IEC TS 62361-102

Edition 1.0 2018-03

TECHNICAL SPECIFICATION

colour inside

Power systems management and associated information exchange – Interoperability in the long term – Part 102: CIM – IEC 61850 harmonization

IEC TS 62361-102:2018-03(en)

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INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

ICS 33.200

ISBN 978-2-8322-5454-7

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Technical specifications are subject to review within three years of publication to decide whether they can be transformed into International Standards.

IEC TS 62361-102, which is a technical specification, has been prepared by IEC technical committee 57: Power systems management and associated information exchange.

The text of this technical specification is based on the following documents:

Enquiry draft	Report on voting
57/1706/DTS	57/1948/RVDTS

Full information on the voting for the approval of this technical specification can be found in the report on voting indicated in the above table.

This document has been drafted in accordance with the ISO/IEC Directives, Part 2.

A list of all parts in the IEC 62361 series, published under the general title *Power systems management and associated exchange – Interoperability in the long term*, can be found on the IEC website.

In this publication, the following print types are used:

– *Associations: in italic type.*

The committee has decided that the contents of this publication will remain unchanged until the stability date indicated on the IEC website under "http://webstore.iec.ch" in the data related to the specific publication. At this date, the publication will be

- transformed into an International standard,
- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

A bilingual version of this publication may be issued at a later date.

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INTRODUCTION

The IEC focuses primarily on specifying the payload of various functionally oriented messages or file exchanges. This concept includes configuration files like those developed in all IEC power systems management standards. The different smart grid initiatives in the USA, Europe and Asia have all recognized the necessity to establish solid standards for communicating between all the "smart" devices. For interoperability purposes, it has been recognized, at an early stage, that widely shared semantics would be necessary. Unfortunately, the semantic models used by the technical groups have differed from the start due to the different needs for information exchange within substations and information exchange within control centres. This has led to some gaps between the models within different standards, even though they reflected the same power system entities. Various institutions have requested that we narrow the gaps:

- NIST has recommended harmonization as a mechanism to decrease cost of integration in the Smart Grid.
- CEN/CENELEC/ETSI Smart Grid Coordination Group report states: "Harmonized electronic data model and description language are missing" and strongly recommends the study of “Harmonized glossary, semantic & modelling between CIM and IEC 61850”.
- ENTSO-E letter states: "There is also a need to perform a harmonization between IEC 61850 and IEC CIM (Common Information Model) Standards [...] There are applications which use both set of standards and significant improvements on interoperability and data exchange between the applications should take place."

A number of studies and reports have already been produced on the subject of Harmonization as listed in the Bibliography.

POWER SYSTEMS MANAGEMENT AND ASSOCIATED INFORMATION EXCHANGE – INTEROPERABILITY IN THE LONG TERM –

Part 102: CIM – IEC 61850 harmonization

1 Scope

This part of IEC 62361, which is a Technical Specification, outlines a technical approach for achieving effective information exchange between power system installations governed by IEC 61850 and business systems integrated with IEC CIM standard data exchanges, based on a selected specific set of use cases, but also with the goal of creating a framework that will extend successfully to other use cases in the future. This document includes proposals to 'harmonize' the two standards by adapting or extending existing information models and/or defining new models, where such changes will enable more effective communication. Both current and future directions of models will be considered. The report will take into account existing standards for semantics, services, protocols, system configuration language, and architecture.

It was intended to be coordinated with IEC 61850 and all affiliated subgroups as well as IEC 61968 and IEC 61970. This edition of the document was prepared based on Edition 2 of IEC 61850-6 (2009), IEC 61850-7-3 and IEC 61850-7-4 and has been updated to match the forthcoming Edition 2.1. Mapping to other parts of IEC 61850 is incomplete. Mapping has been considered for the CIM classes defined in IEC 61970-301. The mapping to CIM classes defined in IEC 61968-11 and other standards is incomplete.

This document suggests a technical approach by which two of the leading standards for software interoperability that serve the electric utility industry (the Common Information Model, CIM, and the IEC 61850 model) can cooperate in order to enable effective data exchanges between the domains covered by these standards. Both of these standards are maintained by the International Electrotechnical Committee (IEC).

A number of studies and reports have already been produced on the subject of harmonization as listed in the Bibliography.

The work leading to this Technical Specification has considered how exchanges required by commonly understood use cases might be mapped between the standard models in order to determine the harmonizing changes suggested for the relevant models. The report references any papers, reports or other documents that provided data for this harmonization.

The approach is to define a transformation of the data governed by IEC 61850 SCL XSD to data governed by CIM UML. The transformations in this document are defined based on the use cases presented in this document. Only SCL data relevant to these use cases is transformed.

The aim is to allow the development of tools that perform automatic transformation from an SCL instance file into a CIM based instance model that can then be exported using existing standards such as IEC 61970-552: CIMXML Model exchange format.

These transformations will result in CIM-side processes that can distribute the information as needed for configuration of specific CIM applications. It is also presumed that the result of this exchange will be to enable creation of real-time CIM-side clients for IEC 61850 system data.

The heart of the SCL to CIM transformation specification defined in this document is a mapping between the two information models. Wherever this mapping has been judged to be unnecessarily complex, changes have been recommended to the existing information models.

A major objective, however, has been to define a solution that does not change either SCL or CIM UML without a mechanism to supply backward compatibility.

The transformation specification is only for structural modelling. IEC 61970-301 states "CIM entities have no behaviour." IEC 61850-5 states "the behaviour of the functions itself are … outside the scope of this standard".

This document is a Technical Specification – not a standard. Paragraphs introduced by the word Recommendation are recommendations for revisions to some of the IEC 61850 and CIM standards. It is anticipated that if these recommendations are accepted, then this report can be revised and elevated to a standard.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC TS 61850-2, *Communication networks and systems in substations – Part 2: Glossary*

IEC 61850-6:2009, *Communication networks and systems for power utility automation – Part 6: Configuration description language for communication in electrical substations related to IEDs*

IEC 61850-7-3, *Communication networks and systems for power utility automation – Part 7-3: Basic communication structure – Common data classes*

IEC 61850-7-4, *Communication networks and systems for power utility automation – Part 7-4: Basic communication structure – Compatible logical node classes and data object classes*

IEC TS 61850-80-1:2009, *Communication networks and systems for power utility automation – Part 80-1: Guideline to exchanging information from a CDC-based data model using IEC 60870-5-101 or IEC 60870-5-104*

IEC 61968-11, *Application integration at electric utilities – System interfaces for distribution management – Part 11: Common information model (CIM) extensions for distribution*

IEC TS 61970-2, *Energy management system application program interface (EMS-API) – Part 2: Glossary*

IEC 61970-301:2013, *Energy management system application program interface (EMS-API) – Part 301: Common information model (CIM) base*

IEC 61970-452:2015, *Energy management system application program interface (EMS-API) – Part 452: CIM static transmission network model profiles*

IEC 81346-1, *Industrial systems, installations and equipment and industrial products – Structuring principles and reference designations – Part 1: Basic rules*

3 Terms, definitions and abbreviated terms

For the purposes of this document, the terms and definitions given in IEC TS 61850-2, IEC 61850-6 and IEC TS 61970-2 and the following apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- IEC Electropedia: available at http://www.electropedia.org/
- ISO Online browsing platform: available at http://www.iso.org/obp

NOTE The following terms and definitions are critical to the understanding of this document and are repeated here for convenience.

3.1 Terms and definitions

3.1.1
Common Information Model
CIM
abstract model that represents all the major objects in an electric utility enterprise typically needed to model the operational aspects of a utility, which includes public classes and attributes for these objects, as well as the relationships between them

Note 1 to entry: The objects represented in the CIM are abstract in nature and may be used in a wide variety of applications. The use of the CIM goes far beyond its application in an EMS. This document should be understood as a tool to enable integration in any domain where a common power system model is needed to facilitate interoperability and plug compatibility between applications and systems independent of any particular implementation.

Note 2 to entry: IEC 61970-301 defines the CIM Base set of packages which provide a logical view of the functional aspects of an Energy Management System including SCADA. Other functional areas are standardized in separate IEC documents that augment and reference this base CIM standard. For example, IEC 61968-11 addresses distribution models and references this base CIM standard. While there are multiple IEC standards dealing with different parts of the CIM, there is a single, unified information model comprising the CIM behind all these individual standards documents.

[SOURCE: IEC 61970-301:2016, Introduction]

3.1.2
System Configuration description Language
SCL
file format for describing communication-related IED (Intelligent Electronic Device) configurations and IED parameters, communication system configurations, switch yard (function) structures, and the relations between them, the main purpose of which is to exchange IED capability descriptions and SA system descriptions between IED engineering tools and the system engineering tools of different manufacturers in a compatible way

3.2 Abbreviated terms

In general, the abbreviations defined in IEC TS 61850-2 or IEC TS 61970-2 apply. The following abbreviations are particularly useful for understanding this document and are repeated here for convenience:

CDC	Common Data Class [IEC 61850]
CIM	Common Information Model
DA	Data Attribute [IEC 61850]
DMS	Distribution Management System
DO	Data Object [IEC 61850]
EMS	Energy Management System
ICD	IED Capability Description [IEC 61850]
IID	Instantiated IED Description [IEC 61850]
IED	Intelligent Electronic Device [IEC 61850]
LD	Logical Device [IEC 61850]
LN	Logical Node [IEC 61850]

SCADA	Supervisory Control and Data Acquisition
SCD	System Configuration Description [IEC 61850]
SCL	System Configuration description Language [IEC 61850]
SCT	System Configuration Tool
SED	System Exchange Description [IEC 61850]
SSD	System Specification Description [IEC 61850]
UUID	Universally Unique Identifier

4 Use case summary

4.1 General

A number of use case titles were proposed. As the subject is complex, it was decided to concentrate on the use case SCADA/EMS/DMS configuration from IEC 61850 SCL. This is based on the top-down approach to substation automation design described in IEC 61850-4 and IEC 61850-6.

It is expected that the mapping rules determined by mapping from IEC 61850 to CIM will be a good base for developing mappings for other use cases that take information from CIM to IEC 61850.

The following use cases have been considered. For further details, see Annex A, Use case details.

4.2 SCADA/EMS/DMS configuration from IEC 61850 SCL

NOTE This use case is written using the example of a transmission substation automation system, but the general steps are applicable to any power system related local automation system.

- The use case starts with requirements specification determined by a planning department e.g. following a request for a new connection or a review of assets or load growth. In this use case the requirements are expected to be defined in paper form, not in a CIM electronic format. [Managing requirements in electronic format is another use case]

The next few steps of the use case use the top-down engineering process described in more detail in IEC 61850-4 and IEC 61850-6. IEC 61850-6 refers to a number of different types of software tool for creating and editing different types of SCL file. In this document the term System Configuration Tool (SCT) is used as a generic term for multi-function software tools that are capable of system specification and system configuration.

- The System Configuration Tool (SCT) is used by a System Engineer to model any SCL defined installation, for example an electrical substation. The process starts by creating a formal specification of the system requirements. The engineer inputs information on primary equipment types, names and connectivity, typically based on the station's single line diagram. The required monitoring, protection, local automation and other functions may be described as template Logical Nodes that are allocated to the equipment or container instances.
- This formal model can be exported from the System Configuration Tool as a System Specification Description (SSD) file.
- This SSD file can then be transformed and/or imported into a CIM based modelling tool for review. If necessary, comments may be provided on paper or verbally for the System Engineer to update the model in the SCT. The review cycle may be repeated several times.
- In the next phase of the design process, the System Configuration Tool is used to import descriptions of the capabilities of specific Intelligent Electronic Devices (IEDs). The System Engineer extends the automation system model by redefining the required Logical

Nodes with specific instances of Logical Nodes with specific types of IEDs. The final phase of the automation system design is to define the communication configuration.

- At any stage during this process, the automation system model can be exported as a System Configuration Description (SCD) file.
- IEC 61850-6 describes how this SCD file is used as an input to IED tools in order to provide the IED specific configuration including the configuration of the communication between IEDs.

This use case describes additional steps

- The same SCD file is also used as an input for a CIM based modelling tool. If necessary, the model may be updated in the SCT and the review cycle repeated.
- CIM information which is required for EMS or DMS applications, but which is not present or derived from information in the SCD file, is added within a CIM based modelling tool.
- The output of the CIM model tool is an incremental update that can be applied to SCADA/EMS/DMS control centre systems.

NOTE The mapping is independent of whether the SCL describes a proxy view of the data as presented by a gateway device, or the more detailed view of the physical IEDs.

IEC TR 61850-90-2 states "... a logical node that appears in the data model of the Proxy/Gateway includes all mandatory data and those optional data of the respective logical node of the IED, which are used by the control centre." It should be noted that some of the data items defined as mandatory by IEC 61850 are not relevant for control centre communications.

4.3 Importing SCADA/EMS/DMS requirements into IEC 61850 SCL

4.3.1 General

Requirements may be expressed in a CIM based electronic format. The translation into a human readable format or automatic translations into a format that can be imported into the IEC 61850 System Configuration Tool are considered as a separate use case to that of translating SCL to CIM.

The CIM based electronic format would be used to define that part of the SCL "Substation / Line / Process: [that] describes the primary process related functions and devices, electrical connections on single line level (topology), and the designation of equipment and functions."

The information of the Substation/Line/Process section is usually not used within IEDs. It is usually used only within system configuration tools.

4.3.2 Recommendation for harmonization: SCL Process/Substation/Line section

Recommendation R1: In the medium to long term, investigate the mapping for the transformation of CIM models into SCL. It may be possible to generate the SCL Process/Line/Substation section with an XML schema directly generated from an appropriate CIM profile or profiles. It may be necessary to consider extensions to the CIM in order to model additional types of assets, functions and equipment, and/or IEC 61850 model features such as Logical Nodes.

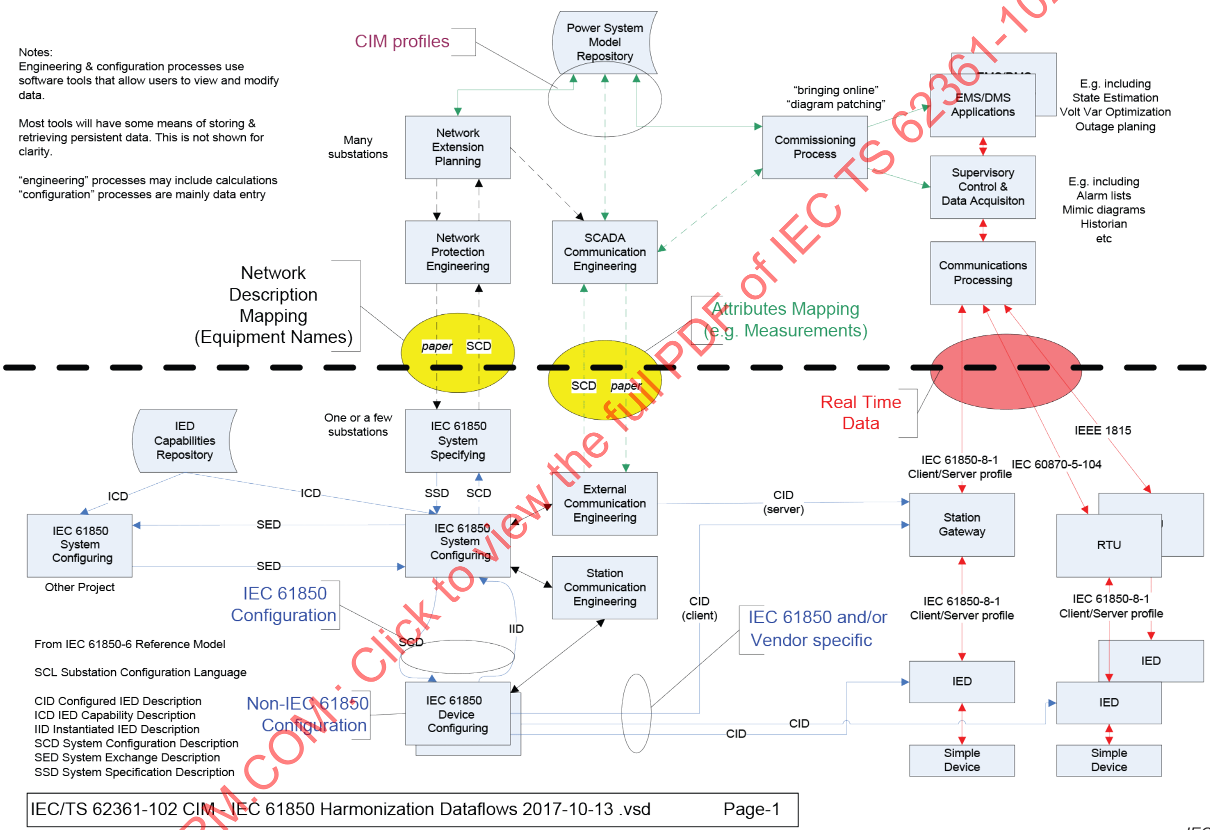
4.4 SCADA commissioning use case

The final step of the SCADA/EMS/DMS commissioning use case is "Perform Test and Validation to turn on SCADA and receive IEC 61850 data, and execute commands". This can also be considered as part of the SCADA Commissioning Use Case. The CIM update information will be incorporated into the online SCADA and the new measurements and controls commissioned. Bi-directional real time end-to-end data transfer between IEDs and the control centre can then take place.

Commissioning requires that the configuration of the communication links in the control centre is consistent with the configuration of the communication links with the IEDs in the field. The communication with the IEDs may be direct or via proxy or gateway devices. The communication messages may use IEC 61850 client-server services for all communication or they may use other standard or proprietary communication protocols for some of the communication links.

Typical engineering data exchanges used in the configuration and commissioning use cases are shown in Figure 1. The upper half of the diagram shows the CIM based control centre processes and the lower half of the diagram shows the IEC 61850 based processes.

The left side of the diagram shows the engineering data exchanges required for engineering design and configuration. The right side of the diagram shows the real-time data communication that can take place after all the systems have been correctly configured.



IEC

Figure 1 – IEC 61850 and CIM data flows

Substation to control centre communication via IEC 61850-8-1 is expected to use the guidelines from IEC TR 61850-90-2. Communication via IEC 60870-5-104 is expected to use the mapping guidelines defined in IEC TS 61850-80-1.

4.5 Volt Var control use case

This use case builds on the configuration and real time data use cases. Coordinated volt var control requires that the control centre has a consistent view of not only the network equipment and its measurements as described in the configuration use case, but also appropriate information about the equipment parameters, the remote control capabilities and settings used by local automation. This use case was considered relevant but was not examined in detail due to time constraints. The particular issues for volt-var control including the modelling of distributed energy resources (DER) will be addressed in detail in a future document.

For an example, see Tanaka, T; Tsuchiya, T; Katayama, S; Serizawa, Y; Fujikawa, F; Otani, T, "Basic Concept and Verification of Distributed Real-time Computer Network Architecture for Power systems", CIGRE 2004, D2-105, 29 August-3 September 2004.

4.6 Wide Area Monitoring, Protection and Control (WAMPAC) for transient stability

This is a particular example of using a model of the power system network with specific status and analog measurements as shown in Figure 2. Details of the use case are given in Annex B.

To maintain the transient stability, a high-speed control architecture is required. Hierarchical WAMPAC can be utilized as a last-resort control system, which executes the minimum required control action defined by CE in order to minimize the impact to power grid and to main the transient stability.

In addition, power grid operators are required to mitigate possible severe consequences by taking minimum required control actions every time when they face severe operating conditions. As a mitigation measure, hierarchical WAMPAC can provide the preventive control or enhancement control by shifting an operating point.

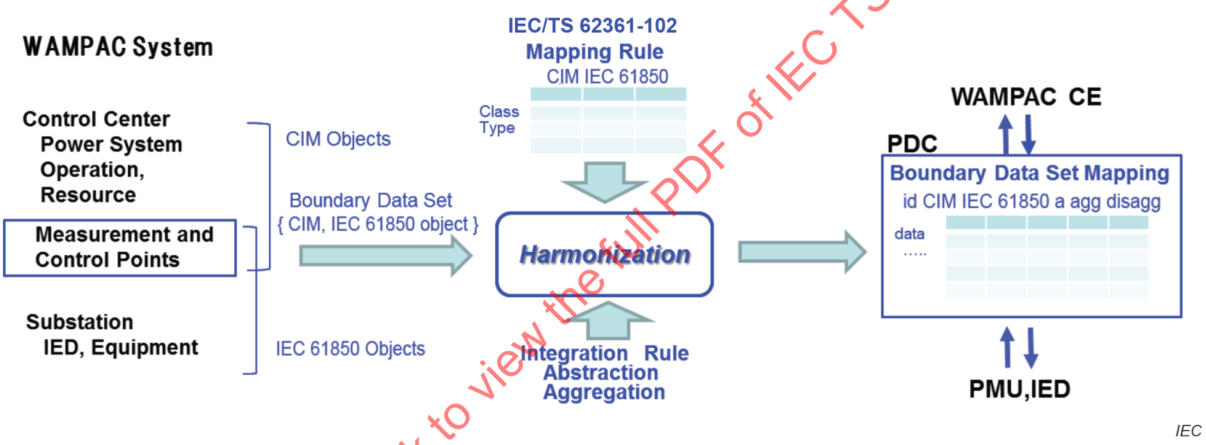


Figure 2 – Mapping for Wide Area Monitoring Protection and Control

NOTE CE: Central Equipment, PDC: Phasor Data Concentrator, PMU: Phase Measurement Unit, IED: Intelligent Electric Device.

5 Mapping SCL to SCADA/EMS/DMS relevant CIM

5.1 Business requirements

The use case gives the context for some high level business requirements for transformation and mapping. There are two main variants, create a new CIM model, or update an existing CIM model.

- Importing and transforming an SSD or SCD file with minimal, partial or full logical node details into a CIM based SCADA/EMS/DMS modelling tool (see Appendix A for more on modelling tools) to create a new CIM model for review and/or subsequent processing.
- Importing and transforming an SSD or SCD file with partial or full logical node details into a CIM based modelling tool to create, delete or update the relevant instances and associations within an existing CIM model.

A CIM based modelling tool should allow CIM information not modelled in the SSD or SCD file to be added to an imported and transformed model. As far as practical, the tool should preserve this additional information during any updates.

5.2 Profiles

This Technical Specification provides a general mapping but does not define whether data elements are mandatory or optional. It is expected that subsets of the mappings, including definitions of mandatory data, may be specified in the form of profiles that apply either to the SCL or the CIM models.

5.3 IEC 61850 modelling principles

5.3.1 Introduction

The initial scope of the IEC 61850 series was communication in substation automation systems. This included the definition of communication services, data models and a configuration description language. The initial application use cases were concerned with protection, control and monitoring. From 2009 and onwards the IEC 61850 series has been updated and extended for other domains. Edition 2 also redefined the models for statistical and historical data handling.

The concepts defined in IEC 61850 have been applied beyond the substation domain including modelling automation systems for hydropower plants, distributed energy resources, and wind turbines. Work is in progress for other applications such as distribution feeder automation.

Subclauses 5.3.2 to 5.3.4 are a summary of the key features of the IEC 61850 System Configuration description Language.

5.3.2 System Configuration description Language (SCL)

IEC 61850-6 specifies a file format for describing communication and parameters related to IED (Intelligent Electronic Device) configurations, communication system configurations, switchyard (function) structures, and the relations between them. The main purpose of the format is to exchange IED capability descriptions, and system level descriptions between engineering tools of different manufacturers in a compatible way.

The file format language is called System Configuration description Language (SCL).

It provides a way of describing the following:

- Primary system equipment and connectivity (single line) description,
- Communication connection description,
- Intelligent Electronic Device (IED) capabilities,
- Allocation of logical nodes within physical IEDs to the corresponding primary equipment or container.

5.3.3 Logical Devices and Logical Nodes

IEC 61850 is concerned with automation systems that consist of one or more Intelligent Electronic Devices (IEDs) connected by a communication system. Typically, IEDs are communication servers. The IED model is also used for clients, routers or clock sources.

The principle use case for this document is concerned only with IEDs that are servers providing data that may be of interest in the control centre. The following summary is an overview of the data models for these types of IED.

- An Intelligent Electronic Device is a physical device
- Each IED/physical device contains one or more instances of Logical Devices (LD)
- Each Logical Device contains at least one instance of a Logical Node (LN)

- Each Logical Node is a standardised set of related Data Objects (DO)
- Data Objects have standard types called Common Data Classes (CDC)
- Common Data Classes define a set of Data Attributes (DA)
- Data attributes can be
  - Status information (digital values)
  - Substituted values
  - Measurands (analogue values)
  - Operation or control requests
  - Settings
  - Description
  - Configuration
  - Name space definitions

Some of the IEC 61850 data attributes correspond to traditional SCADA digital, analogue and counter objects. Controls are modelled as services that can be applied to relevant Data Objects.

Compared to the data point lists of traditional SCADA protocols, IEC 61850 allows systems to be designed and configured using fewer but more complex objects.

5.3.4 SCL sections

The SCL as defined in IEC 61850-6 has a number of sections:

a) **Substation / Line / Process Section:** describes the primary process related functions and devices like a switch yard in the functional view according to IEC 81346-1, electrical connections on single line level (topology), and the designation of equipment and functions

b) **IED Section:** describes the capabilities or configuration of each IED in terms of communications and logical nodes. It may also define the default or configured values for individual data objects.

c) **Communications Section:** contains communication-related object types such as subnetworks and communication access points, and describes the communication connections between IEDs as a base for communication paths between logical nodes as clients and servers.

d) **Data Type Templates section:** defines instantiable logical node types. A logical node type is an instantiable template of the data of a logical node. A LN type is referenced each time that this type is or shall be instantiated within an IED. A logical node type template is built from data objects (DO) elements, which have a DO type. DOTypes consist of attributes (DA) or other defined DO types. The data attributes (DA) can either have a basic type, be an enumeration, or a structure of a DAType built from basic types or other defined DA types.

In the SCL context the term “logical node container” means the primary equipment or substation/line/process that is *associated* with zero or more logical nodes.

Technically, the Logical Nodes are software entities contained within physical IEDs.

5.4 Mapping overview

5.4.1 SCL Document Types

Different subsets of the SCL language are used at different stages of the design, installation and commissioning processes. Mapping to the CIM is concerned with the following document types:

- System Specification Description (SSD). This describes the primary equipment, single line diagram and functions of the substation, plus the required logical nodes. It must contain a substation description section and may contain the needed data type templates and logical node type definitions.
- System Configuration Description (SCD). This file contains the substation description section; the IED description section including the data flows and Data Type Templates; plus, a section to describe the local communication configuration.

5.4.2 General mapping principles

Table 1 shows an overview of the main categories of data within SSD or SCD documents, together with their main CIM counterparts. The details are considerably more complex and are described in Subclauses 5.4 to 5.9.

Table 1 – Overview of SCL and CIM counterparts

SCL Section	SCL Description	CIM
Header	SCL schema version and document revision history	No equivalent
Substation / Line / Process	Equipment, SubEquipment Function, SubFunction = primary process related functions and devices	Substation, Plant, Lines or other location containers Voltage Level Bay PowerSystemResources
Substation / Line / Process	Terminals, ConnectivityNodes = electrical connections on single line level (topology)	Terminals, Connectivity Nodes & associations
Diagram coordinates (optional – see note below)	coordinates to draw a single-line diagram corresponding to the electrical connectivity	Diagram layout
IED Instances	Containers for Logical Devices and Logical Nodes.	Remote Unit or EndDevice
IED instances containing specific types of Logical Nodes, Data Objects, Data Attributes	Analogue Measurands, Status and Controllable objects	CIM measurements (analogs, discretes, accumulators) & controls (commands, setpoints)
IED instances containing specific types of Logical Nodes, Data Objects, Data Attributes	Settings and Parameters	CIM object attributes or associations
Communication	Description of the communication configuration	CommunicationLink or classes from IEC 61968-11

Each of these data categories requires a set of mapping and/or transformations.

SCL files include a header section which can be used to define the revision history or version management information of the contents. At present the core IEC 61970-301 model does not define any specific model for version management. A generic method for modelling proposed or implemented changes for any CIM based application is currently under discussion.

The Substation / Line / Process section describes the primary system equipment and therefore has considerable overlap with the CIM. This section may also describe the one-line connectivity. Whilst both models have classes for Terminals and Connectivity Nodes, the treatment of phase information in the SCL and CIM models is different.

IEC 61850 defines an informative i.e. optional extension format to allow diagram coordinates and symbol orientation to be defined for the primary equipment and/or for the communications system. However, it is not as rich as the CIM diagram layout model; for instance, it does not define how to define symbol scaling.

All equipment and equipment containers defined in the Substation / Line / Process section can have associated Logical Nodes. Within a SSD document, these Logical Nodes are template types. Within a SCD document, the Logical Nodes are specific instances within specific IEDs.

IEC 61850-7-4 defines a set of Data Objects for each type of Logical Node. IEC 61850-7-3 defines standard Data Attributes for Data Objects. Many of these Data Objects or Data Attributes are optional. The IED and Data Type Template sections of the SCL file are used to define the types or instances of Data Objects and Data Attributes for each type or instance of Logical Nodes for specific IEDs.

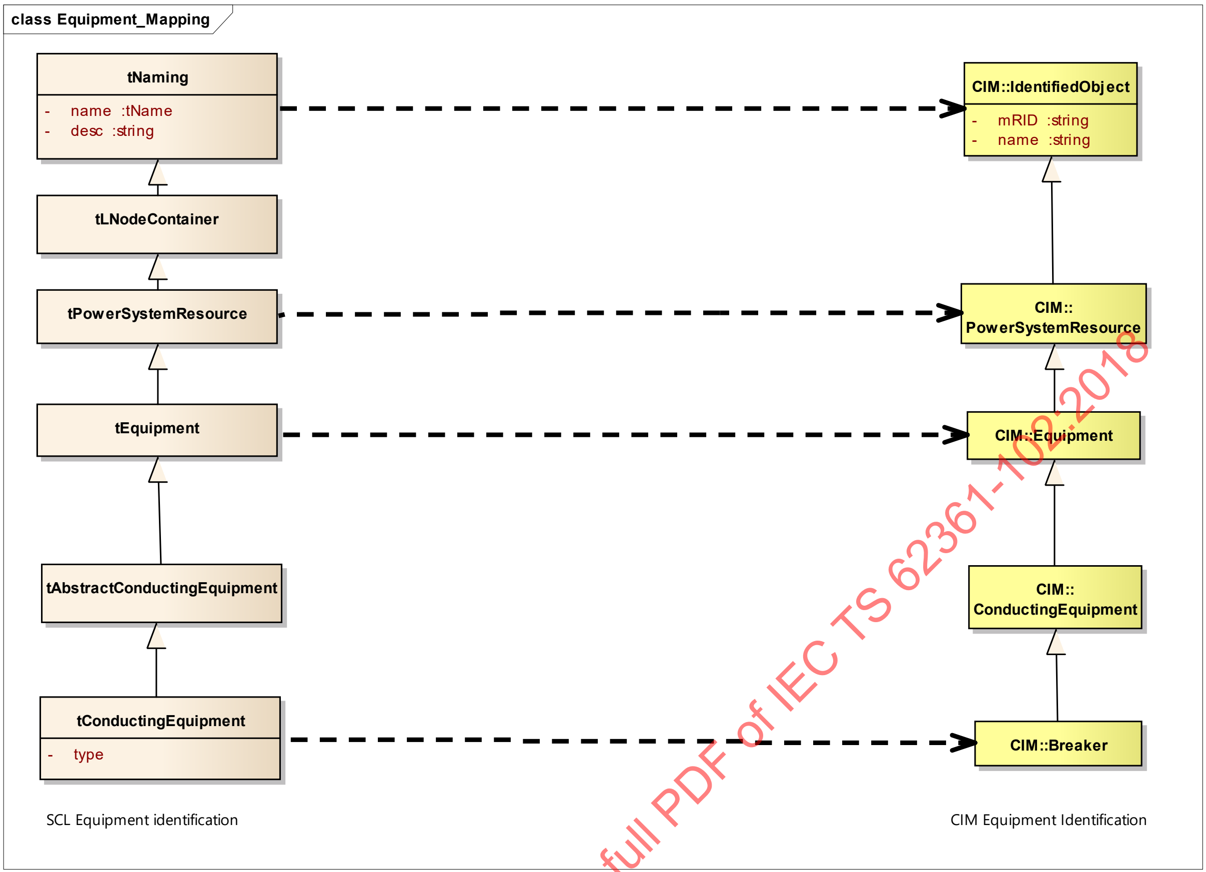
Some of these Data Objects / Data Attributes correspond to CIM Measurements. In these cases, the association {*Equipment –> Logical Node –> Data Object –> Data Attribute*} is equivalent to the CIM association of {*Power System Resource -> MeasurementValue* or *Asset->MeasurementValue}*.

Other Data Objects correspond to CIM Controls. In these cases, the association {*Equipment –> Logical Node –> Data Object –> Data Attribute*} is equivalent to the CIM association of *Power System Resource -> Control* or *Asset->Control*.

The Substation / Line / Process section only defines the basic types, names and descriptions for the primary system equipment. A limited number of attributes are available such as the nominal voltage and nominal frequency. In the IEC 61850 model, settings and configuration parameters may be defined within associated Logical Nodes. For some (but not all) of the settings the associations {*Equipment –> Logical Node –> Data Object –> Data Attribute*} may map to attributes belonging to the CIM object classes.

Some of the general mapping principles described above are shown in Figures 3 and 4. Figure 3 shows a simplified representation of the main equipment hierarchy in the SCL and in CIM.

The inheritance hierarchy of the SCL is similar but not the same as that of the CIM. Within SCL, the type of conducting or non-conducting equipment is defined by a type code, whilst in the CIM the equipment type is defined by a concrete class.



IEC

Figure 3 – Equipment mapping

Figure 4 shows a correspondence between Data Objects in the SCL and some of the CIM classes in the Measurement package. Comparing the measurement models, equipment in SCL is associated with zero or more Logical Nodes, whereas in the CIM, Equipment, or more generally, PowerSystemResources, are associated with zero or more Measurement instances.

Note that in IEC 61850 the term Measurand is used for some types of Data Object that contain analogue values, whereas the CIM Measurement class is a generic class that may have discrete, analogue or accumulator subclases.

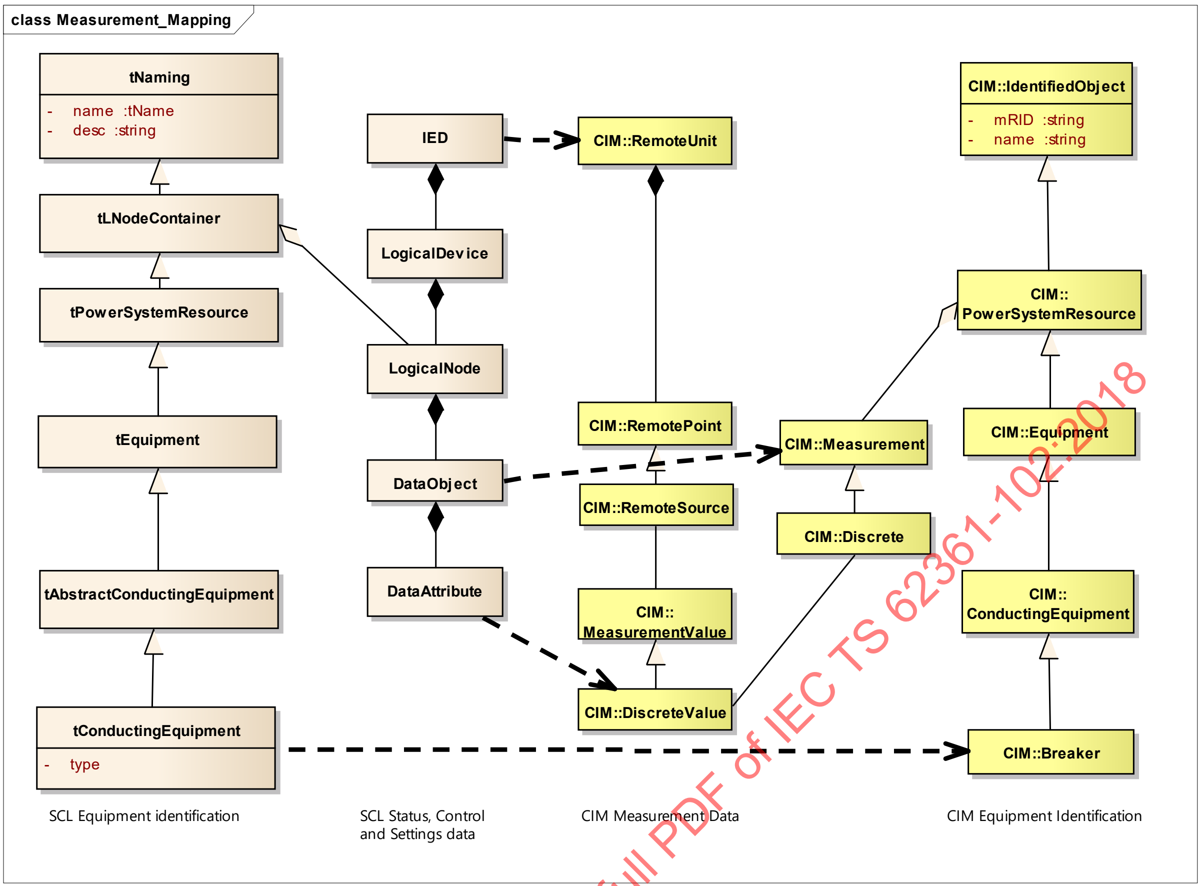


Figure 4 – Example of equipment and status measurement mapping

5.5 SCL Substation section mapping

5.5.1 Overview

The following text is reproduced from IEC 61850-6:

The Process model is an object hierarchy based on the functional structure of the primary process. Special primary processes are the Substation and the Line, which have their own SCL elements. [The generic Process element shall be used] … *to model any additionally needed structuring levels of a power grid above the substation … Although each object is self-contained, its reference designation is derived from its place in the hierarchy. Because LNs perform functions within the complete context of the Process / Substation, they can be attached as functional objects at each function level. Typically, a switch controller LN is attached to a switching device, while a measuring LN is attached to the bay, which delivers the measurands, and transformer-related LNs are attached to the appropriate transformer.*

The purpose of the process model is

- *to relate a logical node and its function to a process function (substation, process or line part or equipment or sub-equipment);*
- *to derive a functional designation for the logical node from the substation structure.*

Logical nodes (LNode) can be attached at each level of the structure (i.e., substation, voltage level, bay, equipment, subequipment respective function, subfunction). Power transformers (PowerTransformer) can also be attached at the structure levels substation, voltage level and bay. Conducting equipments (ConductingEquipment) can only be attached to the bay level. Logical node instances at the same level shall have different identifications.

NOTE 1 In the first paragraph “function” is used in the general sense and not the specific SCL element type called function.

NOTE 2 In practice measurement logical nodes may be attached to any of the elements that inherit from tLNodeContainer including ConnectivityNodes. However logical nodes cannot be allocated to terminals.

Figures 5 to 7 show UML class diagrams that correspond to the entities in the IEC 61850 SCL Process/Line/Substation section. For clarity, this is presented as several diagrams and the classes EqFunction and EqSubFunction have been omitted.

Figure 5 shows the main inheritance structure for equipment and equipment containers. Equipment may be either GeneralEquipment without electrical connectivity; or conducting equipment with terminals that connect to connectivity nodes. Power transformers, windings and tap changers have specific entities.

The SCL inheritance hierarchy is similar but not the same as that of the CIM. Within the SCL, the type of equipment is defined by a type code whilst in the CIM the equipment type is defined by its concrete class.

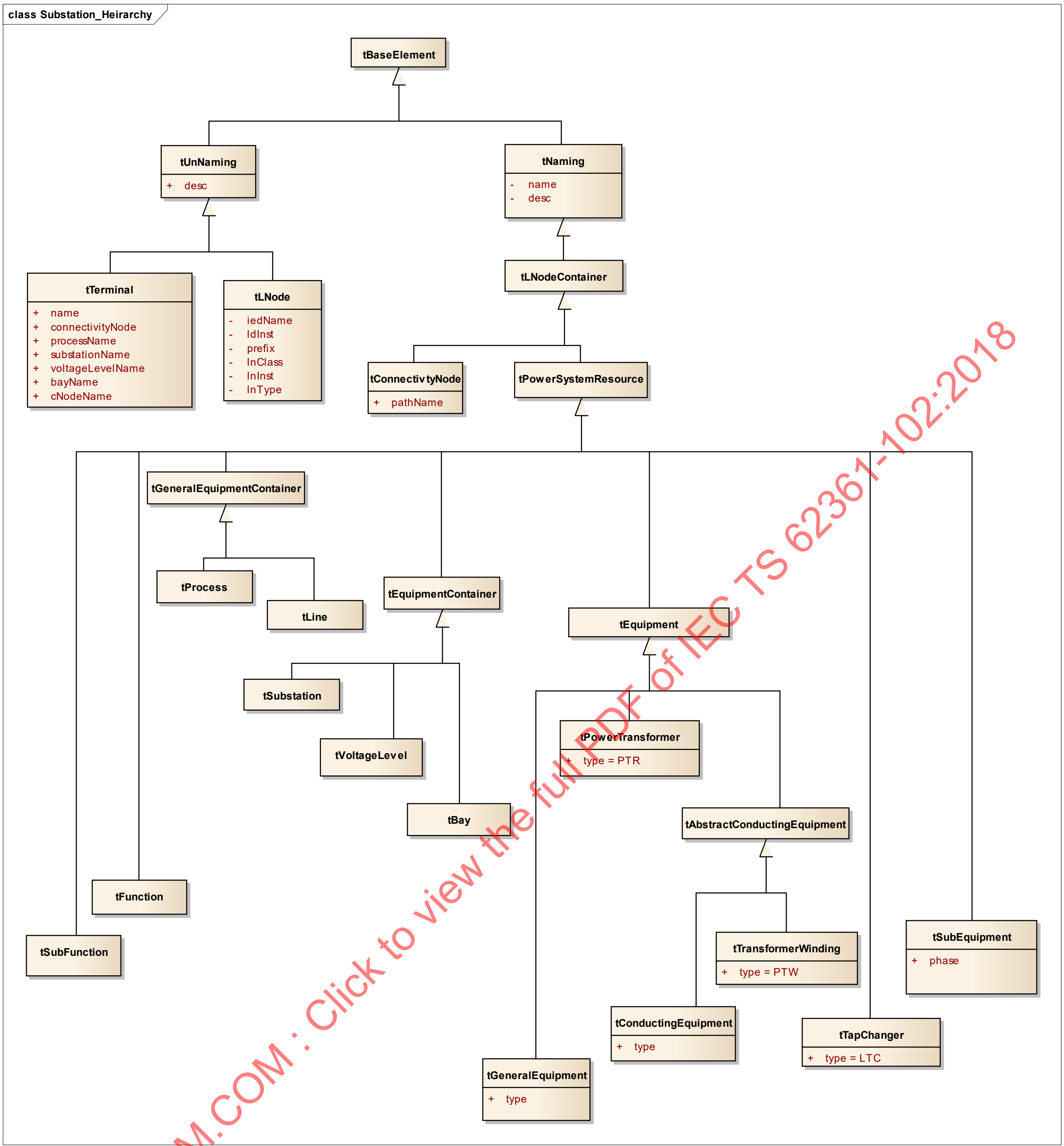


Figure 5 – UML class diagram of SCL entities showing inheritance

Figure 6 shows both the inheritance structure and the containment associations for equipment.

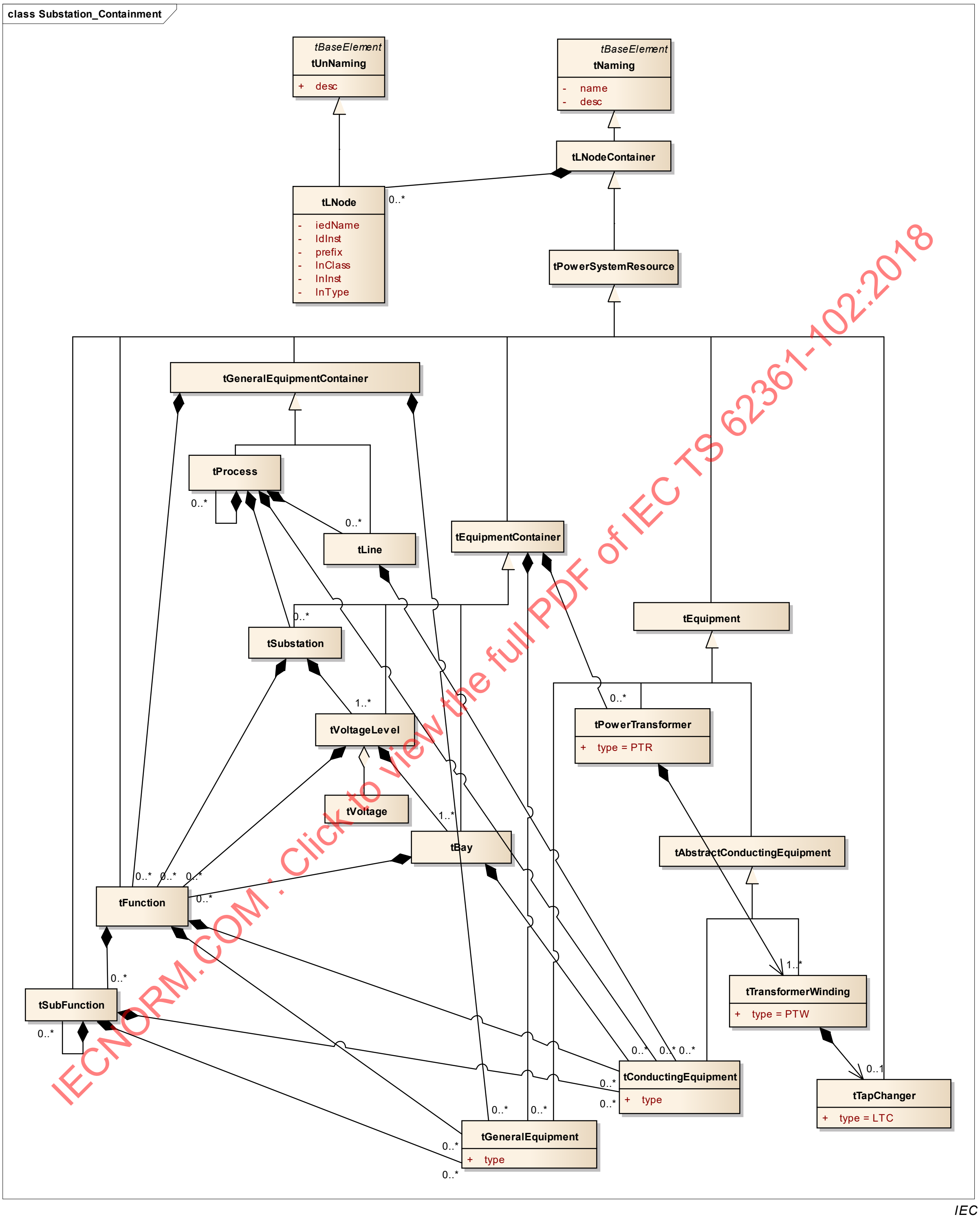


Figure 6 – UML class diagram of SCL entities showing inheritance and containment

Figure 7 shows the connectivity modelling using Terminals and ConnectivityNodes. It also shows that phase information may be defined in SubEquipment instances associated with power transformers, windings, tap changers and all other types of ConductingEquipment.

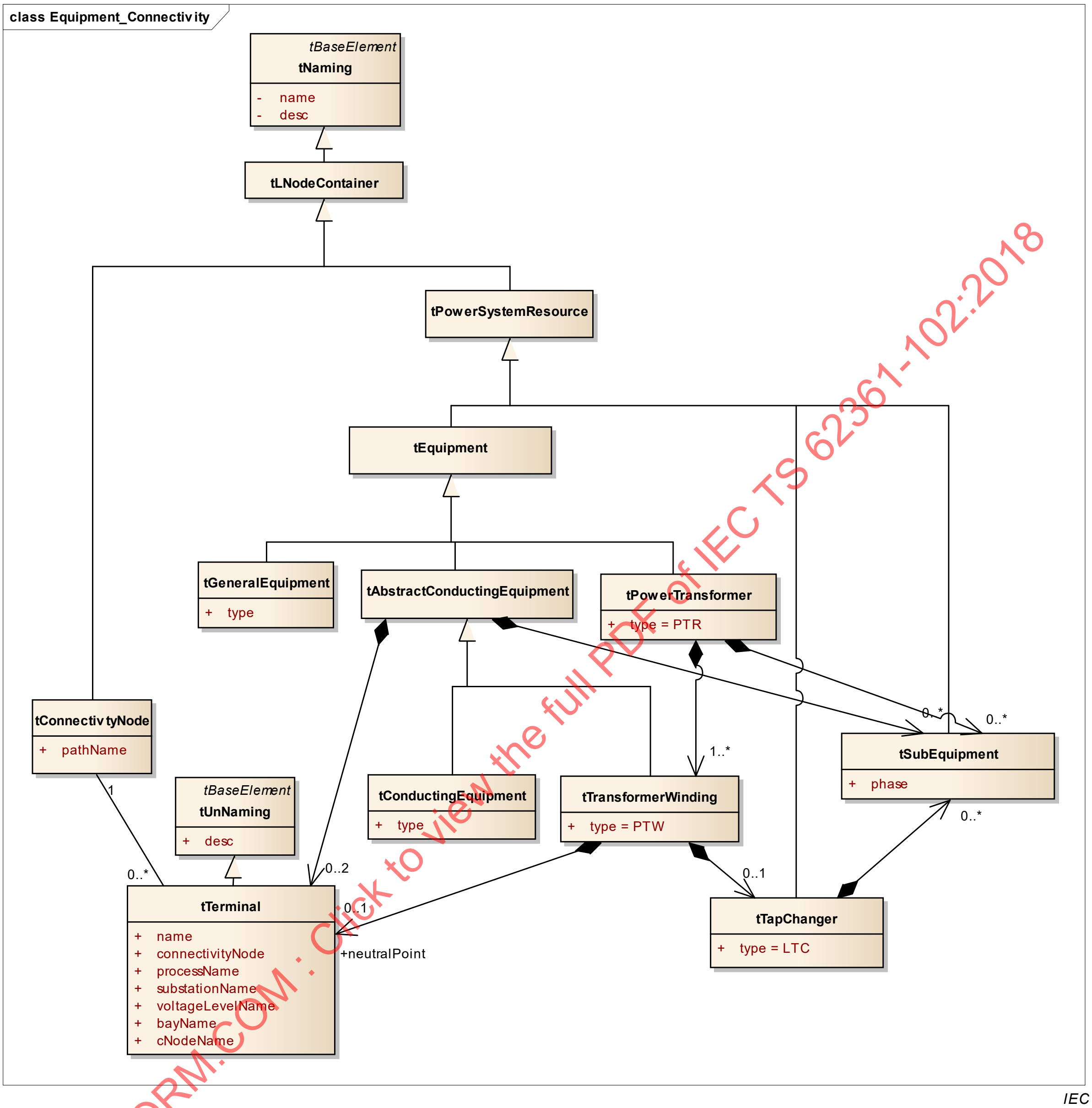


Figure 7 – UML class diagram of SCL equipment connectivity and phase information

5.5.2 SCL elements and CIM classes mapping

The high-level mapping between SCL elements and CIM classes is shown in Table 2. Some elements such as Process or Function map to more than one CIM class. In these cases, any SCL to CIM implementation must use local mapping rules, for example based on the element names.

Table 2 – Mapping between SCL data types and CIM classes

SCL element	SCL description	CIM Class
Process	the whole or part of a primary process. Parts of power grids containing several substations or lines. a logical node container, which can be used for other processes than substations, or to group several substations into parts of a power grid. For the first purpose, it can also contain equipment elements. It can be recursively used	Plant GeographicalRegion SubGeographicalRegion
Line	a power line connecting several substations. a logical node container, which can be used to model lines between substations of a power grid. It can contain equipment elements modelling line segments, general equipment and connectivity nodes	Line
Substation	the object identifying a whole substation	Substation
VoltageLevel	an identifiable, electrically connected substation part having an identical voltage level.	VoltageLevel
Voltage	states the voltage used at a voltage level	BaseVoltage
Bay	an identifiable part or subfunction of the switch yard (substation) within one voltage level.	Bay
Equipment	an apparatus within the switch yard, for example circuit breaker, disconnector, voltage transformer, power transformer winding etc. Equipment has an attribute 'type' which is an enumerated code.	See the descriptions for ConductingEquipment and GeneralEquipment
ConductingEquipment	Subclass of Equipment for equipment that forms part of the primary power system.	Subclass of AuxiliaryEquipment e.g. SurgeArrester or subclass of ConductingEquipment
GeneralEquipment	Subclass of Equipment for auxiliary equipment	Subclass of AuxiliaryEquipment or subclass of ConductingEquipment e.g. AsynchronousMachine
SubEquipment	a part of an Equipment, which might especially be one phase of a three-phase equipment.	ACLineSegmentPhase SwitchPhase EnergyConsumerPhase ShuntCompensatorPhase TransformerTankEnd
ConnectivityNode	the (electrical) connectivity node object connecting different primary devices. Typical connectivity node examples are: connecting nodes within a bay, bus bars connecting several bays in the same voltage level, lines connecting bays in different substations.	ConnectivityNode plus BusbarSection or Junction

SCL element	SCL description	CIM Class
Terminal	an electrical connection point of a primary apparatus at single line level. A terminal can be connected to a ConnectivityNode. Within SCL terminals can be explicitly named, or exist implicitly.	Terminal
Function	allows additional functions at substation, voltage level or bay level, either independent from the basic switch yard functionality like firefighting or building supervision, or as part of the switch yard like main 1 protection and main 2 protection.	AuxiliaryEquipment ProtectionEquipment AssetFunction Contained logical nodes may be mapped to the measurements associated of the parent equipment class.
SubFunction	a hierarchical subpart of a Function or SubFunction, e.g. earth fault protection as subpart of the main 1 function.	As Function
EqFunction	allows additional functions at or below Equipment level, e.g. redundant functions on the same equipment. Contained by tConductingEquipment, tGeneralEquipment , tSubEquipment, tPowerTransformer, tTransformerWinding, tTapChanger.	As Function
EqSubFunction	a hierarchical subpart of an EqFunction or EqSubFunction.	As Function
PowerTransformer	special equipment, which can hierarchically be located below Substation, VoltageLevel or Bay. It contains Transformer windings as equipment, which might again have a relation to a tap changer. A power transformer usually connects between two or more voltage levels.	PowerTransformer
TransformerWinding	Part of a PowerTransfomer	TransformerEnd PowerTransformerEnd TransformerTankEnd
TapChanger	Part of a PowerTransfomer	TapChanger PhaseTapChanger RatioTapChanger

Some equipment such as extra high voltage switch gear and transformers may be physically separate equipment per phase. This may be represented in the SCL as one instance of the three-phase equivalent equipment with three instances of sub-equipment, one for each of the phases. Depending on the application of the CIM model, the CIM model could be either the three-phase equivalent or the three single-phase equipments. For more details, see 5.10, Phase modelling.

IEC 61850-6 has the definition of Function/SubFunction that represents application aggregates of PowerSystemResources and/or LogicalNodes. Currently, there are no clear corresponding entities within CIM for mapping this concept.

5.6 Equipment types and codes

5.6.1 General

Within the SCL, the type of equipment is defined by a type code whilst in the CIM the equipment type is defined by its concrete class.

5.6.2 Equipment type code mapping

Table 3 shows all the type codes defined in IEC 61850-6:2009 Table 5 and Table 9 with a correspondence to one or more CIM classes defined in IEC 61970-301. It also includes some CIM classes that are used in IEC 61970-452, but do not have corresponding type codes in IEC 61850.

If details of network connectivity are not required e.g. for condition monitoring, then equipment can be mapped to instances of CIM Asset.

Table 3 – Equipment type codes

Type Code	IEC 61850 Meaning	Number of terminals	CIM (IEC 61970-301) class
AXN	Auxiliary Network	None	No corresponding CIM class
BAT	Battery [and charging system]	1 (Note 1)	No corresponding CIM class
BSH	Bushing	2	Connector
CAB	Power cable	2	ACLineSegment DCLineSegment
CAP	Capacitor bank	1/2	ShuntCompensator SeriesCompensator
CBR	Circuit Breaker	2	ProtectedSwitch Breaker Recloser
CON	Converter	1/2	FrequencyConverter
CTR	Current Transformer	2	CurrentTransformer
DIS	Disconnector or earthing switch	2	Switch Disconnector Fuse Jumper LoadBreakSwitch GroundDisconnector Sectionaliser
EFN	Earth Fault Neutralizer (Petersen coil)	1	PetersenCoil
FAN	Fan	0 or 1 (Note 1)	No corresponding CIM class
FIL	Filter	0 or 1 (Note 1)	No corresponding CIM class
GEN	Generator	1	GeneratingUnit
GIL	Gas Insulated Line (or line segment)	2	ACLineSegment DCLineSegment

Type Code	IEC 61850 Meaning	Number of terminals	CIM (IEC 61970-301) class
IFL	Infeeding line; substation limiting object; models a possibly infeeding power network line outside the substation at the single line border	1	ACLineSegment DCLineSegment EquivalentBranch
LIN	Power overhead line or line segment	2	ACLineSegment DCLineSegment
LTC	Load Tap Changer	Part of winding	TapChanger RatioTapChanger PhaseTapChanger
MOT	Motor	0 or 1 (Note 1)	AsynchronousMachine
PMP	Pump	0 or 1 (Note 1)	No corresponding CIM class
PSH	Power Shunt (bypass for transformer star point grounding resistor)	2	GroundingImpedance
PTR	Power Transformer	Implicit via windings	PowerTransformer
PTW	Power Transformer Winding	1/2	TransformerEnd PowerTransformerEnd TransformerTankEnd
REA	Reactor	1/2	ShuntCompensator SeriesCompensator
RES	Neutral resistor	2	EarthFaultCompensator
RRC	Rotating reactive component	1	SynchronousMachine
SAR	Surge arrester	1	SurgeArrester
SCR	Semiconductor controlled rectifier	2	ACDCConverter
SMC	Synchronous Machine	1	SynchronousMachine
TCF	Thyristor controlled frequency converter	2	FrequencyConverter
TCR	Thyristor controlled reactive component	2	StaticVarCompensator
TNK	Tank	0	TransformerTank
VLV	Valve	0 or 1 (Note 1)	No corresponding CIM class
VTR	Voltage Transformer	1	PotentialTransformer
Note 2	Bus bar section	1	BusbarSection
Note 2	Identified connection point that is not a bus bar (see 5.6.5 below)	1	Junction
Note 2	Identified connection point to ground	1	Ground

NOTE 1 IEC 61850-6 allows equipment of type codes AXN, BAT, MOT, FAN, PMP, VLV to be defined as general equipment without terminals, or as conducting equipment with terminals. Equipment such as filters and pumps may be monitored by a central SCADA or asset management system. Their status may be useful for assessing operational limits.

NOTE 2 IEC 61850-6 does not model bus bar sections or junctions as identified equipment, but simply as connectivity nodes.

In some cases, it is possible to use other information from the SCL in addition to the type code to define a more complex mapping to the appropriate CIM class. For example, if one of the terminals for a SCL switch is connected to a SCL connectivity node called "grounded", then the CIM switch type is a "GroundDisconnector".

Within SCL, DC lines can be modelled with equipment of type LIN/GIL/CAB within (or connected to) a voltage level with nominal frequency 0. However, for control centre applications, there are fundamental differences between AC and DC equipment. The CIM therefore uses different sets of classes for AC lines and for DC lines

The SCL is intended to describe the power system such that the primary equipment type does not depend on the associated logical nodes. However, if logical node information is available it may allow the CIM model to be refined. This additional information could simply be the logical node class type as listed in Table 13, or it could be the configured value for a data object within the logical node. For example, the XSWI logical node has a data object that defines the sub-type of the associated switch equipment. See Table 22.

IEC 61850 has no special modelling for temporary equipment which will be installed to provide safety during maintenance or erection work. Temporary equipment must be pre-defined in the SCL in the same way as permanent equipment.

IEC 61850-6 allows private type codes. To allow compatibility with future enhancements of the standard, they shall start with the character E, contain only capital letters, and have at least three letters. The mapping of private type codes requires local mapping rules.

5.6.3 Recommendation for harmonization: SCL Equipment Type codes

5.6.3.1 New and deprecated type codes

Recommendation R2: The list of device type codes in IEC 61850-6 should be extended to correspond better with the IEC 61970 / IEC 61968 Common Information Model, particularly to support applications related to distribution networks. This would allow the Substation section to be used to more fully describe the power system equipment and its connectivity without needing any details of Logical Nodes. The aim is that the type code indicates the fundamental nature of the physical equipment, not necessarily its usage within a particular software application.

Details:

1) Add new type codes for Busbar section and Junction. Conducting Equipment of these types would be defined within Bays together with their associated Terminal and ConnectivityNode.
2) Add new type codes to distinguish types of switch. DIS is ambiguous as it can be mapped to several different sub-types of CIM Switch.
3) It is confusing to have type codes for capacitor device types with a variable number of terminals. Add new type codes to distinguish series and shunt capacitors.
4) It is confusing to have type codes for reactor device types with a variable number of terminals. Add new type codes to distinguish series and shunt reactors.
5) It is not clear what the difference is between type code CON "converter" compared with the SCR "rectifier" and TCF "frequency converter". The type code CON should be deprecated.
6) Add a new type code for Composite Switches i.e. a set of individual Switches normally enclosed within the same cabinet or cubicle, possibly with interlocks that restrict the combination of switch positions. These are typically found in medium voltage distribution networks or high-voltage gas insulated switchgear. The purpose is to allow the cabinet or cubicle to be represented as equipment with its own identity and status, in addition to its constituent switches.

7) The IFL type code should not be used for new designs. The differentiation with between outgoing and infeeding lines is not relevant in many transmission networks and is becoming artificial in distribution grids with high level of dispersed generation. The power flow direction may change in a few seconds. Allow LIN and CAB to be modelled with one terminal when they cross the substation or system border, and modelled with two terminals if the SCL models a full line.

8) For CIM applications, there are fundamental differences between AC and DC equipment. It is complex to distinguish AC lines and DC lines based on the association with a voltage level that has a frequency attribute with value zero. Add new type codes DLN and DCA.

These recommendations are summarized in Tables 4 and 5.

Table 4 – Equipment type codes – proposed modified descriptions

Type Code	Meaning	Number of terminals	CIM class
DIS	Disconnector or earthing switch (generic) Deprecated – use SDC or SES	2	
CAP	Capacitor bank (generic) Deprecated – use CSE or CSH	1 or 2	ShuntCompensator if number of terminals =1 SeriesCompensator if number of terminals =2
REA	Reactor (generic) Deprecated – use RSE or RSH	1 or 2	ShuntCompensator if number of terminals =1 SeriesCompensator if number of terminals =2
CON	Converter (generic). Deprecated – use TCF or SCR as applicable	1 or 2	
IFL	Infeed line Deprecated – use CAB, LIN or GIL		

Table 5 – Equipment type codes – proposed additional codes

Type Code	Meaning	Number of terminals	CIM class
BUS	Busbar section – a low impedance conductor to which several instances of conduction equipment can be separately connected	1	BusbarSection
BJN	Junction – connection between two or more instances of conduction equipment	1	Junction
CSE	Capacitor bank – series	2	SeriesCompensator
CSH	Capacitor bank – shunt	1	ShuntCompensator
DLN	DC Line	2	DCLineSegment
DCA	DC Cable	2	DCLineSegment
RSE	Reactor – series	2	SeriesCompensator
RSH	Reactor – shunt	1	ShuntCompensator
CSW	Composite Switch (set of individual Switches normally enclosed within the same cabinet and possibly with interlocks that restrict the combination of switch positions) See example in Figure 8		CompositeSwitch
SWI	Switch – generic	2	Switch
SLB	Switch – Load break switch	2	LoadBreakSwitch
SDC	Switch – Disconnector	2	Disconnector
SES	Switch – Earthing switch	2	EarthingSwitch
SHS	Switch – High speed earthing switch	2	EarthingSwitch
SFS	Switch – Fuse	2	Fuse
SJP	Switch – Jumper	2	Jumper

Figure 8 shows a Ring Main Unit modelled as a composite switch containing several individual switches.

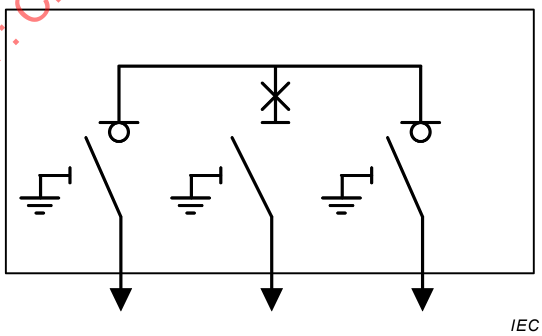


Figure 8 – Composite Switch example.

5.6.4 Recommendation for harmonization: SCL PSRType

In the CIM, instances of power system resources may be associated with zero or one instances of PSRType. This is used for "classifying instances of the same class, e.g. overhead and underground ACLineSegments. This classification mechanism is intended to provide flexibility outside the scope of this standard, i.e. provide customisation that is non-standard."

This custom classification is particularly useful for modelling distribution network equipment, as a way of defining individual instances with reference to template or catalogue objects that contain sets of reference parameters.

It would also help mapping algorithms to choose the appropriate CIM class when there is a choice, e.g. a physical line could be modelled as an ACLineSegment, but for transmission network applications it could be modelled as an EnergyConsumer (a point of consumption on the power system model)

Recommendation R3: An optional string attribute `psrType` should be added to the SCL definition for tPowerSystemResource. It may be appropriate to use a specific namespace for this and other CIM related attributes.

5.6.5 Recommendation for harmonization: CIM BusbarSection and Junction

The CIM has two classes called BusbarSection and Junction which have the same attributes and associations. From a topology processing point of view clearly the two classes are equivalent.

Recommendation R4: Explanatory text should be added to IEC 61970-301 to explain the differences and where connectivity nodes are defined without either, e.g.

"For topology processing, a BusbarSection is identical to a Junction. The BusbarSection class is intended to represent physical parts of bus bars. It can be used to connect any number of equipment terminals.

The Junction class is intended for those cases where it provides a place to connect additional information for a connectivity node that is formed by connecting two or three equipment terminals such as a tee-point or the connection point between two switches.

Typically, BusbarSections and Junctions are represented by different symbols on diagrams."

5.6.6 Recommendation for harmonization: CIM Fan, Motor, Batteries and charging systems

The IEC 61850 SCL allows fans, motors and battery systems to be defined either as types of general equipment or as types of conducting equipment. When defined as conducting equipment they will have terminals to allow modelling of their electrical supplies. There is no corresponding CIM class for these types of equipment within the connectivity model except the generic EnergyConsumer class.

Auxiliary equipment may be relevant for asset management purposes. The status and measured values for such equipment are defined in IEC TR 61850-90-3 and may be considered in a future edition of this document.

Recommendation R5: The business needs for modelling fans, motors and battery systems and similar types of auxiliary equipment in control centre applications should be considered.

5.7 Naming and identification mapping

5.7.1 General

The SCL and CIM models have different principles for naming and identification.

[From IEC 61850-6:2009, 8.5.2] *In case of the hierarchically structured objects of the substation structure and the product structure, both name and desc attributes for each object contain only that part which identifies the object within this level of the hierarchy. The full object reference is a pathname and consists of the concatenation of all name parts of higher hierarchy levels up to this level.*

NOTE ConnectivityNode is an exception. It includes a full pathname that should be unique within the SCL file.

IEC 61850-6:2009 defines two conventions for concatenating names. Subclause 8.5.2 recommends using a dot (.) as a separator, however Subclause 9.2.3 states "The separator "/" has been purposely selected, because the dot "." might appear as part of the names at higher hierarchy levels, for example at bay level."

Table 6 shows the mapping between name/identification attributes in SCL and the corresponding attributes in CIM.

Table 6 – Name mapping

Attribute	SCL Description	CIM Mapping
name	identification of each object within its container. Must be unique within the container. Must be unique within the file for top level objects	IdentifiedObject,name Name.name where Name is associated with a NameType "SCL.name"
desc	user oriented textual designation	IdentifiedObject.description
	pathname: concatenation of all name parts of higher hierarchy levels up to this level.	Name.name where Name is associated with a NameType "SCL.id"
□missing□	Master resource identifier issued by a model authority. The mRID is globally unique within an exchange context.	1. Generate a system unique object reference as per IEC 61850-6 Clause 8.5.2. The full object reference is a pathname and consists of the concatenation of all name parts of higher hierarchy levels up to this level. 2. Use the pathname as a key in some sort of registry to look up a UUID

5.7.2 Naming and identification example

ConnectivityNodes have an additional pathname attribute – this is discussed in more detail in Subclause 5.9.

If the SCL file contains the following:

```
<Substation name="S12" desc="Baden">
<VoltageLevel name="E1">
<Bay name="Q1">
<ConductingEquipment name="QA1" type="CBR">
```

using the existing SCL schema, it is possible to generate a CIM model using SCL pathnames as mRIDs. This satisfies the requirement for unique identifiers but does not satisfy the common business requirement that the same mRIDs are used even if the object names are changed.

```
Substation.name    =    Baden
Substation.mRID    =    S12

VoltageLevel.name  =    E1
VoltageLevel.mRID  =    S12E1

Bay.name           =    Q1
Bay.mRID           =    S12E1Q1

Breaker.name       =    QA1
Breaker.mRID       =    S12E1Q1QA1
```

5.7.3 Recommendation for harmonization: SCL naming and identification

IEC 61970-301 defines mRID as “Master resource identifier issued by a model authority. The mRID is globally unique within an exchange context. Global uniqueness is easily achieved by using a UUID, as specified in RFC 4122, for the mRID. The use of UUID is strongly recommended.”

It is possible to define unique mRIDs using additional mapping information; however, there are many advantages if the mRIDs are contained with the SCL. This means that for exchanges from SCL to CIM, the creator of the SCL becomes the Model Authority for the mRIDs imported from the SCL file.

Recommendation R6: Add mRID to SCL as an optional attribute to type tBaseElement in SCL_BaseTypes.xsd allowing mRIDS to be defined for Equipment, Terminals and ConnectivityNodes.

```
<xs:complexType name="tBaseElement" abstract="true">
  <xs:sequence>
   <xs:any namespace="##other" processContents="lax" minOccurs="0" maxOccurs="unbounded"/>
   <xs:element name="Text" type="tText" minOccurs="0"/>
   <xs:element name="Private" type="tPrivate" minOccurs="0" maxOccurs="unbounded"/>
  </xs:sequence>
<xs:attribute name=”mRID” type=”tmRID” use=”optional”/>
  <xs:anyAttribute namespace="##other" processContents="lax"/>
 </xs:complexType>
```

5.7.4 Recommendation for harmonization: CIM naming and identification:

Recommendation R7: IEC 61970-301:2013, 4.4.3, Names model, should define additional standard name types for SCL.

Table 7 – Proposed CIM NameType class naming conventions

Name	Description
ICCP	Reserved for ICCP (TASE-2) names. Used to describe ICCP point names for the MeasurementValue class and ICCP source names for the MeasurementValueSource class
SCL.name	Reserved for entity names defined in IEC 61850 Substation Configuration Language (SCL) files. Within SCL the name is the identification of the object within its container. It is unique within the container.
SCL.id	Reserved for entity path names defined in IEC 61850 Substation Configuration Language (SCL) files. Within SCL the path name is the identification of the object within the file. It is unique within the file.

5.8 Voltage mapping

5.8.1 General

The Voltage entity states the nominal voltage used at the containing voltage level, and maps directly to the CIM BaseVoltage entity.

Table 8 – Base voltage mapping

Attribute	SCL Description	CIM Mapping
multiplier	Character representing the unit multiplier enumeration e.g. ‘k’ means 1000	BaseVoltage.nominalVoltage.unitMultiplier
unit	Character string representing the units e.g. ‘V’ means volts	BaseVoltage.nominalVoltage.unit
value	Numeric value for the voltage	BaseVoltage.nominalVoltage.value

5.8.2 Voltage mapping example

```
<Voltage multiplier="k" unit="V">220</Voltage>
```

```
BaseVoltage.nominalVoltage.value = 220
BaseVoltage.nominalVoltage.unit = “V”
BaseVoltage.nominalVoltage.multipler = “k”
```

5.8.3 Voltage level additional attributes

The SCL voltage level has the following additional attributes:

Attribute	SCL Description	CIM Mapping
nomFreq	the nominal frequency in Hz, 0 for DC systems. If missing, the nominal frequency is not known	BaseFrequency.frequency
numPhases	the number of phases of the single line considered, typically 1, 2 or 3. If missing, not known.	No direct mapping Can be used for consistency checking with phase information – see 5.10

5.9 Connectivity modelling

5.9.1 SCL Connectivity (single line diagram) modelling

The connectivity UML model is shown in Figure 7.

[IEC 61850-6:2009, 6.2] *The single line diagram of a switch yard shows the electrical connections between these primary devices. Connectivity node objects model these connections. Therefore, each primary device can contain at its terminals references to the connectivity nodes to which it is connected. At single line level, one or two terminals (connections) per equipment are normally sufficient.*

[IEC 61850-6:2009, 9.2.4] … *The second terminal for a power transformer winding is only foreseen for a neutral point connection terminal, to which e.g. (one phase) earthing switches can be connected. Only one neutral point connection terminal is allowed per winding.*

Equipment terminal identifications are in general only needed if the device polarizes the power flow, i.e. the connections are not interchangeable. If the terminal name attribute is left empty, but a terminal designation is needed, then the default is the equipment identification (substationName voltageLevelName bayName equipmentName) together with the connectivity node identification connectivityNode.

There is one predefined connectivity node with the name ***grounded****. This is used to model earth potential. Thus, an earthing switch is an isolator (equipment type DIS) that is connected on one side to the connectivity node* ***grounded****.*

Following the normal rules for unique names, there can only by one connectivity node called “grounded” per bay.

Table 9 shows the mapping for attributes of Terminal and Table 10 shows the attributes for ConnectivityNode.

Table 9 – Attributes for terminal

Attribute	SCL Description	CIM mapping
name	(optional) The relative name of the terminal at this Equipment. The default is the empty string, which means that the name of the ConnectivityNode is also the terminal identification.	Name.name where Name is associated with a NameType “SCL.name” If empty, then copy the connectivityNode attribute
desc	Descriptive text to the terminal	IdentifiedObject.name If blank use ‘1’ or ‘2’ depending on the order in the source file
connectivityNode	Unique pathname of the connectivity node to which this terminal connects. See recommendation in following section	Use to determine association with ConnectivityNode
processName	The name of the process containing the connectivityNode	Not required Can be used to validate the association with ConnectivityNode
lineName	(optional) The name of a line element containing the connectivityNode (only used inside Line element)	Not required Can be used to validate the association with ConnectivityNode
substationName	(optional) The name of the Substation containing the connectivityNode	Not required Can be used to validate the association with ConnectivityNode
voltageLevelName	The name of the VoltageLevel containing the connectivityNode	Not required Can be used to validate the association with ConnectivityNode
bayName	The name of the Bay containing the connectivityNode	Not required Can be used to validate the association with ConnectivityNode
cNodeName	The (relative) name of the connectivityNode within its bay	Not required Can be used to validate the association with ConnectivityNode

NOTE The path name reference allows checking of the connection consistency already on XML schema level, while the attribute list is easier to interpret by most tools.

Table 10 – Attributes for ConnectivityNode

Attribute	SCL Description	CIM mapping
name	identifies the ConnectivityNode instance within the bay	Name.name where Name is associated with a NameType "SCL.name"
desc	user oriented textual designation	IdentifiedObject.name
pathName	is an absolute reference within the SCL file. The pathname is built by all higher-level references down to the connectivity nodes name, concatenated with the character "/" For instance, if the connectivity node L1 is within bay Q2 of voltage level E1 of substation Baden, then the pathname is "Baden/E1/Q2/L1".	Name.name where Name is associated with a NameType "SCL.id"

5.9.2 Recommendation for harmonization: SCL unconnected terminals

The SCL method of modelling equipment that is not connected is inconsistent with CIM models. The CIM allows Equipment and their Terminals to be defined regardless of whether they are connected or not. Allowing unconnected terminals to be indicated by possible (but not guaranteed) removal of a terminal element does not facilitate automatic mapping.

Recommendation R8: In IEC 61850-6:2009, Table 6, Attributes of the Terminal element, change the description ConnectivityNode.

Current text: "If the Equipment shall not be connected, then the whole Terminal element shall be removed."

Proposed text: "If the Equipment shall not be connected, then the whole Terminal element shall be preserved. The Terminal attribute connectivityNode may be the name of a normal ConnectivtyRule or it may have the special value 'None'".

5.9.3 Connectivity and Terminal example

Figure 9 shows an example of part of a system specification SSD. This defines a substation with two voltage levels E1 (220kV) and F1 (110kV), connected by a transformer T1. Each voltage level contains a bay (E1/Q1 or F1/Q1) that contains a busbar; and other bays (E1/Q2 or F1/Q2) for the switch-gear. The bay F1/Q2 has a circuit breaker (CB12), a disconnector (DIS13) and instrument transformers for measuring current (CT1) and voltage (PT1).

SCL rules require that equipment names are unique within the containing bay. As shown in the example, it is equally possible to use unique names for each of the switch gear within the substation.

Within the SCL file, each equipment has one or two child Terminal entities which are connected to ConnectivityNodes. Each ConnectivityNode has a unique pathname based on the containment hierarchy, for example S1/F1/Q1/BB2.

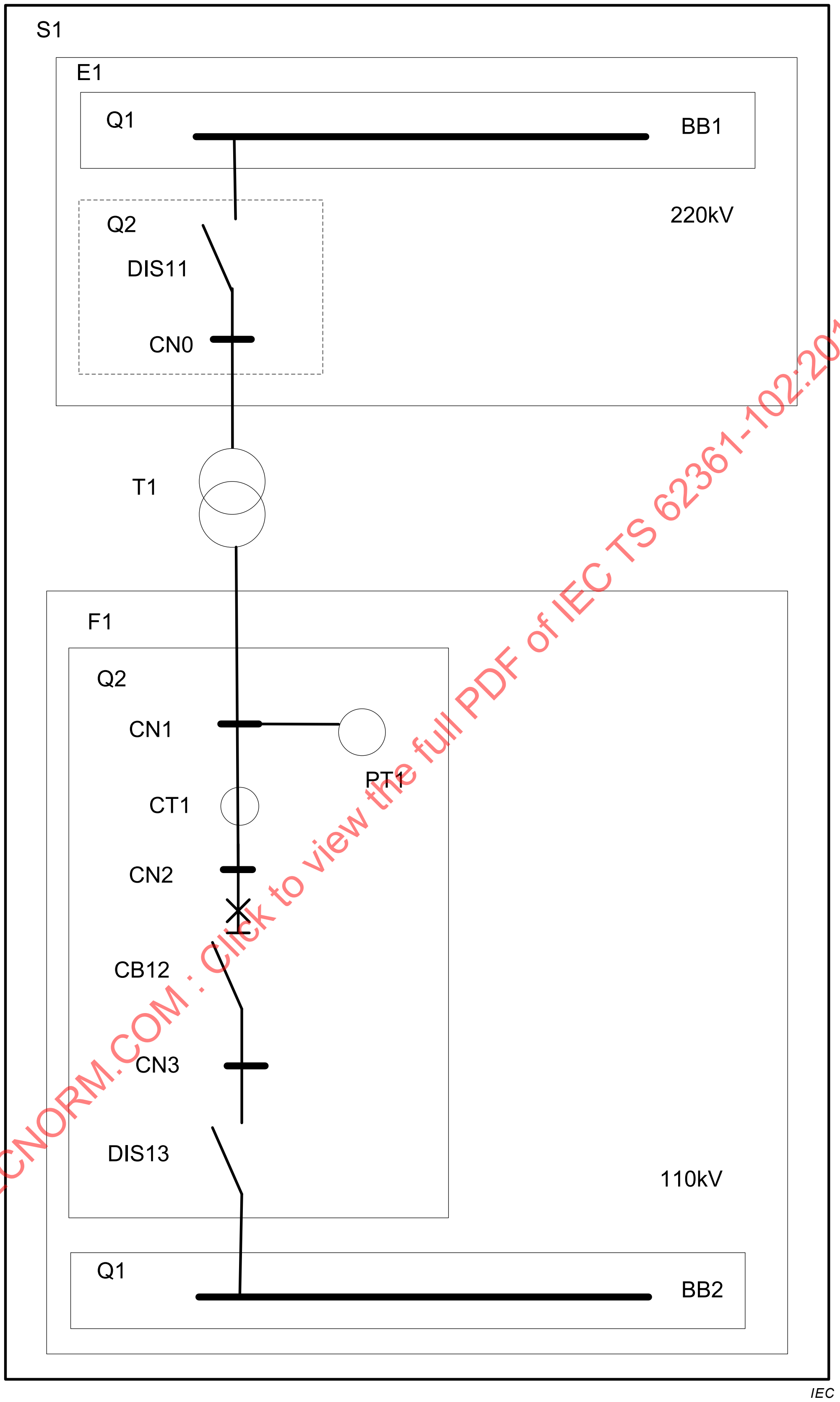


Figure 9 – Substation section connectivity example

The corresponding SCL model is:


```xml
<?xml version="1.0" encoding="utf-8"?>
<SCL version="2007" revision="B" xmlns="http://www.iec.ch/61850/2003/SCL"
xsi:schemaLocation="http://www.iec.ch/61850/2003/SCL SCL.xsd"
xmlns:xsd="http://www.w3.org/2001/XMLSchema" xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance">
  <Header id="ConnectivityExample" version="0" revision="1" toolID="SchneiderElectric-SET"
nameStructure="IEDName" />

  <Substation name="S1" desc="Grenoble North">
    <PowerTransformer type="PTR" name="T1" desc="">
      <TransformerWinding type="PTW" name="W1">
        <Terminal name="TERMINAL0" connectivityNode="S1/E1/Q2/CN0"
          substationName="S1" voltageLevelName="E1" bayName="Q2" cNodeName="CN0"/>
      </TransformerWinding>
      <TransformerWinding type="PTW" name="W2">
        <Terminal name="TERMINAL0" connectivityNode="S1/F1/Q2/CN1"
          substationName="S1" voltageLevelName="F1" bayName="Q2" cNodeName="CN1"/>
      </TransformerWinding>
    </PowerTransformer>

    <VoltageLevel name="E1" desc="220 kV">
      <Voltage unit="V" multiplier="k">220</Voltage>
      <Bay name="Q1" desc="220kV Busbar">
        <ConnectivityNode pathName="S1/E1/Q1/BB1" name="BB1" desc=""/>
      </Bay>
      <Bay name="Q2" desc="T1 HV side">
        <ConductingEquipment type="DIS" name="DIS11" desc="">
          <Terminal name="TERMINAL0" connectivityNode="S1/E1/Q1/BB1"
           substationName="S1" voltageLevelName="E1" bayName="Q1" cNodeName="BB1"/>
          <Terminal name="TERMINAL1" connectivityNode="S1/E1/Q2/CN0"
           substationName="S1" voltageLevelName="E1" bayName="Q2" cNodeName="CN0"/>
        </ConductingEquipment>
        <ConnectivityNode pathName="S1/E1/Q2/CN0" name="CN0" />
      </Bay>
    </VoltageLevel>

    <VoltageLevel name="F1" desc="110 kV">
      <Voltage unit="V" multiplier="k">110</Voltage>
      <Bay name="Q1" desc="110kV Busbar">
        <ConnectivityNode pathName="S1/F1/Q1/BB2" name="BB2" desc=""/>
      </Bay>
      <Bay name="Q2" desc="T1 LV side">
        <ConductingEquipment type="DIS" name="DIS13" desc="">
          <Terminal name="TERMINAL0" connectivityNode="S1/F1/Q1/BB2"
           substationName="S1" voltageLevelName="F1" bayName="Q1" cNodeName="BB2"/>
          <Terminal name="TERMINAL1" connectivityNode="S1/F1/Q2/CN3"
           substationName="S1" voltageLevelName="F1" bayName="Q2" cNodeName="CN3"/>
        </ConductingEquipment>
        <ConductingEquipment type="CTR" name="CT1" desc="">
          <Terminal name="TERMINAL0" connectivityNode="S1/F1/Q2/CN1"
           substationName="S1" voltageLevelName="F1" bayName="Q2" cNodeName="CN1"/>
          <Terminal name="TERMINAL1" connectivityNode="S1/F1/Q2/CN2"
           substationName="S1" voltageLevelName="F1" bayName="Q2" cNodeName="CN2"/>
        </ConductingEquipment>
        <ConductingEquipment type="VTR" name="PT1" desc="">
          <Terminal name="TERMINAL0" connectivityNode="S1/F1/Q2/CN1"
           substationName="S1" voltageLevelName="F1" bayName="Q2" cNodeName="CN1"/>
        </ConductingEquipment>
        <ConductingEquipment type="CBR" name="CB12" desc="">
          <Terminal name="TERMINAL0" connectivityNode="S1/F1/Q2/CN2"
           substationName="S1" voltageLevelName="F1" bayName="Q2" cNodeName="CN2"/>
          <Terminal name="TERMINAL1" connectivityNode="S1/F1/Q2/CN3"
           substationName="S1" voltageLevelName="F1" bayName="Q2" cNodeName="CN3"/>
        </ConductingEquipment>
        <ConnectivityNode pathName="S1/F1/Q2/CN1" name="CN1" desc=""/>
        <ConnectivityNode pathName="S1/F1/Q2/CN2" name="CN2" desc=""/>
        <ConnectivityNode pathName="S1/F1/Q2/CN3" name="CN3" desc=""/>
      </Bay>
```

```
  </VoltageLevel>
 </Substation>
</SCL>
```

5.9.4 Transformation of current transformer models

In the SCL a current transformer is modelled as a two-terminal device. In the CIM a current transformer is modelled as a single terminal device. In the example, this means the mapping process must merge the two connectivity nodes `S1/F1/Q2/CN1` and `S1/F1/Q2/CN2`.

It is typical that CIM Network topology processing ignores CT and PT placement. However, the model differences may still need to be reconciled if the CT failure can disrupt power flow.

Therefore, if the CT is not removed from the CIM model, it is suggested that the Terminal/ConnectivityNode with the fewest Terminals attached to the ConnectivityNode be removed. The removal of the ConnectivityNode should not occur if there are more than two terminals attached to the ConnectivityNode. If both SCL ConnectivityNodes have the same number of Terminals connected, then the choice is a local issue.

NOTE Future versions of CIM may change the CurrentTransformer to be a specialization of ConductingEquipment (e.g. it may become a type of FlowSensor). If this change occurs within CIM, then no removal or transformation from SCL ConnectivityNodes/Terminals to CIM would be required.

5.10 Phase modelling

5.10.1 General

High voltage switchgear may physically consist of separate equipment for each phase. As described in IEC TR 61850-7-500, for switchgear like circuit breakers with three-phase control (i.e. all the three phases are operated always together) only one instance of equipment and one XCBR logical node may be sufficient for modelling.

If it is possible to operate individual phases independently then it is necessary to model this in the SCL as one instance of Equipment and three instances of SubEquipment each with a XCBR node, i.e. a total of four XCBR nodes. The actual transformation that will need to occur is dependent upon the target CIM model being a three-phase equivalent model or modelling of individual phases.

This is shown in Figure 10 (from IEC TR 61850-7-500). Normally, this would be modelled as a single instance of a switch on the CIM side. In general, it is recommended to avoid the modelling of the individual phases of the SubEquipment in CIM.

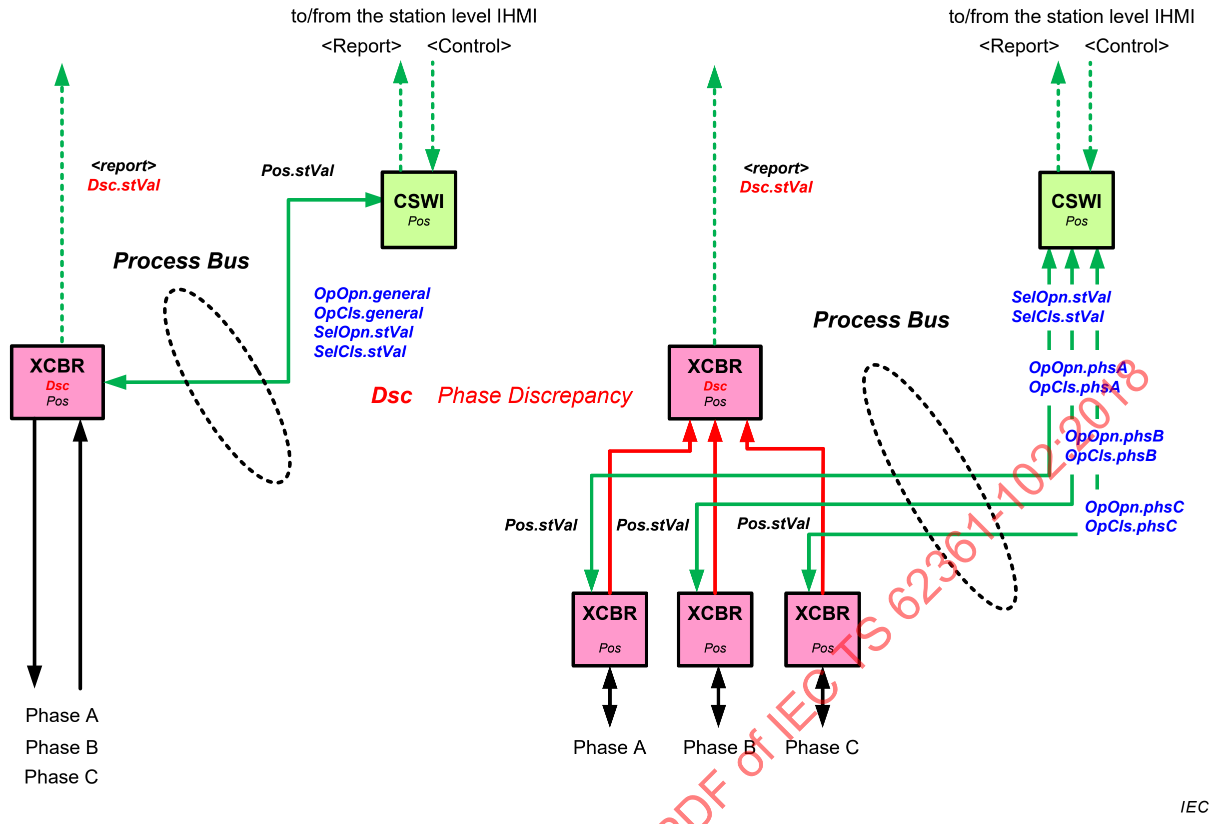


Figure 10 – Three-phase (left) and single-phase control (right)

Each of the three instances of SubEquipment will have a different value for its “phase” attribute. This is an enumeration to describe the “The phase to which the subEquipment belongs. The following phase values are allowed: A, B, C, N (neutral), all (meaning all three phases), none (default, meaning not phase related). The following additional values are only allowed, if the ConductingEquipment above has type VTR: AB, BC, CA, meaning a VT connected in between the appropriate phases.”

Distribution networks often use two phase circuits in rural areas, and may use single-phase or two-phase switchgear and transformers to supply individual premises. For these types of equipment, the SCL model requires one instance of Equipment, and two instances of SubEquipment in order to specify which phases are connected. If both phases are always operated together, then the CIM model only needs one instance corresponding to the Equipment.

Within CIM, phases are described by the phases attribute in the Terminal classes associated with the Breaker, Switch or other type of conducting equipment. Table 11 shows the phase codes in SCL and CIM.

Table 11 – Comparison of IEC 61850 and CIM Phase values

IEC 61850 SCL	CIM (PhaseCode)	CIM (SinglePhaseKind)	Comment
A	A	A	
B	B	B	
C	C	C	
N	N	N	
all	ABC		all means all three phases
none			Indicates non-phase related
AB	AB		
BC	BC		
CA	AC		
	AN		
	BN		
	CN		
	ABCN		
	ABN		
	ACN		
	BCN		
	s1	s1	Secondary Phase 1
	s2	s2	Secondary Phase 2
	s12		Secondary Phase 1 and 2
	s1N		Secondary Phase 1 and Neutral
	s2N		Secondary Phase 2 and Neutral
	s12N		Secondary Phase 1 and 2 and Neutral

5.10.2 Phase mapping example

5.10.2.1 General

Table 12 shows the mapping for various scenarios using a Breaker as an example.

Table 12 – Breaker mapping scenarios

Scenario	SCL	CIM mapping
Three-phase equipment	One instance of Equipment, no instances of SubEquipment	One instance of Breaker, Terminal.phases = ABC
3 times 1 phase equipment	One instance of Equipment Three instances of SubEquipment	One instance of Breaker, Terminal.phases = ABC
2 phase equipment operated with both phases together	One instance of Equipment Two instances of SubEquipment	One instance of Breaker, with Terminal.phases = concatenation of SubEquipment[1] phase and SubEquipment[2].phase
Two breakers operating on different phases	Two instance of Equipment each with one instances of SubEquipment	Two instances of Breaker One with Terminal.phases = A One with Terminal.phases = B

Two examples are described below: a two phase breaker example and an unbalanced switching example.

5.10.2.2 Two Phase Breaker Example

The example SCL in clause 5.9.3 is for three-phase equipment (first line of Table 12). If the transformer or switch-gear used two phases only but with a simultaneous command (third line of Table 12), then the corresponding SCL would be:

```
<Bay name="Q02" desc="T1 LV side">
 <ConductingEquipment type="CBR" name="CB12" desc="">
  <Terminal name="TERMINAL0" connectivityNode="S1/F1/Q2/CN2" substationName="S1"
voltageLevelName="F1" bayName="Q2" cNodeName="CN2"/>
  <Terminal name="TERMINAL1" connectivityNode="S1/F1/Q2/CN3" substationName="S1"
voltageLevelName="F1" bayName="Q2" cNodeName="CN3"/>
      <SubEquipment name="X1" phase="A />
      <SubEquipment name="X1" phase="B" />
 </ConductingEquipment>
</Bay>
```

The equivalent CIM model would be to have a Circuit Breaker XA2 with Terminals T1 and T2. The phases attribute in both T1 and T2 would have the value of “AB”.

5.10.2.3 Unbalanced example

Figure 11 illustrates the mapping for an unbalanced system where each phase can be independently controlled.

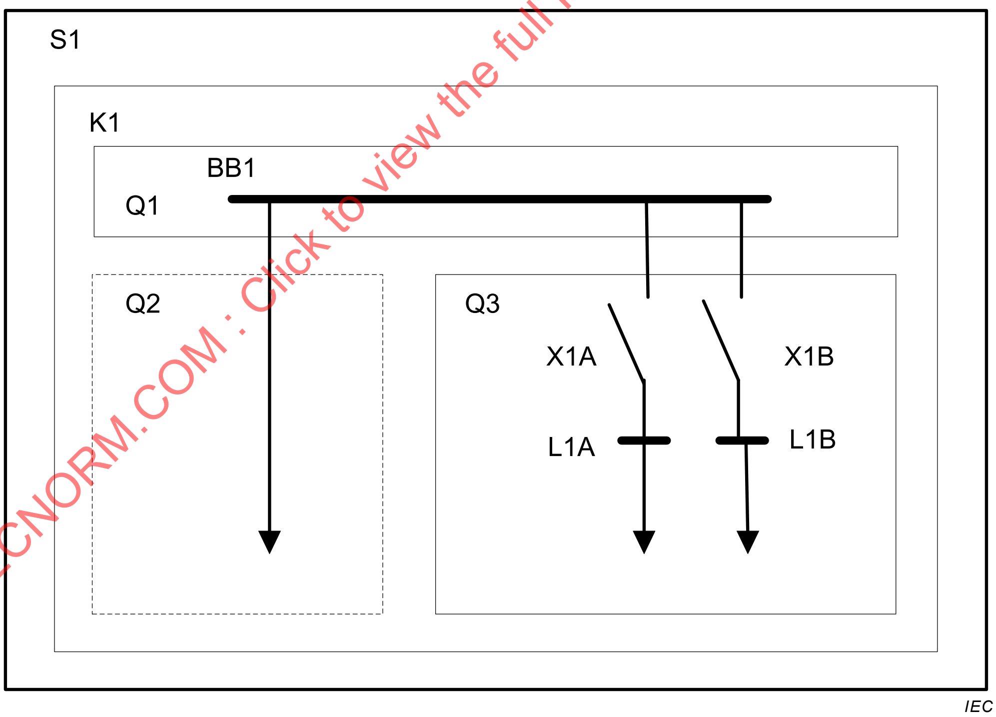


Figure 11 – Unbalanced phase switching example

The SCL would be:

```
<?xml version="1.0" encoding="utf-8"?>
<SCL version="2007" revision="B" xmlns="http://www.iec.ch/61850/2003/SCL"
xsi:schemaLocation="http://www.iec.ch/61850/2003/SCL SCL.xsd"
xmlns:xsd="http://www.w3.org/2001/XMLSchema" xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance">
  <Header id="UnbalancedPhases" version="0" revision="1" toolID="SchneiderElectric-SET"
nameStructure="IEDName" />
  <Substation name="S1" desc="">
    <VoltageLevel name="K1" desc="">
      <Voltage unit="V" multiplier="k">20</Voltage>
      <Bay name="Q1" desc="Busbar">
        <ConnectivityNode pathName="S1/K1/Q1/BB1" name="BB1" desc=""/>
      </Bay>

      <Bay name="Q2" desc="Infeed">
        <ConductingEquipment type="IFL" name="IFL1" desc="">
          <Terminal name="TERMINAL0" connectivityNode="S1/K1/Q1/BB1"
           substationName="S1" voltageLevelName="K1" bayName="Q1" cNodeName="BB1"/>
        </ConductingEquipment>
      </Bay>

      <Bay name="Q3" desc="Outgoing feeders">
        <ConductingEquipment type="LIN" name="LIN1" desc="">
          <Terminal name="TERMINAL0" connectivityNode="S1/K1/Q3/L1A"
            substationName="S1" voltageLevelName="K1" bayName="Q3" cNodeName="L1A"/>
          <SubEquipment name="phsA" phase="A"/>
          <SubEquipment name="neut" phase="N"/>
        </ConductingEquipment>
        <ConductingEquipment type="LIN" name="LIN2" desc="">
          <Terminal name="TERMINAL0" connectivityNode="S1/K1/Q3/L1B"
            substationName="S1" voltageLevelName="K1" bayName="Q3" cNodeName="L1B"/>
          <SubEquipment name="phsB" phase="B"/>
          <SubEquipment name="neutB" phase="N"/>
        </ConductingEquipment>
        <ConductingEquipment type="DIS" name="X1A" desc="">
          <Terminal name="TERMINAL0" connectivityNode="S1/K1/Q3/L1A"
           substationName="S1" voltageLevelName="K1" bayName="Q3" cNodeName="L1A"/>
          <Terminal name="TERMINAL1" connectivityNode="S1/K1/Q1/BB1"
           substationName="S1" voltageLevelName="K1" bayName="Q1" cNodeName="BB1"/>
          <SubEquipment name="X1" phase="A"/>
        </ConductingEquipment>
        <ConductingEquipment type="DIS" name="X1B" desc="">
          <Terminal name="TERMINAL0" connectivityNode="S1/K1/Q3/L1B"
           substationName="S1" voltageLevelName="K1" bayName="Q3" cNodeName="L1B"/>
          <Terminal name="TERMINAL1" connectivityNode="S1/K1/Q1/BB1"
           substationName="S1" voltageLevelName="K1" bayName="Q1" cNodeName="BB1"/>
          <SubEquipment name="X1" phase="B"/>
        </ConductingEquipment>e<ConnectivityNode pathName="S1/K1/Q3/L1A"e"L1A" desc=""/>
        <ConnectivityNode pathName="S1/K1/Q3/L1B" name="L1B" desc=""/>
      </Bay>
    </VoltageLevel>
  </Substation>
</SCL>
```

This example shows that each circuit breaker is associated with a single phase. Each outgoing feeder has two child SubEquipment, one for the phase connection and one for the neutral connection.

The equivalent CIM model would be to have two Circuit Breakers X1A and X1B. Each terminal of Breakers X1A and X1B would have a different value for the phases attribute.

5.10.3 Recommendation for harmonization: SCL Phase modeling

The SCL enumeration for phases is more restricted than the PhaseCode enumeration defined in the CIM. It suits the physical equipment found in large substations but is inefficient for modelling equipment found in distribution networks or consumer premises. At present users are forced to define sets of Equipment and SubEquipment instances in order to model single real-world devices.

Recommendation R9: In IEC 61850-6, extend the existing PhaseEnum to use the same enumerations as the CIM PhaseCode. Since IEC 61850 Equipment is for topology purposes only, there are no real attributes that can be defined except the use of SubEquipment.

5.10.4 Recommendation for harmonization: CIM SinglePhaseKind

Recommendation R10: There are two enumerations in CIM: one for single phase and the other for all phase enumerations. It is recommended that the CIM is updated to state that the SinglePhaseKind enumerations should not be used in new projects.

6 Extension syntax for drawing layout coordinates

6.1 General

IEC 61850-6:2009, C.1 defines a simple SCL extension to add coordinates to objects, so that they can be easily shown on a drawing. This is sufficient for a lot of drawing tasks, and serves here as an example of an extension of the SCL language by another name space.

The handling (for example drawing) of object connections as well as the packaging of objects into drawing pages is private to the interpreting application. Typical drawings could be that of a substation as substation single line, a bay as bay single line and the communication section as a communication configuration drawing.

The coordinate system is a relative *x, y* system with coordinates using positive integer numbers. The point (0,0) is the upper left point of a drawing plane which is unlimited to downwards and right direction. The unit 1 principally refers to the size of an object. If different object sizes are used, then 1 is the size of the smallest object. This is similar to the graphics information within CIM.

However, recent testing and utility requests have indicated that the use of x, y coordinates is not sufficient. There are several functional areas that have been requested to be addressed:

- X,Y coordinates do not provide the same visual layout as algorithms differ, users of IEC 61850 would like “portable” displays.
- The current technology, in IEC 61850 or CIM, does not have explicit behaviour associated with the objects. Users of IEC 61850 would like the “portable” displays to have defined behaviour (e.g. colours/blinking for certain values).
- The X, Y coordinates, in both IEC 61850 and CIM, do not allow for animated text. The technology being investigate as a replacement for X, Y coordinates will need to allow text/values to be placed on the display as well as Equipment/Conducting Equipment.

6.2 Recommendation for harmonization: Drawing layout syntax

Recommendation R11: Create a joint task force to produce a document defining drawing layout syntax using technology similar to Scalable Vector Graphics (SVG) to replace the X, Y coordinate/graphics in both IEC 61850 and CIM. This task force should consider the requirements and objectives which may be different for configuration tools, control centre applications or local SCADA HMIs. There may be several views or diagrams for the same equipment.

7 Logical Node mapping

7.1 Logical Node containers

A full System Configuration Description file will define the instances of Logical Nodes that are attached to containers such as substation, voltage level, bay, equipment, sub-equipment, function, or sub-function. Within IEC 61850, Logical Node instances are contained by IEDs. These IEDs may be located in close proximity to the primary or auxiliary equipment that the IED is controlling or monitoring, or they may be located in a centralised control cubicle connected by the communication network. In all cases, it is the equipment/power system resource to which the Logical Node is associated that determines the measurements that are produced. The physical location of the IED has no bearing on these measurements. In some instances, the IED may act as a Bay Controller or a Substation Controller.

IEC 61850 allows Logical Nodes to be associated at all levels of the PowerSystem hierarchy e.g. Substation, VoltageLevel, Bay, and primary equipment. Therefore, the SCL System designer has no restriction on where the Logical Nodes are placed, or to what type of equipment/PowerSystemResources, within the Substation section of an SCL file. In general, Logical Nodes placed at the substation or bay level represent calculated or aggregate values.

Measurements that are to be used by network analysis functions such as State Estimation, or Load flow need to be associated with the specific equipment terminals.

As described in 5.10, Phase modelling, high voltage switchgear or other equipment may physically consist of separate equipment for each phase. For switchgear like circuit breakers with three-phase control (i.e. all the three phases are always operated together), it usually sufficient to model this with one instance of equipment and one XCBR logical node. If it is possible to operate individual phases independently, then the CIM model should have an equipment instance for each phase, each of which could have its own associated Logical Nodes.

7.2 CIM Measurement associations

7.2.1 General

A IEC 61850 IED is a type of a CIM RemoteUnit. RemoteUnits are associated with Communication Links. This association corresponds to IEC 61850 Communication Access Points as described in Clause 12, Communication model.

The current CIM SCADA package differentiates between {RemotePoints, RemoteSource} versus {MeasurementValues, MeasurementValueSource}. It is proposed that the current SCADA package be changed (see Figure 12) in order to more closely align with IEC 61850.

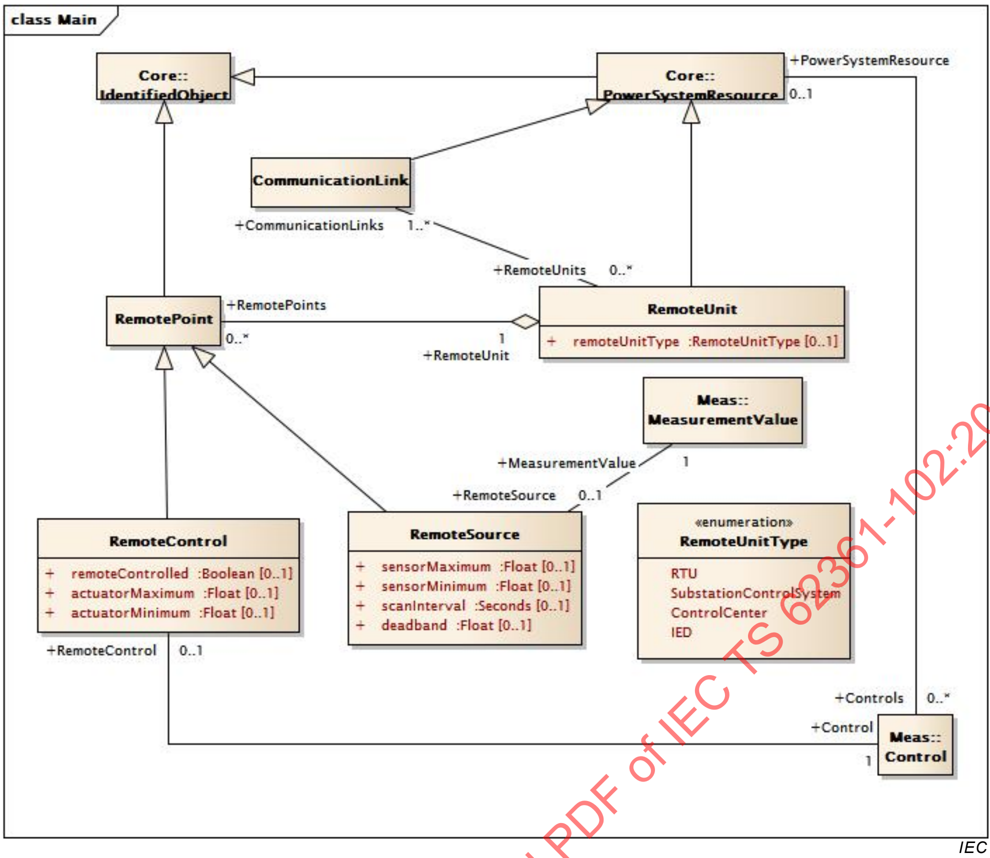


Figure 12 – Current CIM SCADA package

7.2.2 Recommendation for harmonization: CIM SCADA package

Recommendation R12: Revise the IEC 61970 SCADA package as proposed in Figure 13. The major change is to make a RemoteUnit a specialization of MeasurementValueSource and to separate the semantics of scan/update interval versus SCADA limit information. This change allows the merging of the Measurement and SCADA models and allows RemoteUnits and IEDs to be directly associated with the MeasurementValues that are being sourced.

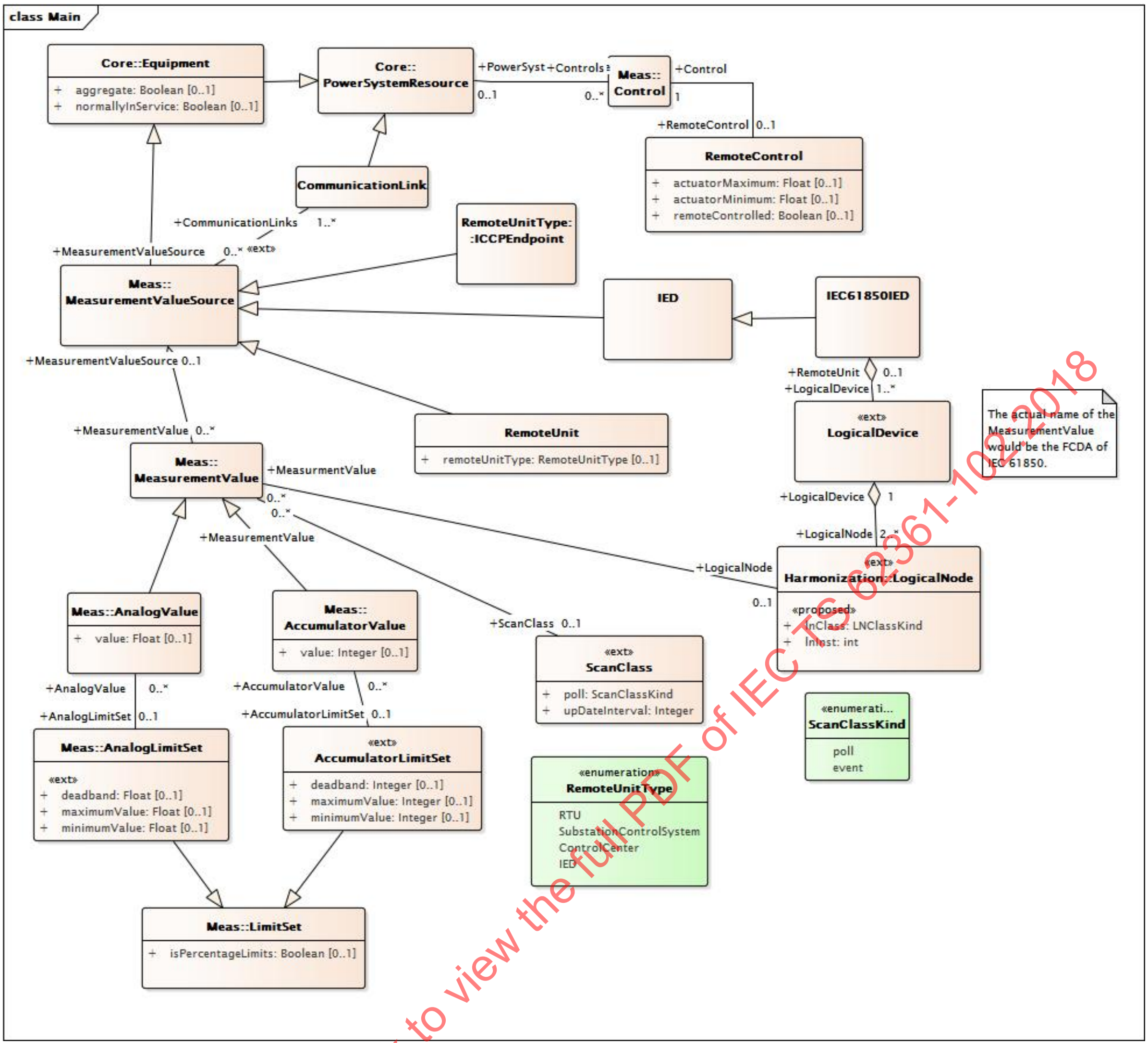


Figure 13 – Revised SCADA package

7.3 Logical Node classes relevant to CIM

Table 13 lists logical nodes classes from IEC 61850-7-4 that have information relevant to specific CIM entities in applications such as state estimation. Logical Nodes for automation (Axxx), control (Cxxx) and Supervisory (Sxxx) functions have been grouped with the logical nodes directly associated with the primary equipment ((Xxxx, Yxxx, Zxxx).

Most Logical Nodes for instrument transformers and sensors (Txxx) have been omitted from the list as their outputs are expected to be internal to any IEC 61850 automation system and not transmitted directly to a control centre.

Logical Nodes that are not listed have no specific corresponding model in CIM. Some of these Logical Nodes, for example STMP for temperature supervision, may also have data that is useful to CIM applications. Data objects within these Logical Nodes can be mapped to Discrete or Analog measurements associated with any type of CIM power system resource.

From the IEC 61850 communication perspective, there is no difference between alarms and events. Communication events can be generated for any status change. IEC 61850-7-4 defines around 50 status data objects for specific alarm conditions. GGIO and GAPC logical nodes have no standard semantic meaning and hence any mapping to CIM must use local mapping rules or tables.

Clause 8 describes the data objects related to real time information exchange. Clause 13 describes data objects related to settings and other attributes.

Table 13 – Mapping IEC 61850 Logical Nodes to CIM classes

Logical Nodes IEC 61850-7-4	Node Description IEC 61850-5	Associated CIM Classes
GGIO	Models in a generic way process devices that are not predefined by the groups S, T, X, Y, or Z.	Discrete
GUNT	Production unit operating mode [Draft IEC 61850-7-410]	GeneratingUnit
MMXN	Calculation of currents, voltages, powers and impedances in a system where voltages and currents are not phase-related, mainly for operative applications	Several instances of Analog
MMXU	Calculation of currents, voltages, powers and impedances in a three-phase system. The main use is for operative applications	Several instances of Analog
MMTN	Calculation of energy in a single-phase system, for billing purposes.	Several instances of Accumulator
MMTR	Calculation of energy in a three-phase system, for billing purposes.	Several instances of Accumulator
MSQI	Sequence and imbalance measurements	Several instances of Analog
PIOC, PTOC	Instantaneous over-current, time over-current	CurrentRelay (a subtype of ProtectionEquipment)
Pxxx	Any protection functions other than PIOC, PTOC	ProtectionEquipment see Clause 11
RREC	A function that controls the automatic reclosing and locking out of an a.c. circuit breaker.	RecloseSequence
RSYN CSYN	A synchronizing function that produces a release for a closing command of a circuit breaker between two circuits whose voltages are within prescribed limits of magnitude, phase angle, and frequency. CSYN is used to control the synchronizing conditions	SynchrocheckRelay
SFPI	Fault Passage Indication Proposed in draft IEC TR 61850-90-6	FaultIndicator
SIML, SIMG	Media supervision typically associated with insulation liquid and gas supervision of PowerTransformers.	PowerTransformer Breaker
TCTR	instrument transformers with all its data and related settings (if applicable), and communication relevant behaviour	CurrentTransformer
TVTR	instrument transformers with all its data and related settings (if applicable), and communication relevant behaviour	PotentialTransformer
XCBR, CSWI, SCBR	The LN “circuit breaker” covers all kind of circuit breakers, i.e. switches able to interrupt short circuits	Breaker
XFUS	Models a fuse which can be described as a switch that is normally closed but can only open once. This equipment cannot be controlled. [IEC 61850-7-420]	Fuse

Logical Nodes IEC 61850-7-4	Node Description IEC 61850-5	Associated CIM Classes
XSWI, CSWI, SSWI	The LN “switch” covers all kind of switching devices not able to switch short circuits	Switch Disconnector Jumper LoadBreakSwitch GroundDisconnector
YEFN, ANCR	Variable inductance (plunge core coil) allowing adaptive grounding of transformer star point to minimize the ground fault current. (Petersen coil monitoring)	PetersenCoil
YLTC, ATCC, SLTC, AVCO	Transformer tap changer, automatic tap change controller, tap changer supervision, automatic voltage controller	TapChanger RatioTapChanger PhaseTapChanger others
YPSH	Power shunt to bypass the resistor of a resistive grounded transformer star point for fault handling.	GroundingImpedance
YPTR, SPTR	Connects in different configurations (∆, Y, two/three windings) the voltage levels of the power system.	PowerTransformer
ZAXN	Generic node for information exchange with auxiliary networks (power supplies)	No corresponding CIM class
ZBAT	Provides data about battery status and for control of the charging/de-charging cycles	No corresponding CIM class
ZBTC	Remote monitoring and control of critical auxiliary battery chargers [IEC 61850-7-420]	No corresponding CIM class
ZBSH	Provides properties and supervision of bushings as used for transformers or GIS-line connections	Connector
ZCAB	Supervised power system element	ACLineSegment
ZCAP, ARCO, AVCO	Controls reactive power flow	ShuntCompensator SeriesCompensator
ZCON	Frequency conversion including AC/DC conversion	FrequencyConverter
ZGEN, AVCO	Generic node for information exchange with generators	GeneratingUnit
ZGIL	Mixture of data from SIMS, SARC and SPDC	ACLineSegment
ZINV	Inverter for converting direct current to alternating current (DC -> AC) [IEC 61850-7-420]	ACDCConverter
ZLIN	Supervised overhead line	ACLineSegment
ZMOT	Generic node for information exchange with motors	AsynchronousMachine
ZRCT	Rectifier for converting alternating current to continuous, direct current (AC -> DC), [IEC 61850-7-420]	ACDCConverter
ZREA, ARCO, AVCO	Controls reactive power flow	ShuntCompensator SeriesCompensator
ZRES, ARIS	Used to represent an ohmic resistor. A typical application is the resistor of the star point (a neutral resistor). This resistor is normally not controlled.	EarthFaultCompensator
ZRRC	Controls reactive power flow	SynchronousMachine
ZSAR	Generic node for information exchange with surge arresters	SurgeArrester

Logical Nodes IEC 61850-7-4	Node Description IEC 61850-5	Associated CIM Classes
ZSCR	Used to represent a controllable rectifier. A typical use is to provide the controllable d.c. current within an excitation system.	ACDCConverter
ZSMC	Logical node ZSMC shall be used to represent any type of synchronous machine. The logical node only includes rating data.	SynchronousMachine
ZTCF	Frequency conversion (thyristor controlled) including AC/DC conversion	FrequencyConverter
ZTCR	Reactive component (thyristor controlled), for reactive power control	StaticVarCompensator

8 Measurement mapping

8.1 General

Mapping IEC 61850 measurements to the CIM requires mapping of Logical Node classes, Data Object names, and Data attribute names.

This document is mainly concerned with IEC 61970-301 and the mapping for IEC 61968-11 is incomplete. See description of IEC 61968-11 ReadingType in 8.6.

8.2 CIM Measurement Types – Logical Node and Data Object mapping

8.2.1 General

IEC 61970-301:2013, Table 2 presents a list of measurementType naming conventions but states “It shall be noted that Table 2 is not an exhaustive list”. Other lists of measurement types are given for specific profiles, e.g. IEC 61970-452, *Energy management system application program interface (EMS-API) – Part 452: CIM Static transmission network model profiles*.

IEC 61850-7-4 defines a large number of data objects for different types of measurement. Some of these data objects are controllable. The same data object identification is used for both monitoring and control services. In some cases, such as temperature, there may be specific data objects depending on what is being measured by the Logical Node.

Table 14 is based on IEC 61970-301:2013, Table 2 and shows how the currently defined CIM Measurement Types can be mapped onto IEC 61850 logical node and data objects. Table 15 is the equivalent list for non-phase related measurements. There are many other data objects such as minimum or maximum measurement values which are not referred to in the IEC 61970 series. Such data objects can be mapped based on their IEC 61850 Common Data Class (CDC) as described in Table 17.

IEC 61970-301 has a similar modelling concept for Controls and controlType but does not define a table of naming conventions. Table 16 shows some typical control data objects from IEC 61850.

The relevant Data Attributes are described in Table 19

Table 14 – IEC 61850 DataObjects vs Current CIM measurement types

IEC 61850 Logical Node	IEC 61850 Data Object	IEC 61850 CDC	IEC 61850 Description	IEC 61970-301 or IEC 61970-452 MeasurementType	Subclass of CIM Measurement
MMXU	TotVA	MV	Total apparent power in a three phase circuit	ThreePhasePower	Analog
MMXU	TotW	MV	Total real power in a three phase circuit	ThreePhaseActivePower	Analog
MMXU	TotVAr	MV	Total reactive power in a three phase circuit	ThreePhaseReactivePower	Analog
MMXU	TotPF	MV	Average power factor (total PF)	ThreePhasePowerFactor	Analog
MMXU	A	WYE	Phase currents (magnitude and angle)	LineCurrent [IEC 61970-452] PhaseCurrent [IEC 61970-301] Angle	3 or more instances of Analog
MMXU	AvAPhs	MV	Arithmetic average of the magnitude of current of the 3 phases. Average(Ia,Ib,Ic)		Analog
MMXU	PhV	WYE	Phase to ground voltages (magnitude and angle)	PhaseVoltage Angle	3 or more instances of Analog
MMXU	AvPhVPhs	MV	Arithmetic average of the magnitude of phase to reference voltage of the 3 phases.		Analog
MMXU	PPV	DEL	Phase to phase voltages (VL1, VL2, …)	LineToLineVoltage Angle	3 or more instances of Analog
MMXU	Hz	MV	Frequency	Frequency	Analog
PSDE	Ang	MV	Angle between voltage and current	Angle	Analog
MMTR	TotVAh	BCR	Apparent energy	ApparentEnergy	Accumulator
MMTR	TotVArh	BCR	Reactive energy	ReactiveEnergy	Accumulator
MMTR	TotWh	BCR	Real energy	ActiveEnergy	Accumulator
CSWI, XCBR, XSWI	Pos	DPC	Switch position [2bits= intermediate, open, closed, bad-state]	SwitchPosition	Discrete
LLN0, XCBR, XSWI, ATCC and many others	Loc	SPS	Local control behaviour	LocalOperation	Discrete
ARCO, ATCC, AVCO	Auto	SPC	Automatic/Manual operation	Automatic	Discrete
ATCC YLTC	TapPos	ISC	Tap position of power transformer or phase shifter	TapPosition	Analog
ANCR YEFN	ColTapPos	ISC	Petersen coil coil tap position	Not specified	Analog
STMP, SIMG, SIML, SCBR and others	Tmp xxxTmp	MV	Temperature	Temperature	Analog
SPRS, SIML, SIMG	Pres	MV	Pressure	Pressure	Analog

Table 15 – IEC 61850 DataObjects for non-three phase measurements

IEC 61850 Logical Node	IEC 61850 Data Object	IEC 61850 CDC	IEC 61850 Description	IEC 61970-301	Subclass of CIM Measurement
MMXN	Amp	MV	Current I not allocated to a phase	Current	Analog
MMXN	Vol	MV	Voltage V not allocated to a phase	Voltage	Analog
MMXN	VoltAmp	MV	Apparent power (S) not allocated to a phase	ApparentPower	Analog
MMXN	VoltAmpr	MV	Reactive power (Q) not allocated to a phase	ReactivePower	Analog
MMXN	Watt	MV	Power (P) not allocated to a phase	ActivePower	Analog
MMXN	PwrFact	MV	Power factor not allocated to a phase	PowerFactor	Analog
MMXN	Hz	MV	Frequency	Frequency	Analog

Table 16 – IEC 61850 DataObjects for CIM control types

IEC 61850 Logical Node	IEC 61850 Data Object	IEC 61850 CDC	IEC 61850 Description	CIM Control Types	Subclass of CIM Measurement
CSWI	Pos	DPC	Switch position [2 bits, valid values are open, closed]		Command
ATCC YLTC	TapPos	ISC	Set tap position of power transformer or phase shifter		Setpoint
ATCC YLTC	TapChg	BSC	Change tap position (alternative to TapPos control)		Command
ARCO	TapChg	BSC	Change reactive power (stop, higher, lower)		Command
AVCO	SptVol	APC	Voltage setpoint		Setpoint
ANCR YEFN	ColTapPos	ISC	Petersen coil coil tap position		Setpoint

8.2.2 Recommendation for harmonization: CIM Measurement types

IEC 61850 defines considerably more data objects than the list of measurement type names in IEC 61970. A generic solution is to add a new attribute in the CIM Measurement class to hold a IEC 61850 data object name.

Recommendation R13: CIM based standards should use selected IEC 61850 data object names as MeasurementType names.

Recommendation R14: [Alternative to R13] add a new attribute in the CIM Measurement class called IEC 61850 DataObject, which is an enumeration and the value will be any data object that is defined in IEC 61850.

It may be necessary to review and clarify some of the descriptions in IEC 61850 to avoid ambiguities.

The declaration of an actual UML Enumeration, for this purpose, is out of scope of this document.

8.3 Measurement associations

IEC 61850-6:2009/AMD1:2018, 6.2, states that typically, a switch controller LN (CSWI) is attached to a switching device, while a measuring LN (MMXU) is attached to the bay, which delivers the measurands, and transformer-related LNs are attached to the appropriate transformer.

This is not a prescriptive rule and in practice measurement logical nodes may be attached to any of the elements described in Table 2.

There are several types of mappings for measurement associations:

- Discrete status mapping where a CIM Discrete measurement associated with some equipment can be directly mapped to Logical Nodes associated with the SCL representation of the same equipment.
- Analogue or Accumulator measurements not related to voltage or current, may be associated in the same manner as discrete status measurements. For measurements used by CIM applications, such as a state estimator, it is necessary to identify the connectivity nodes connected to the current and voltage transformers. The measurement maps to the terminal that references the corresponding ConnectivityNode. The rules of IEC 61970-452:2015, 3.5 (Use of Measurement Classes) shall be followed.
- Measurements not associated with individual equipment should be associated with the appropriate EquipmentContainer or other PowerSystemResource (e.g. Substation, Bay, Plant, or Line).

All IEC 61850 sourced measurements shall be associated with the appropriate MeasurementValueSource.

8.4 CSWI or XSWI/XCBR as source of switch position information

IEC 61850-7-4 does not distinguish between the value of switch position reported by XCBR or XSWI and that reported by CSWI. Document IEC TR 61850-7-500 shows the XCBR is used to report the actual breaker position based on the physical inputs and is used for interlocking, while CSWI is used to report a copy of the XCBR or XSWI status to the station HMI.

In some cases, IEC 61850 has multiple functions/Logical Nodes that can convey the same information. As an example, consider CSWI and XCBR. For CIM interactions to control a position of a switch, the CSWI is required to be used. The CSWI also provides a filtered position status (e.g. the CSWI position status may not include transient state information) of the switch/breaker. IEC 61850 uses the CSWI to provide commands/information to an instance of the XCBR to actually perform the control. CIM based SCADA systems should be capable of receiving both status (e.g. from the CSWI and XCBR) for monitoring purposes. The system that converts IEC 61850 to CIM information must be capable of being configured to use either or both status position signals.

8.5 Direction of positive flow

8.5.1 General

The Measurement logical nodes that supply measurements of power and current do not have any settings/configuration to indicate the direction of positive flow relative to the primary equipment connectivity.

It is common practice to indicate the earthing point (terminal) of CTs in the drawings, which is either 'towards the busbar' or 'towards the line'. All other engineering artefacts must follow the given/defined scheme for the project. As IEC 61850 is focussed on the functions rather than on the type of bays, there is no means to indicate the producer/consumer use of them. TVTR and TCTR, which could be the appropriate LNs to host this information, do not include it today.

For physical devices, the international convention is to use the terminal designations ‘P1’ and ‘P2’ on the primary, ‘S1’ and ‘S2’ on the secondary side, where ‘1’ is the one closer to the energy source.

The CIM attribute is named “Analog.positiveflowin” and has the following definition:

> *If true then this measurement is an active power, reactive power or current with the convention that a positive value measured at the Terminal means power is flowing into the related PowerSystemResource.*

8.5.2 Recommendation for harmonization: SCL power flow direction

Recommendation R15: IEC 61850 should add a SPG setting called PosFlwIn, to the Measurement logical nodes, to indicate the direction of positive flow relative to the primary equipment connectivity

The description of this setting would be:

> The attribute is applicable for measurements of active power, reactive power or current. TRUE means a positive measurement value indicates power is flowing into the related PowerSystemResource. FALSE means a positive measurement value indicates power is flowing out of the related PowerSystemResource.

8.5.3 Recommendation for harmonization: CIM power flow direction

Recommendation R16: The CIM definition for Analog.positiveflowin should be aligned with the more semantically pure definition being proposed for IEC 61850.

8.6 CIM Extensions for Distribution – Metering Model and Reading Types

IEC 61968-11 defines a Metering package including classes such as ReadingType to support enterprise integration of metering systems. A ReadingType instance is used as a unique identifier that specifies the attributes required to fully characterize a Reading. A Reading is a specific value measured or calculated by a Meter or system. Attributes of ReadingType are defined as strings in the UML model but are represented by integer codes in data exchanges.

Some of the IEC 61850 data objects clearly correspond to at least part of the ReadingType codes defined in IEC 61968-9. This states that “data elements can be described in terms of 18 key attributes (several of which are compound attributes)”. The task force believes that some of these attributes correspond to part of the IEC 61970-301 CIM measurement package including the changes recommended in this document. This implies some adaption of the IEC 61968 model, but at the present time, there is not been a strong wish to harmonize.

9 Real time data exchange mapping

9.1 Measurement identification

IEC 61850 defines a nested data model based on Logical Nodes. These may contain more than 100 individual information attributes organised in a hierarchical structure of data objects and data attributes. Both data object names and data attribute names can be structured. Data items are uniquely identified using a name of the form

LDName / LNName. DataObjectName[.SubDataObjectName[. ...]].DataAttributeNam[.SubDataAttributeName[. ...]]

Where

LDName is Logical Device name

LNName is Logical Node name

The logical device name identifies a logical device that contains one or more logical nodes. The logical device name may use product-related naming fixed by the vendor, or it may be configured with function oriented naming. In the context of mapping SCL to CIM, either type of naming convention may be used. To be mapped to CIM, Logical Nodes must be associated with the Node containers defined in the Substation section of the SCL. The actual values of the LDName are not important.

The logical node name is made up of a standard class name with non-standard prefixes and instance numbers. The logical node prefixes and instance numbers may be fixed by the IED vendor, or may be configurable.

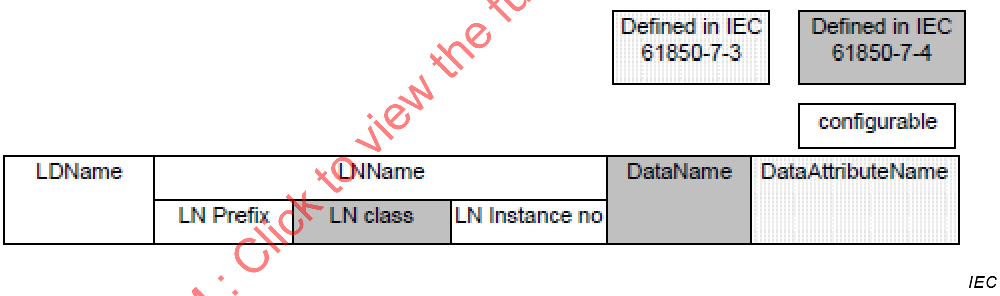


Figure 14 – Signal identification as defined in IEC 61850-7-2

9.2 Common Data Class mapping

IEC 61850-7-3 describes Common Data Classes (CDC) for status information, measured information, controls, settings and their attribute types. These CDCs are structures that contain DataAttributes and may contain other simpler CDCs. For example, the WYE common data class contains one to six data attributes of type CMV, each of which contains more nesting of structures or attributes as shown in Figure 15 (partial example).

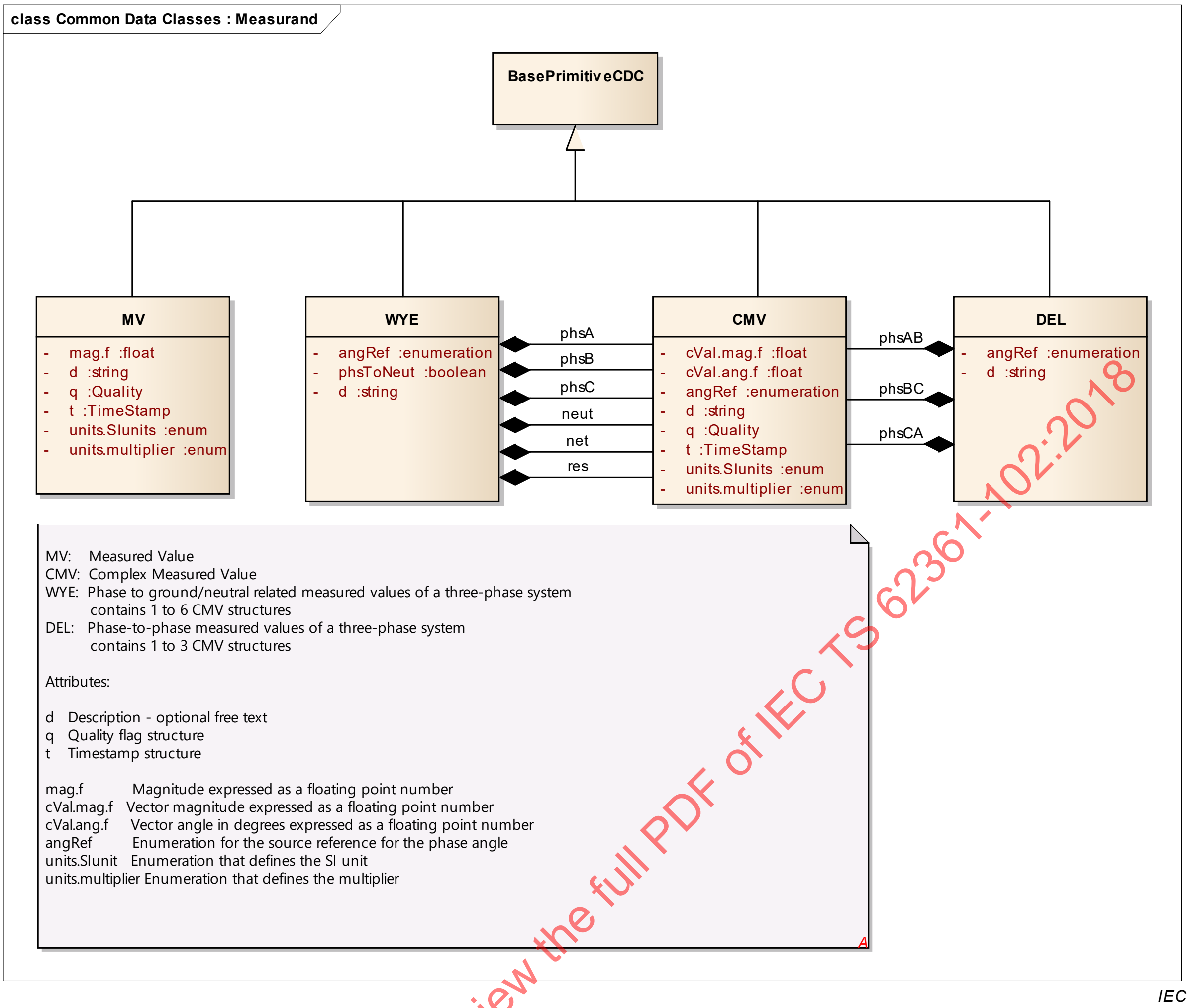


Figure 15 – UML model of MV, DEL and WYE data classes

9.3 Common Data Class mapping to IEC 60870 and CIM Measurements

The SCADA commissioning use case (See 4.4) can include both direct mapping and via intermediate protocols.

IEC TS 61850-80-1 describes standardized mapping to exchange information from CDC-based data models (for example IEC 61850) using IEC 60870-5-101 or IEC 60870-5-104. A typical application is a gateway device that communicates between a substation and a control centre.

IEC 60870-5-101/104 defines Application Service Data Units (ASDU). An ASDU is composed of a data unit identifier and one or more Information Objects. Different ASDUs may be used with the same information objects e.g. with or without timestamp information. For clarity, this document refers only to the information objects.

This document extends the mapping defined in IEC TS 61850-80-1 in order to define a mapping between IEC 61850 Common Data Classes, IEC 60870-5-101/104 Information Objects and classes from the CIM Measurement package.

The information objects defined within IEC 60870-5-101/104 are straight-forward to map to classes from the CIM Measurement package as shown in Table 17 below. Instances of ValueAliasSet and ValueToAlias are used for discrete measurements and describe mappings from specific integer values to symbolic names. Common data classes that contain description data have no corresponding IEC 60870 real time information objects.

The mapping of CDC attributes to CIM attributes is shown in Table 19.

Table 17 – Mapping IEC 61850 Common Data Classes to IEC 60870 information objects and CIM classes

IEC 61850 Functional Constraint or Service	IEC 61850 CDC	Common Data Class description	IEC 60870-5-101/104 Information Object	CIM Class
Status(ST)	SPS	Single point status	single-point information	DiscreteValue
Status(ST)	DPS	Double point status	double-point information	DiscreteValue ValueAliasSet ValueToAlias
Status(ST)	ENS	Enumerated Status	measured value integer Or one or more instances of single-point information	DiscreteValue ValueAliasSet ValueToAlias Or 1 or more instances of DiscreteValue
Status(ST)	INS	Integer status	bitstring of 32 bits	1 or more instances of DiscreteValue
Status(ST)	ACT	Protection activation information	One or more instances of single-point information	1 or more instances of DiscreteValue
Status(ST)	ACD	Protection activation information with direction	One or more instances of single-point information	1 or more instances of DiscreteValue
Status(ST)	SPC	Controllable single point	In monitor direction: single-point information	DiscreteValue
Status(ST)	DPC	Controllable double point	In monitor direction: double-point information	DiscreteValue ValueAliasSet ValueToAlias
Status(ST)	ENC	Controllable enumerated status	In monitor direction: measured value integer Or one or more instances of single-point information	DiscreteValue ValueAliasSet ValueToAlias Or 1 or more instances of DiscreteValue
Status(ST)	INC	Controllable integer status	In monitor direction: measured value integer	DiscreteValue
Status(ST)	ISC	Integer controlled step position information	In monitor direction step position information	DiscreteValue
Status(ST)	SEC	Security violation counting	integrated totals	AccummulatorValue
Status(ST)	BCR	Binary counter reading	integrated totals	AccummulatorValue
Measurand (MX)	MV	Measured value	measured value, short floating number or integer	AnalogValue
Measurand (MX)	CMV	Complex measured value (magnitude and phase)	One or two instances of short floating point number or integer	One or two instances of AnalogValue

IEC 61850 Functional Constraint or Service	IEC 61850 CDC	Common Data Class description	IEC 60870-5-101/104 Information Object	CIM Class
Measurand (MX)	WYE	Phase to ground/neutral related measured values of a three-phase system (set of CMV)	Via CMV Many instances of measured value, short floating number or integer	Many instances of AnalogValue E.g. Four instances for phase A, B,C, neutral magnitudes
Measurand (MX)	DEL	Phase to phase related measured values of a three-phase system (set of CMV)	Via CMV Many instances of measured value, short floating number or integer	Many instances of AnalogValue E.g. three instances for AB, BC, CA magnitudes
Measurand (MX)	HMV	Array of harmonic values	Via CMV	Many instances of AnalogValue
Measurand (MX)	HWYE	Array of harmonic wye values	Via CMV	Many instances of AnalogValue
Measurand (MX)	HDEL	Array of harmonic delta values	Via CMV	Many instances of AnalogValue
Measurand (MX)	SAV	Samples of instantaneous analogue values (see note below)	measured value, short floating number or integer	AnalogValue
Control Service	SPC	Controllable single point	In command direction: single command	Command
Control Service	DPC	Controllable double point	In command direction: double command	Command
Control Service	ENC	Controllable Enumerated Status	In command direction: set point command, scaled integer 1 or more instances of single commands	Setpoint Or 1 or more instances of Command
Control Service	INC	Controllable integer status	In command direction: set point command, scaled integer	Command
Control Service	BSC	Binary controlled step position information	In command direction: set point command, scaled integer	Command
Control Service	ISC	Integer-controlled step position information	In command direction: set point command, scaled integer	Command
Control Service	APC	Controllable analogue process value	In command direction: set point command, short floating number or integer	Setpoint
Control Service	SPG	Single point setting	In command direction: single command	Command
Control Service	ING	Integer status setting	In command direction: set point command, scaled integer	Command
Control Service	ASG	Analogue setting	In command direction: set point command, short floating number or integer	Setpoint

IEC 61850 Functional Constraint or Service	IEC 61850 CDC	Common Data Class description	IEC 60870-5-101/104 Information Object	CIM Class
Setpoint(SP) or SettingGroup (SE)	CURVE	Setting curve	n/a	Curve
Setpoint(SP) or SettingGroup (SE)	CSG	Curve shape setting	n/a	CurveData
Description	CSD	Curve shape description	n/a	Curve
Description	DPL	Device name plate	n/a	Non-real time data attributes Or 1 or more StringMeasurementValues
Description	LPL	Logical node name plate	n/a	Non-real time data attributes Or 1 or more StringMeasurementValues

NOTE Data objects with class SAV are samples of raw instantaneous analogue values. It is expected that data with this class type will be further processed into RMS or average values with class MX or WYE before transmission to a control centre.

9.4 Common Data Class mapping to IEEE1815 and CIM

An alternative standard intermediate protocol for communication to control centres is IEEE1815 (DNP). A supplementary standard IEEE1815.1 defines full details of mapping of IEC 61850 Common Data Classes to IEEE 1815 (DNP) data point types.

Table 18 is a summary of the mapping of IEC 60870 information objects to IEEE1815 data point types, plus the corresponding CIM classes.

Table 18 – Mapping IEEE1815 data point types to CIM classes

IEC 60870-5-101/104 Information Object	IEEE 1815 Data point type	CIM Class
single-point information	Binary input	DiscreteValue
double-point information	Binary input	DiscreteValue
single command	Binary output	Command
double command	Binary output	Command
measured value, short floating number or integer	Analog Input	AnalogValue
set point command	Analog Output	Setpoint
integrated totals	Counter	AccummulatorValue

9.5 Data Attribute mapping

9.5.1 General

The attributes for real-time data can be mapped to CIM classes and attributes as shown in Table 19.

If a value is substituted within the IED (subEna is TRUE), then the value to be used in the control centre should be a copy of the subVal attribute and the MeasurementValueQuality should indicate the source as “substituted”.

Table 19 – Mapping IEC 61850 real time data attributes to CIM classes/attributes

CDC	Attribute	Description	CIM Class	CIM Attribute
Various	q	Quality of the main data attribute e.g. stVal	MeasurementValue	MeasurementValueQuality See note below
Various	t	Time stamp of the main data attribute e.g. stVal	MeasurementValue	timeStamp
SPS	stVal	Status value	DiscreteValue	value
SPC	stVal	Status value	DiscreteValue	value
DPC	stVal	Status value	DiscreteValue	value
DPC	stVal	Status value	DiscreteValue	value
ENS	stVal	Status value	DiscreteValue	value
INS	stVal	Status value	DiscreteValue	value
ISC	valWtr.posVal	Value with transient indication, step position value	DiscreteValue	value
ACT	general phsA phsB phsC neut	General indication plus indications per phase and neutral	One or more instances of DiscreteValue	value
ACD	As ACT plus dirGeneral dirPhsA dirPhsB dirPhsC dirNeut	General indication plus indications per phase and neutral Plus directional information	One or more instances of DiscreteValue	value
MV	mag	Magnitude (with deadband filtering)	AnalogValue	value
CMV	cVal.mag cVal.ang	Magnitude and phase (with deadband filtering)	One or two instances of AnalogValue	value
WYE	phsA.cVal.mag phsB.cVal.mag phsC.cVal.mag neut.cVal.mag net.cVal.mag res.cVal.mag	For each phase and neutral, magnitude (with deadband filtering)	1 to 6 instances of AnalogValue	value
DEL	phsAB.cVal.mag phsBC.cVal.mag phsCA.cVal.mag	For each pair of phases, magnitude (with deadband filtering)	Three instances of AnalogValue	value
BCR	actVal	Counter value	AccummulatorValue	value

9.5.2 Quality flag mapping

CIM MeasurementValueQuality has type Quality61850. Quality flags in this class are as defined in IEC 61850-7-3, with the addition of estimatorReplaced, which has been included in this class for convenience. The CIM does not model the detailed quality flags “inaccurate” or “inconsistent”.

9.5.3 Non-real time measurement attribute mapping

The real-time data classes may also have data attributes for non-real-time data that can be mapped to CIM classes and attributes as shown in Table 20.

Table 20 – Mapping IEC 61850 Non-real time data attributes to CIM classes/attributes

CDC	Attribute	Description	CIM Class	CIM Attribute
Various	d	Textual description	Measurement	name or description
MV CMV	units.SIUnit	Units of the attribute(s) representing the value of the data	Analog	unitSymbol
MV CMV	units.multiplier	Units of the attribute(s) representing the value of the data	Analog	unitMultiplier
MV CMV	rangeC.min	minimum process measurement	Analog	minValue
MV CMV	rangeC,max	maximum process measurement	Analog	maxValue
APC	minVal	Setting range	Setpoint	minValue
APC	maxVal	Setting range	Setpoint	maxValue

9.5.4 Recommendation for harmonization: CIM measurement classes

Recommendation R17: Add additional CIM measurement classes to hold multiple measured values with the same timestamp and quality.

These classes would be similar to the SvPowerFlow or SvVoltage classes for state variables.

For example:

- MeasurementVector would have attributes “magnitude” and “angle” and would correspond to the CMV common data class.
- MeasurementComplexValue would have attributes “real” and “imaginary” and would typically be used to hold values for real and reactive power.

10 Control Model

10.1 CIM Control Modelling

10.1.1 General

The control model needs to be able to allow high level information exchange regarding capabilities. However, it is not required to convey specific control service information (e.g. directControl, selectBeforeOperate, etc.) that may be required to actually issue the telecontrol to the field. Configuration of the service specific information is intended to be performed in a protocol specific manner and is out of scope of this document. This area may be a topic for future work.

The current CIM control model lacks some of the aspects that are needed in order to allow telecontrol to field devices. The current IEC 61970 control model is shown in Figure 16.

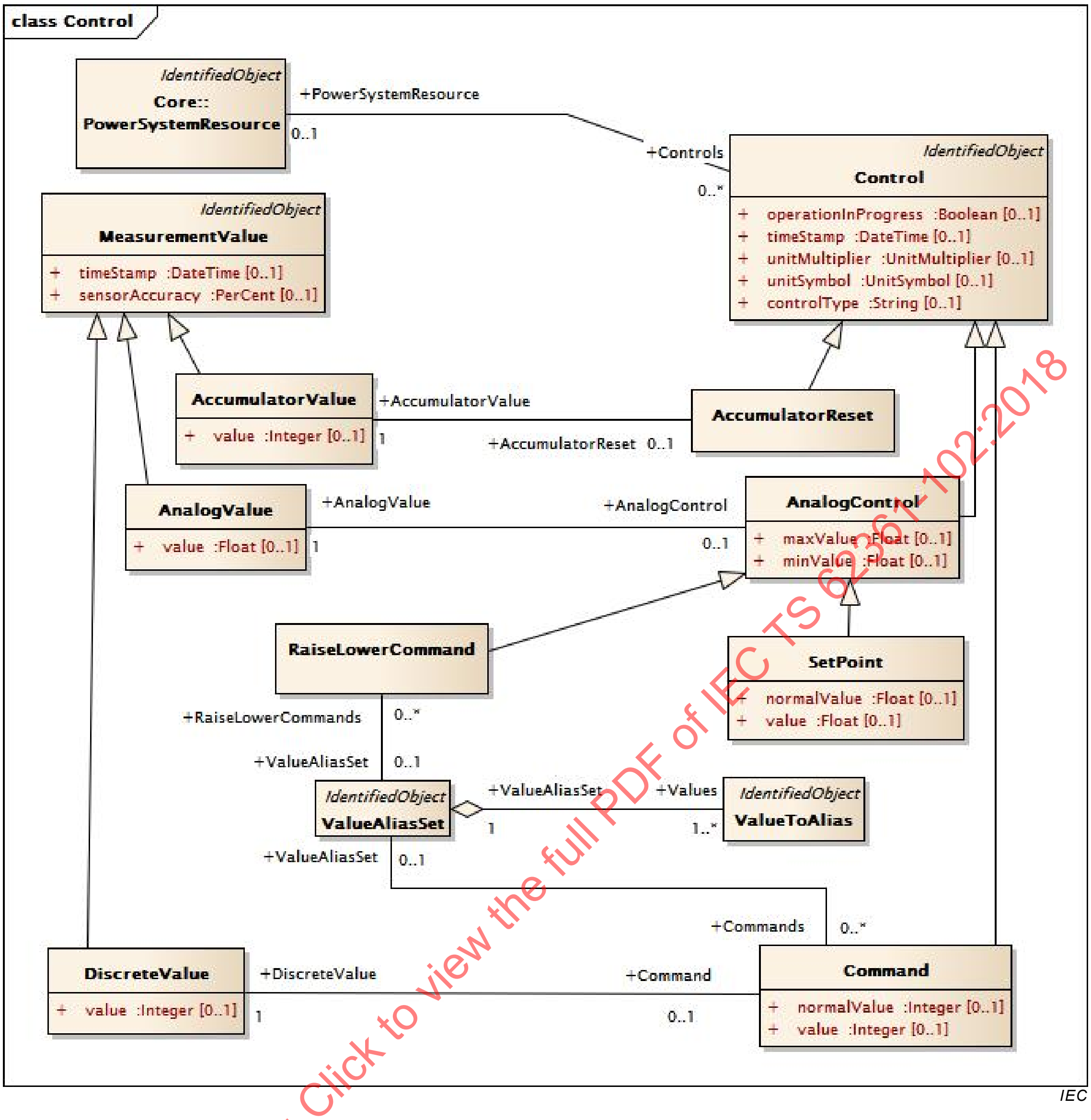


Figure 16 – Current CIM Control Model

10.1.2 Recommendation for harmonization: CIM control model

Recommendation R18: Modify the CIM control model as shown in Figure 17.

The changes from the current model to the proposed model are based upon the need to:

- Generalized Raise/Lower into a DiscreteCommand. The DiscreteCommand allows an enumerated control to be sent, and the MeasurementValue whose value should change based upon the control, to be specified.
- The value and normalValue attributes in Command were removed and equivalent attributes of the appropriate type, were placed into DiscreteCommand and AnalogControl.

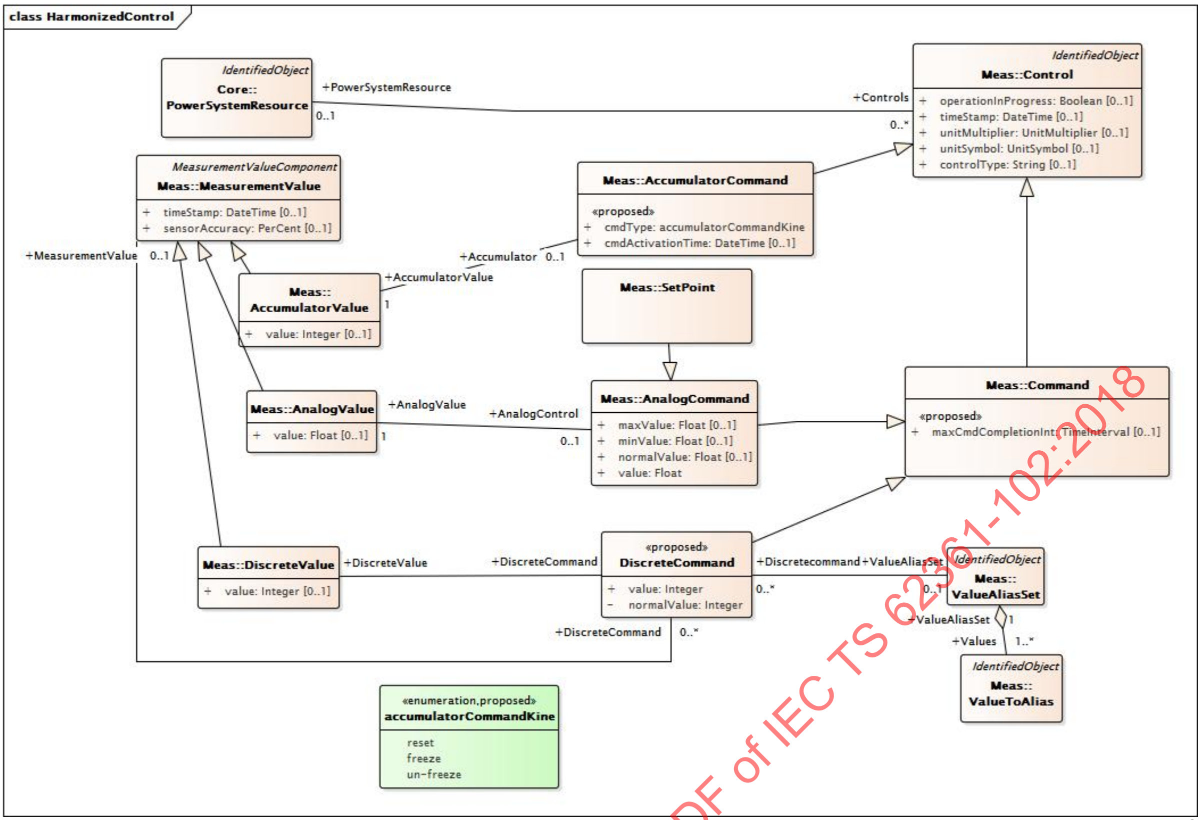


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Figure 17 – Proposal for revised CIM Control Model

10.1.3 Recommendation for harmonization: CIM CONTROL TYPES

Control Types are analogous to measurementTypes but apply to commands. IEC 61970-301 does not define a standard list of control types.

Recommendation R19: CIM based standards should use selected IEC 61850 data object names as ControlType names or add a specific attribute as recommended for MeasurementTypes.

10.2 Automated control sequences

Models to enable the exchange of automated control sequences (e.g. System Integrity Protection Schemes and/or switching sequences) are currently being developed by working groups or task forces responsible for both IEC 61970 and IEC 61850.

Recommendation R20: The relevant working groups and task forces should coordinate to propose a harmonized models and mappings for automated control sequences.

11 Protection modelling

There is a general agreement within the IEC that the IEC 61970 Protection Model (see Figure 18) needs to be re-evaluated prior to attempts to perform harmonization with IEC 61850. This re-evaluation will probably cause a refactoring/redesign of the protection model based upon the newer concepts of protection functions instead of protection equipment as well as accommodating requirements for System Integrity Protection Schemes (SIPS).

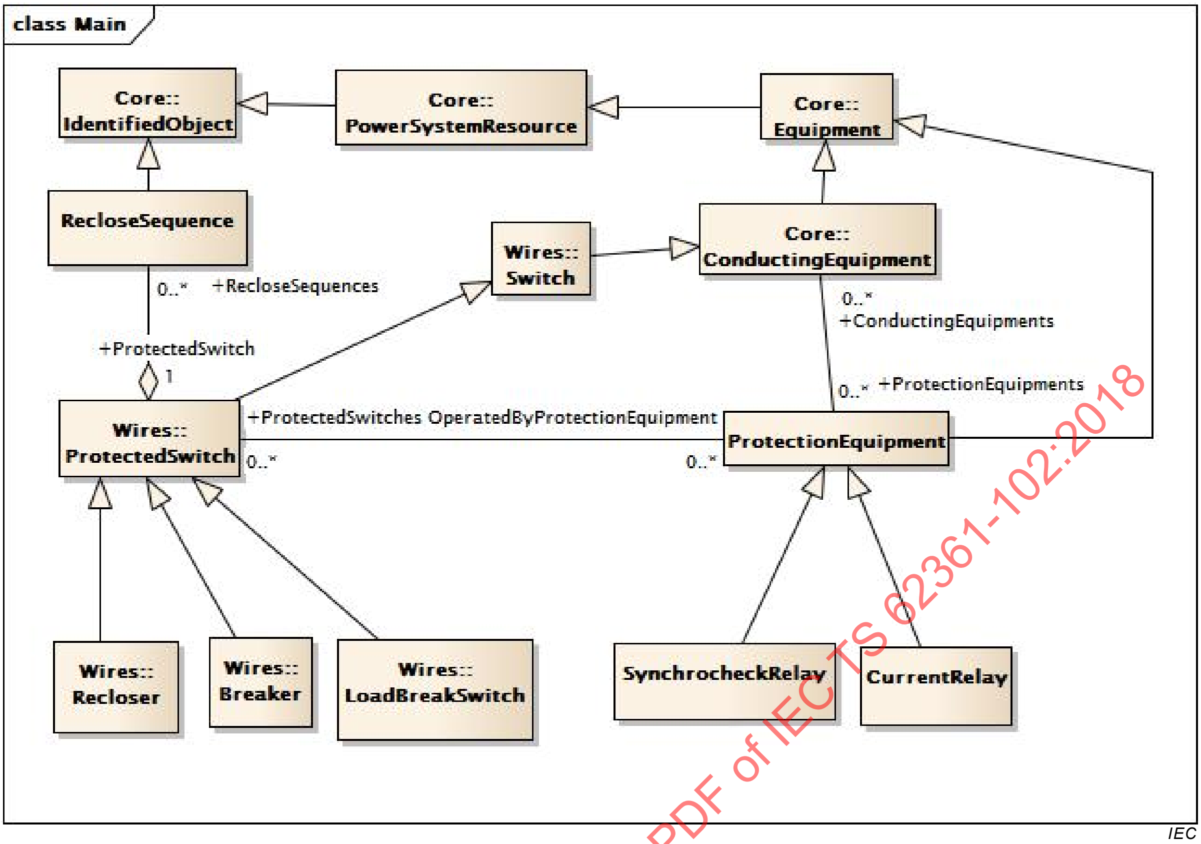


Figure 18 – Present IEC 61970 Protection Model

The IEC 61850 protection functions (e.g. PIOC, PTOC etc.) are not aligned with the physical device oriented ProtectionEquipment model within CIM. The mapping between these particular sub-domains will require the analysis of several additional use cases that are currently not in scope of this document:

- Training simulation
- Protection Coordination
- System Integrity Protection Schemes (SIPS)
- Asset Management

At present the only detailed models within the CIM Protection package are for protection functions that are relevant to training simulators or distribution network fault location applications. Slow-acting over-current protection functions may be modelled within training simulators to simulate scenarios involving line tripping due to overloads and especially for scenarios requiring operator action to avoid cascade tripping.

All equipment types including Protection Equipment are assets. A CIM based asset management application may need to use nameplate information from protection or other IEDs.

Recommendation R21: IEC should re-evaluate the CIM Protection Model and model protection functions that are aligned with IEC 61850.

12 Communication model

IEC 61850-6:2009, Subclause 6.4 defines *"The IEC 61850 communication model … [describes] the connections between IEDs … across subnetworks by means of access points. A subnetwork is … a connecting node between access points, not a physical structure. … Although subnetworks only model logically possible connections, a correlation to the physical structure can be built up by appropriate naming of subnetworks and access points, and by the relation of access points to (one or more) physical connection points. … The description and maintenance of the physical structure is beyond the scope of SCL, although some features allow to model it at least partly."*

The CIM defines two classes. CIM RemoteUnit is used to model gateway devices or IEC 61850 IEDs. CIM RemoteUnits are associated with CommunicationLinks.

IEC 61970-301:2016, Subclause 6.17.2 defines the CIM CommunicationLink as *"The connection to remote units is through one or more communication links. Redundant links may exist. The CommunicationLink class inherits from PowerSystemResource. The intention is to allow CommunicationLinks to have Measurements. These Measurements can be used to model link status as operational, out of service, unit failure etc."*

There are no specific attributes for RemoteUnit or CommunicationLink for recording address information e.g. IP addresses or RTU numbers used by other protocols. However, the CIM does not provide a simple way to identify multiple access points on the same IED.

It is possible to record some identification text using the generic naming facilities inherited from IdentifiedObject together with specific NameTypes. Table 21 shows the mapping for communication elements.

Table 21 – Mapping SCL Communication elements

SCL element	SCL description	CIM Class
IED	An automation device	RemoteUnit
Subnetwork	A connecting node for direct (link layer) communication between access points	CommunicationLink
Access point	A communication access point of the logical device(s) of an IED to a subnetwork.	Association between RemoteUnit and CommunicationLink
Router	An IED with a router function can be connected with two different access points to two different subnetworks and allow TCP-based messages to reach IEDs within the other subnetwork;	No specific CIM class. A RemoteUnit with a specific NameType could be used.
Clock	Indicates where a subnetwork master clock is located	No specific CIM class. A RemoteUnit with specific NameType could be used.

13 Settings and attributes

A System Configuration Description (SCD) file can contain the values of instantiated settings using the DOI and DAI elements (IEC 61850-6:2009, 9.3.6). Some of these settings can be mapped to CIM classes and attributes as listed in Table 22. Note that the IEC 61850 settings and the CIM attributes may have different units.

As described in Clause 11 Protection Modelling, the CIM Protection package IEC 61850 protection functions (e.g. PIOC, PTOC etc) are not aligned with the physical device oriented ProtectionEquipment model within CIM. The IEC 61850 settings for protection logical nodes do not correspond well with the CIM protection model attributes and are therefore not listed in Table 22. Settings that cannot be mapped to existing CIM attributes may be copied to instances of AnalogValue or DiscreteValue. As recommended in 8.2.2 the associated Analog or Discrete instances will have an attribute called 61850DataObject whose value is one of the data object names defined in IEC 61850.

Note that the majority of the attributes required by CIM based analysis applications are not available in the IEC 61850 model and appropriate values must be defined with CIM based modelling tools.

Logical Nodes listed in IEC 61850-7-4 but not listed in Table 22 either have no settings elements, or they have no settings relevant to CIM.

Table 22 – Mapping IEC 61850 settings to CIM attributes

Logical node	Logical node description	Data object	Type	(Used in) Data object description	CIM class	CIM attribute
ARCO	Reactive power control			no settings	RegulatingControl	n/a
ATCC	Automatic tap changer controller	BlkLV	ASG	(ATCC) Control (secondary) voltage below which the automatic lower commands are blocked.	(RegulatingControl)	n/a
ATCC	Automatic tap changer controller	BlkRV	ASG	(ATCC) Control (secondary) voltage above which the automatic raise commands are blocked.	(RegulatingControl)	n/a
ATCC	Automatic tap changer controller	BlkVHi	ASG	(ATCC) Control (secondary) voltage above which the automatic lower commands are blocked. If the control voltage is over this limit, the ATCC issues no lower commands until the control voltage exceeds this limit.	(RegulatingControl)	n/a
ATCC	Automatic tap changer controller	BlkVLo	ASG	(ATCC) Control (secondary) voltage below which the automatic raise commands are blocked. If the control voltage is under this limit (e.g. because that part of the network is switched off), the ATCC issues no raise commands until the control voltage exceeds this limit.	(RegulatingControl)	n/a
ATCC	Automatic tap changer controller	BndCtr	ASG	(ATCC) Centre of voltage control bandwidth (forward power flow presumed).	RegulatingControl	targetValue targetValueUnitMultiplier
ATCC	Automatic tap changer controller	BndWid	ASG	(ATCC) Control (secondary) voltage bandwidth (i.e., range), given either as voltage value or percentage of the nominal voltage (forward power flow presumed).	RegulatingControl	targetDeadband
ATCC	Automatic tap changer controller	CtlDlTmms	ING	(ATCC) Time to wait before operating, after reaching the control point (forward power flow presumed).	TapChanger	initialDelay subsequentDelay
ATCC	Automatic tap changer controller	LDC	SPG	(ATCC) If true, line drop compensation is R and X model, otherwise it is Z model.	(TapChangerControl)	n/a Determines whether to calculate from LDCR, LDCR or LDCZ

Logical node	Logical node description	Data object	Type	(Used in) Data object description	CIM class	CIM attribute
ATCC	Automatic tap changer controller	LDCR	ASG	(ATCC) Line drop voltage due to line resistance component (forward power flow presumed) at rated current.	TapChangerControl	lineDropR Conversion requires rated current for correct side of associated transformer
ATCC	Automatic tap changer controller	LDCX	ASG	(ATCC) Line drop voltage due to line reactance component (forward power flow presumed) at rated current.	TapChangerControl	lineDropX Conversion requires rated current for correct side of associated transformer
ATCC	Automatic tap changer controller	LDCZ	ASG	(ATCC) Line drop voltage due to line total impedance (forward power flow presumed) at rated current.	TapChangerControl	lineDropR lineDropX Conversion requires rated current for correct side of associated transformer plus nominal R/X value for circuit
ATCC	Automatic tap changer controller	LimLodA	ASG	(ATCC) Current above which the automatic commands are suspended.	(TapChanger)	n/a
ATCC	Automatic tap changer controller	ParTrfMod	ENG (ParallelTransfModeKind)	(ATCC) Parallel transformer mode setting.	(TapChanger)	n/a
ATCC	Automatic tap changer controller	RnbkRV	ASG	(ATCC) Runback raise voltage, i.e., the control voltage above which an automatic lower command is issued.	(TapChanger)	n/a
ATCC	Automatic tap changer controller	TapBlkL	ING	(ATCC) Tap position where automatic lower commands are blocked.	TapChanger	lowStep
ATCC	Automatic tap changer controller	TapBlkR	ING	(ATCC) Tap position where automatic raise commands are blocked.	TapChanger	highStep
ATCC	Automatic tap changer controller	TmDlChr	SPG	(ATCC) If true, time delay characteristic is linear, otherwise it is inverse.	(TapChanger)	n/a
AVCO	Voltage control	LimAOv	ASG	(AVCO) Current limit for overflow blocking.	(RegulatingControl)	n/a

Logical node	Logical node description	Data object	Type	(Used in) Data object description	CIM class	CIM attribute
AVCO	Voltage control	LimVOv	ASG	(AVCO) Voltage limit for overflow blocking.	(RegulatingControl)	n/a
CSWI	Switch controller			no settings	Switch Breaker	
KFAN	Fan	MinOpTmm	ING	Minimum operation time in minutes	Load	n/a
KFAN	Fan	MaxOpTmm	ING	Maximum operation time in minutes	Load	n/a
SCBR	Circuit breaker supervision			alarm and warning levels for operation counts	Breaker	n/a
SIMG	Insulation medium supervision (gas)			no relevant settings	PowerTransformer	n/a
SIML	Insulation medium supervision (liquid)			no settings	PowerTransformer	n/a
SLTC	Tap changer supervision			no settings	TapChanger	n/a
SPTR	Power transformer supervision			no settings	PowerTransformer	n/a
SSWI	Circuit switch supervision			alarm and warning levels for operation counts	Switch	n/a
SFPI	Fault Passage Indication			Confirmation mode, reset mode, timeouts	FaultIndicator	n/a
SVPI	Voltage Presence Indication			no settings	PostLineSensor	n/a
XCBR	Circuit breaker	CBTmms	ING	(XCBR) Closing time of the breaker. The time is used to compensate for the breaker closing time, i.e., the closing command will be given a defined time before phase coincidence. This is a property of the breaker that is subject to ageing.	Breaker	inTransitTime
XFUS	Fuse	FuA	ASG	Fuse current rating	Fuse	ratedCurrent
XSWI	Circuit switch	SwTyp	ENS (SwitchFunctionKind)	(XSWI) Type of the switch. 1 Load break switch 2 Disconnector 3 Earthing switch 4 High speed earthing switch	Sub-type of Switch	
YEFN	Earth fault neutralizer (Petersen coil)			no settings	TransformerWinding	n/a

Logical node	Logical node description	Data object	Type	(Used in) Data object description	CIM class	CIM attribute
YLTC	Tap changer			no settings	TapChanger	n/a
YPSH	Power shunt (including switch)			no settings	ShuntCompensator Switch	n/a
YPTR	Power transformer	HiVRtg	ASG	(YPTR) High voltage rating.	PowerTransformerEnd where endNumber = 1	ratedU
YPTR	Power transformer	LoVRtg	ASG	(YPTR) Low voltage rating.	PowerTransformerEnd where endNumber <> 1	ratedU
YPTR	Power transformer	MaxVASpt	ASG	(YPTR) Maximum permissible permanent power (overload) setting.	PowerTransformerEnd	n/a
YPTR	Power transformer	OvlTmEmgSpt	ASG	(YPTR) Maximum permissible overload time setting without cooling unit (emergency case) [min].	PowerTransformerEnd	n/a
YPTR	Power transformer	OvlTmSpt	ASG	(YPTR) Maximum permissible overload time setting with cooling unit [min].	PowerTransformerEnd	n/a
YPTR	Power transformer	VARtg	ASG	(YPTR) Rated apparent power.	PowerTransformerEnd	ratedS
ZAXN	Auxiliary network			no relevant settings	Load	n/a
ZBAT	Battery			no relevant settings	Load	n/a
ZBTC	Battery charger			no relevant settings	Load	n/a
ZBSH	Bushing			no relevant settings	Junction	n/a
ZCAB	Power cable			See ZLIN Power overhead line	ACLineSegment	
ZCAP	Capacitor bank			no settings	ShuntCompensator SeriesCompensator	n/a
ZCON	Converter	VArRtg	ASG	(BaseConverterLN) Rated bi-directional reactive power.	ACDCConverter	n/a
ZCON	Converter	VRtg	ASG	(BaseConverterLN) Rated voltage (intrinsic property).	ACDCConverter	ratedUdc

Logical node	Logical node description	Data object	Type	(Used in) Data object description	CIM class	CIM attribute
ZGEN	Generator	DmdW	ASG (This may change to APC in future editions of IEC 61850)	(ZGEN) Demanded active power.	RotatingMachine	p
ZGEN	Generator	VRtg	ASG	(ZGEN) Rated voltage (intrinsic property).	RotatingMachine	ratedU
ZGEN	Generator	WRtg	ASG	(ZGEN) Rated active power.	RotatingMachine	ratedPowerfactor = Rated active power / Rated apparent power
ZGEN	Generator	VARtg	ASG	(ZGEN) Rated apparent power.	RotatingMachine	ratedS
ZGIL	Gas insulated line			no settings	ACLineSegment	n/a
ZINV	Inverter	GriMod	ENG (GridConnectModeKind)	(ZINV) Power system connect modes to the power grid.	(ACDCConverter)	n/a
ZINV	Inverter	GriModSt	ENS (GridConnectStateKind)	(ZINV) Current mode of connection to the grid.	(ACDCConverter)	n/a
ZINV	Inverter	InvSwTyp	ENG (InverterSwitchKind)	(ZINV) Type of inverter switch.	(ACDCConverter)	n/a
ZINV	Inverter	MaxVArRtg	ASG	(ZINV) Maximum reactive power rating.	(ACDCConverter)	n/a
ZINV	Inverter	MaxWRtg	ASG	(ZINV) Maximum active power rating.	(ACDCConverter)	n/a
ZINV	Inverter	OutHzSet	ASG	(ZINV) Frequency setpoint.	(ACDCConverter)	n/a
ZINV	Inverter	OutPFSet	ASG	(ZINV) Power factor setpoint as angle.	(ACDCConverter)	n/a
ZINV	Inverter	OutVArSet	ASG	(ZINV) Output reactive power setpoint.	(ACDCConverter)	n/a
ZINV	Inverter	PhsACfg	ENG (PhaseFeedKind)	(ZINV) Inverter phase A feed configuration.	(ACDCConverter)	n/a
ZINV	Inverter	PhsBCfg	ENG (PhaseFeedKind)	(ZINV) Inverter phase B feed configuration.	(ACDCConverter)	n/a

Logical node	Logical node description	Data object	Type	(Used in) Data object description	CIM class	CIM attribute
ZINV	Inverter	PhsCCfg	ENG (PhaseFeedKind)	(ZINV) Inverter phase C feed configuration.	(ACDCConverter)	n/a
ZINV	Inverter	SwHz	ASG	(ZINV) Nominal frequency of switching.	(ACDCConverter)	n/a
ZINV	Inverter	VARtg	ASG	(ZINV) The continuous apparent power capability of the power converter.	ACDCConverter	baseS
ZINV	Inverter	WVArVLim	CSG	(ZINV) PQV set of limiting curves.	(ACDCConverter)	n/a
ZINV	Inverter	WVArVLimSet	CSG	(ZINV) Active curve characteristic curve for PQV limit.	(ACDCConverter)	n/a
ZLIN	Power overhead line	LinLenkm	ASG	(ConductorLN) Line length [km].	ACLineSegment	length
ZLIN	Power overhead line	RPs	ASG	(ConductorLN) Positive sequence line resistance.	ACLineSegment	r
ZLIN	Power overhead line	RZer	ASG	(ConductorLN) Zero sequence line resistance.	ACLineSegment	r0
ZLIN	Power overhead line	RmZer	ASG	(ConductorLN) Mutual resistance coupling from parallel line.	MutualCoupling	r0
ZLIN	Power overhead line	XPs	ASG	(ConductorLN) Positive sequence line (reach) reactance.	ACLineSegment	x
ZLIN	Power overhead line	XZer	ASG	(ConductorLN) Zero sequence line reactance.	ACLineSegment	x0
ZLIN	Power overhead line	XmZer	ASG	(ConductorLN) Mutual reactance coupling from parallel line.	MutualCoupling	x0
ZLIN	Power overhead line	ZPsAng	ASG	(ConductorLN) Angle of positive sequence line impedance.	ACLineSegment	ZPsMag, ZPsAng -> r,x
ZLIN	Power overhead line	ZPsMag	ASG	(ConductorLN) Magnitude of positive sequence line impedance.	ACLineSegment	ZPsMag, ZPsAng -> r,x
ZLIN	Power overhead line	ZZerAng	ASG	(ConductorLN) Angle of zero sequence line impedance.	ACLineSegment	ZZerMag, ZZerAng => r0, x0
ZLIN	Power overhead line	ZZerMag	ASG	(ConductorLN) Magnitude of zero sequence line impedance.	ACLineSegment	ZZerMag, ZZerAng => r0, x0
ZLIN	Power overhead line	ZmZerAng	ASG	(ConductorLN) Angle of mutual impedance coupling from parallel line.	MutualCoupling	ZmZerMag, ZmZerAng => r0, x0

Logical node	Logical node description	Data object	Type	(Used in) Data object description	CIM class	CIM attribute
ZLIN	Power overhead line	ZmZerMag	ASG	(ConductorLN) Magnitude of mutual impedance coupling from parallel line.	MutualCoupling	ZmZerMag, ZmZerAng => r0, x0
ZMOT	Motor			no settings	InductionMotorLoad	n/a
ZRCT	Rectifier	CnvTyp	ENG (ACToDCConversionKind)	(ZRCT) Type of AC to DC conversion.	(ACDCConverter)	n/a
ZRCT	Rectifier	InWavTyp	ENG (WaveformConditioningKind)	(ZRCT) Type of input waveform conditioning.	(ACDCConverter)	n/a
ZRCT	Rectifier	OutALim	ASG	(ZRCT) Output current limit	(ACDCConverter)	n/a
ZRCT	Rectifier	OutFilTyp	ENG (OutputFilterKind)	(ZRCT) Type of output filter.	(ACDCConverter)	n/a
ZRCT	Rectifier	OutVSet	ASG	(ZRCT) Output voltage setpoint.	ACDCConverter	targetUdc
ZRCT	Rectifier	VRegTyp	ENG (VoltageRegulationKind)	(ZRCT) Type of voltage regulation.	(ACDCConverter)	n/a
ZREA	Reactor	PwrRtg	ASG	(ZREA) Rated apparent power.	ShuntCompensator	no direct mapping – could be used for consistency check
ZREA	Reactor	ARtg	ASG	(ZREA) Rated current.	ShuntCompensator	no direct mapping – could be used for consistency check
ZREA	Reactor	VArRtg	ASG	(ZREA) Rated reactive power.	ShuntCompensator	no direct mapping – could be used for consistency check
ZREA	Reactor	VRtg	ASG	(ZREA) Rated voltage (intrinsic property).	ShuntCompensator	nomU
ZRES	Resistor			no settings	n/a	
ZRRC	Rotating reactive component			no settings	SynchronousMachine	n/a
ZSAR	Surge arrester			no settings	n/a	n/a

Logical node	Logical node description	Data object	Type	(Used in) Data object description	CIM class	CIM attribute
ZSCR	Semi-conductor controlled rectifier	OpModRect	ENG (RectifierControlModeKind)	(ZSCR) Rectifier control mode setting.	ACDCConverter	n/a
ZSCR	Semi-conductor controlled rectifier	SetA	ASG	(ZSCR) Setting for the current (if operating to a fixed current).	ACDCConverter	n/a
ZSCR	Semi-conductor controlled rectifier	SetV	ASG	(ZSCR) Setting for the voltage (if operating to a fixed voltage).	ACDCConverter	targetUdc
ZSMC	Synchronous machine	ARtg	ASG	(ZSMC) Rated stator current.	SynchronousMachine	could be used to validate ratedS
ZSMC	Synchronous machine	BaseImp	ASG	(ZSMC) Base for per unit impedance definition, per phase (resistance SIUnit [ohm]).	SynchronousMachineDynamics	
ZSMC	Synchronous machine	FldAmpRtg	ASG	(ZSMC) Rated field current.	SynchronousMachine	n/a
ZSMC	Synchronous machine	FldAmpRtgZer	ASG	(ZSMC) No-load field current for rated stator voltage.	SynchronousMachine	n/a
ZSMC	Synchronous machine	FldRis	ASG	(ZSMC) Field resistance.	SynchronousMachineDynamics	
ZSMC	Synchronous machine	FldRisTmp	ASG	(ZSMC) Reference temperature for field resistance (typically in °C).		n/a
ZSMC	Synchronous machine	Iner	ASG	(ZSMC) Moment of inertia (turbine inertia SIUnit [kgm2]).	SynchronousMachineDynamics	
ZSMC	Synchronous machine	PFRtg	ASG	(ZSMC) Rated power factor.	SynchronousMachine	ratedPowerFactor
ZSMC	Synchronous machine	SatCffS10	ASG	(ZSMC) Saturation coefficient S1.0 (corresponding to 1.0 pu).	SynchronousMachineDynamics	
ZSMC	Synchronous machine	SatCffS12	ASG	(ZSMC) Saturation coefficient S1.2 (corresponding to 1.2 pu).	SynchronousMachineDynamics	
ZSMC	Synchronous machine	SpdCrit	ASG	(ZSMC) Critical speed of the synchronous machine (rotational speed SIUnit [s-1]).	SynchronousMachineDynamics	
ZSMC	Synchronous machine	SpdRtg	ASG	(ZSMC) Rated rotational speed (rotational speed SIUnit [s-1]).	SynchronousMachine	n/a
ZSMC	Synchronous machine	SttLeakX	ASG	(ZSMC) Per unit stator leakage reactance.	SynchronousMachineDynamics	
ZSMC	Synchronous machine	SttRis	ASG	(ZSMC) Stator resistance.	SynchronousMachineDynamics	

Logical node	Logical node description	Data object	Type	(Used in) Data object description	CIM class	CIM attribute
ZSMC	Synchronous machine	SttRisTmp	ASG	(ZSMC) Reference temperature for stator resistance (typically in °C).		n/a
ZSMC	Synchronous machine	TmTa	ASG	(ZSMC) Unsaturated armature time constant Ta (typical range is s).	SynchronousMachineDynamics	
ZSMC	Synchronous machine	TmTd0p	ASG	(ZSMC) Unsaturated d-axis open circuit transient time constant Td0' (typical range is s).	SynchronousMachineDynamics	
ZSMC	Synchronous machine	TmTd0s	ASG	(ZSMC) Unsaturated d-axis open circuit subtransient time constant Td0'' (typical range is s).	SynchronousMachineDynamics	
ZSMC	Synchronous machine	TmTdp	ASG	(ZSMC) Unsaturated d-axis short circuit transient time constant Td' (typical range is s).	SynchronousMachineDynamics	
ZSMC	Synchronous machine	TmTds	ASG	(ZSMC) Unsaturated d-axis short circuit subtransient time constant Td'' (typical range is s).	SynchronousMachineDynamics	
ZSMC	Synchronous machine	TmTq0p	ASG	(ZSMC) Unsaturated q-axis open circuit transient time constant Tq0' (typical range is s).	SynchronousMachineDynamics	
ZSMC	Synchronous machine	TmTq0s	ASG	(ZSMC) Unsaturated q-axis open circuit subtransient time constant Tq0'' (typical range is s).	SynchronousMachineDynamics	
ZSMC	Synchronous machine	TmTqp	ASG	(ZSMC) Unsaturated q-axis short circuit transient time constant Tq' (typical range is s).	SynchronousMachineDynamics	
ZSMC	Synchronous machine	TmTqs	ASG	(ZSMC) Unsaturated q-axis short circuit subtransient time constant Tq'' (typical range is s).	SynchronousMachineDynamics	
ZSMC	Synchronous machine	X0	ASG	(ZSMC) Per unit unsaturated zero sequence reactance.	SynchronousMachine	x0
ZSMC	Synchronous machine	X2	ASG	(ZSMC) Per unit unsaturated negative sequence reactance.	SynchronousMachine	x2
ZSMC	Synchronous machine	Xd	ASG	(ZSMC) Per unit unsaturated d-axis synchronous reactance.	SynchronousMachineDynamics	
ZSMC	Synchronous machine	Xdp	ASG	(ZSMC) Per unit unsaturated d-axis transient reactance Xd'.	SynchronousMachineDynamics	

Logical node	Logical node description	Data object	Type	(Used in) Data object description	CIM class	CIM attribute
ZSMC	Synchronous machine	Xds	ASG	(ZSMC) Per unit unsaturated d-axis subtransient reactance Xd''.	SynchronousMachineDynamics	
ZSMC	Synchronous machine	Xq	ASG	(ZSMC) Per unit unsaturated q-axis synchronous reactance.	SynchronousMachineDynamics	
ZSMC	Synchronous machine	Xqp	ASG	(ZSMC) Per unit unsaturated q-axis transient reactance Xq'.	SynchronousMachineDynamics	
ZSMC	Synchronous machine	Xqs	ASG	(ZSMC) Per unit unsaturated q-axis subtransient reactance Xq''.	SynchronousMachineDynamics	
ZSMC	Synchronous machine	VARtg	ASG	(ZSMC) Rated apparent power.	SynchronousMachine	ratedS
ZSMC	Synchronous machine	VRtg	ASG	(ZSMC) Rated voltage (intrinsic property).	SynchronousMachine	ratedU
ZSMC	Synchronous machine	WRtg	ASG	(ZSMC) Rated active power.	SynchronousMachine	could be used to validate ratedPowerFactor
ZTCF	Thyristor controlled frequency converter	PwrHz	ASG	(ZTCF) Target frequency setting.	FrequencyConverter	frequency
ZTCR	Thyristor controlled reactive component			no settings	StaticVarCompensator	n/a

Annex A
(informative)

Use case details

A.1 SCADA/EMS/DMS configuration from IEC 61850 SCL – Description

A.1.1 Name of use case

Use case identification		
ID	**Domain(s)**	**Name of use case**
		SCADA/EMS/DMS configuration from IEC 61850 SCL

A.1.2 Scope and objectives of use case

Scope and objectives of use case	
Related business case	Network or System Extension Planning
Scope	Use a IEC 61850 system configuration description (SCD) to configure part of a CIM based control centre model used for any CIM based applications such as SCADA, EMS, DMS, Asset Monitoring or other applications.
Objective	Use the IEC 61850 information as the master system of record to update the SCADA/EMS/DMS There are two major variations: (1) For new 61850 system(s)/substation(s): use the SCD to create the relevant CIM based model instances and associations. (2) For modifications to 61850 system(s)/substation(s): use the SCD to create, delete or modify the relevant CIM based model instances and associations.

A.1.3 Narrative of use case

Narrative of use case
Short description – max 3 sentences
An engineer, using a System Configuration Tool (SCT), defines the primary equipment, single line connectivity, associations and IEDs for a local automation system. This information is used to create the SCD file that is used within IED Configuration tool(s) to configure the 61850 devices. This same SCD file can be used to provide information for the model used within CIM-based applications using IEC 61970 or IEC 61968.

Complete description
NOTE The use case is written using the example of a transmission substation automation system, but the general steps are applicable to any power system related local automation system. The use case starts with requirements specification determined by a planning department e.g. following a request for a new connection or a review of assets or load growth. In this use case the requirements are expected to be defined in paper form, not in a CIM electronic format. The next few steps of the use case use the top-down engineering process described in more detail in IEC 61850 Part 4 and Part 6. They are described in summary form in this document to introduce the concepts for the benefit of readers who are not familiar with IEC 61850. The System Configuration Tool (SCT) is used by a System Engineer to model any SCL defined installation, for example an automation system for an electrical substation. The process starts by creating a formal specification of the system requirements. The engineer inputs information on primary equipment types, names and connectivity, typically based on the station's single line diagram. The required monitoring, protection, local automation and other functions are described as template Logical Nodes that are allocated to the equipment instances This formal model can be exported from the System Configuration Tool as a System Specification Description (SSD) file. This SSD file can then be transformed and/or imported into a CIM based modelling tool for review. If necessary, comments may be provided on paper or verbally for the System Engineer to update the model in the SCT. The review cycle may be repeated several times. In the next phase of the design process, the System Configuration Tool is used to import descriptions of the capabilities of specific Intelligent Electronic Devices (IEDs). The System Engineer extends the automation system model by redefining the required Logical Nodes with specific instances of Logical Nodes with specific types of IEDs. The final phase of the automation system design is to define the local communication configuration. At any stage during this process, the automation system model can be exported as a System Configuration Description (SCD) file. IEC 61850-6 describes how this SCD file is used as an input to IED tools in order to provide the IED specific configuration using either proprietary formats or Instantiated IED Description (IID) files. The details of this are not included in this document. This use case describes additional steps, where the same SCD file is also used to as an input for a CIM based modeling tool. If necessary, the model may be updated in the SCT and the review cycle repeated. CIM information that is not present or derived from in the SCD file is added within a CIM based modeling tool. The output of a CIM model tool is an incremental update that can be applied to SCADA/EMS/DMS control center systems.

A.1.4 General remarks

General remarks
The IEC 61850 standard initial scope was communication in substation automation systems and was primarily related to protection, control and monitoring. From 2009 and onwards the IEC 61850 series have been updated and extended for more general measurements (including statistical and historical data handling) and power quality. The concepts defined in IEC 61850 have been applied beyond the substation domain including modelling automation systems for hydropower plants, distributed energy resources, and wind turbines. Work is in progress for other applications such as distribution feeder automation. The first edition of IEC 61850 did not include communication to network control centres. There are now a number of standards and technical reports that address the mappings for SCADA communications. This is associated with a requirement for better vertical integration of the data models which is the subject of this use-case. IEC 61850-6 specifies a file format for describing communication and parameters related to IED (Intelligent Electronic Device) configurations, communication system configurations, switchyard (function) structures, and the relations between them. The main purpose of the format is to exchange IED capability descriptions, and system level descriptions between engineering tools of different manufacturers in a compatible way. The file format language is called System Configuration description Language (SCL). It provides a way of describing • primary system equipment and connectivity (single line) description, • communication connection description, • Intelligent Electronic Device (IED) capabilities. • Allocation of IED logical nodes to the primary equipment. Different subsets of the SCL language may be used at different stages of the design, installation and commissioning processes. This use case is mainly concerned with the following types: SSD System Specification Description. This describes the primary equipment, single line diagram and functions of the substation, plus the required logical nodes. It must contain a substation description section and may contain the needed data type templates and logical node type definitions. SCD System Configuration Description. This file contains the substation description section; the IED description section including the data flows and Data Type Templates; plus, a section to describe the local communication configuration. See: IEC 61850-6: Communication networks and systems for power utility automation – Part 6: Configuration description language for communication in power utility automation systems related to IEDs

A.2 Use case diagrams

The activity diagrams in Figures A.1 to A.3 show the main activities from the main actors and the key deliverables.

It should be noted that the use case is informative only and is intended to illustrate a typical engineering process. The use case is equivalent to the process described in IEC 61850-4, but it concentrates on the data exchanges between IEC 61850 based engineering tools and CIM based engineering tools.

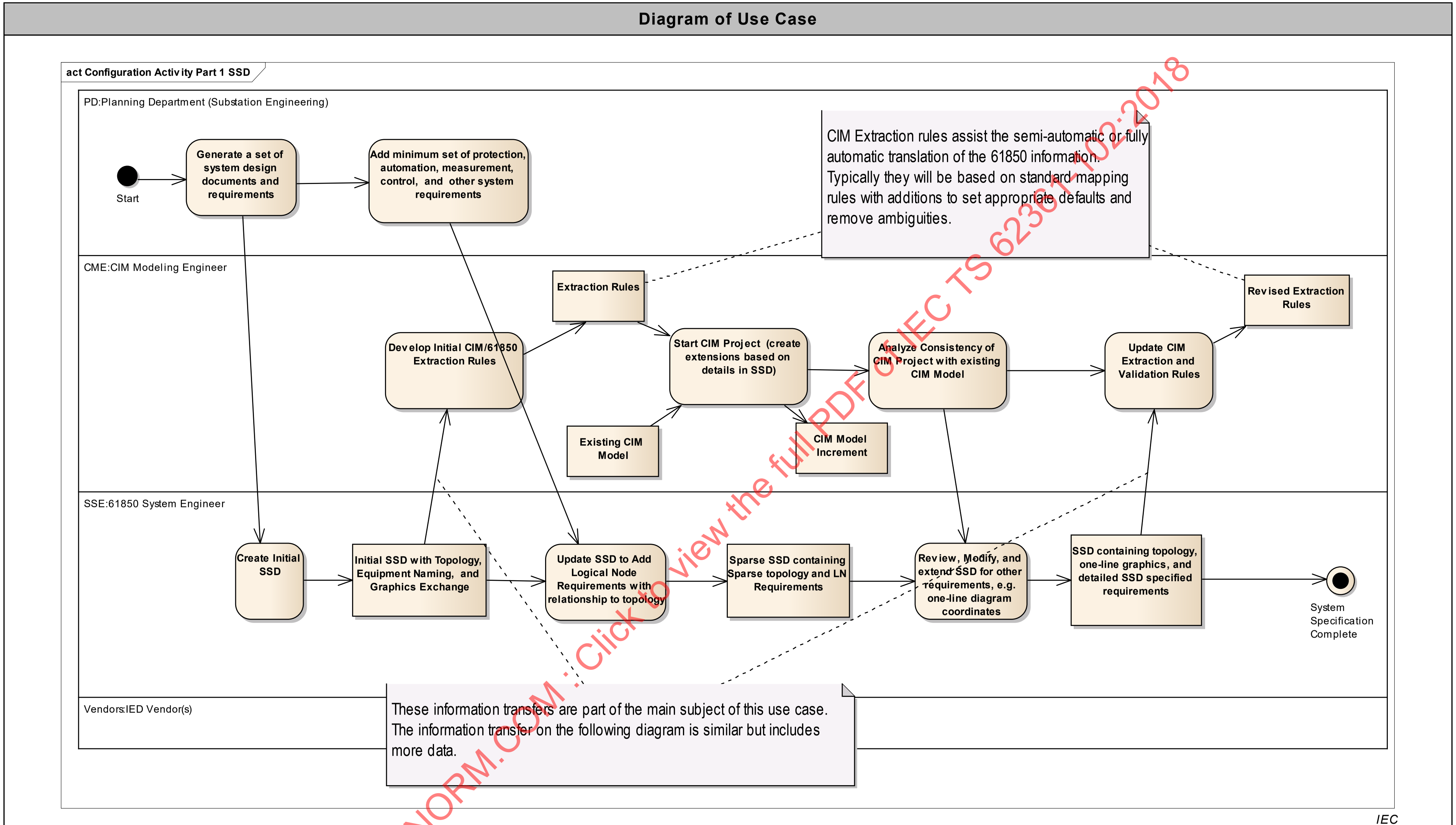


Figure A.1 – Activity diagram part 1 – Create and review system specification description

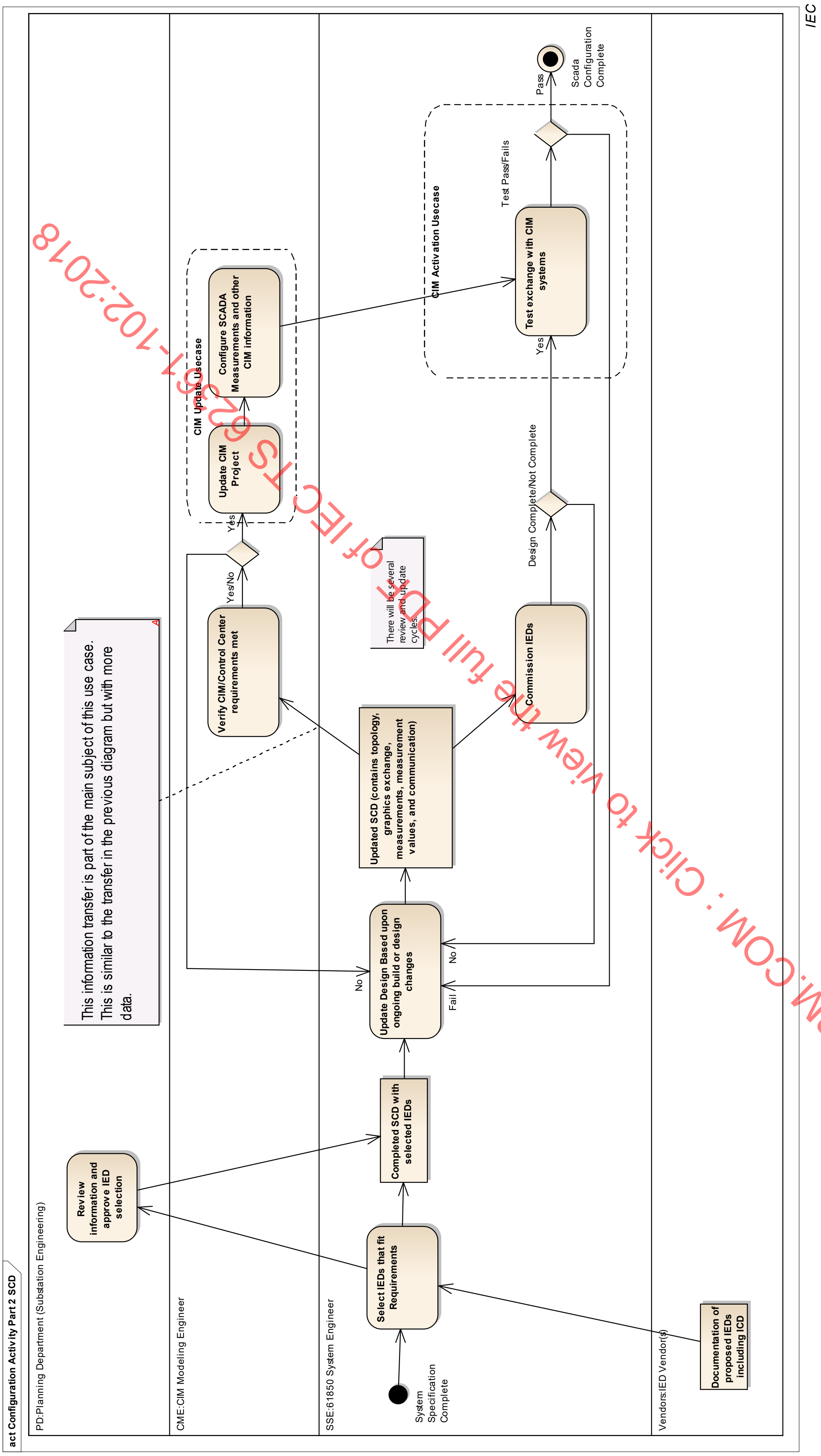


Figure A.2 – Activity diagram part 2 – Create and review system configuration description

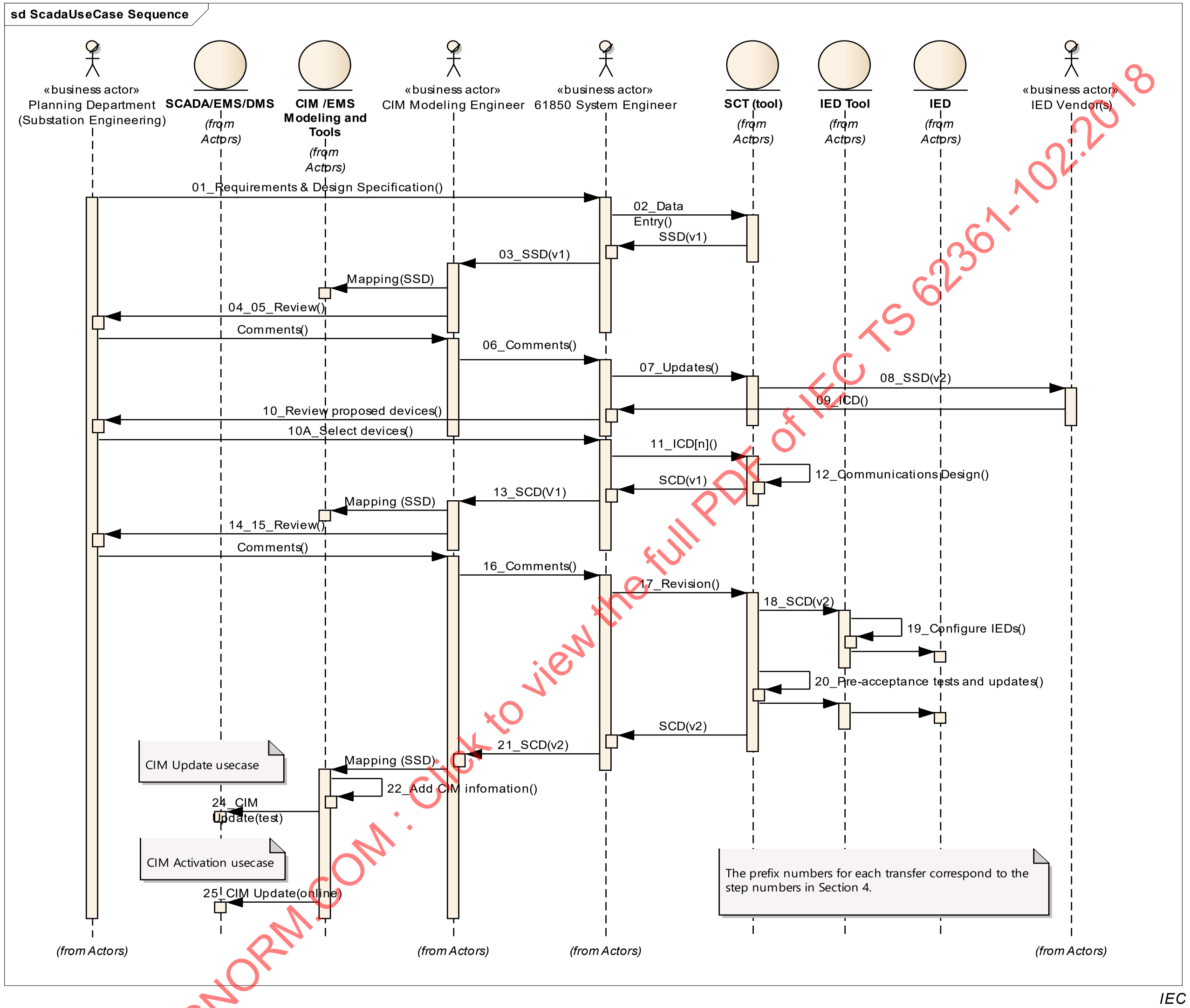


Figure A.3 – Sequence diagram

Figure A.3 shows the simplified data flows with a limited number of review cycles.

A.3 Technical details

A.3.1 Actors: People, systems, applications, databases, the power system, and other stakeholders

This use case is written using the following actors:

Actors			
Grouping (community)		**Group description**	
Actor name see Actor list	**Actor type see Actor list**	**Actor description see Actor list**	**Further information specific to this use case**
Planning Department (Substation Engineering)	Organization	Designs and/or specifies the substation, primary equipment and functional requirements.	Part of the role of IEC 61850-4 actor "Project requirements engineer" concerned with project scope
CIM Modeling Engineer	Person	Supports the SCADA and EMS systems. Does all data modeling using the modeling tools within the SCADA/EMS/DMS system.	
CIM/EMS Modeling tools	System	Sub-system of a SCADA/EMS/DMS used to create and update the model	
SCADA/EMS/DMS	System	A system that provides for monitoring, control, reporting and analysis of transmission or distribution networks.	
61850 [Automation] System Engineer	Person	Configures and supports the 61850 automation systems.	Equivalent to the combined roles of IEC 61850-4 actors: Project requirements Engineer (details), Project design engineer, System integrator, IED parameterizing engineer, Testing and commissioning engineer
Substation Configuration Tool (SCT)	System	A tool for configuring automation systems. This includes describing the system/substation equipment, connectivity model, IED devices and the local communications.	"System Configurator" in IEC 61850-6
IED Vendor	Organization	Vendor of IEDs and/or IED Tools that are or might be potential solution providers.	Same as IEC 61850-4 actor "Manufacturer"
IED Tool	System	Vendor and/or product specific application for the configuration or integration of IEDs	"IED Configurator" in IEC 61850-6

Actors			
Grouping (community)		**Group description**	
Actor name see Actor list	**Actor type see Actor list**	**Actor description see Actor list**	**Further information specific to this use case**
IED	System	Any device incorporating one or more processors with the capability of receiving or sending data/control from or to an external source (for example, electronic multifunction meters, digital relays, controllers)	

IEC 61850-4 describes a typical system engineering processes in more detail using the following actors and tools:

Actors			
Grouping (community)		**Group description**	
Actor name see Actor list	**Actor type see Actor list**	**Actor description see Actor list**	**Further information specific to this use case**
Project requirements engineer	Person / Role	sets up the scope of the project, its boundaries, interfaces, functions and special requirements ranging from needed environmental conditions, reliability and availability requirements up to process related naming and eventual specific address range restrictions or product usage. He defines what he wants to have application wise and how he wants to operate the system (project requirement specification). He finally accepts the delivered system	"Planning Department (Substation Engineering)" defines the project scope. "61850 [Automation] System Engineer" defines the details
Project design engineer	Person / Role	defines, based on the requirements specification, how the system shall look like; its architecture, requirements on the products needed to fulfil the required functions, how the products should work together. He thus defines the system design specification.	Role played by "61850 [Automation] System Engineer"
Manufacturer	Organisation	Supplies the products from which the system is built. If necessary, it supplies a project specific IED configuration	Same as "IED Vendor"

Actors			
Grouping (community)		**Group description**	
Actor name see Actor list	**Actor type see Actor list**	**Actor description see Actor list**	**Further information specific to this use case**
System integrator	Organisation	Builds the system, engineers the interoperation between its components based on the system design specification and the concretely available products from the manufacturers, and integrates the products into a running system. This results in a system configuration description	Role played by "61850 [Automation] System Engineer"
IED parameterizing engineer	Person / Role	uses the set-up possibilities of the system and device configuration to adjust the process, functional and system parameters of an IED to the project-specific characteristics.	Role played by "61850 [Automation] System Engineer"
Testing and commissioning engineer	Person / Role	tests the system on the basis of the system con-figuration description, system design and requirements specification and additional documentation, and puts the system into operation	Role played by "61850 [Automation] System Engineer"
System specification tool	System	specifying the system and device requirements regarding the needed system functional and process capabilities	Part of "Substation Configuration Tool (SCT)"
system configuration (system design) tool	System	allows selection of needed IEDs based on a system (requirements) specification, and defines the communication connections between the IEDs of the system and the logical relations between IED functionality and the primary equipment	Part of "Substation Configuration Tool (SCT)"
IED configuration (parameterization) tool	System	allows making the detailed parameterization of an IED based on a system design and requirement specification beforehand and a system description delivered by the system configuration tool after the system configuration process.	Same as "IED Tool"

A.3.2 Preconditions, assumptions, post condition, events

Use case conditions			
Actor/System/ Information/Contract	**Triggering event**	**Pre-conditions**	**Assumption**
System Planning determines the need for a new or expanded station.	Requests for new connections or periodic reviews		Planning Department (Substation Engineering) specifies the station layouts and request equipment to be ordered.
Asset Management makes funds available for the construction of the station	Business decision	Planning Department (Substation Engineering) has completed design of station	Equipment is ordered and project is released for construction
Construction Management build station	Equipment for station has been received	Funds and approval to construct have been received	
Protection and Control Technicians wire the station automation system.	Primary equipment has been installed		This activity includes the physical devices and communication network equipment.
Extraction Rules			The rules for extracting the appropriate information from the SSD or SCD into a CIM model, will be a combination of generic mapping rules to be defined in an IEC technical report, plus application and/or project specific selection criteria

A.3.3 References / Issues

References						
No.	**References type**	**Reference**	**Status**	**Impact on use case**	**Originator / Organisation**	**Link**

A.3.4 Further Information on the use case for classification / mapping

Classification information
Relation to other use cases
The use case is written using the example of a transmission substation automation system e.g. – Configuration of SCADA and EMS for State Estimation. – The general steps are applicable to any power system related local automation system e.g. – Configuration of Distribution Feeder Automation – Configuration of Asset Management/Asset Health Systems – Configuration of Distributed Energy Resource Management Systems These uses cases will have different Actors that provide the original requirements specification and perform the reviews, but the general flow will be the same. This use case describes a one-way information flow in electronic format from a 61850 configuration tool to a CIM based system. The information flow in the other direction is via paper or verbal instructions. There is a complementary use case in the other direction "Using CIM information as input to the 61850 configuration process". This use case is a pre-requisite for other use cases that transfer real time data to/from the 61850 based local automation systems to CIM based control centers e.g. – Volt-Var optimisation – System Integrity Protection Schemes (SIPS) – Self Healing in distribution networks – Micro-Grid applications – Virtual power plant applications Etc.
Level of depth
Prioritisation
Generic, regional or national relation
View
Further keywords for classification

A.4 Step by step analysis of use case

A.4.1 Pre-conditions

Scenario conditions					
No.	**Scenario name**	**Primary actor**	**Triggering event**	**Pre-condition**	**Post-condition**
4.1		System Engineering	Project is funded	System Planning determines need for station	Design package is provided to the Modeling and System Engineers. This is a manual transfer

A.4.2 Steps – Normal

Scenario								
Scenario name:		**Use SCD to create the relevant CIM based model instances and associations.**						
Step No.	**Event**	**Name of process/ activity**	**Description of process/ activity**	**Ser-vice**	**Information producer (actor)**	**Information receiver (actor)**	**Information exchanged**	**Requi-rement, R-ID**
1			Create requirements and design specification.		Planning Department (Substation Engineering)	61850 System Engineer	Station design documents including requirements for measurements	
2			Inputs design requirements into SCT		61850 System Engineer	SCT		
3			Issues System Specification Document for review		61850 System Engineer	CIM Modeling Engineer	Substation equipment types, names, connectivity, assignment to template Logical Nodes	
4			Review of station design from power systems perspective		CIM Modeling Engineer with help from Planning Department (Substation Engineering)		Check list for equipment and connectivity	
5			Review of station design from measurements perspective		CIM Modeling Engineer			
6			Provide review comments		CIM Modeling Engineer	61850 System Engineer	Paper or verbal	
7			Revise station specification		61850 System Engineer	SCT		
8			[Optional] issue SSD as IED requirements		61850 System Engineer	IED Vendors	SSD	
9			Supply IED capability descriptions		IED Vendors	61850 System Engineer	IED Capability Description (ICD) files	
10			Select vendor equipment/ products		61850 System Engineer			
10A			Review product selection		Planning Department	61850 System Engineer		
11			Import IED capability descriptions. Allocate specific IEDs		61850 System Engineer	SCT	IED section of SCD	
12			Start communications design		61850 System Engineer	SCT	Communications section of SCD	

Scenario								
Scenario name:	**Use SCD to create the relevant CIM based model instances and associations.**							
Step No.	**Event**	**Name of process/ activity**	**Description of process/ activity**	**Ser-vice**	**Information producer (actor)**	**Information receiver (actor)**	**Information exchanged**	**Requi-rement, R-ID**
13			Issue draft System Configuration Description for review		61850 System Engineer	CIM Modeling Engineer	Substation equipment types, names, connectivity, assignment to specific Logical Nodes for specific IED instances	
14			Review of station design from power systems perspective		CIM Modeling Engineer + Planning Department (Substation Engineering)		Check list for equipment and connectivity	
15			Review of station design from measurements perspective		CIM Modeling Engineer + SCADA/EMS users		Check list for equipment + associated measurements	
16			Provide review comments		CIM Modeling Engineer			
17			Revise station configuration, complete communications design		61850 System Engineer	SCT		
18			Export SCD and import into IED configuration tools		61850 System Engineer	SCT		
19			Configure IEDs		61850 System Engineer	IED Tools, IEDs	IED specific configuration	
20			Local system pre-acceptance tests Correct SCD and IED configurations as needed		61850 System Engineer			
21			Issue as-built System Configuration Description		61850 System Engineer	Modelling Engineer		
22			Add CIM specific information. Produce update for test SCADA/EMS/DMS		Modelling Engineer	SCADA/EMS/DMS (model management)	CIM update(s) Note 1	
23			Repeat review cycle steps 12 to 22 as necessary		61850 System Engineer CIM Modeling Engineer			

Scenario								
Scenario name:	**Use SCD to create the relevant CIM based model instances and associations.**							
Step No.	**Event**	**Name of process/ activity**	**Description of process/ activity**	**Ser-vice**	**Information producer (actor)**	**Information receiver (actor)**	**Information exchanged**	**Requi-rement, R-ID**
24			Commissioning and final acceptance		61850 System Engineer CIM Modeling Engineer SCADA/EMS users	SCADA/EMS/DMS (test)		
25			Perform Test and Validation to turn on SCADA and receive 61850 data		SCADA/EMS/DMS (model management)	SCADA/EMS/DMS (online)	CIM update(s) Note 2	

NOTE 1 Step 22 is part of the CIM Update use case. The CIM update information will be incorporated into the EMS/DMS after full validation and verification is complete, e.g. in a test environment. The model update for the online system would be scheduled.

NOTE 2 Step 25 is part of the EMS/DMS Activation Use Case. The CIM update information will be incorporated into the online EMS/DMS and the new measurements activated.

A.4.3 Steps – Alternative, error management, and/or maintenance/backup scenario

Scenario								
Scenario name:	**Use SCD to create, delete or update the relevant CIM based model instances and associations.**							
Step No.	**Event**	**Name of process/ activity**	**Description of process/ activity**	**Service**	**Information producer (actor)**	**Information receiver (actor)**	**Information exchanged**	**Requirements , R-ID**
1-24			Create initial system as normal use case				As step 13 above PLUS, unique object identifiers for instances used in CIM model	
25			Create change request			Substation Engineer		
26			Revise station configuration		61850 System Engineer	SCT		
27			Issue System Configuration Description for review		61850 System Engineer	CIM Modeling Engineer	As step 13 above with same unique object identifiers	
28-end			Same as steps 14-24 above.					

A.5 Information exchanged

Information exchanged		
Name of information exchanged	**Description of information exchanged**	**Requirements to information data** **R-ID**
System or Substation data	"serves to describe the functional structure of a substation, and to identify the primary devices and their electrical connections. ... Includes: Substation, Plant, Lines or other location container name(s) Voltage Level name(s) Bay name(s) Equipment & Sub-equipment names, types Terminals, Connectivity Nodes & associations Functions & Sub-functions	
Diagram data (optional)	Coordinates to draw a single-line diagram corresponding to the electrical connectivity	
Measurements, Status & Controls	IED instances containing Logical Nodes associated with equipment and containing Data Objects Data Attributes that can be mapped to CIM measurements (analogs, digitals, controls, counters)	
Settings & Parameters	IED instances containing Logical Nodes associated with equipment and containing Data Objects Data Attributes for settings that can be mapped to CIM attributes	
Communication configuration	Description of the communication configuration from the control centre view point.	

A.6 Common terms and definitions

Common terms and definitions	
Term	**Definition**

Annex B
(informative)

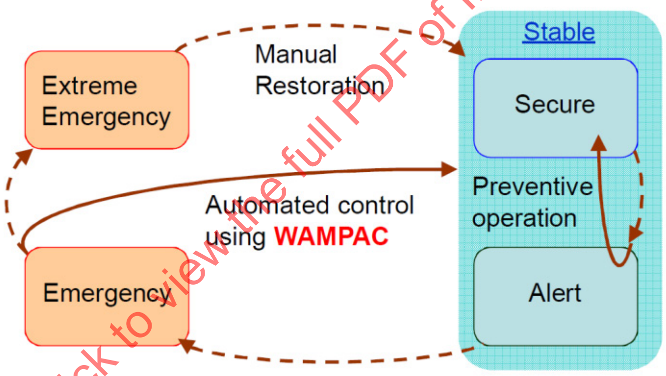
Use case details

B.1 Wide Area Monitoring, Protection and Control system (WAMPAC) for Transient stability

B.1.1 Name of Use Case

Use Case Identification		
ID	***Domain(s)***	***Name of Use Case***
		Wide Area Monitoring, Protection and Control system (WAMPAC) for Transient stability

B.1.2 Scope and objectives of use case

Scope and objectives of use case	
Related business case(s)	Wide Area Monitoring, Protection and Control system (WAMPAC)
Scope	CIM and IEC 61850 harmonization for WAMPAC in engineering phase and real-time control.
Objective(s)	Objectives of the use case is to identify the key standards that will enable the realization of WAMPAC systems with the required level of interoperability, utilizing IEC 61970-CIM, IEC TR 61850-90-5 (synchrophasors) for instance, which will thus enable the introduction of these proven techniques globally. **1. WAMPAC** WAMPAC is a system capable of monitoring the status of a power system in real-time that is able to execute automated control actions such as generator and/or load shedding and control of generator excitation control systems in order to restore the power system network to a stable condition or prevent further deterioration on the occurrence of an emergency condition as illustrated following figure.  IEC

Scope and objectives of use case	
	The target power system phenomena that can be alleviated by WAMPAC systems together with the required response time for their operation are as follows: • Transient stability phenomena (150 ms to 1 s); • Dynamic stability phenomena (1 to 5 s); • Overload (up to a few tens of seconds); • Frequency balancing between supply and demand within a smart grid (up to a few tens of seconds); • Voltage stability (up to a few minutes). There are some proposals with respect to an advanced power system control system ([1],[2],[3]). Especially, Papers [1] and [2] propose a concept of wide-area monitoring, protection and control (WAMPAC). Functions of WAMPAC can be classified as follows [1]: • Wide-area feedback control • Emergency control • Preventive and/or enhancement control by shifting an operating point