convey the relationship of ControlBlocks (e.g. for GSE, SV, and Reporting).

SCADA

The SCADA interface/information exchange is slightly different from the other sections of this example. In the case of the SCADA interface(s), the information from the unified model would need to be put through a set of rules in order to configure the actual SCADA system. Some of these rules are described/proposed in this section. Others are implementation specific. The SCADA system would apply these rules and then update the unified model with the actual changes/instance created.

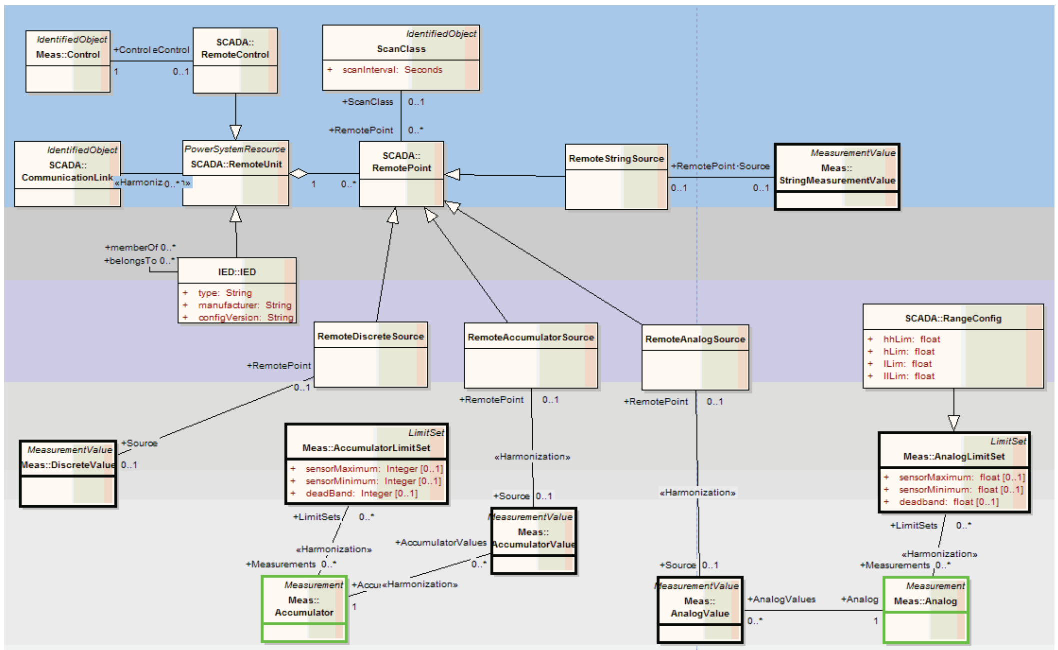


Figure B-9
Revised SCADA UML Model

Based upon the previous process of configuration, the unified model provides:

- The known instances of IEDs. Based upon the SCADA configuration interface rules, the appropriate set of RemoteUnits (e.g. IEDs can be selected to be included in the SCADA configuration).
- Once the selection of RemoteUnits/IEDs is determined, the IED, Server, MeasurementValue relationships can be used to determine which RemotePoints need to be created and the appropriate pre-existing MeasurementValues with which to associate to those points.

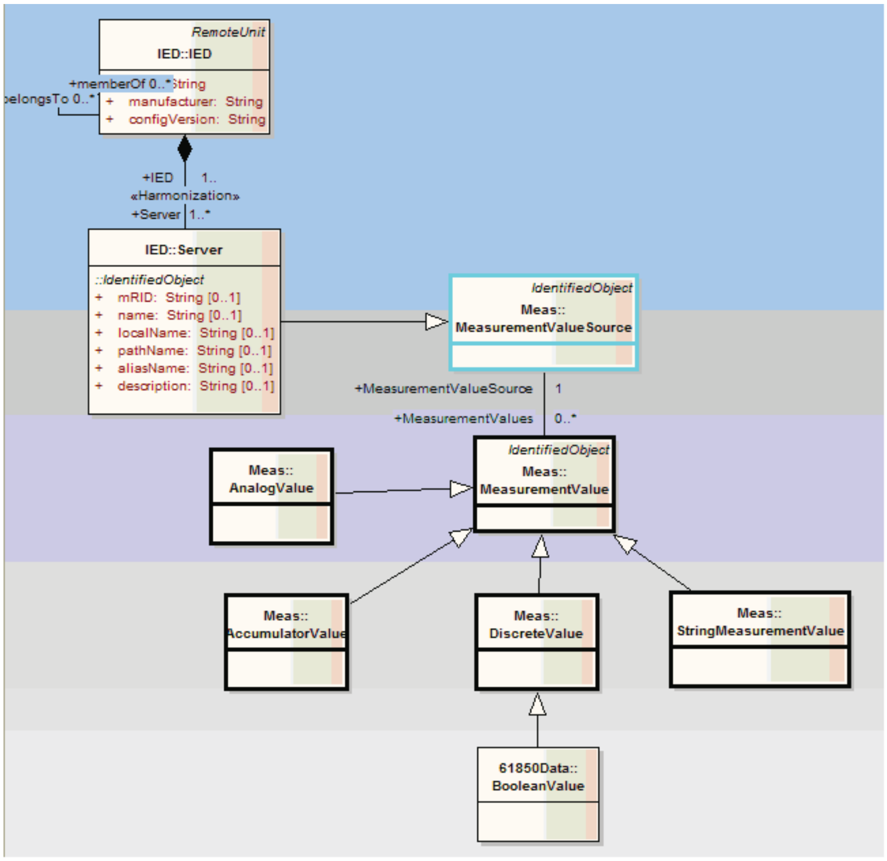


Figure B-10
Relationships between MeasurementValues and IEDs

Based upon the created RemotePoints, the CommunicationLinks/addressing information can be determined through the IED, Server, AccessPoint, CommunicationLink relationships.

In order to understand the relationships, a summary UML of the relevant parts of the model follow:

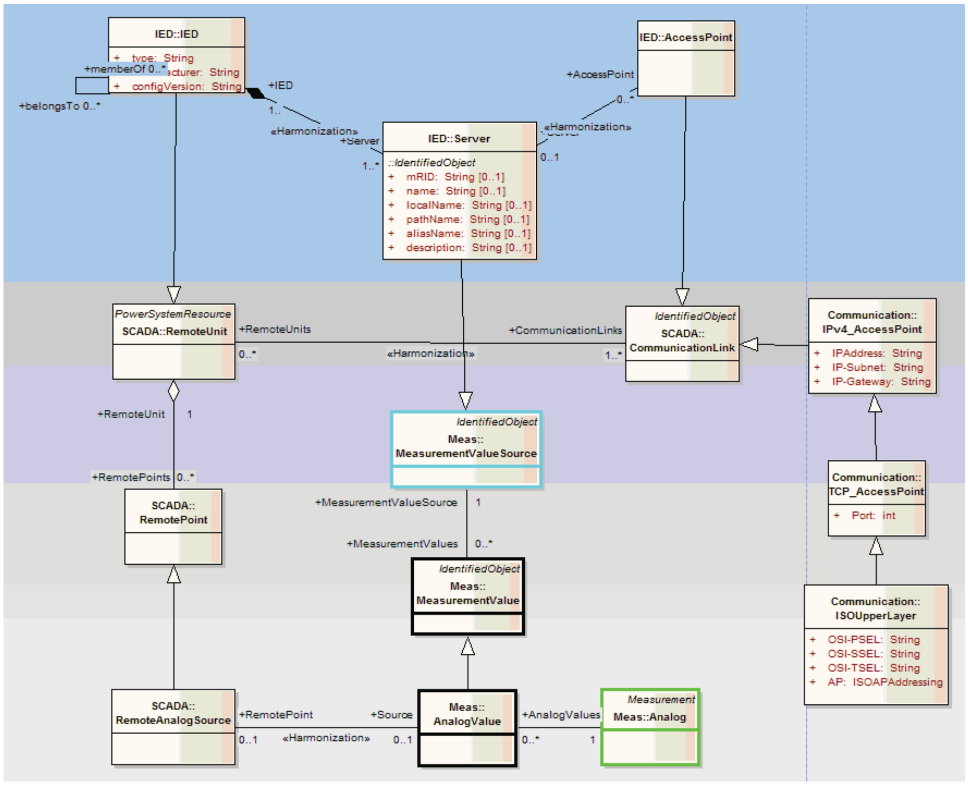


Figure B-11
Simplified Unified Model SCADA UML

The following table shows the information that needs to be translated by an interface that imports/translates a SCL file into the unified model:

SCL Object	Unified Model Objects	
IED	IED	
Server	Server	
LogicalNodeInstance	MeasurementValue	Through the decomposition of a LNInst into various FunctionalCollections that end up as MeasurementValues (see Figure 7-6)

Given the UnifiedModel Objects, the rules to configure a SCADA system can be applied. The following table attempts to summarize that transformation.

Unified Model Objects	SCADA Object	Action
IED	RemoteUnit	There must be a decision to include an IED as a RemoteUnit for SCADA. Note that an IED is already a specialization of RemoteUnit.
Server		Based upon the selection of an IED as a RemoteUnit, determine the Servers associated with the IED. Since an IED is a specialization of Measurement-ValueSource, this allows the determination of all Measure-mentValues associated with the RemoteUnit/IED.
AccessPoint	CommunicationLink	A AccessPoint is already a spe-cialization of Communication-Link and can be used as such.
MeasurementValue	RemotePoint	In order to determine the RemotePoints for a RemoteUnit/IED, the MeasurementValue/Server information can be determined in order to create the appropriate associations/instances.

Example SCL Files

Output from Substation Configuration

The following represents a "simplified" SCL file that might represent the information produced by Sub-station Configuration, but prior to defining the actual communication addressing.

The additional sections are the IED and DataTypeTemplate sections. Based upon the harmonization recommendations, the following key SCL changes can be seen:

- Due to the proposed changes in tNaming, all objects now have an RDFID. This includes:
  1. IED – has a tool assigned ID
  2. Logical Device – has a tool assigned ID
  3. Logical Nodes (e.g. LN0, LPHD, and others)

     Has a tool assigned RDFID and a reference to the standardized LNClass (e.g. lnClass-Ref).

     It is noteworthy that none of the logical node types required an extension to reference the ID assigned to lnType. This is due to the fact that the SSD and SCD files have refer-ential integrity within the file. Therefore, it is sufficient that the actual LNodeType, in the DataTypeTemplates section, has an RDFID.

4. LNodeType has a tool assigned RDFID and a reference to the standardized LNClass (e.g. lnClassRef).

   It is noteworthy that none of the LNodeTypes require an extension to reference the ID assigned to DOtypes. This is due to the fact that the SSD and SCD files have referential integrity within the file. Therefore, it is sufficient that the actual DOType, in the DataTypeTemplates section, has an RDFID.

5. DOType has a tool assigned RDFID and a reference to it standardized CDC (e.g. cdcRef).

   It is noteworthy that none of the DA's require an extension to reference the ID assigned to DATypes. This is due to the fact that the SSD and SCD files have referential integrity within the file. Therefore, it is sufficient that the actual DAType, in the DataTypeTemplates section, has an RDFID.

6. Enumerations refer to their assigned standardized IDs.


```
<Substation name=”AIRPORT” RDFID=”_2”>
        <PowerTransformer name=”TXAP” type=”PTR” RDFID=”_9”>
                <TransformerWinding name=”TXAPH” type=”PTW” RDFID=”_10” >
                        <Terminal RDFID=”_34” substationName=”AIRPORT” voltageLevelName=”VL_AIRP_345”
cNodeName=”CN12”
                                                                        connectivityNodeRef=”#_61”
substationRef=”#_2” voltageLevelRef=”#_3”/>
                        <LNode name=”MMXU” lnclass=”MMXU”/>
                </TransformerWinding>
                <TransformerWinding name=”TXAPX” type=”PTW” RDFID=”_11”>
                        <Terminal RDFID=”_33” connectivityNode=”AIRPORT/VL_AIRP_22/CN11”
substationName=”AIRPORT” voltageLevelName=”VL_AIRP_22” cNodeName=”CN11”
                                                                        connectivityNodeRef=”#_60”
substationRef=”#_2” voltageLevelRef=”#_5”/>
                <LNode name=”MMXU” lnclass=”MMXU” lnClassRef=”#__8435f48a-9fd7-4563-82a8-9dff30cb26d6”/>
                </TransformerWinding>
        </PowerTransformer>
        <ConnectivityNode name=”CN11” RDFID=”_60” pathName=”AIRPORT/VL_AIRP_345/CN11”/>
        <ConnectivityNode name=”CN12” RDFID=”_61” pathName=”AIRPORT/345/CN12”/>
        <ConnectivityNode name=”CN13” RDFID=”_6113” pathName=”AIRPORT/345/CN12”/>
        <ConductingEquipment name=”APLOAD” RDFID=”_8” type=”EnergyConsumer” >
                <Terminal RDFID=”30” connectivityNode=”AIRPORT/VL_AIRP_22/CN13” substationName=”AIRPORT”
voltageLevelName=”VL_AIRP_22” cNodeName=”C11”
                                                        connectivityNodeRef=”#_6113” substationRef=”#_2”
voltageLevelRef=”#_5”/>
        </ConductingEquipment>
        <ConductingEquipment name=”LBS” RDFID=”_0081” type=”EnergyConsumer” >
                <Terminal RDFID=”_3013” connectivityNode=”AIRPORT/VL_AIRP_22/CN13”
substationName=”AIRPORT” voltageLevelName=”VL_AIRP_22” cNodeName=”C13”
                                                        connectivityNodeRef=”#_6113” substationRef=”#_2”
voltageLevelRef=”#_5”/>
                <Terminal RDFID=”_3014” connectivityNode=”AIRPORT/VL_AIRP_22/CN12”
substationName=”AIRPORT” voltageLevelName=”VL_AIRP_22” cNodeName=”C12”
                                                        connectivityNodeRef=”#_61” substationRef=”#_2”
voltageLevelRef=”#_5”/>
                <LNode name=”CSWI” lnclass=”CSWI” lnClassRef=”#_ffcb887a-25e5-43e0-9164-38c3eeebc729”/>
        </ConductingEquipment>
        <VoltageLevel RDFID=”_3” name=”VL_AIRP_345”>
                <Voltage RDFID=”_4” multiplier=”k” unit=”V”>345</Voltage>
        </VoltageLevel>
        <VoltageLevel RDFID=”_5” name=”VL_AIRP_22” RDFID=”_3”>
                <Voltage RDFID=”_6” multiplier=”k” unit=”V”>22</Voltage>
```

```
                </VoltageLevel>
</Substation>
<Communication>
    <SubNetwork RDFID=”_33f759c4-59a5-46c3-9ab4-43ccaaed3160” name=”NONE”>
      <ConnectedAP RDFID=”_77b82466-090d-4912-be3e-89cd902b3df5” iedName=”D1Q1SB4” apName=”S1”>
        <Address RDFID=”_6e4cdd9a-e459-40e4-817c-57b85c295ed4”>
          <P type=”IP”>192.168.1.7</P>
          <P type=”IP-SUBNET”>255.255.255.0</P>
          <P type=”OSI-AP-Title”>1,3,9999,23</P>
          <P type=”OSI-PSEL”>00000001</P>
          <P type=”OSI-SSEL”>0001</P>
          <P type=”OSI-TSEL”>0001</P>
          <P type=”OSI-AE-Qualifier”>1</P>
        </Address>
      </ConnectedAP>
    </SubNetwork>
</Communication>
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                                <GetDataObjectDefinition/>
                                <GetDataSetValue/>
                                <DataSetDirectory/>
                                <ReadWrite/>
                                <FileHandling/>
                                <ConfDataSet max=”4”/>
                                <ConfReportControl max=”12”/>
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optFields=”Conf”/>
                                <ConfLogControl max=”1”/>
                                <GetCBValues/>
                                <GOOSE max=”2”/>
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lnClass=”LLN0”  inst=”” lnClassRef=”#_d0886865-913a-4fe1-95dd-fa7911fdc198”/>
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lnClass=”LPHD” inst=”1” lnClassRef=”#_965b6c44-b538-4d8d-a36b-d80dd0169539”/>
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lnClass=”CSWI” lnType=”CSWIa” lnClassRef=”#_ffcb887a-25e5-43e0-9164-38c3eeebc729”/>
                                                                <LN RDFID= ”_02b3387c-348f-46f8-9969-a38d5d8d4061”  inst=”1”
lnClass=”MMXU” lnType=”MMXUa” lnClassRef=”#_8435f48a-9fd7-4563-82a8-9dff30cb26d6”/>
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                                </Server>
                </AccessPoint>
</IED>
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d0886865-913a-4fe1-95dd-fa7911fdc198”>
                                <DO name=”Mod” type=”INC” RDFID=/>
                                <DO name=”Beh” type=”INS”RDFID=/>
                                <DO name=”Health” type=”INS” RDFID=/>
                                <DO name=”NamPlt” type=”LPL”RDFID=/>
                </LNodeType>
                <LNodeType id=”LPHDa” RDFID=”_41e56aa0-5899-4eac-b109-6b6841877a0f” lnClass=”LPHD”
lnClassRef=”#_965b6c44-b538-4d8d-a36b-d80dd0169539”>

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                <DO name=”PhyHealth” type=”INS”/>
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                <DO name=”Beh” type=”INS”/>
                <DO name=”Health” type=”INS”/>
                <DO name=”Mod” type=”INC”/>
                <DO name=”Beh” type=”INS”/>
                <DO name=”Health” type=”INS”/>
                <DO name=”NamPlt” type=”LPL”/>
                <DO name=”EEHealth” type=”INS”/>
                <DO name=”TotW” type=”MV”/>
                <DO name=”Z” type=”WYE”/>
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lnClassRef=”#_8435f48a-9fd7-4563-82a8-9dff30cb26d6”>
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                    <SDO name=”res” type=”CMV”/>
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                    <DA name=”SBOw” fc=”CO” bType=”Struct” type=”DPCSelectWithValue”/>
                    <DA name=”Oper” fc=”CO” bType=”Struct” type=”DPCOperate”/>
                    <DA name=”Cancel” fc=”CO” bType=”Struct” type=”DPCCancel”/>
                    <DA name=”origin” fc=”ST” bType=”Struct” type=”Originator”/>
                    <DA name=”ctlNum” fc=”ST” bType=”INT8U”/>
                    <DA name=”stVal” fc=”ST” bType=”Dbpos” dchg=”true”/>
                    <DA name=”q” fc=”ST” bType=”Quality” qchg=”true”/>
                    <DA name=”t” fc=”ST” bType=”Timestamp”/>
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4139-a8fb-c9fd69e4a03b”>
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                    <DA name=”serNum” fc=”DC” bType=”VisString255”/>
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830d-e7ced66d6cf4”>
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                    <DA name=”d” fc=”DC” bType=”VisString255”/>
                    <DA name=”dU” fc=”DC” bType=”Unicode255”/>
                    <DA name=”configRev” fc=”DC” bType=”VisString255”/>
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                    <BDA name=”f” bType=”FLOAT32”/>
          </DAType>
          <DAType id=”Originator” RDFID=”_a4b5c133-8230-477b-9367-d9ea89420c1c”>
                    <BDA name=”orCat” bType=”Enum” type=”orCatEnum”/>
                    <BDA name=”orIdent” bType=”Octet64”/>
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        <BDA name="multiplier" bType="Enum" type="multiplierEnum"/>
</DAType>
<DAType id="Vector" RDFID="_7a678d9e-7d1d-469b-8eec-3868e45584d9">
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        <BDA name="ang" bType="Struct" type="AnalogueValue"/>
</DAType>
<DAType id="DPCSelectWithValue" RDFID="_f3adbc8e-c568-4c60-b936-5cb3bdf998e9">
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        <BDA name="operTm" bType="Timestamp"/>
        <BDA name="origin" bType="Struct" type="Originator"/>
        <BDA name="ctlNum" bType="INT8U"/>
        <BDA name="T" bType="EntryTime"/>
        <BDA name="Test" bType="BOOLEAN"/>
        <BDA name="Check" bType="Dbpos"/>
</DAType>
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        <BDA name="origin" bType="Struct" type="Originator"/>
        <BDA name="ctlNum" bType="INT8U"/>
        <BDA name="T" bType="EntryTime"/>
        <BDA name="Test" bType="BOOLEAN"/>
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</DAType>
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		<EnumVal ord=”3”>kilogram</EnumVal>
		<EnumVal ord=”4”>second</EnumVal>
		<EnumVal ord=”5”>ampere</EnumVal>
		<EnumVal ord=”6”>Kelvin</EnumVal>
		<EnumVal ord=”7”>mole</EnumVal>
		<EnumVal ord=”8”>candela</EnumVal>
		<EnumVal ord=”9”>degrees</EnumVal>
		<EnumVal ord=”10”>radian</EnumVal>
		<EnumVal ord=”11”>steradian</EnumVal>
		<EnumVal ord=”21”>Gray</EnumVal>
		<EnumVal ord=”22”>becquerel</EnumVal>
		<EnumVal ord=”23”>degrees Celsius</EnumVal>
		<EnumVal ord=”24”>sievert</EnumVal>
		<EnumVal ord=”25”>farad</EnumVal>
		<EnumVal ord=”26”>coulomb</EnumVal>
		<EnumVal ord=”27”>siemens</EnumVal>
		<EnumVal ord=”28”>henry</EnumVal>
		<EnumVal ord=”29”>volt</EnumVal>
		<EnumVal ord=”30”>ohm</EnumVal>
		<EnumVal ord=”31”>joule</EnumVal>
		<EnumVal ord=”32”>newton</EnumVal>
		<EnumVal ord=”33”>hertz</EnumVal>
		<EnumVal ord=”34”>lux</EnumVal>
		<EnumVal ord=”35”>lumen</EnumVal>
		<EnumVal ord=”36”>weber</EnumVal>
		<EnumVal ord=”37”>tesla</EnumVal>
		<EnumVal ord=”38”>watt</EnumVal>
		<EnumVal ord=”39”>pascal</EnumVal>
		<EnumVal ord=”41”>square meter</EnumVal>
		<EnumVal ord=”42”>cubic meter</EnumVal>
		<EnumVal ord=”43”>meters per second</EnumVal>
		<EnumVal ord=”44”>meters per second2</EnumVal>
		<EnumVal ord=”45”>cubic meters per second</EnumVal>
		<EnumVal ord=”46”>meters/cubic meter</EnumVal>
		<EnumVal ord=”47”>kilogram meter</EnumVal>
		<EnumVal ord=”48”>kilogram/cubic meter</EnumVal>
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		<EnumVal ord=”50”>watt/meter Kelvin</EnumVal>
		<EnumVal ord=”51”>joule/Kelvin</EnumVal>
		<EnumVal ord=”52”>parts per million</EnumVal>
		<EnumVal ord=”53”>rotations per second</EnumVal>
		<EnumVal ord=”54”>radian per second</EnumVal>
		<EnumVal ord=”61”>volt ampere</EnumVal>
		<EnumVal ord=”62”>watts</EnumVal>
		<EnumVal ord=”63”>volt ampere reactive</EnumVal>
		<EnumVal ord=”64”>phase angle degrees</EnumVal>
		<EnumVal ord=”65”>Power factor</EnumVal>
		<EnumVal ord=”66”>volt seconds</EnumVal>
		<EnumVal ord=”67”>volt square</EnumVal>
		<EnumVal ord=”68”>amp second</EnumVal>
		<EnumVal ord=”69”>amp square</EnumVal>
		<EnumVal ord=”70”>amp square second</EnumVal>
		<EnumVal ord=”71”>volt ampere hours</EnumVal>
		<EnumVal ord=”72”>watt hours</EnumVal>
		<EnumVal ord=”73”>volt ampere reactive hours</EnumVal>
		<EnumVal ord=”74”>volts per hertz</EnumVal>
</EnumType>
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		<EnumVal ord=”-21”>Zepto</EnumVal>
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            <EnumVal ord=”-15”>Femto</EnumVal>
            <EnumVal ord=”-12”>Pico</EnumVal>
            <EnumVal ord=”-9”>Nano</EnumVal>
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            <EnumVal ord=”-2”>Centi</EnumVal>
            <EnumVal ord=”-1”>Deci</EnumVal>
            <EnumVal ord=”0”>zeroNoValue</EnumVal>
            <EnumVal ord=”1”>Deca</EnumVal>
            <EnumVal ord=”2”>Hecto</EnumVal>
            <EnumVal ord=”3”>Kilo</EnumVal>
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            <EnumVal ord=”24”>Yotta</EnumVal>
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            <EnumVal ord=”1”>high</EnumVal>
            <EnumVal ord=”2”>low</EnumVal>
            <EnumVal ord=”3”>high-high</EnumVal>
            <EnumVal ord=”4”>low-low</EnumVal>
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</DataTypeTemplates>
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