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

Intégration d'applications pour les services électriques – Interfaces système pour la gestion de distribution –
Partie 11: Extensions du modèle d'information commun (CIM) pour la distribution

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

APPLICATION INTEGRATION AT ELECTRIC UTILITIES – SYSTEM INTERFACES FOR DISTRIBUTION MANAGEMENT –

Part 11: Common information model (CIM) extensions for distribution

FOREWORD

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International Standard IEC 61968-11 has been prepared by IEC technical committee 57: Power systems management and associated information exchange.

The text of this standard is based on the following documents:

FDIS	Report on voting
57/1295/FDIS	57/1326/RVD

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

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

This second edition cancels and replaces the first edition published in 2010. It constitutes a technical revision.

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Major changes with respect to the first edition are summarised below[1];

- Introduction of new classes to support flexible naming of identified objects (new classes available in base CIM, IEC 61970-301).
- Introduction of new classes to support single line diagrams exchange (new classes available in base CIM, IEC 61970-301).
- Consolidated transmission and distribution models for lines, transformers, switching, sensing and other auxiliary equipment (some Ed.1 classes slightly changed and moved from DCIM to base CIM, IEC 61970-301, other new classes available in base CIM, IEC 61970-301).
- Support for separate phase definitions, typically needed for unbalanced network modelling (new classes available in base CIM, IEC 61970-301).
- Support for temporary network changes through models of cuts, jumpers and clamps (new classes available in base CIM, IEC 61970-301).
- Flexible model for organisations and their roles.
- Support for coordinate systems in description of geographical locations.
- Support for configuration events tracking.
- Lightweight model for assets and asset catalogues.
- Support for linkage between network-oriented models and premises-oriented (metering) models.
- Support for premises area network devices.

In informative sections of this document, words printed in Arial Black apply to terms that are used as tokens in the normative clauses (to facilitate the reading and the text search).

A list of all parts of the IEC 61968 series, under the general title: *Application integration at electric utilities – System interfaces for distribution management* can be found on the IEC website.

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

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

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IMPORTANT – The 'colour inside' logo on the cover page of this publication indicates that it contains colours which are considered to be useful for the correct understanding of its contents. Users should therefore print this document using a colour printer.

[1] For enhancements in the base CIM, see IEC 61970-301 documenting CIM15.

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INTRODUCTION

The IEC 61968 series of standards is intended to facilitate inter-application integration as opposed to intra-application integration. Intra-application integration is aimed at programs in the same application system, usually communicating with each other using middleware that is embedded in their underlying runtime environment, and tends to be optimised for close, real-time, synchronous connections and interactive request/reply or conversation communication models. Therefore, these inter-application interface standards are relevant to loosely coupled applications with more heterogeneity in languages, operating systems, protocols and management tools. This series of standards is intended to support applications that need to exchange data every few seconds, minutes, or hours rather than waiting for a nightly batch run. This series of standards, which are intended to be implemented with middleware services that exchange messages among applications, will complement, not replace utility data warehouses, database gateways, and operational stores.

As used in IEC 61968, a distribution management system (DMS) consists of various distributed application components for the utility to manage electrical distribution networks. These capabilities include monitoring and control of equipment for power delivery, management processes to ensure system reliability, voltage management, demand-side management, outage management, work management, automated mapping and facilities management. Standard interfaces are defined for each class of applications identified in the interface reference model (IRM), which is described in IEC 61968-1.

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APPLICATION INTEGRATION AT ELECTRIC UTILITIES – SYSTEM INTERFACES FOR DISTRIBUTION MANAGEMENT –

Part 11: Common information model (CIM) extensions for distribution

1 Scope

This part of IEC 61968 specifies the distribution extensions of the common information model (CIM) specified in IEC 61970-301. It defines a standard set of extensions of common information model (CIM), which support message definitions in IEC 61968-3 to IEC 61968-9, IEC 61968-13 and IEC 61968-14[2]. The scope of this standard is the information model that extends the base CIM for the needs of distribution networks, as well as for integration with enterprise-wide information systems typically used within electrical utilities. The information model is defined in UML which is platform-independent and electronically processable language that is then used to create message payload definitions in different required formats. In this way, this standard will not be impacted by the specification, development and/or deployment of next generation infrastructures, either through the use of standards or proprietary means.

For the purposes of this part of IEC 61968, the distribution CIM (DCIM) model refers to the IEC CIM model as defined by IEC 61970-301 and this part of IEC 61968.

The common information model (CIM) is an abstract model of the major objects in an electric utility enterprise typically involved in utility operations. By providing a standard way of representing power system resources as object classes and attributes, along with their relationships, the CIM facilitates the integration of software applications developed independently by different vendors. The CIM facilitates integration by defining a common language (i.e., semantics and syntax) based on the CIM to enable these applications or systems to access public data and exchange information independent of how such information is represented internally.

IEC 61970-301 defines a core CIM for energy management system (EMS) applications, including many classes that would be useful in a wider variety of applications. Due to its size, the CIM classes are grouped into logical packages, and collections of these packages are maintained as separate International Standards. This document extends the core CIM with packages that focus on distribution management systems (DMS) including assets, work, customers, load control, metering, and others. IEC 62325-301[3] extends the CIM with packages that focus on market operations and market management applications. Other CIM extensions may be published as International Standards, each maintained by a separate group of domain experts. Depending on a project's needs, the integration of applications may require classes and packages from one or more of the CIM standards.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60076-1, *Power transformers – Part 1: General*

---

2 IEC 61968-5, IEC 61968-6, IEC 61968-7, IEC 61968-8 and IEC 61968-14 are under consideration.

3 Under consideration.

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IEC 61968-1, *Application integration at electric utilities – System interfaces for distribution management – Part 1: Interface architecture and general requirements*

IEC 61968-2, *Application integration at electric utilities – System interfaces for distribution management – Part 2: Glossary*

IEC 61970-301, *Energy management system application program interface (EMS-API) –Part 301: Common information model (CIM) base*[4]

IEC 61970-501, *Energy management system application program interface (EMS-API) – Part 501: Common Information Model Resource Description Framework (CIM RDF) schema*

IEC 62361-100, *Naming and Design Rules for CIM Profiles to XML Schema Mapping*[5]

IEEE 802.3, *IEEE Standard for Information technology-Specific requirements – Part 3: Carrier Sense Multiple Access with Collision Detection (CSMA/CD) Access Method and Physical Layer Specifications*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 61968-2 and the following apply.

NOTE Refer to International Electrotechnical Vocabulary, IEC 60050, for general glossary definitions.

3.1
energy management system
EMS
computer system comprising a software platform providing basic support services and a set of applications providing the functionality needed for the effective operation of electrical generation and transmission facilities so as to assure adequate security of energy supply at minimum cost

3.2
distribution management system
DMS
computer system comprising a software platform providing basic support services and a set of applications providing the functionality needed for the effective operation of electrical distribution facilities so as to assure adequate security of energy supply at minimum cost

3.3
unified modeling language
UML
formal and comprehensive descriptive language with diagramming techniques used to represent software systems, from requirements analysis, through design and implementation, to documentation

Note 1 to entry: UML has evolved from a collection of methods contributed by different practitioners, into an International Standard. The CIM relies on UML for defining the model, and automated tools generate the documentation, schemas, and other artefacts directly from the UML. A basic understanding of UML is necessary to understand the CIM.

[4] 5th edition. Under consideration.

[5] Under consideration.

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3.4
common information model with distribution extensions
DCIM
union of the base CIM in IEC 61970-301 and additional packages defined in this document, IEC 61968-11

Note 1 to entry: The DCIM is intended to address most of the domain modelling needs of a DMS; however, a specific project may require other CIM packages or extensions.

3.5
profile
subset of DCIM classes, associations and attributes needed to accomplish a specific type of interface

Note 1 to entry: It may be expressed in XSD, RDF, and/or OWL files. A profile can be tested between applications. A profile is necessary in order to "use" the DCIM. Several profiles are defined in other parts of the IEC 61968 family of standards.

3.6
XML schema
schema used to define the structure, content, and semantics of extensible mark-up language (XML) files

Note 1 to entry: XML schemas are generally found in files with an "xsd" extension. The DCIM uses XSD files to define inter-application messages in most domain areas, except for power system model exchange.

3.7
resource description framework
RDF
web (W3C) standard used to represent information models

Note 1 to entry: RDF is more powerful than XSD because it can describe a data model, not just an XML file. The DCIM uses a subset of RDF to support power system model exchange.

3.8
web ontology language
OWL
another Web (W3C) standard that includes RDF and extends it

Note 1 to entry: OWL is more powerful than RDF in supporting data types, enumerations, more details of class relationships and associations, etc. Future DCIM profiles may use OWL.

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4 CIM specification

4.1 CIM modelling notation

The CIM is defined using object-oriented modelling techniques. Specifically, the CIM specification uses the Unified modeling language (UML) notation, which defines the CIM as a group of packages.

Each package in the CIM contains one or more class diagrams showing graphically all the classes in that package and their relationships. Each class is then defined in text in terms of its attributes and relationships to other classes.

The UML notation is described in Object Management Group (OMG) documents and several published textbooks.

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4.2 CIM packages

4.2.1 General

The CIM is partitioned into a set of packages. A package is a general purpose means of grouping related model elements. The packages have been chosen to make the model easier to design, understand and review. The common information model consists of several sets of packages. Entities may have associations that cross many package boundaries. Each application will use information represented in several packages.

4.2.2 CIM packages

The comprehensive CIM is partitioned into groups of packages for convenience. The groups comprising DCIM are:

- IEC 61970-301 (base CIM, defining data types and power system resources as required by typical EMS and DMS control centre applications);
- this part of IEC 61968.

Figure 1 shows the relevant[6] currently defined CIM normative packages and their dependency relationships. The dashed line indicates a dependency relationship, with the arrowhead pointing from the dependent package to the package on which it has a dependency.

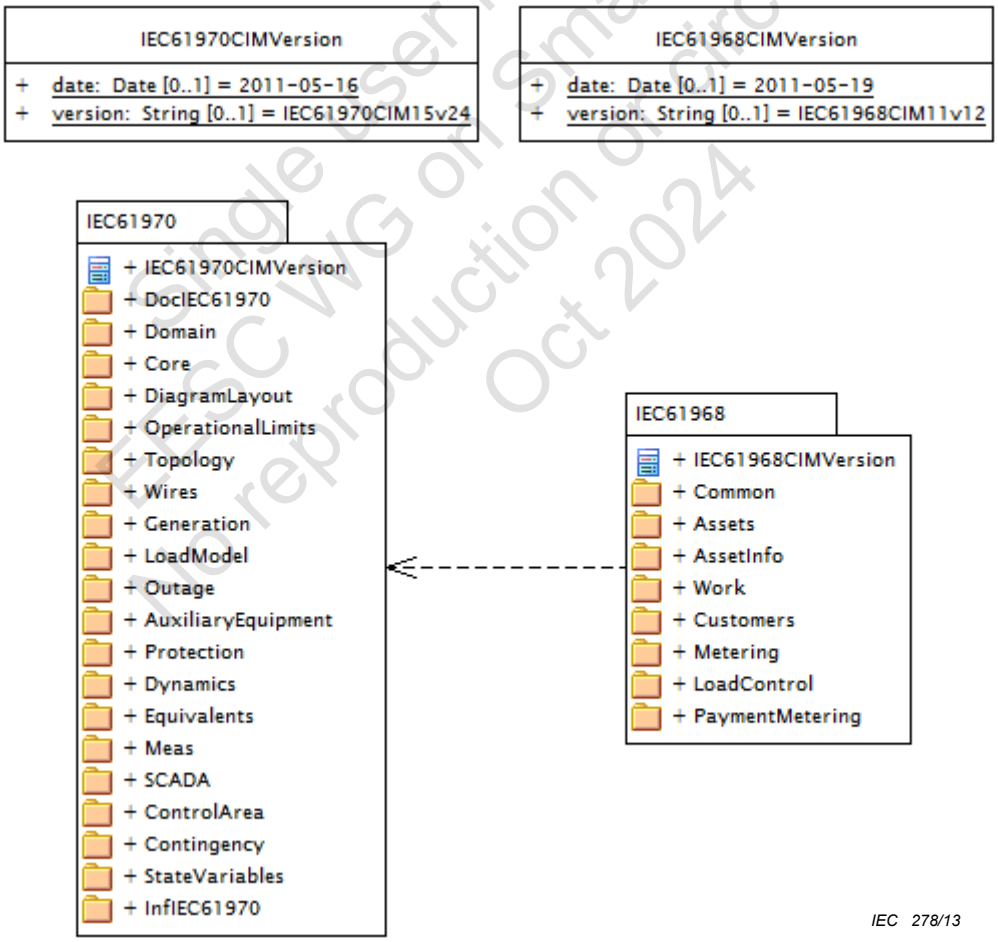

Figure 1 – CIM packages

6 CIM extensions for markets, IEC 62325-301 are also CIM normative packages, but not used in DCIM and thus not displayed.

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NOTE The contents of the base CIM referred to from within this part of IEC 61968 were auto-generated from the base CIM UML electronic model release IEC61970CIM15v31.

4.2.3 CIM extensions for distribution packages (this part of IEC 61968)

The base CIM model as defined by IEC 61970-301 defines a set of sub-packages which includes **Domain**, **Wires**, **AuxiliaryEquipment**, **Topology**, **Measurements**, **Equivalents** and **Core**, as well as several other ones. IEC 61968-3 to IEC 61968-9 and IEC 61968-13 required extensions to the CIM model as specified by IEC 61970-301 in order to describe the objects and associated properties which are relevant to distribution modelling and information exchanges applicable not only to typical control room systems, but also with enterprise and partner systems, as well as metering systems and devices. Therefore, just as applications in the distribution domain use classes from the base CIM, so might applications outside the distribution domain use classes defined in this document (for instance, market extensions in IEC 62325-301).

Figure 2 shows the packages defined for IEC 61968-11 CIM extensions for distribution. Notes on the left hand side of the figure indicate the part of IEC 61968 that has been driving the definition of classes within the respective package. Note, however, that different documents in the IEC 61968 series, as well as different applications that use CIM for information exchange will typically define message payloads using classes from several packages, including some defined outside of this document.

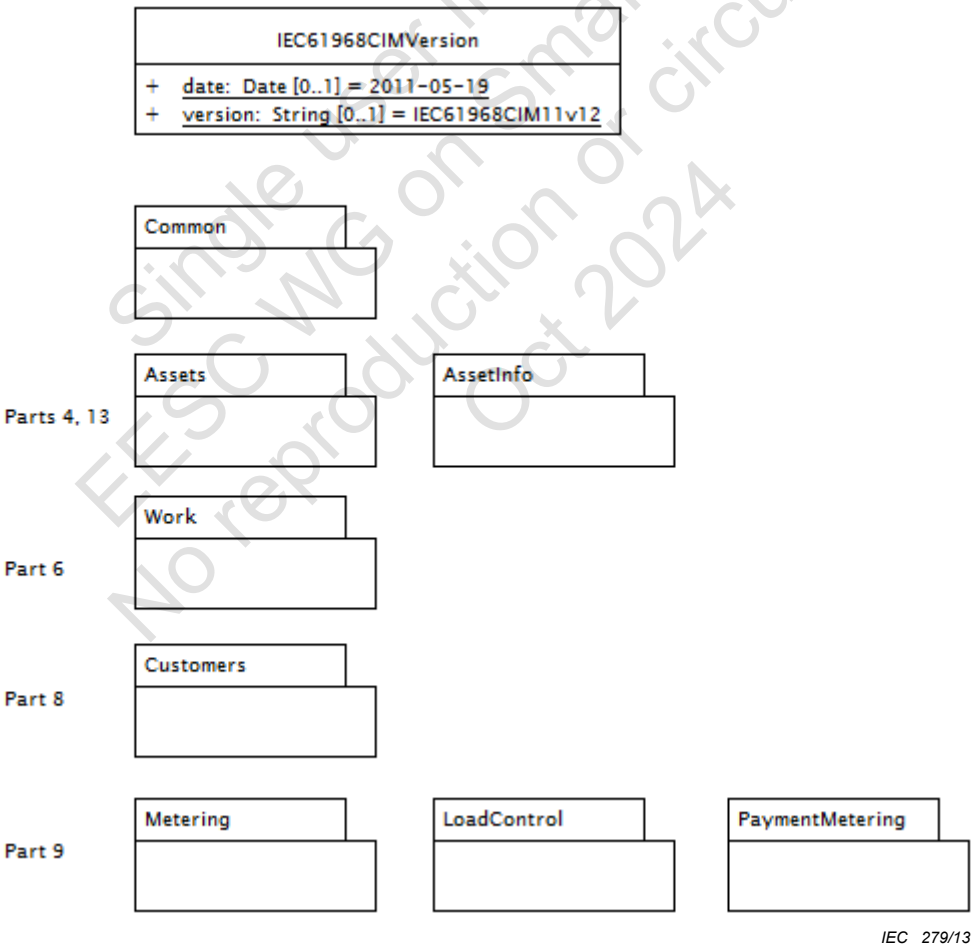

Figure 2 – CIM extensions for distribution (DCIM) top-level packages

Clause 6 contains the specification for each of the distribution CIM packages.

NOTE The contents of the CIM defined in this part of IEC 61968 were auto-generated from the CIM UML electronic model release IEC61968CIM11v13.

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4.3 CIM UML modelling

4.3.1 General

The CIM model is defined and maintained using UML. The source and point of maintenance for the CIM model is currently an Enterprise Architect (EA) file. This permits the model to be viewed and maintained graphically. The same tool is used to generate web pages which can be viewed over the internet. From the EA file, XMI file is also generated that can be used within various tools that support generation of context specific message payloads in XSD, RDF, or OWL format for IEC 61968-3 to IEC 61968-9 and IEC 61968-13.

The purpose of 4.3 is to define some principles with respect to the IEC 61968 information model and associated information exchanges. For description of different UML constructs used in the CIM model, refer to 4.3 of IEC 61970-301:—, CIM classes and relationships.

4.3.2 Scope of UML model

It is not the intent of this part of IEC 61968 and associated models to define models which satisfy all information requirements, as this would be an impossible task. The standard model is a canonical data model for enterprise systems integration and thus needs to satisfy requirements for information exchanges among different systems, i.e., message payloads defined in IEC 61968-3 to IEC 61968-9 and IEC 61968-13. Custom extensions are the matter of non-standard projects and products. They can be used to leverage CIM for information models of specific applications or systems, or for non-standard integration needs. However, custom extensions are not maintained by IEC.

The overall DCIM model has been evolving during many years, and has been published as an IEC standard only in 2010. Since that first edition, the UML model has been split into normative and informative classes and their relationships. Only normative classes, with their attributes and normative relationships, are fully documented in Clause 6. At the time of editing, the normative classes and relationships are those required for IEC 61968-4, IEC 61968-9 and IEC 61968-13[7]. They are considered stable and are expected to change little.

In contrast, informative classes and their informative relationships are not documented in this specification. They are present in the electronic UML model and will be promoted to normative classes stepwise, with the new editions of IEC 61968-3 to IEC 61968-9 and IEC 61968-13. Some of those classes will be kept informative as long as they are considered unstable and likely to change, and others might be removed because they do not participate in standard information exchange.

NOTE The next anticipated set of classes that is to be promoted from informative to normative in DCIM 12 for the next edition of IEC 61968-11 are those needed to support the maintenance cycle of IEC 61968-3, IEC 61968-4, IEC 61968-9 and IEC 61968-13, and IEC 61968-6 (1st edition) and IEC 61968-8 (1st edition).

4.3.3 Extensibility

It is fully the intent to permit extensions to the information exchange model. Extensions should utilize a local namespace. The namespace shall also serve to identify the origination of the class or property.

An extension can be defined in a UML model and/or a physical model such as XML schema:

- If an extension is made in UML model, such extension should be made in a different package as a separate model layer or context rather than be added or modified into CIM model directly. A “targetNamespace” tagged value may be used for this purpose if such extension is meant for an XSD generation.

[7] The only profile defined in the draft 2nd edition of IEC 61968-3 as of this writing is fully supported by base CIM classes, IEC 61970-301.

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- If an extension is made for XSD only, a target namespace has to be different than a CIM XSD namespace to identify the origin of the extension.

The extension namespace may follow a naming convention: http://<organization>/<version control>/<profile>.

4.3.4 Message payload (profile) definition

4.3.4.1 General

A profile is a restricted subset of DCIM classes, associations and attributes needed to accomplish a specific type of interface. A profile defines the message payload from CIM model (IEC 61968-11 and IEC 61970-301) and the header format (from implementation profiles IEC 61968-100 or IEC 61970-552) and information to exchange (specific to profile document in IEC 61968-3 to IEC 61968-9 and IEC 61968-13).

One way of defining standard message payloads (profiles) is by using applications such as various available open source tools providing support for CIM-based profile creation. Other methods and tools may be used, including hand coding.

Currently, two grammars of XML are used for DCIM-based profile definition in IEC 61968 series.

4.3.4.2 XML schema syntax

IEC 61968-3 to IEC 61968-9 define profiles in XML syntax according to IEC 62361-100. These profiles specify the format and content of the DCIM-based payload part of the message that gets exchanged in various integration scenarios, as defined in IEC 61968-100. Message headers use combinations of nouns and verbs. The nouns usually refer to the concepts defined within the DCIM model (payload), and the verbs are in support of transport technology.

The verb usually indicates which attributes are required. In the case of **create/created** verbs, typically all attributes defined in a profile are required, while with **get**, **cancel/cancelled**, **delete/deleted** and **close/closed** verbs only object identifiers are typically required. The **change/changed** verb would require an object identifier and the values of attributes to be changed.

The recommendations for defining DCIM-based profiles for data exchange are given in IEC 61968-1.

The verbs defined for use within IEC 61968 compliant interfaces, as well as message envelope, are specified in IEC 61968-100.

The nouns defined for use within IEC 61968 compliant interfaces are specified in IEC 61968-3 to IEC 61968-9.

4.3.4.3 RDF schema syntax

IEC 61970-501 defines a subset of RDF schema that is used for bulk network model exchanges. The profile format and header information is specified in IEC 61970-552[8], and is currently used by the profiles defined in IEC 61968-4 and IEC 61968-13.

[8] Under consideration.

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4.3.4.4 Data exchange contexts supported by DCIM

DCIM-based profiles defined in IEC 61968 cover two major data exchange contexts among enterprise systems:

- Bulk data exchanges, for the purpose of configuration of systems. This kind of business process is also known as model management, master data management, or data engineering. It requires message payloads that allow for establishing and maintaining the relationships between instances of various business entities common to two or more enterprise systems.
- Operational (dynamic) data exchanges among running systems. The data exchanged over this kind of interface assumes previous configuration of business entities in various systems to their common, DCIM-based representation at the interface, but not necessarily within the system.

As of this writing, profiles in RDFS and OWL syntax are mainly used for bulk, file-based data exchanges of large data sets, while XSD profiles are used in both bulk and operational message payloads.

4.4 DCIM model concepts and examples

4.4.1 General

4.4 describes some examples of modelling in the distribution domain and general electrical utility enterprise with DCIM. Some concepts are complementary to the base CIM examples presented in IEC 61970-301 (such as network modelling typical for distribution networks). Other concepts are general for any electrical utility enterprise (such as locations, documents, organisations), or specific to distribution domain (e.g., metering and customers).

4.4.2 Common concepts

4.4.2.1 Key classes in DCIM

Base CIM in IEC 61970-301 mainly defines the function of electrical network elements through **PowerSystemResource** class and its specialisations, for the needs of information exchange in the context of control centre applications and systems. DCIM in this part of IEC 61968 adds some key classes to support (a) physical description of those network elements, (b) the whole model for metering domain, as well as (c) information exchange related to network operations and planning and meter management and control, in the context of the whole utility enterprise (including outage, customers and work management).

Figure 3 shows key classes defined in the DCIM. Relationships between them, if existing, are not shown in this figure, but rather in the following subclauses. In fact, there are relatively few direct relationships between these key DCIM classes, in favour of more specific relationships among their specialisations. The UML diagram in Figure 3 shows that all the key classes are identified objects, i.e., the name of their superclass, **IdentifiedObject**, is displayed in the upper right corner of a class.

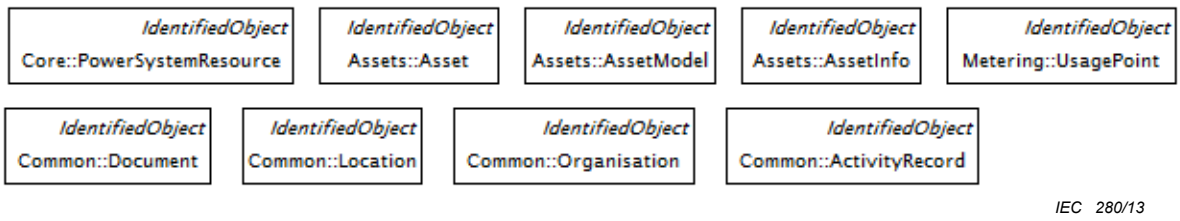

Figure 3 – DCIM key classes

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An **Asset** is a tangible resource of the utility, including power system equipment, end devices, vehicles, tools, cabinets, buildings, etc. For electrical network equipment, the function of the asset is modelled with the **PowerSystemResource** hierarchy, defined fully[9] in the wires model (refer to IEC 61970-301 and model package **IEC61970::Wires**). Asset description places emphasis on the physical characteristics and the lifecycle of the equipment performing that function, and relies on **PowerSystemResource** hierarchy for electrical connectivity.

AssetModel provides details about the **Asset** as a product of a given manufacturer, so one **AssetModel** and its associated **AssetInfo** can describe many instances of **Asset**.

AssetInfo is the container for datasheet information about **Asset** and **AssetModel**, and it can also be referenced by multiple instances of **Asset** and **PowerSystemResource** (i.e., shared).

A **Location** is the place, scene, or point of something where someone or something has been, is, and/or will be at a given moment in time. It is defined with one or more position points (coordinates) in a given coordinate system.

A **UsagePoint** is the logical or physical point in the network to which meter readings or events may be attributed. It is used at the place where a physical and virtual meter may be located. This class provides the link between the network-oriented model of electrically connected equipment (**PowerSystemResource** specialisations) and the asset and premises-oriented model of the metering domain.

A **Document** is a grouping of information collected, often managed as a part of a business process. It will frequently contain references to other objects, such as assets, persons and power system resources. **Organisations** are business entities that may have roles as utilities, contractors, suppliers, manufacturers, customers, tax authorities, etc.

ActivityRecord records activity for an entity at a point in time. Activity may be for an event that has already occurred or for a planned activity.

Following subclauses discuss in some more detail the key DCIM classes, their specialisations and relationships, and indicate their intended usage.

4.4.2.2 Locations and geographical representations

To allow for locating different entities and activities in space, DCIM provides the class **Location**. Entities and activities can be located by their different kinds of addresses as well as by position coordinates, **PositionPoint** in a given **CoordinateSystem**. Changes in configuration of a **Location** can be tracked with instances of a special **ActivityRecord**, **ConfigurationEvent**.

Location class is not intended to be used for graphical data exchange, although its **PositionPoint**s can be used to derive initial layouts for graphical applications. Exchange of single line diagrams representing **PowerSystemResource**s is supported by model package **IEC61970::DiagramLayout** defined in base CIM in IEC 61970-301.

NOTE Support for complex geo-spatial data exchanges is out of the scope of this part of IEC 61968, since there are widely used and adopted standards (e.g. GML) for other domains that can be applied to electrical networks as well.

Figure 4 shows how **Location** class is used in relation with **Asset**s, **PowerSystemResource**s and **UsagePoint**s.

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9 In this part of IEC 61968 (2nd edition), all the DCIM classes that were defined in the model package **IEC61968::WiresExt** of IEC 61968-11:2010 (1st edition), have been moved to base CIM, IEC 61970-301 (5th edition) and model package **IEC61970::Wires**, to ensure functional integrity of the overall CIM network model, for both transmission and distribution networks.

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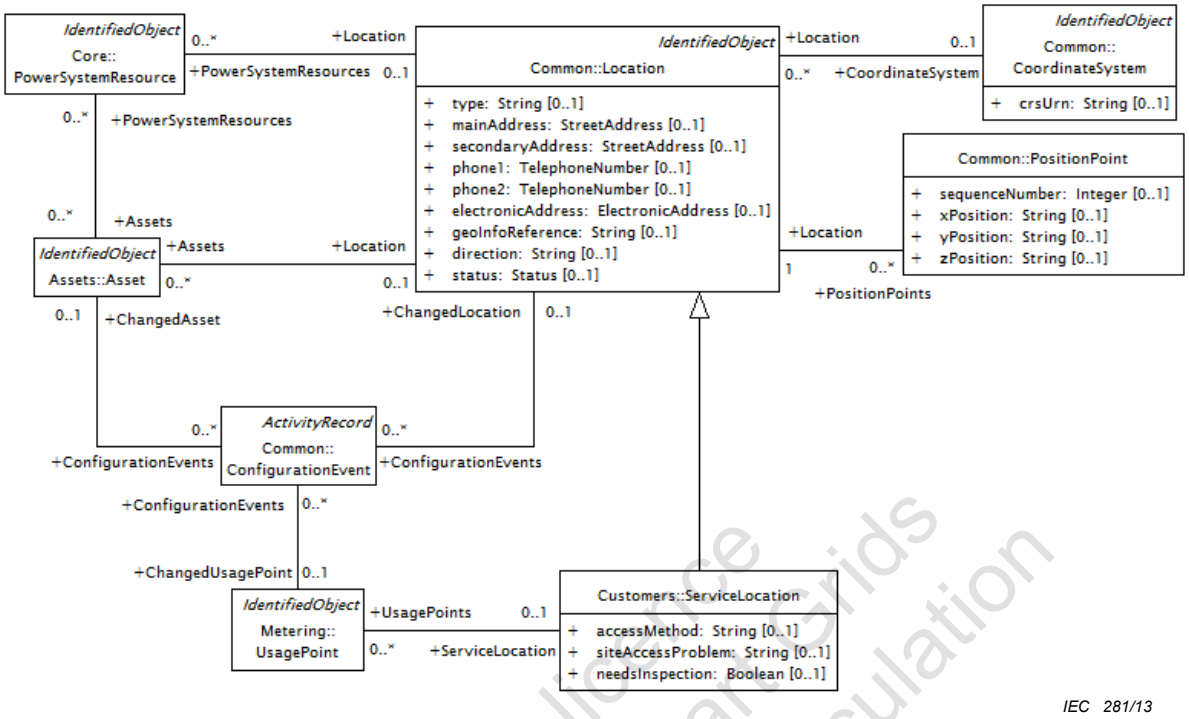

Figure 4 – DCIM power system resource and asset locations

An **Asset** or a **PowerSystemResource** directly associate with a **Location**, because the "general" **Location** provides all the information required (such as **mainAddress**, **electronicAddress**, or associated **PositionPoint**s). In contrast, a **UsagePoint** references a specialised type of location, **ServiceLocation**, with additional attributes relevant for service only, such as **needsInspection**. This is a commonly used pattern in DCIM: To provide associations among specialisations where applicable and to relate high level classes where the generic relationship applies to all the specialisations.

4.4.2.3 Organisations

Figure 5 illustrates two major classes used to model organisations, **Organisation** and **OrganisationRole**, and their intended usage.

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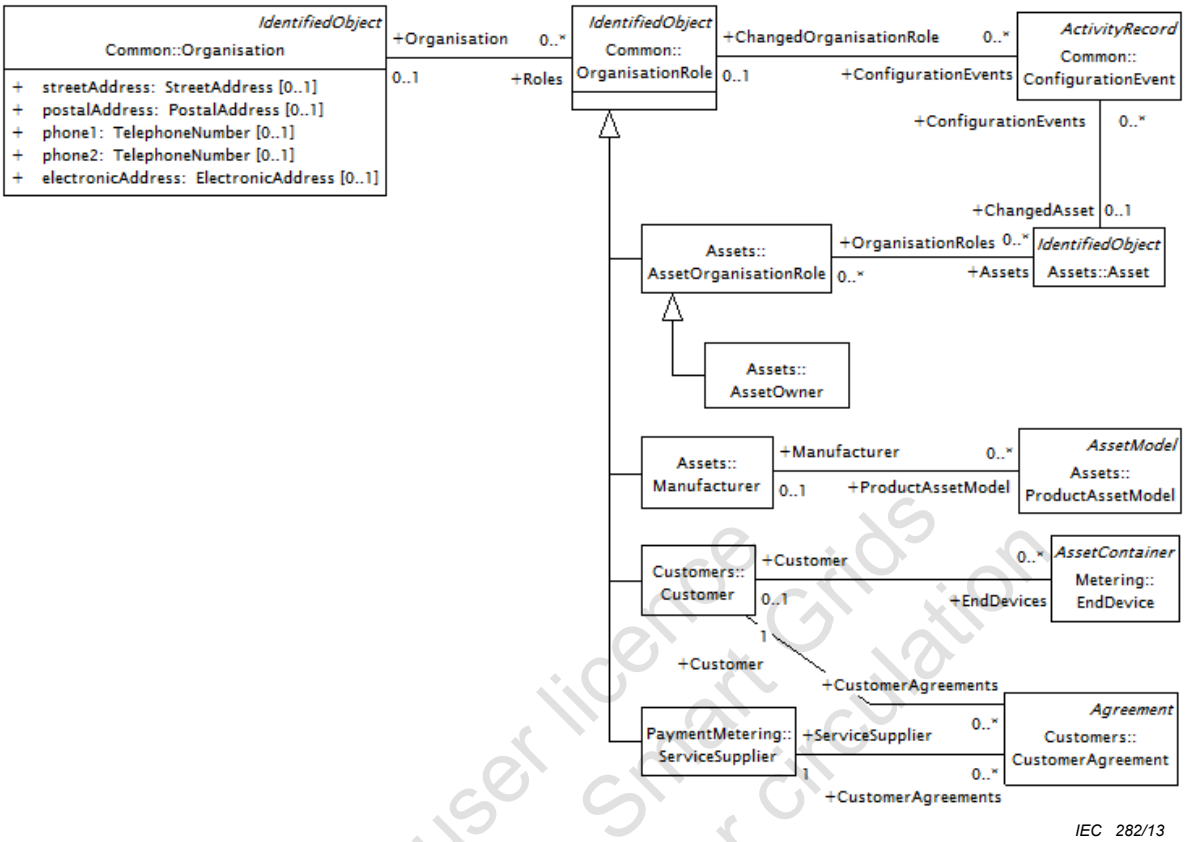

Figure 5 – DCIM organization model

Business entities modelled with DCIM are often used in many disparate contexts. For example, the same instance of **Organisation** may have the role of a **Customer** in a context dealing with service requests for **EndDevice**s, and the role of a **Manufacturer** of a **ProductAssetModel** in a context of asset maintenance; or the role of an **AssetOwner** in the context of asset management, and the role of a **ServiceSupplier** in the context of service requests and according to **CustomerAgreement**. This is modelled in DCIM with the association of an **Organisation** with multiple **OrganisationRole**s, whereas each **OrganisationRole** may reference a single **Organisation**, as a business entity.

Figure 5 shows the **OrganisationRole** as the common supertype of various roles. They are introduced on need, when there are specific attributes (not shown in the figure) and/or associations applicable to only certain domain of usage. One such example is **Manufacturer**: that role is applicable to a given **ProductAssetModel**, not to the **Asset** in general, and therefore there is an explicit association of that specific **OrganisationRole** specialisation with the **ProductAssetModel**, while there are other specific roles in relation to **Asset**s (e.g., **AssetOwner**).

In DCIM, **Organisation** as a business entity is never specialised.

Configuration changes of **OrganisationRole**s can also be tracked with instances of **ConfigurationEvent**.

4.4.2.4 Assets

4.4.2.4.1 Major classes in assets model

Whereas IEC 61968-11:2010 (1st edition) contained **Asset** and **AssetModel** classes required only in the context of metering (IEC 61968-9), this part of IEC 61968 (2nd edition) provides a more elaborate assets model, supporting the needs for data exchanges in the context of

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network model exchanges (IEC 61968-4 and IEC 61968-13). Figure 6 gives an overview of major classes that are included in the DCIM assets model.

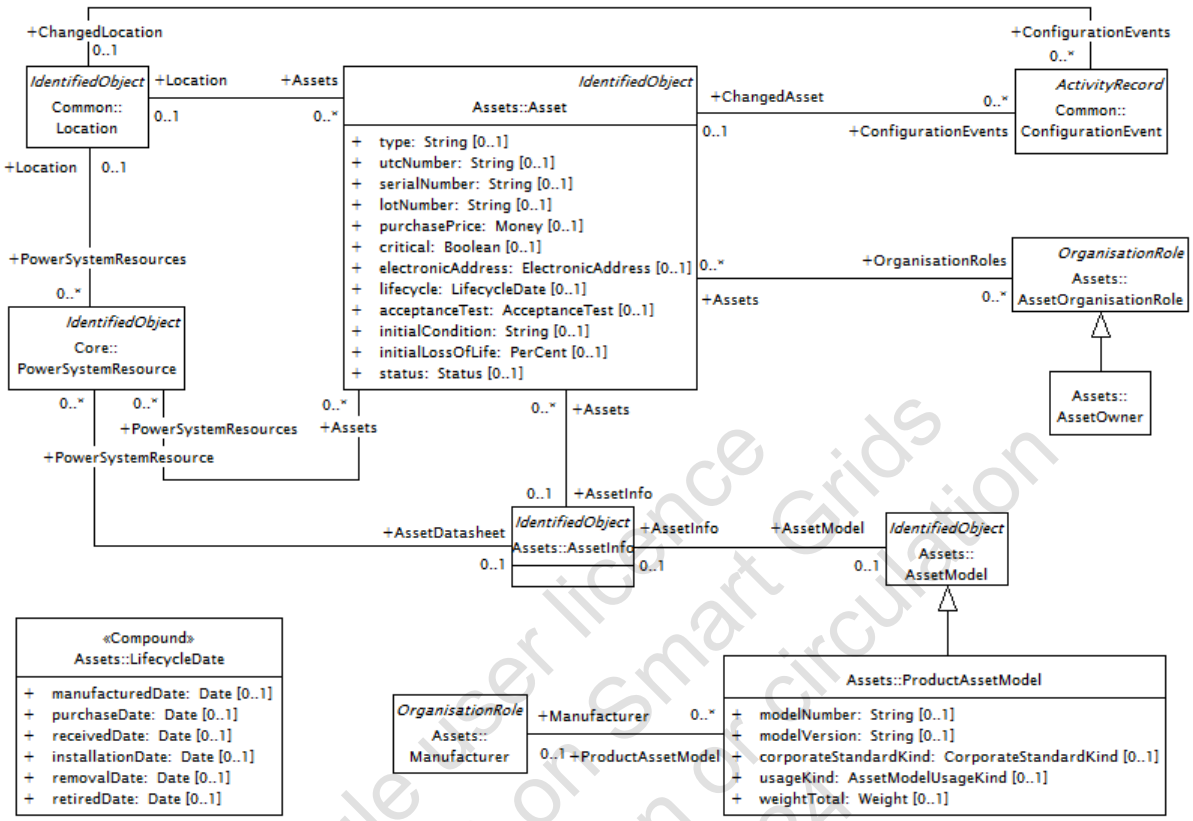

Figure 6 – DCIM assets model

Asset is a tangible resource of the utility, including power system equipment, various end devices, cabinets, vehicles, buildings, etc. An **Asset** instance is a managed resource that can be in operation or in stock, and that is characterised with its **lifecycle** attribute, the possible values being defined by the compound **LifecycleDate**. It may be described with a **Location** and its configuration may be tracked with instances of **ConfigurationEvent**. An Asset may be related to organisations through multiple **AssetOrganisationRole**s, such as **AssetOwner**.

NOTE In this part of IEC 61968 (2nd edition) (documenting DCIM11), there is a single specialisation of **AssetOrganisationRole**. It is anticipated that the next edition (documenting DCIM12) will add more organisation roles with respect to assets, such as maintainer or user, in support of data exchanges required by IEC 61968-3 and IEC 61968-6.

Some data exchanges will require electrical equipment connectivity model, in which case an **Asset** may reference one or more **PowerSystemResource** instances, which model the electrical function of the equipment represented by the physical **Asset** – see also 4.4.2.5. The inverse applies as well, namely, some data exchanges between operational and other systems (such as planning or asset management systems) will require a physical view associated with the electrical model of the power system, and in that case a **PowerSystemResource** may refer to the relevant **Asset** and/or **AssetInfo** instances. Finally, some data exchanges will completely ignore electrical connectivity model and will work exclusively with the assets model.

Another essential class in the assets model is **AssetInfo**, which is an identifiable container for various physical parameters describing associated **Asset**s. An **Asset** without the associated concrete **AssetInfo** instance is not fully described. **AssetInfo**, modelling what is sometimes called “catalogue”, “library” or “code”, is a set of attributes of an asset, representing typical

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datasheet information of a physical device that can be instantiated and shared in different data exchange contexts:

- as attributes of an asset instance (installed or in stock);
- as attributes of an asset model (product by a manufacturer);
- as attributes of a type asset (generic type of an asset as used in designs/extension planning)[10].

Because datasheet attributes of physical devices depend on the type of device they describe, **AssetInfo** is the class that is specialised with concrete types that hold the attributes and associations specific to that specialisation (see 4.4.2.4.2).

The main characteristic of a concrete **AssetInfo** instance is the fact that it is possible to reference it from multiple instances of **PowerSystemResource** or **Asset**. This is a major requirement in distribution network modelling, where the equipment characteristics are rarely defined per **PowerSystemResource** or **Asset**, due to the nature and amount of the equipment used. Typically, one instance of a specific **AssetInfo** may be referenced by thousands of instances of **PowerSystemResource** or **Asset**. Similar requirement exists for calculated electrical parameters, such as line or transformer impedances, and this is reflected through the relevant electrical catalogue classes (see 4.4.3.3.1).

The third major abstraction related to assets is the concept of **AssetModel**. It represents the model of an **Asset**, either a product of a specific manufacturer (**ProductAssetModel**) or a generic asset model or material item (not shown in Figure 6, because that class is still informative). Datasheet characteristics of the **AssetModel** are available through the associated **AssetInfo** specialisation and can be shared with **Asset** or **PowerSystemResource** instances.

4.4.2.4.2 Specialisations in assets model

In the earlier versions of the electronic UML model of DCIM, there used to be three parallel inheritance hierarchies related to assets, in addition to the **PowerSystemResource** inheritance hierarchy of base CIM, in IEC 61970-301. This part of IEC 61968 (2nd edition) presents a simplified assets model, well consolidated with the function model of **PowerSystemResource**, and with the major classes introduced in 4.4.2.4.1.

4.4.2.4.2 gives the modelling guidelines that have been established and applied in this edition of IEC 61968-11, and that should be followed in the future standard editions of DCIM as well as for custom extensions of the standard DCIM.

a) Among classes **Asset**, **AssetModel**, **ProductAssetModel** and **AssetInfo**: **ProductAssetModel** should never be specialised in the standard DCIM, and **AssetModel** is specialised only with **ProductAssetModel**[11]. **AssetInfo** will always be specialised. **Asset** may be specialised according to guideline d) only.

b) If a device/equipment exists in **IEC61970::Wires** model package of IEC 61970-301 (as a specialisation of, or related to **PowerSystemResource**), it is not allowed to define its counterpart as a specialisation of **Asset**. In contrast, a specialisation of **AssetInfo** shall be defined with its datasheet properties, where applicable.

c) Relationship between functional and physical models is established between relevant specialisations of **PowerSystemResource** and **AssetInfo** through inherited relationship,

[10] Among informative classes in the electronic UML model of DCIM, there is one more specialisation of **AssetModel** which is anticipated to become normative in some of the later editions of IEC 61968-11.

[11] Among informative classes in the electronic UML model of DCIM, there is one more specialisation of **AssetModel** which is anticipated to become normative in some of the later editions of IEC 61968-11.

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either **PowerSystemResource–AssetInfo** (if asset instance does not exist) or **PowerSystemResource–Asset–AssetInfo** (if asset instance is available).[12]

d) If there is a device/equipment/network-related entity not modelled in **IEC61970::Wires** model package of IEC 61970-301, it should be inheriting from **Asset** or **AssetContainer**, and its name need not contain the (now redundant) word "Asset".[13]

e) According to a), the specialisations of **Asset**, **AssetModel**, **ProductAssetModel** should be eliminated as follows: The required attributes and association ends should be moved into either an **Asset** specialisation (if they are applicable to an instance of **Asset**), or to an **AssetInfo** specialisation (if they represent datasheet information, applicable to many **Asset** instances).[14]

Figure 7 shows some DCIM examples that reflect the above guidelines and also illustrates the usage of some more classes from the assets model.

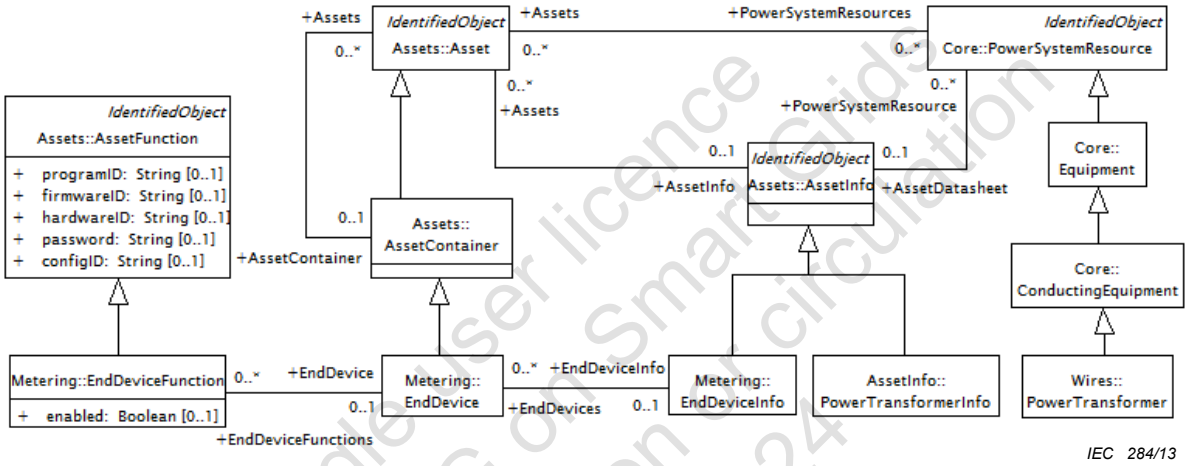

Figure 7 – DCIM assets – specialising guidelines

AssetContainer is the specialisation of **Asset**, and also the container for multiple **Asset**s. As a specialisation, it inherits the attributes and associations with other classes. As a container, it allows to model composite **Asset**s. One such example is the **EndDevice**, which may contain other entities that may have independent lifecycle (such as communication modules, not shown in the figure). Other examples of **AssetContainer**s would be towers or vaults (currently not in the normative DCIM). Neither of these real world objects is defined in the functional, **PowerSystemResource** model (guideline d)).

Figure 7 shows only two among many specialisations of **AssetInfo**: **EndDeviceInfo** and **PowerTransformerInfo**. The latter one inherits an association to **PowerTransformer**s either through **AssetInfo–PowerSystemResource** or **AssetInfo–Asset–PowerSystemResource** (guideline c); for details, see 4.4.3.4). There is no **Asset** specialisation corresponding to **PowerTransformer** (guideline b)).

For **EndDeviceInfo**, it is directly associated with multiple instances of **EndDevice**, and it also inherits the association **AssetInfo–Asset**. In such a case, it is the most specific relationship that should be used. At present, there are few specialisations of **Asset**, and it is acceptable to

[12] Due to application of this guideline, some direct associations between specialisations of **PowerSystemResource** and **AssetInfo** have been eliminated in favour of using the new inherited association defined between **PowerSystemResource** and **AssetInfo**.

[13] Due to application of this guideline, some classes from **Metering** model package have been renamed in order not to use the suffix "Asset".

[14] Due to application of this guideline, some classes from **Metering** model package have "lost" their instance attributes, which have been moved to the corresponding **AssetInfo** specialisation.

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define such concrete associations among specialisation, even where the inherited association exists. For the case of relationships between **AssetInfo** and **PowerSystemResource** specialisations, they have been considered too numerous to define all the explicit relationships among them.

Finally, the class **AssetFunction** and its specialisation **EndDeviceFunction** demonstrate the preferred design, when feasible: to start with only direct associations between the relevant specialisations, such as **EndDevice**–**EndDeviceFunction** in Figure 7. In the future DCIM editions, if there are several cases where the need for relationship between the specialisations of **AssetFunction** and **Asset** or **AssetContainer** are identified, the concrete relationship would likely be replaced with a generic one.

4.4.2.5 Electrical model vs. physical model

The distribution CIM covers both electrical and physical representation of an object. The **PowerSystemResource** class models the electrical representation and is often used for network operation, monitoring, outage management, and operations planning, while the **Asset** class models an object's physical representation and is mainly used for asset and work management, but also for network extension planning, outage management and network studies. For instance, the physical representation may be essential in deriving attributes for the electrical representation, even if no explicit **Asset** class is used. For instance, 4.4.3.3.3 explains how the asset model can help calculate the electrical characteristic of a distribution line. The relationship between the two aspects of the electrical equipment also provides key information for extension planning, work management and outage management.

The relationship between **Asset** and **PowerSystemResource** allows for navigation between the two different representations (models) of a real world object. Connectivity and operational aspects (such as operational limits or energisation status) are always modelled through **PowerSystemResource** and its specialisations, while physical aspects (such as data sheet ratings, dimensions or asset lifecycle and financial data) are always modelled through **Asset** and its related classes.

It can be noticed that both **Asset** and **AssetInfo** have relationships to **PowerSystemResource**. The relationship between **PowerSystemResource** and **Asset** is typically used for data exchanges when the **Asset** is in operation, to give the physical view of electrical network equipment being operated, or in the other direction, to give the electrical connectivity view to the system working with physical representation. The relationship between **PowerSystemResource** and **AssetInfo** can be used even if there is no actual **Asset** instance available or needed; typical example are planning applications, or network calculation applications used in operational systems (such as distribution power flows).

4.4.3 Network modelling concepts and examples

4.4.3.1 Connectivity and phase modelling

The distribution CIM connectivity model is identical with the base CIM connectivity model, i.e., it relies on **ConductingEquipment**, **Terminal**, and **ConnectivityNode** classes (refer to IEC 61970-301:—, 4.4.4, Connectivity model and 4.4.8, Phase wire modelling). With the **Terminal.phases** attribute, phase information of each **ConductingEquipment** can be expressed for a multi-phase distribution network. It also allows one to represent normal network phase mismatch cases. In distribution networks, there are some rare cases where a normal open switch may be connected to the phase A on one side and the phase B on the other side. **Jumper**s could introduce normal phase mismatch as long as one side is de-energised before the **Jumper** is connected. For instance, a **Jumper** could connect an energised normal phase A to a normal phase B that is currently de-energised. This case is only allowed when all downstream loads are on the same phase(s).

For an extensive example of balanced three-phase sample network, refer to IEC 61970-301:—, 4.4.4.2, Connectivity and containment example, and for an example illustrating how the CIM

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connectivity model can be used to represent a multi-phase network, refer to IEC 61970-301:—, 4.4.8, Phase wire modelling.

Figure 8 gives an overview of phase-related classes used typically for distribution network modelling and applications.

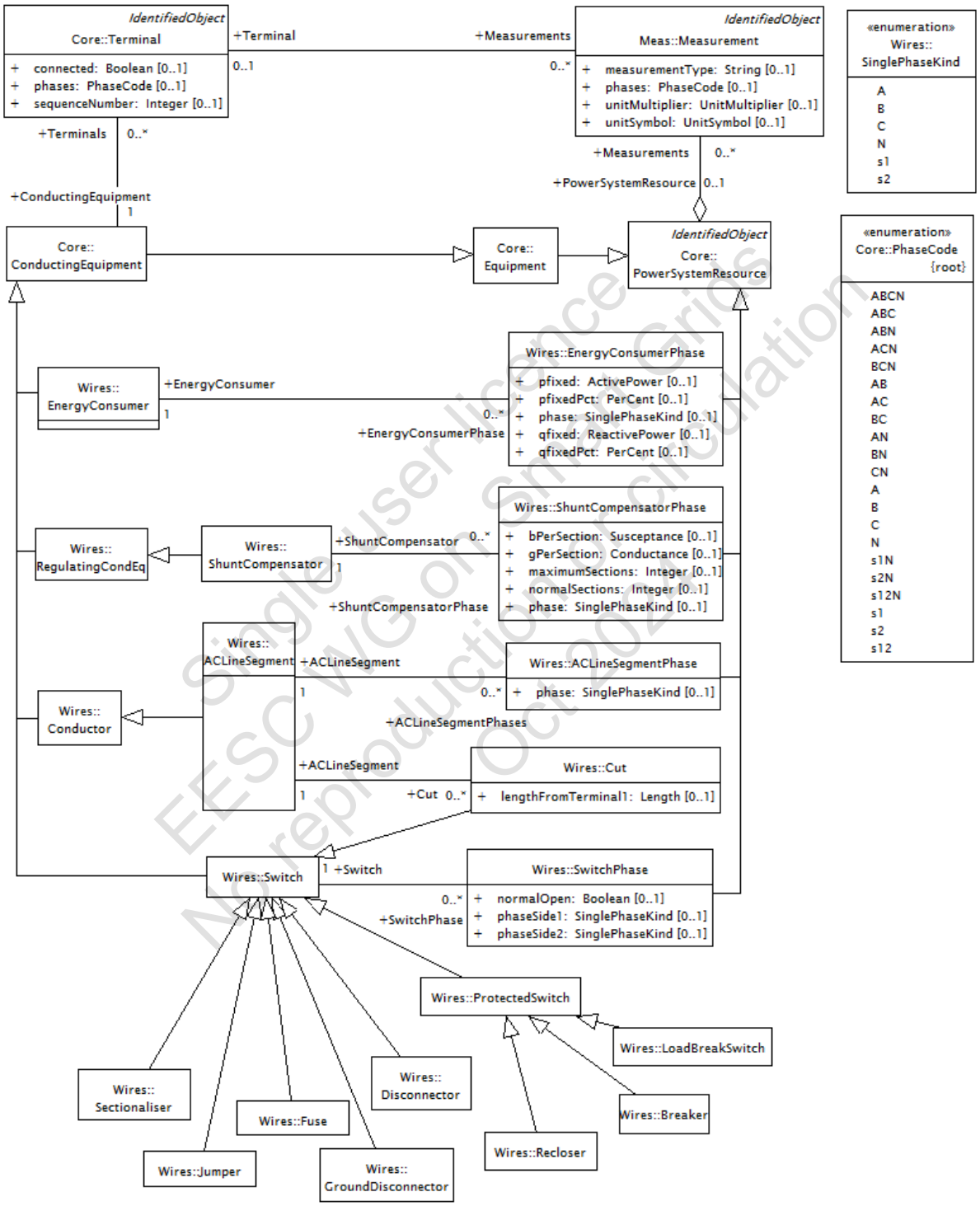

Figure 8 – DCIM phase modelling

In distribution networks, some of the devices could have different electrical and operating characteristics on each phase. For instance, a three-phase **Switch** (whether it is a **Breaker**, a

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Fuse, or any other specialisation of **Switch**) may be composed of three separate physical switches, one for each phase. In the majority of cases the three individual switches have the same physical properties. If such a switch is gang operated (i.e., all the physical switches have the same normal and/or the real-time operational state), it can be modelled with a single instance of **Switch**. However, it may happen that the individual phases have different physical properties. For instance, in the case of a **Fuse**, at least theoretically, different fuse ratings might be used on each phase. Also, for un-ganged switches there may be cases where the normal and/or the real-time operational state of each phase could be different. This case is then modelled as one instance of **Switch** containing three instances of **SwitchPhase**, one for each phase. Important point is that there is one **Switch** instance in every case, and that one instance can be referenced from different contexts (e.g., configuration, operations).

NOTE This part of IEC 61968 does not support multi-state switches (modelled by **CompositeSwitch**).

From this part of IEC 61968, similar to **Terminal** class, **Measurement** class has defined the **phases** attribute to provide detailed phase description for a measurement. In most cases the attribute is optional since the measurement on a **Terminal** matches its phase. However, for a **ConductingEquipment** that could be operated separately on each individual phase, the **Measurement.phases** attribute provides the capability to specify measurements on each phase. Based on the CIM control model defined in base CIM, IEC 61970-301:—, 4.4.10, Measurements and controls, controls can be applied to separate phases as well.

From this part of of IEC 61968, the distribution CIM model provides support for representing temporary changes in the network. For detailed description and example, refer to IEC 61970-301:—, 4.4.9, Cuts, clamps and jumpers model.

4.4.3.2 Single-phase and unbalanced loads

Figure 9 shows the classes available to model distribution loads, which are often unbalanced among the three phases at a location. In some cases, single-phase and two-phase loads will occur.

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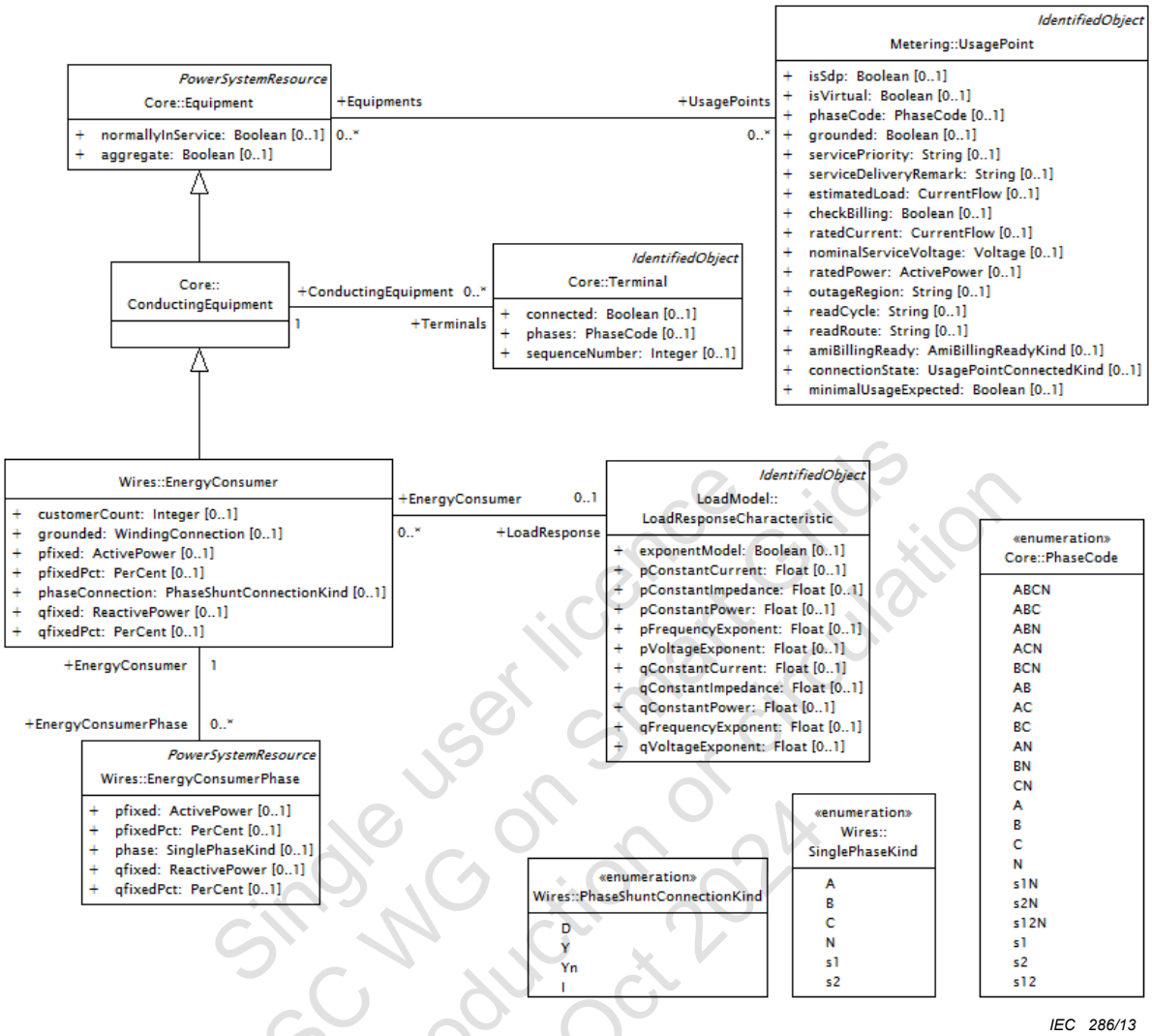

Figure 9 – DCIM load model

The **EnergyConsumer** class should be used to instantiate the load model, which can optionally be associated with a meter through **UsagePoint**. **EnergyConsumer** inherits from **ConductingEquipment** which is associated with **Terminal**. **Terminal** has **phases** attribute, which may be assigned a **PhaseCode** enumeration literal. For example, **AN** describes a single-phase load from A to neutral, **BC** describes a single-phase load from B to C, **ABCN** describes a three-phase, wye-grounded load, **ABC** describes a three-phase delta-connected load, etc.

The **phaseConnection** attribute of **EnergyConsumer** should be **Y** or **Yn** for a wye connected or phase-to-neutral load; it should be **D** for a delta or phase-to-phase load. For a balanced three-phase load, specify the total real and reactive power on **EnergyConsumer** attributes, for equal distribution among the three phases.

If a three-phase load is unbalanced, it can still be modelled with the same **EnergyConsumer** instance, now referring to three additional **EnergyConsumerPhase** instances, each representing one phase with its **phase** attribute. This makes it possible to use an **EnergyConsumer** with its identity for unbalanced modelling as well. With single-phase or two-phase loads, the model should also include correctly phased conductors or transformers that establish connectivity back to the source. The total real and reactive power need not be specified on **EnergyConsumer** attributes, because they can be derived from the distribution among phases specified on **EnergyConsumerPhase** attributes. Each **phase** can be **A**, **B**, **C**, **S1**

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or **S2** (**N** does not apply to this case). For a delta or phase-to-phase connected load, which is indicated with **D** for **phaseConnection**:

- use **A** for the load connected between phases **A** and **B**;
- use **B** for the load connected between phases **B** and **C**;
- use **C** for the load connected between phases **C** and **A**;
- use **S1** for the load connected between phases **S1** and **S2**.

In case the load is a combination of constant current, constant power, or constant impedance, an instance of **LoadResponseCharacteristic** should be associated with the **EnergyConsumer** instance.

NOTE This part of IEC 61968 does not provide the means to define different load characteristics per phase.

4.4.3.3 Distribution line segments

Figure 10 shows the classes available to model AC line segments (i.e., conductors). There are three ways to describe the impedance parameters of an **ACLineSegment** using only the **Wires** package, and a fourth way making use of the **AssetInfo** package.

NOTE This part of IEC 61968 (documenting DCIM11) and the corresponding IEC 61970-301 (documenting base CIM15) reflect consolidated line segment models for transmission and distribution (T&D). Therefore, the classes from IEC 61968-11:2010 (1st edition) have been slightly modified and moved from model package **IEC61968::WiresExt** into model package **IEC61970::Wires** of the base CIM, IEC 61970-301 (5th edition).

In order to represent a single-phasesingle-phase, two-phase, or unbalanced three-phase line using different wires, one **ACLineSegmentPhase** instance should be associated with each phase or neutral wire retained in the model. The applicable **phase** attribute values are **A**, **B**, **C** for three-phase lines, **S1** and **S2** for single-phase secondary circuits, and **N** for cases where the neutral wire is modelled. Each **ACLineSegmentPhase** has an optional association to **WireInfo**, described later in more detail, but all other characteristics come from its associated **ACLineSegment**.

For an unbalanced line, the calculated impedances reflect physical wire positions on the tower or pole, and these positions are typically ordered from left-to-right and top-to-bottom based on their horizontal and height coordinates. For example, consider a pole with crossarm having 3 wire positions numbered 1 (left-most), 2 (offset from centre), and 3 (right-most), impedances could be calculated with phase A's wire in position 1, phase B's in position 2, and phase C's in position 3. A different **ACLineSegment** might use the same pole type and wires, but with phase C's wire in position 1, phase B's in position 2, and phase A's in position 3. The calculated impedance parameters will be different than the first case. They are mathematically related by impedance matrix row and column operations, but such operations are not supported in the CIM, nor is there a concept of ordering phases in CIM. This means that each different physical phase ordering requires a different impedance description in the CIM. This consideration affects the use of **PerLengthPhaseImpedance** and **WireSpacingInfo** in Figure 10.

Transposed lines can be modelled with a different **ACLineSegment** for each section, and a different impedance description for each section as just discussed. The impedance description should use either **PerLengthPhaseImpedance** or **WireSpacingInfo**, because sequence parameters assume continuous transposition. It is not necessary to use **ACLineSegmentPhase** instances for transposed three-phase line sections, if all phase wire types are identical within a section.

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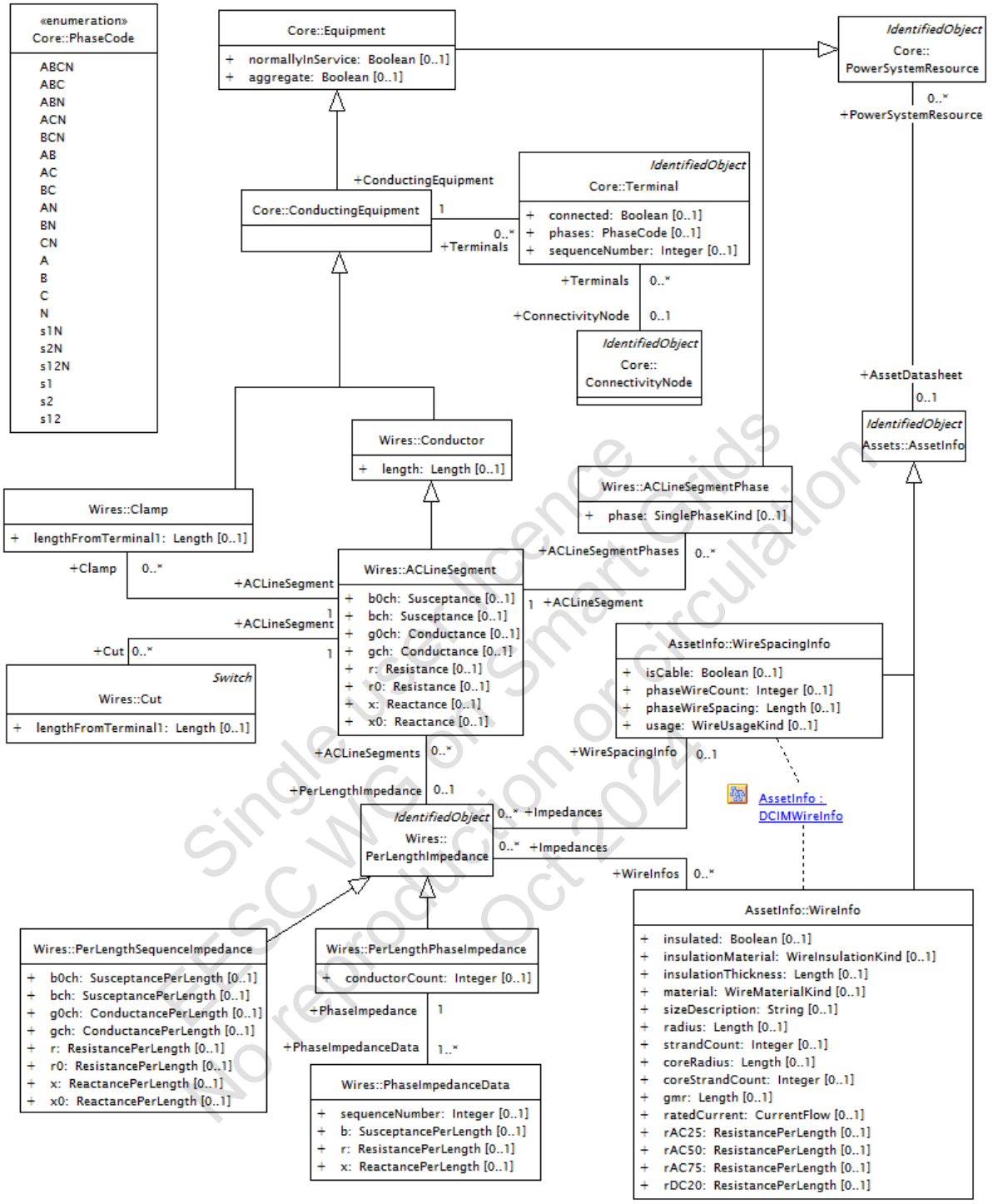

Figure 10 – DCIM line connectivity model

There are three ways to specify line impedances using only the **IEC61970::Wires** model package from IEC 61970-301:

- The **ACLineSegment** attributes **r**, **r0**, **x**, **x0**, **bch**, **bch0**, **gch**, and **gch0** may be used for a balanced model. See 4.4.3.3.1 for usage with single-phase and two-phase line segments.
- Provide an association to **PerLengthSequenceImpedance**. This class models an electrical catalogue, or a library of "line codes" that have sequence impedances and line charging per unit length. Multiple **ACLineSegment**s will share one instance of **PerLengthSequenceImpedance** and will calculate impedance with their **length** attribute

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inherited from **Conductor**. See 4.4.3.3.1 for usage of sequence parameters with single-phase and two-phase line segments.

- Provide an association to **PerLengthPhaseImpedance**, which references pre-calculated NxN symmetric impedance and admittance matrices per unit length. This class also models an electrical catalogue and the inherited **length** attribute is required. The **conductorCount** has to be at least equal to the number of phases, but it could be higher if the neutral (or other grounded conductor) is retained in the matrix. **PhaseImpedanceData** implements Z and Y matrix elements, stored in column order. The attributes **r**, **x**, and **sequenceNumber** are all required, while **b** is optional. Only the lower triangular elements are stored, so that a 3x3 matrix would have 6 elements (i.e., instances of **PhaseImpedanceData**). The matrix rows and columns have to be in phase order. A referencing **ACLineSegment** will assign row 1 to the first phase present from the ordered list (**A**, **B**, **C**, **s1**, **s2**, **N**), row 2 to the next phase present, and so on. See also 4.4.3.3.2 below.

To specify impedances using the **AssetInfo** package, the **Conductor.length** attribute is required, because the instance electrical parameters are defined as (per-unit length parameters) × (**Conductor.length**). See also 4.4.3.3.3 below.

A **WireSpacingInfo** can be associated to the **ACLineSegment** using either of two methods:

- (**PowerSystemResource**–**AssetInfo**) Use the inherited **AssetDatasheet** association end of **ACLineSegment** to reference **WireSpacingInfo**. This method can also be used to associate **WireInfo** for its **ratedCurrent** attribute.
- (**PowerSystemResource**–**Asset**–**AssetInfo**) Instantiate the **Asset** class, in which **AssetInfo** association end references the **WireSpacingInfo**, and multiple **PowerSystemResource**s reference each **ACLineSegment** using that **WireSpacingInfo**.

For impedance calculations, it is also necessary to associate **WireInfo**s to each referencing **ACLineSegment** or **ACLineSegmentPhase**. Either **AssetDatasheet** (**PowerSystemResource**–**AssetInfo**) or **Asset** class (**PowerSystemResource**–**Asset**–**AssetInfo**) navigation pattern accomplishes this. Whenever the **ACLineSegment** has associated **ACLineSegmentPhases**, each **ACLineSegmentPhase** should have its own **WireInfo**. If not:

- At least one **WireInfo** shall be associated to the **ACLineSegment**, and it is assumed to apply for all phase wires. It also applies to any neutral wires, unless a second, identifiable **WireInfo** can be associated.
- An optional second **WireInfo** may be associated for the neutral wire, identified as the one with smallest **WireInfo.radius** attribute value. Whenever this assumption does not apply to the line, use by-phase modelling with **ACLineSegmentPhase**.

Figure 10 shows associations between **PerLengthImpedance**, **WireSpacingInfo**, and **WireInfo**. However, these are for asset library management and not for impedance calculations. Either the **AssetDatasheet** or **Asset** class pattern is required to use **WireSpacingInfo** and **WireInfo** for impedance calculations.

Figure 11 shows the **WireInfo** class hierarchy, used for defining line segment impedances from physical data (sometimes referred to as “line codes” and “cable codes”). **WireInfo** is a base class that should not be instantiated directly. Its attributes describe the physical data for an overhead wire (note that derived **OverheadWireInfo** currently has no attributes of its own), or a cable’s core phase conductor.

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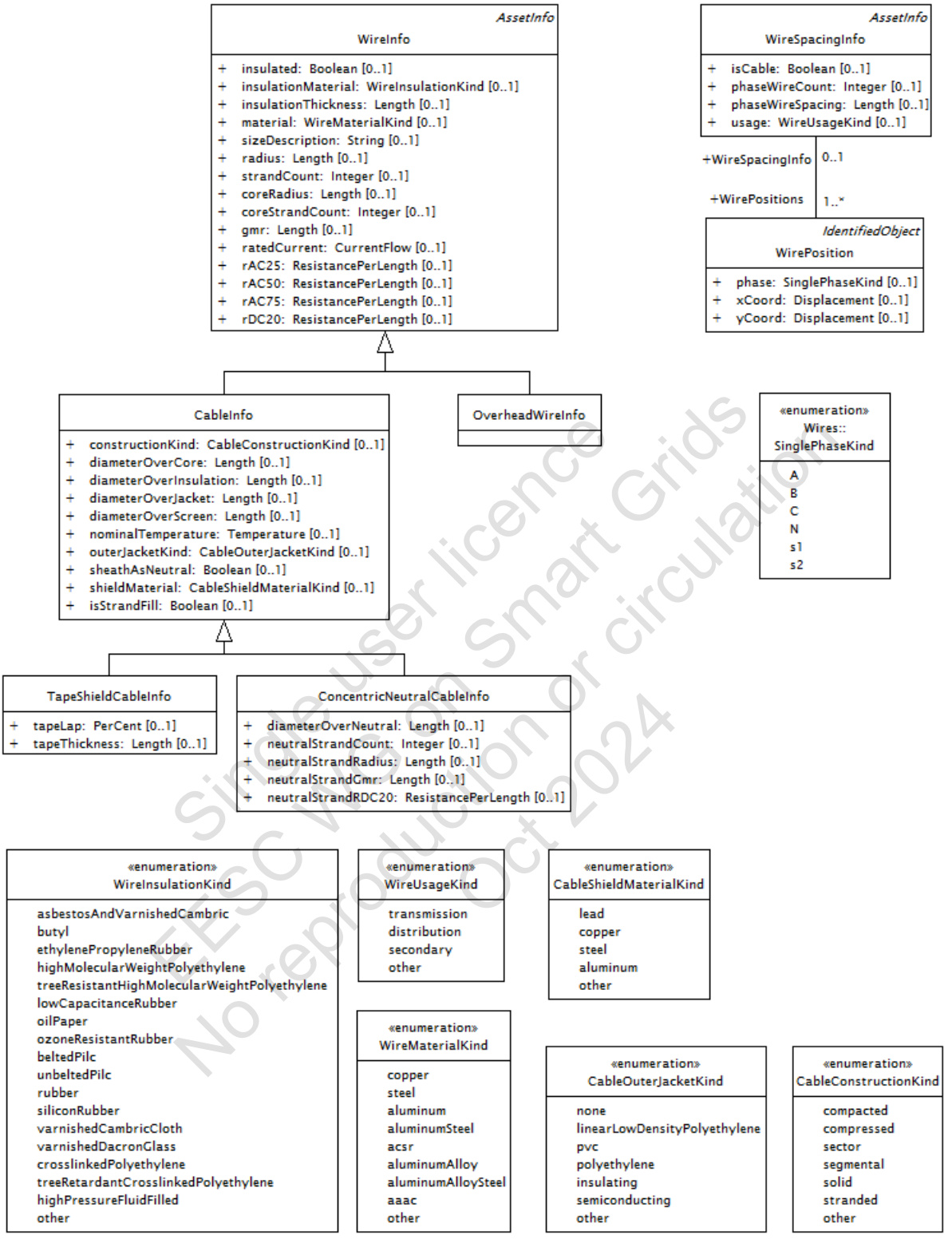

Figure 11 – DCIM conductor (line and cable datasheet) model

WireInfo attributes **material**, **sizeDescription**, **strandCount**, and **coreStrandCount** (for ACSR, aluminium conductor steel reinforced wire) help to identify the wire, and are often coded into the instance local name. The minimum required electrical attributes are **gmr**, **radius**, and **rAC50**. A complete wire table would usually have resistances defined at other temperatures and frequencies, such as **rAC25**, **rAC75**, and **rDC20**. For ACSR wires, the **coreRadius** is optional for frequency-dependent calculation of the **gmr.** The **coreRadius** is zero for non-ACSR wires. The **ratedCurrent** is the ampacity at 50 ˚C. The **ratedCurrent** is necessary to interpret

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power flow output, but not for the power flow solution itself. The **insulated**, **insulationMaterial**, and **insulationThickness** attributes apply mainly to the derived cable classes, but they also support triplex secondary lines and overhead spacer cable. The **CableInfo** attributes describe additional properties of layers over the conducting core. The **diameterOverCore** includes both conductor and semi-conducting screen; it should be the insulation's inside diameter. The **diameterOverInsulation** is the insulating layer's outside diameter, not including any outside screens or semi-conducting layers. The **diameterOverScreen** includes the insulation plus screen or semi-conducting layer; it should be the shield's or sheath's inside diameter. The **diameterOverJacket** is the cable's outside diameter; it should be the largest diameter value specified except for concentric neutrals.

The **TapeShieldCableInfo** attributes **tapeLap** and **tapeThickness** describe a thin tape covering the cable, usually made of copper, in overlapping turns. The **ConcentricNeutralCableInfo** has attributes for the outer neutral conductors, which typically consist of several solid copper wires. The number of wires is **neutralStrandCount**, the radius is **neutralStrandRadius**, the geometric mean radius is **neutralStrandGmr**, and the resistance per wire is **neutralStrandRDC20**. These wires are so small that AC resistance is typically not used or specified. The **diameterOverNeutral** is the diameter over the concentric neutral strands, which may be the same as **diameterOverJacket**.

NOTE The model shown in Figure 11 currently supports the two types of single-conductor cable most commonly found on distribution systems. Many other cable types found in transmission or industrial systems are not supported; these include 3-conductor, pipe-type, submarine, and others.

WireSpacingInfo identifies the line geometry data. The **phaseWireCount** and **phaseWireSpacing** attributes refer to sub-conductor bundling, which is not common for distribution lines, but may appear on high-voltage transmission lines in the model.

WirePosition defines the horizontal (**xCoord**) and vertical (**yCoord**) coordinates of each wire on the pole or tower cross section, or in the cable trench/duct, and **phase** identifies which phase wire is mounted there. All three attributes are required. The overhead wire height above ground is **yCoord**, including any sag effects. For underground cables, **yCoord** is the average burial depth, entered as a negative number. The wire horizontal position, **xCoord**, is measured from an arbitrary but consistent reference line. Common choices for the horizontal reference are the pole centreline, and the left-most wire position.

Any wires at a **WirePosition** with **phase=N** are assumed to be continuously grounded. The application may eliminate these conductors from the impedance and admittance matrices through Kron reduction.

Many times, the **WirePosition.phase** attribute value could change depending on the field installation. For example, a single-phase line can be used on phase **A**, **B**, or **C**. This requires three **WireSpacingInfo** instances, the only difference being three different values for one of the associated **WirePosition.phase** values, namely **A**, **B**, or **C**. The **WirePostion.phase** value for a neutral wire would not change; it should always be **N**. In summary, a single-phase line type requires 3 **WireSpacingInfo** instances to cover all phasing possibilities. A two-phase line type requires 6 instances, and a three-phase line type also requires 6 instances.

4.4.3.3.1 Using sequence impedances (balanced case)

The positive and zero sequence impedances may be transferred through the **r**, **x**, **r0**, and **x0** attributes of **PerLengthSequenceImpedance** associated with an **ACLineSegment** instance. The **bch**, **b0ch**, **gch**, and **g0ch** attributes are usually not important for overhead distribution lines. For three phases, this describes a balanced three-phase, or perfectly transposed, line. The attributes in **PerLengthSequenceImpedance** are expressed in units per length, so it is necessary to multiply their values with the **length** attribute of **Conductor**.

NOTE This is equivalent to the attributes of **Wires::ACLineSegment**, which are pre-calculated for the whole length of the segment and are defined on each instance of the segment. In contrast,

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PerLengthSequenceImpedance is referenceable, and as such can be used (through association) by several segment instances, thus decreasing the amount of data transferred in data exchanges.

If the **ACLineSegment** has only one or two phases, a balanced model can still be transferred through the **r**, **x**, **r0**, and **x0** attributes. This represents an impedance matrix with equal complex diagonal elements, Z_s, and equal complex off-diagonal elements, Z_m. For a single-phase line, the attributes to transfer are:

$$Z_1 = Z_0 = Z_s$$

For a two-phase or three-phase line, the attributes to transfer are:

$$Z_1 = Z_s - Z_m$$

$$Z_0 = Z_s + (n - 1)\, Z_m$$

where n is the number of phases. Upon receipt of **r**, **x**, **r0**, and **x0**, the balanced two-phase or three-phase impedance matrix is constructed from:

$$Z_s = (Z_0 + (n - 1)\, Z_1) / n$$

$$Z_m = (Z_0 - Z_1) / n$$

The referencing **ACLineSegment** should have associated instances of **ACLineSegmentPhase**, assigned appropriate **phase** values to show the phases actually present, such as **A**, **B**, **C**, **s1**, or **s2**. The neutral, **N**, should not appear because any neutral conductor must have been incorporated into the earth return when sequence impedances are used.

For underground distribution cables, the sequence impedances are also appropriate, including the **bch** and **b0ch** attributes.

4.4.3.3.2 Using phase impedances (unbalanced case)

Calculated matrix parameters may be transferred by referencing a **PerLengthPhaseImpedance** instance, in lieu of the physical model described in 4.4.3.3.3. A matrix model is useful when:

- the target application has no means of calculating parameters from the physical data;
- the underlying physical data is not readily available;
- it is necessary to match the unbalanced line parameters as closely as possible.

For a two-phase line, with the neutral already reduced, the Z and Y matrices will be 2x2, but due to symmetry, there will only be 3 unique matrix elements. That leads to three associated instances of **PhaseImpedanceData** with column-wise storage:

- **sequenceNumber** = 1 for row 1, column 1 of the matrix;
- **sequenceNumber** = 2 for row 2, column 1 of the matrix;
- **sequenceNumber** = 3 for row 2, column 2 of the matrix.

This instance of **PerLengthPhaseImpedance** could be referenced from an **ACLineSegment** having phases **AB**, **AC**, or **BC**. Row 1 always corresponds to the first phase present and row 2 always corresponds to the second phase present, following the order: **A**, **B**, **C**, **s1**, **s2**, **N**. If the phase wires are installed in different positions, such that **C** (for example) should be in row 1, a new instance of **PerLengthPhaseImpedance** is required.

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4.4.3.3.3 Using physical parameters

For overhead lines, a physical model can be transferred through reference to a **WireSpacingInfo** instance, which is associated with further classes shown in Figure 11. This will support calculation of an unbalanced phase impedance matrix through the use of Carson's equations, or an equivalent method of handling the earth return. For example, suppose there are three phase wires, plus a different size neutral wire, on a pole with horizontal crossarm. This requires one **WireSpacingInfo** instance, four **WirePosition** instances that describe the four conductor positions, and two **WireInfo** instances describing the phase and neutral wire types. The **length** attribute of **Conductor** shall be used, and many **ACLineSegment**s will typically refer to the same **WireSpacingInfo** instance.

The **WirePosition** instances have a **phase** attribute that maps to **ACLineSegmentPhase.phase**. The resistance attribute of **WireInfo** should be supplied for fundamental power frequency, and at the wire's desired operating temperature for calculations.

A single-phase, concentric neutral cable requires one instance of **ConcentricNeutralCableInfo**, one **WireSpacingInfo** with attribute **isCable**=true, and one **WirePosition** instance to specify the burial depth. A three-phase tape shielded cable, with bare neutral conductor, would require one instance of **TapeShieldCableInfo**, one **WireSpacingInfo** with attribute **isCable**=true and four **WirePosition**s for the three phases and neutral. There would also be one **WireInfo** for the neutral.

4.4.3.4 Distribution transformers

4.4.3.4.1 Electrical model

Figure 12 shows the classes that model power transformer instances. They can use the **Wires** package exclusively to define impedance parameters, or make use of the **AssetInfo** classes detailed in Figure 13, to define a library of transformer types.

NOTE This part of IEC 61968 (documenting DCIM11) and the corresponding IEC 61970-301 (documenting base CIM15) reflect consolidated transformer models for transmission and distribution (T&D). Therefore, the classes from IEC 61968-11:2010 (1st edition) have been slightly modified and moved from model package **IEC61968::WiresExt** into model package **IEC61970::Wires** of the base CIM, IEC 61970-301 (5th edition).

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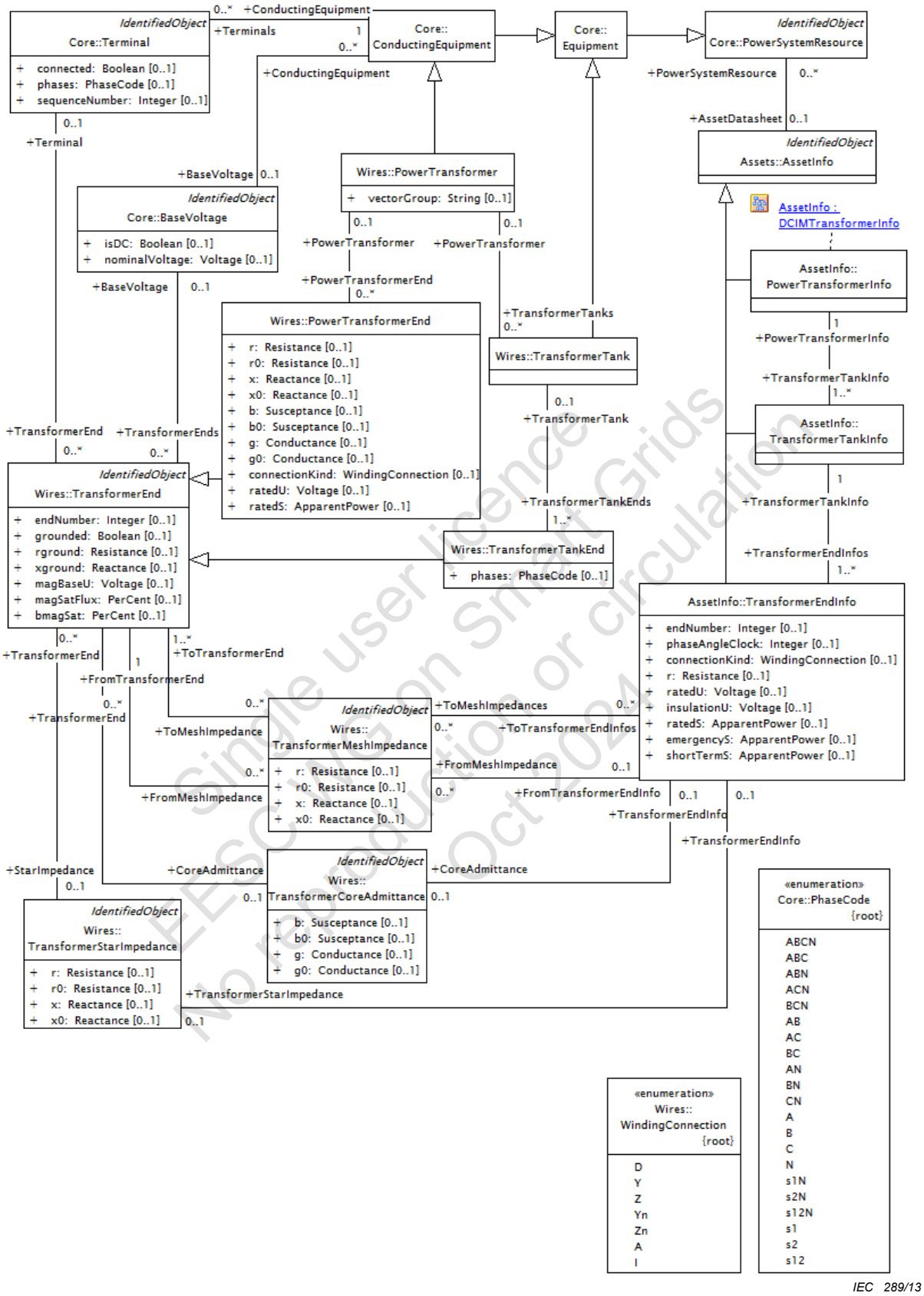

Figure 12 – DCIM transformer connectivity model

PowerTransformer is the top-most instance for a power transformer, whether composed of a three-phase tank, or possibly different single-phase tanks. It descends from

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ConductingEquipment, and therefore, has associated **Terminal**s with **phases** attribute values at each winding connection point. In the CIM, a transformer winding is referred to as an “end”.

When composed of different tanks, a **PowerTransformer** has often been called a “transformer bank”, and the CIM supports modelling with or without tanks. In distribution systems, independent phase voltage regulators and open wye/open delta transformers provide two examples that require tank-level modelling. At the transmission level, EHV transformer banks may also contain single-phase transformers, which need not be identical, especially when a spare is in service. The **vectorGroup** attribute for protective relaying is derived from the internal winding connections and phase angles; it uses IEC 60076-1 nomenclature to describe any number of windings that may be included in the bank.

When used, the **TransformerTank** must be associated with a **PowerTransformer**. It inherits from **Equipment**, not **ConductingEquipment**. The tank may have associated **TransformerTankInfo** from the **AssetInfo** package, for asset datasheet modelling, described in more detail later with Figure 13 and 4.4.3.4.2. Because transformer testing is done on tanks, the datasheets are fundamentally associated with tanks. When not using tanks in the model, the **PowerTransformer** can still have an association to **PowerTransformerInfo**, for asset datasheet modelling. In both cases, the data actually resides in **TransformerEndInfo** instances, associated to a **TransformerTankInfo**.

There are two methods of referencing transformer asset datasheets, and a profile may prefer one over the other:

- (**PowerSystemResource**–**AssetInfo**) Use the **AssetDatasheet** association end of either **PowerTransfomer** or **TransformerTank**, to reference either **PowerTransformerInfo** or **TransformerTankInfo**, respectively, or
- (**PowerSystemResource**–**Asset**–**AssetInfo**) Instantiate the **Asset** class, in which **AssetInfo** association end references either the **PowerTransformerInfo** or **TransfomerTankInfo**, and multiple **PowerSystemResource**s reference each **PowerTransformer** or **TransformerTank** using that datasheet.

TransformerEnd, which was called TransformerWinding in earlier versions of CIM and was a **ConductingEquipment**, is not anymore a **ConductingEquipment**, but it does have one associated **Terminal** with phasing information. The **magBaseU**, **magSatFlux**, and **bmagSat** attributes represent core saturation, typically modelled at no more than one of the ends. The other instance attributes define the grounding options:

- solidly grounded: **grounded** = true, **rground** = 0, **xground** = 0;
- impedance grounded: **grounded** = true, **rground** ≥ 0, **xground** ≥ 0;
- ungrounded: **grounded** = false.

TransformerEnd should not be instantiated directly; one of its two descendants should be instantiated:

- **PowerTransformerEnd**, if not using tank-level modelling. Specify the **ratedU** and **ratedS** attribute values for winding rating data, and **connectionKind** for the wye, delta, or other type of connection.
- **TransformerTankEnd**, if using tank-level modelling. The winding connection and rating values come from a **TransformerTankEndInfo** instance, which means that the **AssetInfo** package is required for tank-level modelling. The **phases** attribute supports by-phase tank modelling.

With **PowerTransformer** and **PowerTransformerEnd**, there are three ways of specifying impedance parameters using only the **IEC61970::Wires** model package from IEC 61970-301:

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- Use the **r**, **x**, **r0**, **x0**, **b**, **b0**, **g**, and **g0** attributes of **PowerTransformerEnd** to specify pi impedance parameters. This is the option most compatible with earlier versions of IEC 61970-301, and there are some important conventions described in that standard.
- Use one associated **TransformerStarImpedance** for each **PowerTransformerEnd**, comprising a star equivalent (also sometimes called tee or wye equivalent). This can be mathematically exact for up to three ends (windings). However, negative attribute values may occur in the case of three ends. Optionally, use one **TransformerCoreAdmittance** associated to one of the **PowerTransformerEnd**s, representing the exciting current and core losses. This can be the lowest-voltage winding (i.e. closest to the core), or the winding that was actually subjected to a no-load test, if known. The reference voltage for all attribute values, which have units of ohms or siemens, must be **ratedU** for the end to which the impedance or admittance is connected.
- Use a **TransformerMeshImpedance** associated to each combination of **PowerTransformerEnd** pairs. There shall be (numberEnds-1) × numberEnds / 2 of these; for example, one **TransformerMeshImpedance** between two ends, three of them between three ends, six of them between four ends, etc. The advantages of a mesh model are: (a) it is mathematically exact for more than three ends, (b) it has no negative attribute values, and (c) it corresponds more directly with transformer short-circuit test data. The reference voltage shall be **ratedU** of the **FromTransformerEnd** (note the other end nearly always has a different rated voltage). Optionally, use one **TransformerCoreAdmittance** as described for the star equivalent.

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4.4.3.4.2 Datasheet model

Figure 13 shows the classes that allow for exchange of transformer datasheet models, sometimes referred to as “transformer codes” in applications.

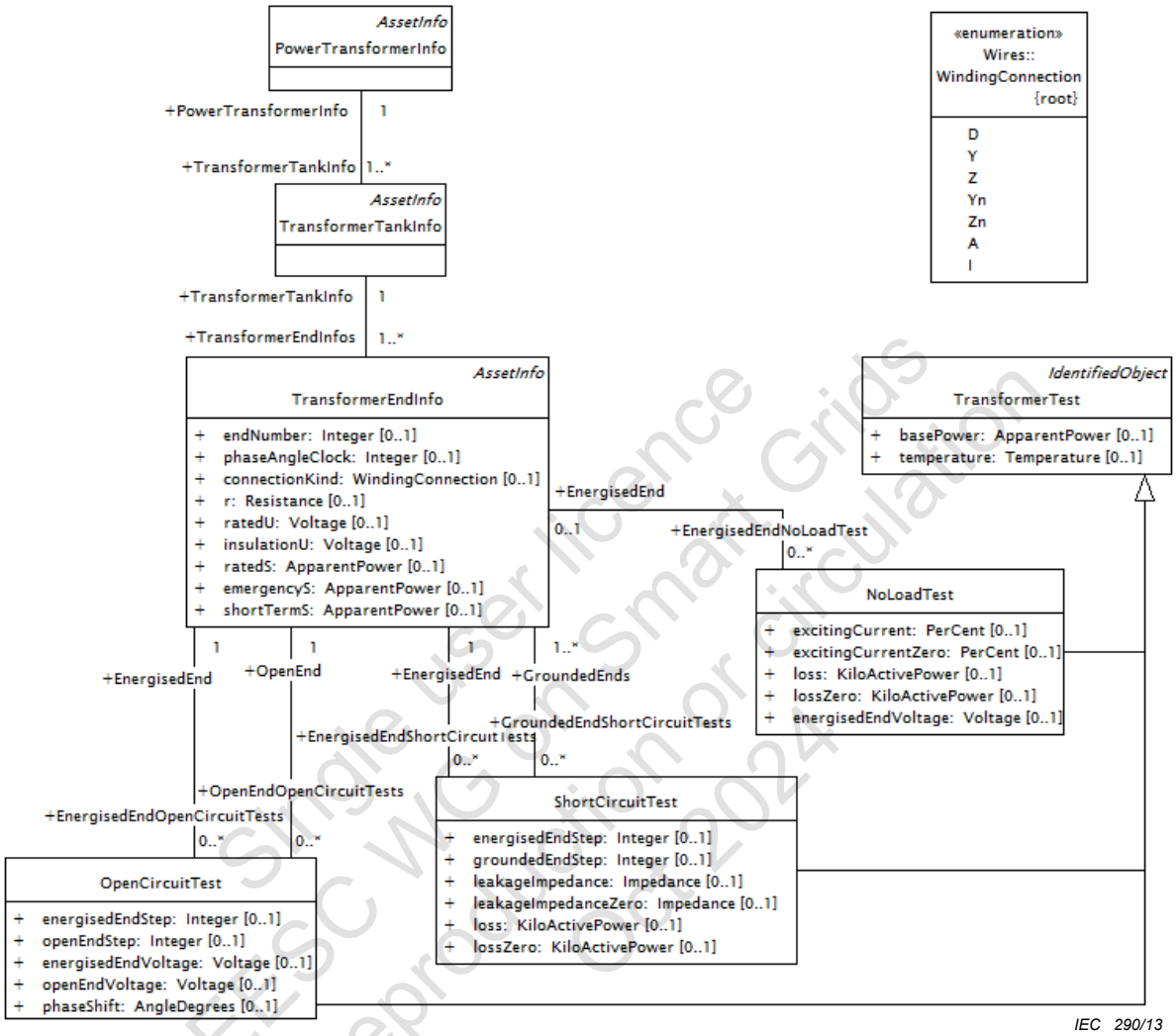

Figure 13 – DCIM transformer datasheet model

The main class is **TransformerEndInfo**, which contains rating and connection data for the corresponding transformer winding. Rating data includes **ratedU**, **ratedS**, **shortTermS**, **emergencyS**, and **insulationU**. The **r** attribute is the winding’s DC resistance.

Connection data is contained in attributes **connectionKind**, **phaseAngleClock** and **endNumber**. The **endNumber** attribute is the winding’s order in the **vectorGroup** of the referencing **PowerTransformer** and is used to map the data to **TransformerEnd.endNumber**. The associated **Terminal.sequenceNumber** could also use the same **TransformerEnd.endNumber**, but this is not required. By convention, the **endNumber** usually starts at 1 for the highest voltage winding, and all other windings are numbered in order of decreasing voltage rating. Some transformers have more than one winding with the same **ratedU**, split-secondary transformers providing just one example, and they shall have different **endNumber**s.

WindingConnection enumeration, used as type for the **connectionKind** attribute, includes the standard **D**, **Y**, **Z**, **Yn**, and **Zn** nomenclature to describe delta, wye, zigzag, and neutral connections in three-phase transformer vector groups. **A** is used for a common autotransformer winding, and **I** for a single-phase transformer winding.

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The **endNumber** attribute allows the datasheet library to be used and updated with just one association to **PowerTransformerInfo** or **TransformerTankInfo**. The **TransformerTankInfo** and **PowerTransformerInfo** provide two navigation paths to **TransformerEndInfo**. With **PowerTransformerInfo**, it may be necessary to create an artificial **TransformerTankInfo** for model transfer, because datasheets are at the tank level. A **PowerTransformerInfo** instance actually refers to a collection of one or more tanks.

TransformerTankInfo is referenced by the **TransformerTank** (inherited **PowerSystemResource**–**AssetInfo**) and **PowerTransformerInfo** (directly). It serves mainly to organize the data into a library with one entry point. **TransformerTankInfo** collects associations to **TransformerEndInfo**, which generalizes to any number of windings.

There are two ways of specifying impedance parameters in a datasheet model:

- Associate **TransformerEndInfo** to the **TransformerMeshImpedance**, **TransformerStarImpedance**, and **TransformerCoreAdmittance** classes of the **IEC61970::Wires** model package from IEC 61970-301. These associations were shown in Figure 12 and described in 4.4.3.4.1.
- Use **TransformerTest** and its three descendant classes, shown in Figure 13. Each application is responsible for converting the test data to mesh equivalent, star equivalent, or some other electrical impedance model.

TransformerTest is the parent class for all of the transformer test classes, with **basePower** and **temperature** attributes applicable to all tests. **basePower** is essential for converting datasheet values to impedance or admittance at the correct reference voltage.

NoLoadTest's attributes **excitingCurrent**, **excitingCurrentZero**, **loss**, and **lossZero** are all measured on the **EnergisedEnd** winding and provide the basic data for a core admittance branch. Positive and zero sequence test data can be reported in the same instance of **NoLoadTest**. This test is generally done with rated voltage applied to the energised winding, but different values can be specified in **energisedEndVoltage**, and several tests may be provided to define core saturation parameters.

ShortCircuitTest is done by circulating rated current through the **EnergisedEnd** winding, with one or more **GroundedEnds** windings short circuited. It provides the basic data for the mesh or star equivalent circuit. If tests were done at different tap settings, the tap values are specified in **energisedEndStep** and **groundedEndStep**. Positive and zero sequence test data can be reported in the same instance of **ShortCircuitTest**. The AC resistances derived from **loss** and **lossZero** are likely to differ from the winding DC resistances, **TransformerEndInfo.r**, which are obtained from a separate test.

OpenCircuitTest's attributes **openEndVoltage** and **phaseShift** are measured on a single open winding, when the **EnergisedEnd** has **energisedEndVoltage** applied to it. Tap settings for both windings are specified in **energisedEndStep** and **openEndStep**. The tests are done to verify the transformer turns ratio, winding connections, and winding polarity. They are usually not required to determine electrical impedance parameters.

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4.4.3.4.3 Tap changer model

Figure 14 shows the classes used to model a possibly unbalanced distribution voltage regulator. A **RatioTapChanger** is associated to a **TransformerEnd**. Each regulator uses autonomous local control, so that **RegulationSchedule** and **TapSchedule** (present in IEC 61970-301 and typically used in transmission) are not used here. Phase angle regulators and variation curves are also not generally used on distribution systems.

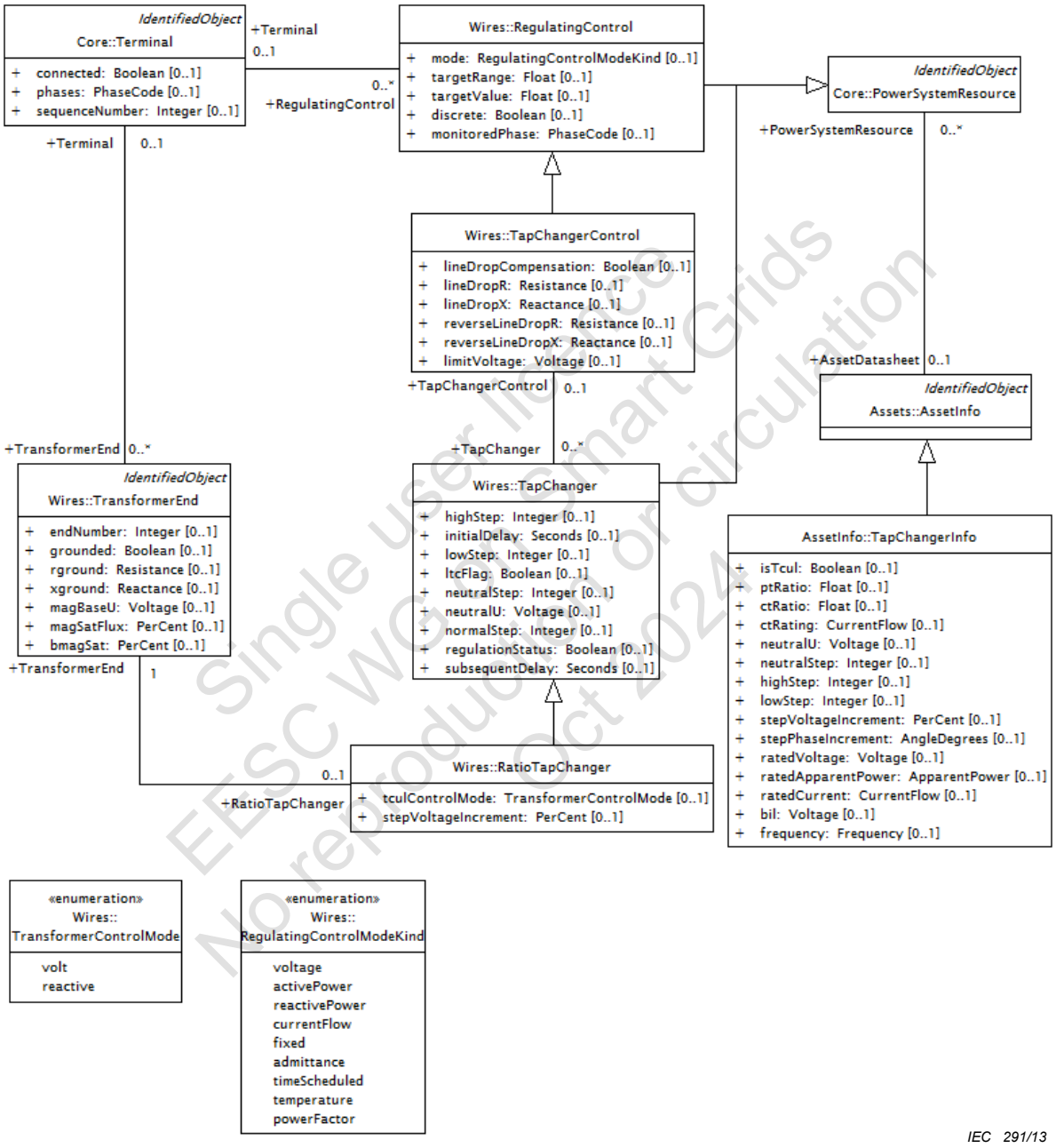

Figure 14 – DCIM tap changer model

A three-phase line voltage regulator usually has three independent regulators to help correct voltage unbalance. The regulators are usually connected in wye. The model starts with a **PowerTransformer** containing three **TransformerTank**s, and a total of six **TransformerTankEnd**s. There will be three instances of **RatioTapChanger**, each associated to a different **TransformerTankEnd**. The **RegulatingControl.monitoredPhase** attribute should be included among the **Terminal.phases** associated with the **PowerTransformer**. The tap positions, and sometimes the other attributes, will not be the same in each phase of the

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