

Report

Long Term Development Statement (LTDS)

Grid Modelling Guidelines

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This document overviews the grid modelling approach and details the grid model data requirements of the proposed LTDS Common Information Model (CIM) revision.

It is part of a package of technical documentation that sets out the outputs delivered by the LTDS reforms working group. We are publishing these documents to ensure all interested parties have full visibility of the outcomes of this programme of work, which is intended to form the basis of a future consultation on a proposed implementation of the Common Information Model (CIM) for the LTDS data. As such, the guidance offered in this document is not mandatory at this stage and will be subject to consultation before any changes to this data requirement are mandated.

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Executive Summary

The Long Term Development Statement (LTDS) requires Distribution Network Operators (DNOs) to provide publicly available network planning data mandated through their licence conditions (SLC25). The LTDS should be high value data that allows users to evaluate opportunities to connect to the network and also to enable flexibility services. The guidance in this document to modernise and digitalise the LTDS is a foundational step in enabling a net zero energy system.

In 2020, Ofgem set out the next steps for progressing the reforms of the LTDS.¹ The reforms commenced in August 2021 and aim to improve network visibility and support an effective connection regime for distribution level resources. Technical developments were delivered through the LTDS reforms Working Group (LTDS WG) of industry experts. Participants included representation across network operators, end users, software vendors and academics.

In April 2023, the LTDS WG concluded, delivering a proposed updated set of data standards implementing the Common Information Model (CIM) for the LTDS requirement on network planning data. The outputs from the LTDS WG development process are the following technical documents along with supporting artefacts:

- **LTDS Grid Modelling Guidelines (this document)**: these overview the grid modelling approach and detail the grid model data requirements of the LTDS CIM revision
- **LTDS Data Exchange Specifications**: these outline the detailed information and requirements related to the exchange of LTDS grid model data using the CIM

The guidance provided in these documents is **not mandatory** at this stage, and LTDS data should continue to be provided as per the current Form of Statement.² Through consultation Ofgem intend to update the Form of Statement to mandate the additional requirement of grid model data using the CIM as detailed in the guidance documents.

¹ [Next steps on our reforms to the Long Term Development Statement \(LTDS\) and the Key Enablers for DSO programme of work | Ofgem](#)

² [Direction pursuant to paragraph 25.2 of the electricity distribution licence relating to the preparation and maintenance of the Long-Term Development Statement | Ofgem](#)

1 Grid Data Modelling Guidelines

1.1 Introduction

This document provides the detailed requirements proposed for expressing LTDS grid model data in CIM. It specifies what distribution grid equipment is to be described by LTDS grid model data and which CIM constructs are to be used to supply and organise the data. It is intended primarily as a guide for the Distribution Network Operator (DNO) grid data modellers responsible for maintaining LTDS grid model data, and for the users who interpret and extract insight from the grid models. Developers of exporting/importing software may also find the document useful.

The CIM and the International Electrotechnical (IEC) 61970 family of standards provide the basis for the structure of the proposed LTDS grid model data. This proposal leverages the information model described in IEC 61970-301:2022³, along with IEC 61970-600-1:2021⁴ and IEC 61970-600-2:2021⁵ - together known as CGMES v3.0 (Common Grid Model Exchange Standard version 3.0) - which describe European CIM usage and profiles.

1.2 LTDS high-level data organisation

The CIM is an information model that defines a common industry structure for a broad range of data critical to electric utilities, including grid model data. IEC CIM standards provide guidance on how the CIM information model can be used to enable data exchange.

The CIM and its related IEC standards provide several basic constructs for the high-level organisation of grid model data. They are:

- Profile – a non-overlapping subset of CIM classes, attributes and associations defined to organise grid model data and support its exchange.
- Full Model – a set of CIM grid instance data conforming to one or more Profiles.
- Difference Model – a set of changes to a Full Model.
- Zipped collections of Full Models and/or Difference Models – a mechanism for grouping related Full Models or Difference Models.

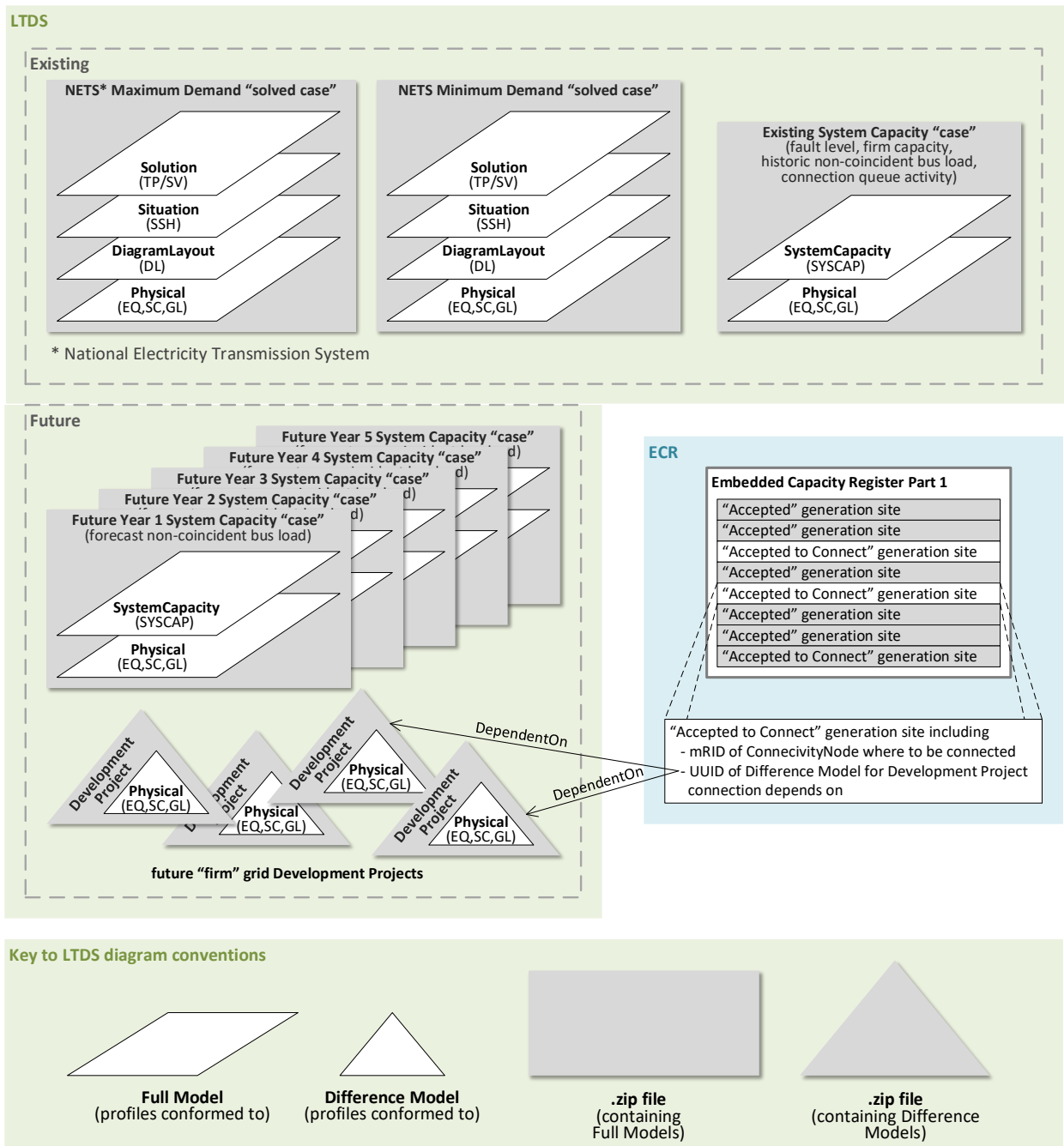
³ [IEC 61970-301:2020+AMD1:2022 CSV | IEC Webstore](#) [IEC 61970-301:2020+AMD1:2022 CSV | IEC Webstore](#)

⁴ [IEC 61970-600-1:2021 | IEC Webstore](#)

⁵ [IEC 61970-600-2:2021 | IEC Webstore](#)

These constructs are used to group and organise the data. While grid instance data – not high-level constructs - are the main focus of this document, an understanding of how the constructs are used in the sharing of the proposed LTDS grid model data is essential background, providing context for the requirements presented in this document. Figure 1 illustrates how the high-level constructs are used to structure a complete set of LTDS grid model data for a licence area.

Figure 1: High-level structure of LTDS grid model data for a licence area



A complete set of LTDS grid model data can be divided into two time frames:

- Existing - information describing the grid as it exists (or has recently existed)
- Future - information reflecting the grid as it is planned to exist at various times in the future.

LTDS grid model data for the existing time frame is to be presented in:

- Two .zip files, each reflecting a previous year National Electricity Transmission System (NETS) grid condition:

- The *NETS Maximum Demand "solved case"* contains four Full Models which together are a solved case representing the licence area grid at the time of the NETS maximum load.
- The *NETS Minimum Demand "solved case"* contains four Full Models which together are a solved case representing the licence area grid at the time of the NETS minimum load.
- The *Existing System Capacity "case"* .zip file contains two Full Models which together provide as-is information on:
 - Bus fault levels
 - Bus firm capacities
 - Previous year bus non-coincident maximum loadings
 - Connection activity aggregated at a bus level.

LTDS grid model data for the future time frame is to be presented in:

- Five .zip files, one for each of the five future years:
 - Each future year .zip file (*Future Year n System Capacity "case"*) contains two Full Models which together provide future-year bus non-coincident maximum loading forecasts.
- Multiple *Development Project* .zip files, each containing a Difference Model describing a "firm" grid development/reinforcement project within the LTDS grid model scope.

The proposed LTDS grid model data, like the data of most implementations of IEC CIM data exchange standards, has local requirements not addressed by the IEC standards. Because ongoing alignment with the IEC 61970 family of standards is key to the long-term usefulness of LTDS data, the LTDS data structure is expressed in terms of the underlying CIM and CGMES v3.0 standards along with a set of LTDS-specific extensions and deviations.

More detail regarding the constructs used for organising LTDS grid model data and information on the approach taken in leveraging CIM and CGMES v3.0 in their definition are provided in the *LTDS Data Exchange Specifications* document.

A note on the role of the Embedded Capacity Register (ECR) in the LTDS in CIM terms proposal:

The existing LTDS calls for aggregated information on both existing and accepted-to-connect generation. The goal of supporting a basic power flow means the proposed LTDS in CIM terms requires more detailed generation modelling: generation above the lowest modelled voltage level needs to be modelled individually and data beyond MW capacity needs to be provided for each individual generator. This is reflected in

the requirements defined by this document but is proposed to apply only to existing generation. It is proposed to rely on the content of the ECR for accepted-to-connect generation information. It is noted that this could be better facilitated by the addition of identifiers to the ECR to facilitate mapping between ECR data and the LTDS models however this remains out of scope of the current proposal.

1.3 Grid data organisation

This document is concerned with the content of the Full Model and Difference Model constructs – the grid model data itself. The document describes the CIM modelling structures used to represent grid equipment, its characteristics and its connectivity and sets out the proposed LTDS grid data population requirements. The requirements are organised as follows:

- First, the data requirements of the three main CIM profile groups are outlined:
 - The **Physical profile group** (whose data requirements are addressed in the [Physical modelling section](#)) describes the grid itself. It provides information about the behaviour, connectivity, and geographic location of the equipment that makes up the electrical system. It has three profiles:
 - The Equipment profile describes basic equipment and connectivity and provides the foundation on which the data of the other Physical profiles are layered.
 - The Short Circuit profile describes equipment electrical behaviour characteristics essential to the execution of short circuit studies.
 - The Geographical Location profile describes the geospatial location of equipment, facilities, and load and generation.
 - The **Situation profile group** (whose data requirements are addressed in the [Situation modelling section](#)) describes a grid operating state and is used, in conjunction with foundational Physical data, as input to network analysis. It has a single profile:
 - The Steady State Hypothesis profile describes load and generation injections, switch states and control settings.
 - The **Solution profile group** (whose requirements are addressed in the [Solution modelling section](#)) describes the output resulting from a successful power flow execution. It has two profiles:
 - The Topology profile describes the output of topology processing which eliminates closed switches and zero impedance branches.

- The State Variables profile describes the output of a power flow calculation, including node voltage and angle and active and reactive power flows.
- Then the data requirements of two additional profiles are described:
 - The System Capacity profile describes bus-related system information, like fault levels, firm capacities, non-coincident maximum loadings, and connection activity. It is the only LTDS-defined extension profile.
 - The Diagram Layout profile describes the layout of CIM objects for visualisation on a display.

Within the Equipment, Short Circuit and Steady State Hypothesis profiles, data requirements are further ordered by the type of data being modelled:

- Bus and bus group
- Switching device
- Circuit and circuit limits
- Transformer and transformer limits
- Load
- Generation
- Compensators
- Containment
- Nominal voltage level
- External connection

The requirements articulated below cover four main areas for each type of data being described:

1. The general approach CIM takes to modelling the particular type of data.
2. The LTDS population requirements for the type of data.
3. The classes and attributes appearing in the profile for the type of data. *Appendix 3 – LTDS Profile Classes and Attributes spreadsheet* and the *LTDS layered profiles in UML* section of the *LTDS Data Exchange Specifications* provide additional detail on profile requirements.
4. The constraints relevant to the type of data. Constraints are special rules which describe population requirements beyond what a profile is able to define. Constraints can specify rules like allowed attribute value ranges and conditions under which objects must be present or optional attributes populated. *Appendix 9 – Grid Data Constraints* contains detail on each constraint.

As described in the [1.2 LTDS high-level data organisation](#) section above, the proposed LTDS grid model data will provide both existing/previous year information and future information. The same CIM data structures are to be used for both and in many cases the data requirements are the same as well.

The Full Models and Difference Models contained in the various .zip files described above have the requirements for their grid model data addressed in the report sections noted below:

.zip file	
Full Model or Difference Model	Report section
<i>NETS Maximum Demand "solved case" .zip file</i>	
<i>NETS Minimum Demand "solved case" .zip file</i>	
Physical Full Model	Physical modelling
Diagram Layout Full Model	Diagram layout profile data
Situation Full Model	Situation modelling
Solution Full Model	Solution modelling
<i>Existing System Capacity "case"</i>	
<i>Future Year n System Capacity "case"</i>	
Physical Full Model	Physical modelling
System Capacity Full Model	System capacity profile data
<i>Development Project</i>	
Difference Model	Development Project

1.4 LTDS grid data requirements

1.4.1 CIM conventions used in requirements definition

The proposed LTDS grid model data population requirements are described using references to objects based on CIM classes, attributes, and associations. A bit of background on CIM conventions is provided in this section to aid in understanding the descriptions.

The basics:

- An instance of a CIM class is identified by its CIM class name (e.g., SynchronousMachine). In some cases, the word object is added after the class name for clarity (e.g., "All Synchronous Machine objects have an associated RegulatingControl.")
- An attribute is identified by its CIM class and attribute name in the following form: <class name>.<attribute name> (e.g., PowerTransformerEnd.connectionKind).
- An association is identified by the CIM class name of the originating class and the role name of the opposite end using the following notation: <class

name>.<association end role name towards the referred class> (e.g., OperationalLimit.OperationalLimitType).

CIM class and attribute names are prefaced with a 2- to 3-character abbreviation indicating the namespace of the information model in which the class is defined. While not strictly necessary for understanding the LTDS requirements, this additional piece of information provides the key to accessing the detailed descriptions for classes and attributes.

- cim: means the class/attribute/association is defined in the underlying CIM information model defined in IEC 61970-301⁶.
- eu: means the class/attribute/association is defined in specific extensions normative for Europe which are also defined in IEC 61970-301.
- nc: means in the class/attribute/association is defined in specific extensions for the implementation of EU Network Codes. These extensions are defined in the ENTSO-E document "Network codes canonical specification"⁷.
- gb: means the class/attribute/association is defined in specific extensions for Great Britain. These extensions are described in *Appendix 2 - LTDS Information Model UML Diagrams and Descriptions*.

The CIM leverages the UML concept of class inheritance, where one class can be a "subtype" of another, inheriting all attributes and associations from its "supertype". This means that the <class name> portion of an attribute name may be the name of a "supertype" class (e.g., cim:Switch has an attribute called cim:Equipment.aggregate which it inherits from cim:Equipment). The same is true for associations (e.g., cim:PhaseTapChangerLinear has an association called cim:PhaseTapChanger.TransformerEnd which it inherits from cim:PhaseTapChanger).

Inheritance also allows the explanations below to be kept as simple as possible, by allowing requirements to be phrased in terms of "subtype objects". For example, if a requirement applied to all five of the subtypes of cim:GeneratingUnit the text would refer to "all cim:GeneratingUnit subtype objects".

⁶ [IEC 61970-301:2020+AMD1:2022 | IEC Webstore](#)

⁷

https://www.entsoe.eu/Documents/CIM_documents/Grid_Model_CIM/NetworkCodes_Related_Canonical_Extensions_v2.2.pdf

The CIM approach to data modelling uses classes as the vehicle for defining enumerated data types (e.g., the `cim:WindingConnection` enumeration class defines possible values of D, Y, Z Yn, Zn, A using attributes). For the sake of brevity, the requirement descriptions below reference only the enumerated value names and not their class names.

Most CIM classes are subtypes of the `cim:IdentifiedObject` class and inherit three attributes from it:

- `cim:IdentifiedObject.mRID`
- `cim:IdentifiedObject.name`
- `cim:IdentifiedObject.description`.

These three attributes are required universally at the profile level as shown below and are not further discussed in the requirements section.

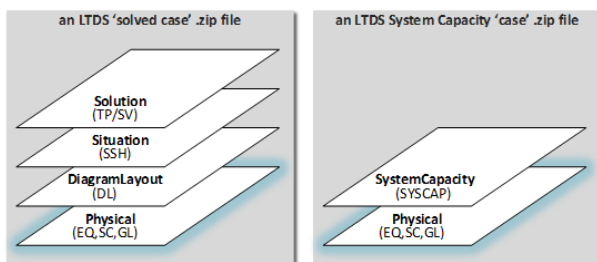
Profile	IdentifiedObject .mRID	IdentifiedObject .name	IdentifiedObject .description
Equipment	required	required	optional
Short Circuit	required		
Geographical Location	required	optional	
Diagram Layout	required	optional	optional
Steady State Hypothesis	required		
Topology	required	optional	optional
State Variables	required	required	
System Capacity	required	optional	optional

1.4.2 General

The proposed LTDS grid model scope is (inclusive) from 132kV networks (EHV in Scotland) to the lower voltage (HV) bus in Primary substations (including details of any interconnectors at lower voltages that are needed to assess the capability of the higher voltage networks).

Only equipment that is normally in service should appear in LTDS modelling.

1.4.3 Physical modelling



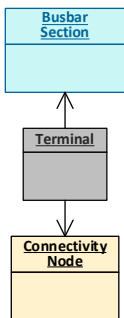
Physical data describes the grid itself. It provides information about the behaviour, connectivity, and geographic location of the equipment that makes up the electrical system.

1.4.3.1 Equipment (EQ) profile data

The Equipment profile describes basic equipment and connectivity and provides the foundation on which the data of the other Physical profiles – Short Circuit and Geographical Location – are layered.

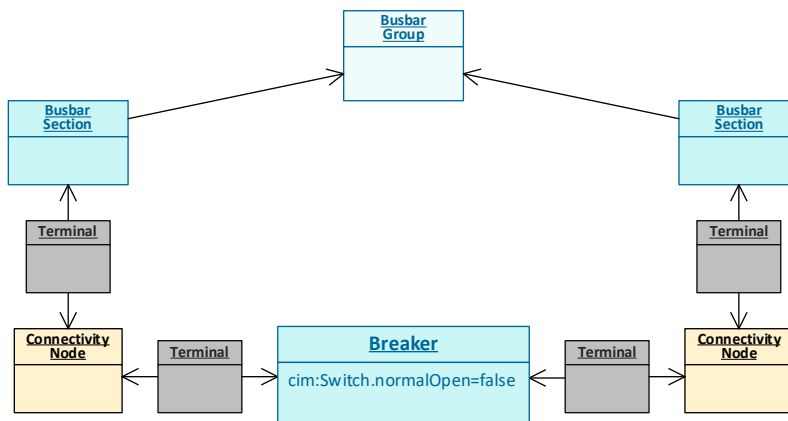
1.4.3.1.1 Bus and bus group

In CIM, a busbar section is modelled with a `cim:BusbarSection` object associated via its `cim:Terminal` to a `cim:ConnectivityNode` object.



Note that `cim:ConnectivityNode` objects are the means by which connectivity is described in CIM and a typical grid model has many `cim:ConnectivityNode` objects that do not represent busbars. Only those that do represent busbars have the `cim:Terminal` of a `cim:BusbarSection` associated with them.

A group of busbar sections normally operated as a single bus are modelled using a `gb:BusbarGroup` object:



A `gb:BusbarGroup` object supports the provision of LTDS bus-level information like:

- Fault levels
- Firm capacities
- Non-coincident bus maximum loadings
- Connection activity.

For additional information on bus-level information, see the System capacity profile data section.

The following requirements apply to the modelling of busbars and busbar groups in the proposed LTDS grid model:

- Every busbar section in scope is modelled individually, except for busses at the lowest modelled voltage level connected by normally closed busbar coupling breakers. These busses are modelled either as individual busses or as a single busbar.
- Every `cim:BusbarSection` is associated with a single `gb:BusbarGroup`.

The classes and attributes in the LTDS Equipment profile which support bus and bus group modelling are:

<code>BusbarSection</code>
<code>BusbarGroup</code>

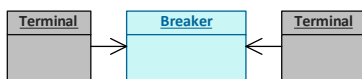
(Note that in this list – and all similar lists throughout this document – the `cim:IdentifiedObject` attributes required by the Equipment profile are not shown. They are covered, at the profile level, in the CIM conventions used in requirements definition section above.)

Also refer to *Appendix 9 - Grid Data Constraints*:

- `C:301:EQ:BusbarSection:numberOfTerminals`

1.4.3.1.2 Switching device

In CIM, a circuit breaker is modelled with a `cim:Breaker` object.



A non-breaker switching device, e.g., a disconnecter, is modelled using a `cim:Disconnecter` object.

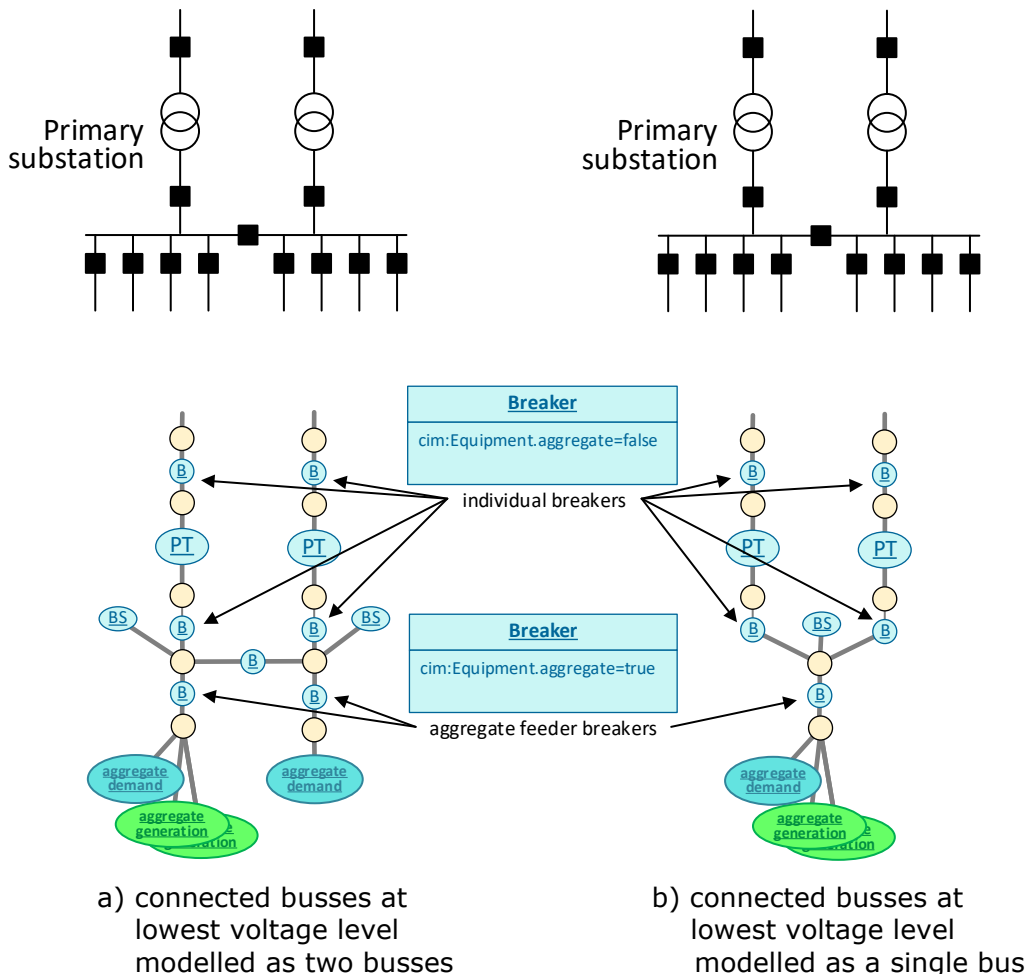


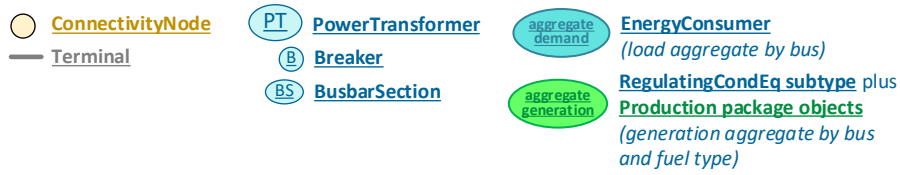
The following requirements apply to the modelling of switching devices in the proposed LTDS grid model:

- Every circuit breaker in scope is modelled, with the exception of normally closed bus coupling breakers connecting busses at the lowest modelled voltage level. These breakers are optionally modelled.

- Other switching devices are modelled as necessary to allow every circuit, transformer, busbar, generator, load, or other equipment to be disconnected from the grid.
- Other cim:Switch subtype objects (for example, cim:LoadBreakSwitch or cim:DisconnectingCircuitBreaker) may be used if more explicit modelling is desired.
- Additional switching devices beyond those required may be modelled.
- A single “aggregate feeder breaker” is modelled (using a cim:Breaker with the cim:Equipment.aggregate=true) for each bus at the lowest modelled voltage level. The aggregate feeder breaker is used to supply make and break current rating information (see Short Circuit (SC) profile data) for the bus’s feeder breakers as a whole. Additionally, aggregate load and generation is connected via the aggregate feeder breaker (see Load and_Generation).

The diagram below illustrates the two approaches to modelling a pair of lowest voltage level busses connected with a normally closed coupling breaker. Their aggregate feeder breakers are also shown with their connected aggregate generation and load.





The classes and attributes in the LTDS Equipment profile which support switching device modelling are:

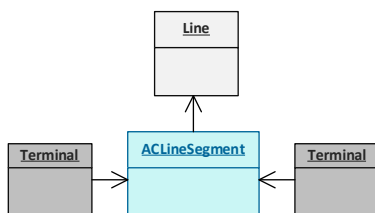
Disconnecter		
REQUIRED	Switch	normalOpen
REQUIRED	Switch	ratedCurrent
Fuse		
REQUIRED	Switch	normalOpen
REQUIRED	Switch	ratedCurrent
GroundDisconnecter		
REQUIRED	Switch	normalOpen
REQUIRED	Switch	ratedCurrent
Breaker		
REQUIRED	Equipment	aggregate
REQUIRED	Switch	normalOpen
REQUIRED	Switch	ratedCurrent
DisconnectingCircuitBreaker		
REQUIRED	Switch	normalOpen
REQUIRED	Switch	ratedCurrent
LoadBreakSwitch		
REQUIRED	Switch	normalOpen
REQUIRED	Switch	ratedCurrent

Also refer to *Appendix 9 - Grid Data Constraints*:

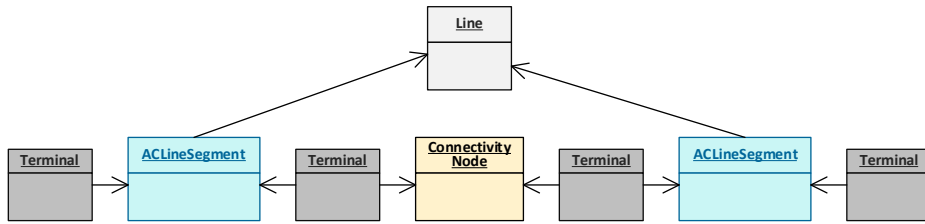
- C:452:EQ:Switch:connection
- C:301:EQ:Switch:numberOfTerminals
- C:301:EQ:Switch.ratedCurrent:valueRange

1.4.3.1.3 Circuit

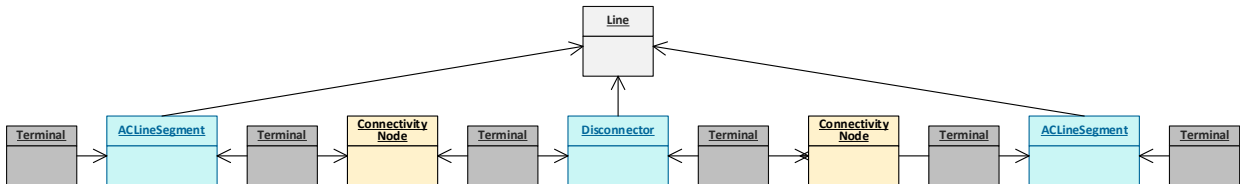
A circuit is modelled using a `cim:Line` object containing at least one `cim:ACLineSegment` object.



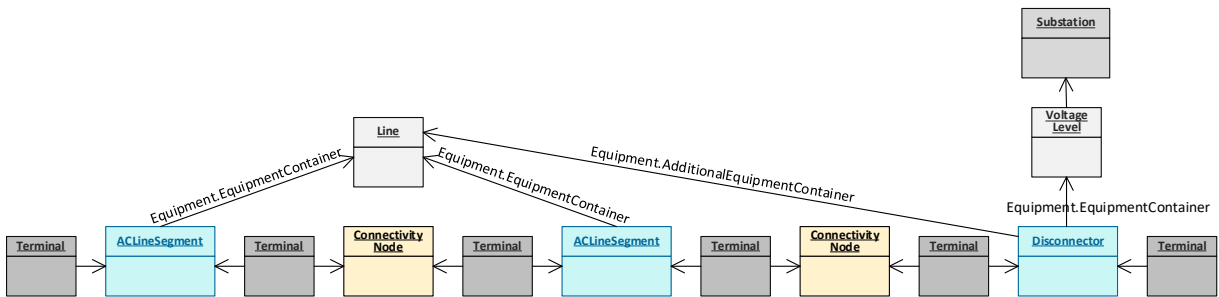
A `cim:Line` may contain multiple `cim:ACLineSegment` objects.



It may also contain other types of `cim:ConductingEquipment` subtype objects (e.g., `Disconnecter`).



A `cim:ACLineSegment` may also have a `cim:ConductingEquipment` subtype object, whose primary containment is in a `cim:VoltageLevel` of a `cim:Substation`, associated with it by means of the `cim:Equipment.AdditionalEquipmentContainer` association.



The `cim:Equipment.AdditionalEquipmentContainer` association allows a `cim:ConductingEquipment` subtype object which is associated with a `cim:VoltageLevel` of `cim:Substation` for naming or display purposes to also be associated with a `cim:Line` for the purpose of circuit limit definition (see Circuit limits).

The following requirements apply to the modelling of circuits in the proposed LTDS grid model:

- Every circuit in scope is modelled. Circuits in the same right-of-way are modelled individually. Sections of tapped lines are modelled individually.
- Modelling of a circuit using multiple `cim:ACLineSegment` objects is recommended especially if the modelling reflects sections with differing impedances or ratings.

The classes and attributes in the LTDS Equipment profile which support circuit modelling are:

Line		
ACLineSegment		
REQUIRED	Conductor	length
REQUIRED	ACLineSegment	bch
OPTIONAL	ACLineSegment	gch
REQUIRED	ACLineSegment	r

REQUIRED	ACLineSegment	x
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Notes on OPTIONAL attributes:

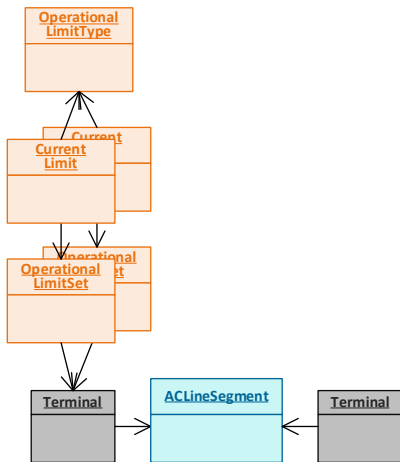
- For all `cim:ACLineSegment` objects, `.gch` is populated at local discretion.

Also refer to *Appendix 9 - Grid Data Constraints*:

- `C:452:EQ:ACLineSegment.r:valueRange`
- `C:452:EQ:ACLineSegment.x:valueRange`

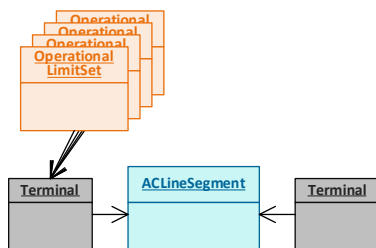
1.4.3.1.4 Circuit limits

In CIM, a circuit limit is modelled by a combination of a `cim:OperationalLimitSet` object and one or more `cim:CurrentLimit` objects, each of which is associated with a `cim:OperationalLimitType`. The `cim:OperationalLimitSet` is associated with a `cim:Terminal` of a `cim:ACLineSegment` (or other `cim:ConductingEquipment` subtype object associated with a `cim:Line`).

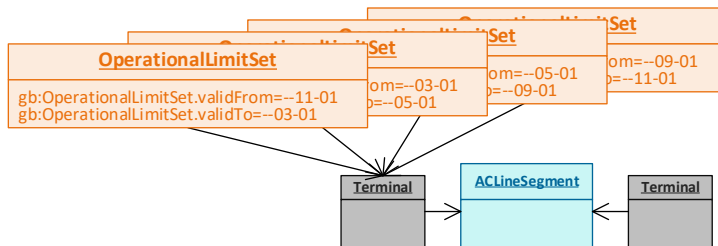


The following requirements apply to the modelling of circuit limits in the LTDS grid model:

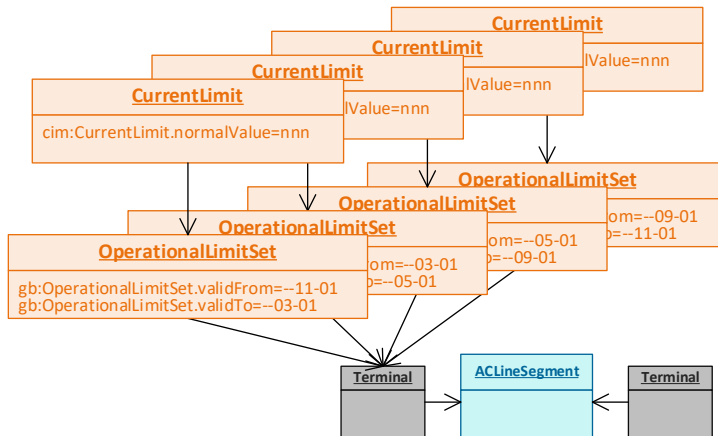
- Every `cim:ACLineSegment` has at least one `cim:OperationalLimitSet` object associated with one of its two `cim:Terminal` objects and can have as many as necessary to accurately reflect the DNO's 'seasonal' limit philosophies.



- Each `cim:OperationalLimitSet` has a period of validity. This period is specified using the `gb:OperationalLimitSet.validFrom` and `gb:OperationalLimitSet.validTo` attributes. There are no prescribed start/end dates for the periods, but the `gb:OperationalLimitSet.validFrom` and `gb:OperationalLimitSet.validTo` dates of the `cim:OperationalLimitSet` objects associated with a given `cim:ACLineSegment` describe periods which completely cover a calendar year in a non-overlapping fashion.



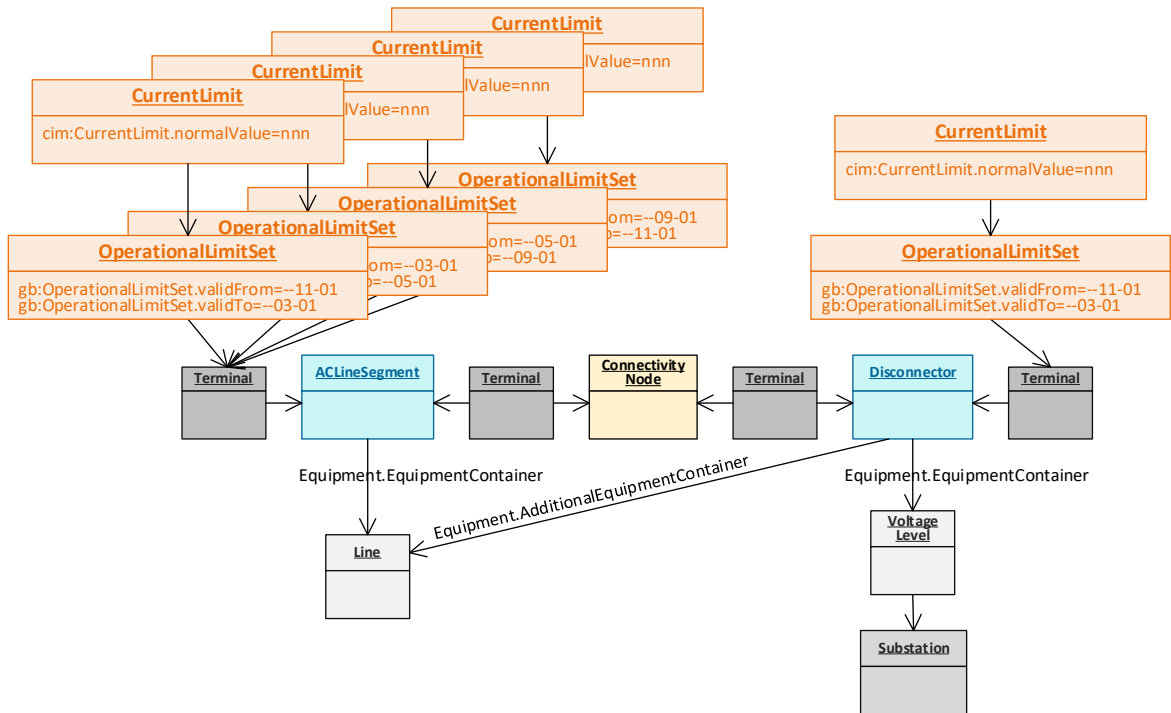
- Each `cim:OperationalLimitSet` associated with a `cim:ACLineSegment`'s `cim:Terminal` is associated with a `cim:CurrentLimit` object whose `cim:CurrentLimit.normalValue` attribute is populated with a value reflecting the seasonal conductor ampere limit typically used in DNO planning and interconnection studies.



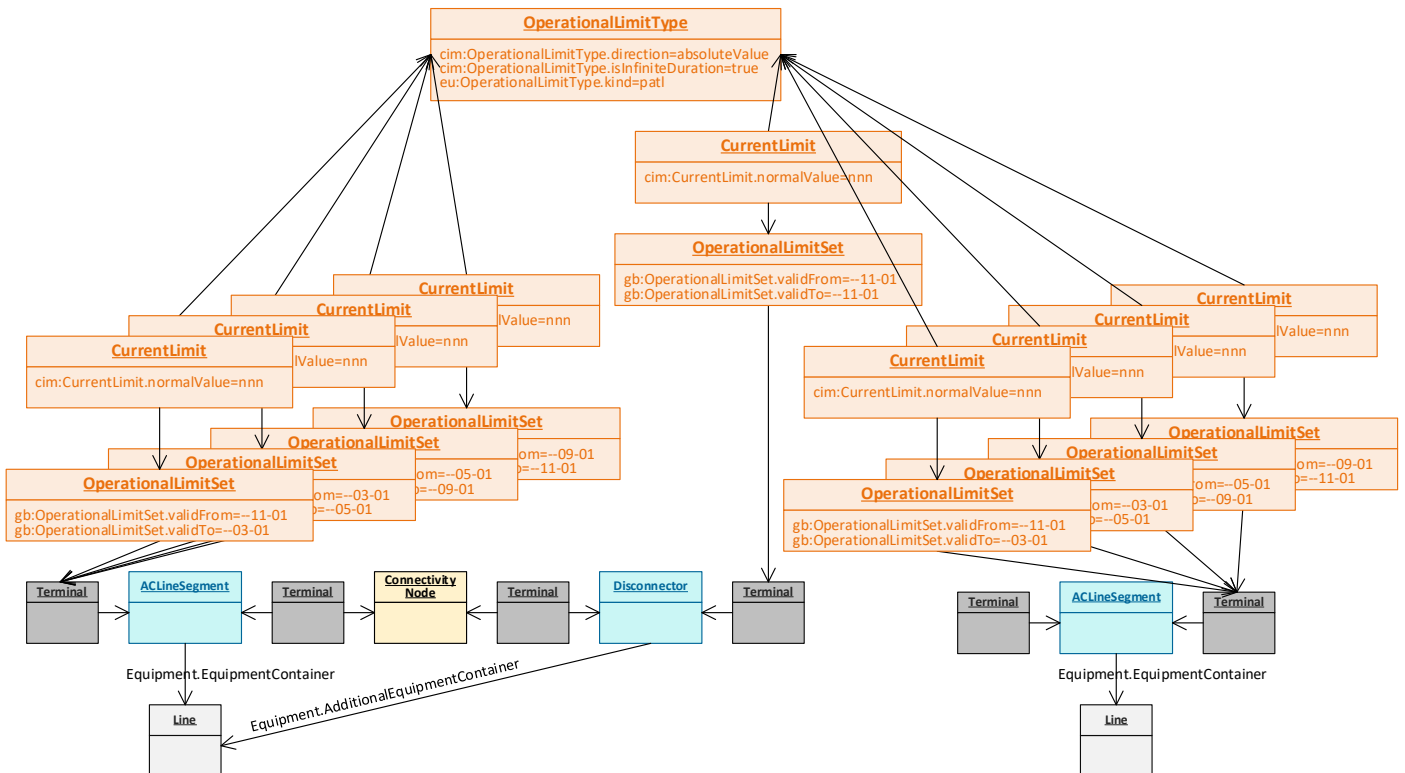
The standard approach used by the DNO in calculating circuit-related limits is documented by the DNO in its concurrently published *LTDS Overview* document. Deviations from the standard calculation approach and additional explanatory information to assist in user interpretation are described in the `cim:IdentifiedObject.description` attribute of the `cim:CurrentLimit`.

- If a device is a limiting element on a circuit, the `cim:Equipment` subtype object representing the device is associated with the circuit's `cim:Line` (via either a `cim:Equipment.EquipmentContainer` association or via a `cim:Equipment.AdditionalEquipmentContainer` association) and can have one or

more `cim:OperationalLimitSet` objects associated with one of its `cim:Terminal` objects.



- A single `cim:OperationalLimitType` is referenced by all `cim:CurrentLimit` objects in a Full Model.



This `cim:OperationalLimitType` has the following attribute values:

- `cim:OperationalLimitType.direction=absoluteValue`

- cim:OperationalLimitType.isInfiniteDuration=true
- eu:OperationalLimitType.kind=patl

The attribute cim:OperationalLimitType.acceptableDuration is not exchanged as cim:OperationalLimitType.isInfiniteDuration is set to true.

The classes and attributes in the LTDS Equipment profile which support circuit limit modelling are:

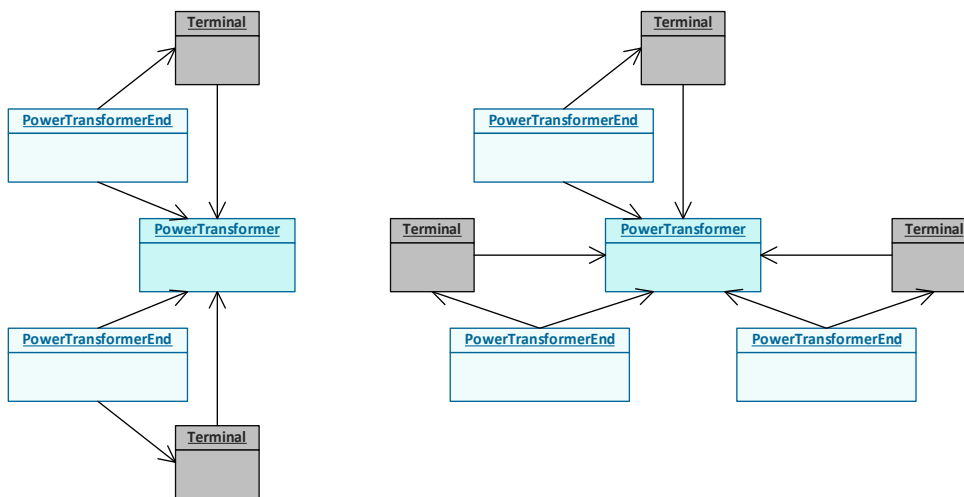
OperationalLimitSet		
REQUIRED	OperationalLimitSet	validFrom
REQUIRED	OperationalLimitSet	validTo
CurrentLimit		
REQUIRED	CurrentLimit	normalValue
OperationalLimitType (one)		
REQUIRED	OperationalLimitType	direction (must=absoluteValue)
REQUIRED	OperationalLimitType	isInfiniteDuration (must=true)
REQUIRED	OperationalLimitType	kind (must=patl)

Also refer to *Appendix 9 - Grid Data Constraints*:

- C:301:EQ:CurrentLimit.normalValue:valueRange

1.4.3.1.5 Transformer

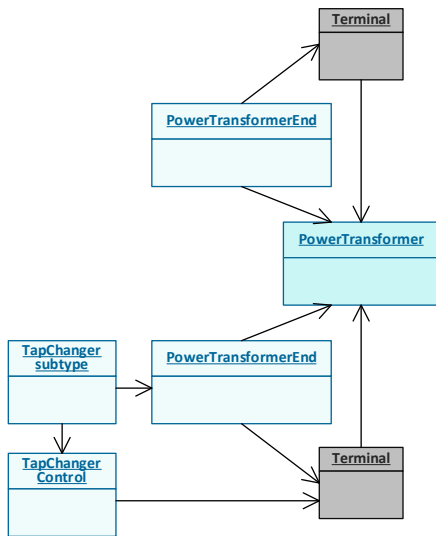
In CIM, a power transformer is modelled using a cim:PowerTransformer object and a set of cim:PowerTransformerEnd objects equal in number to the number of its windings.



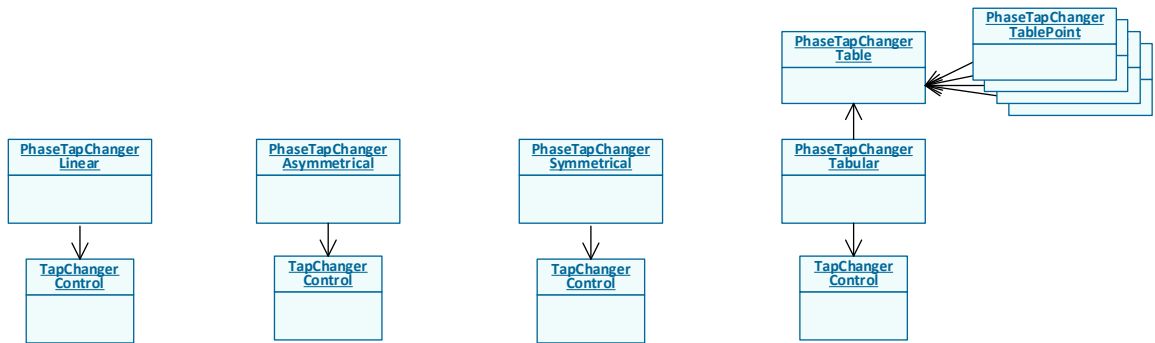
a) two-winding transformer

b) three-winding transformer

For transformers with a tap changer, a cim:TapChanger subtype object appropriate to the type of tap changer (e.g., ratio tap changer or phase tap changer) is associated with the appropriate cim:PowerTransformerEnd and an associated cim:TapChangerControl object is associated with that cim:PowerTransformerEnd’s cim:Terminal.



The cim:TapChanger subtype objects and their associated objects are:



- a) cim:TapChanger Linear
- b) cim:TapChanger Asymmetrical
- c) cim:TapChanger Symmetrical
- d) cim:TapChanger Tabular

The following requirements apply to the modelling of transformers in the proposed LTDS grid model:

- Every DNO-owned transformer in scope (i.e., every transformer associated with Grid or with Primary substation) is modelled, including its control functions, if present.

The classes and attributes in the LTDS Equipment profile which support transformer modelling are:

PowerTransformer		
REQUIRED	PowerTransformer	reverseFlowCapability
PowerTransformerEnd		
REQUIRED	TransformerEnd	endNumber
REQUIRED	TransformerEnd	earthingMethod
REQUIRED	PowerTransformerEnd	b
REQUIRED	PowerTransformerEnd	connectionKind
OPTIONAL	PowerTransformerEnd	g
REQUIRED	PowerTransformerEnd	r

REQUIRED	PowerTransformerEnd	ratedS
REQUIRED	PowerTransformerEnd	ratedU
REQUIRED	PowerTransformerEnd	x

Notes on OPTIONAL attributes:

- For all cim:PowerTransformerEnd objects, .g is populated at local discretion.

The classes and attributes in the LTDS Equipment profile which support transformer tap changer modelling are:

PhaseTapChangerLinear		
REQUIRED	TapChanger	highStep
REQUIRED	TapChanger	lowStep
REQUIRED	TapChanger	ltcFlag
REQUIRED	TapChanger	neutralStep
REQUIRED	TapChanger	neutralU
REQUIRED	TapChanger	normalStep
REQUIRED	PhaseTapChangerLinear	stepPhaseShiftIncrement
REQUIRED	PhaseTapChangerLinear	xMax
PhaseTapChangerAsymmetrical		
REQUIRED	TapChanger	highStep
REQUIRED	TapChanger	lowStep
REQUIRED	TapChanger	ltcFlag
REQUIRED	TapChanger	neutralStep
REQUIRED	TapChanger	neutralU
REQUIRED	TapChanger	normalStep
REQUIRED	PhaseTapChangerNonLinear	voltageStepIncrement
REQUIRED	PhaseTapChangerNonLinear	xMax
REQUIRED	PhaseTapChangerAsymmetrical	windingConnectionAngle
PhaseTapChangerSymmetrical		
REQUIRED	TapChanger	highStep
REQUIRED	TapChanger	lowStep
REQUIRED	TapChanger	ltcFlag
REQUIRED	TapChanger	neutralStep
REQUIRED	TapChanger	neutralU
REQUIRED	TapChanger	normalStep
REQUIRED	PhaseTapChangerNonLinear	voltageStepIncrement
REQUIRED	PhaseTapChangerNonLinear	xMax
PhaseTapChangerTabular		
REQUIRED	TapChanger	highStep
REQUIRED	TapChanger	lowStep
REQUIRED	TapChanger	ltcFlag
REQUIRED	TapChanger	neutralStep
REQUIRED	TapChanger	neutralU
REQUIRED	TapChanger	normalStep
PhaseTapChangerTable		
PhaseTapChangerTablePoint		
OPTIONAL	TapChangerTablePoint	b
OPTIONAL	TapChangerTablePoint	g

OPTIONAL	TapChangerTablePoint	r
OPTIONAL	TapChangerTablePoint	ratio
REQUIRED	TapChangerTablePoint	step
OPTIONAL	TapChangerTablePoint	x
REQUIRED	PhaseTapChangerTablePoint	angle
RatioTapChanger		
REQUIRED	TapChanger	highStep
REQUIRED	TapChanger	lowStep
REQUIRED	TapChanger	ltcFlag
REQUIRED	TapChanger	neutralStep
REQUIRED	TapChanger	neutralU
REQUIRED	TapChanger	normalStep
REQUIRED	RatioTapChanger	stepVoltageIncrement
RatioTapChangerTable		
RatioTapChangerTablePoint		
OPTIONAL	TapChangerTablePoint	b
OPTIONAL	TapChangerTablePoint	g
OPTIONAL	TapChangerTablePoint	r
OPTIONAL	TapChangerTablePoint	ratio
REQUIRED	TapChangerTablePoint	step
OPTIONAL	TapChangerTablePoint	x
TapChangerControl		
REQUIRED	RegulatingControl	mode (must=voltage)

Notes on OPTIONAL attributes:

- For all `cim:PhaseTapChangerTablePoint` and `cim:RatioTapChangerTablePoint` objects,
 - The attributes `.b`, `.g`, `.r`, `.x`, `.ratio` are exchanged depending on the content of the tabular representation of the transformer tap changer.

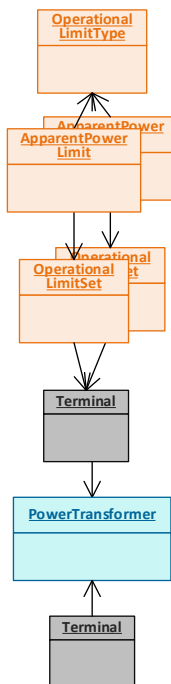
Also refer to *Appendix 9 - Grid Data Constraints*:

- C:301:EQ:TransformerEnd.endNumber:unique
- C:452:EQ:PowerTransformerEnd.b:valueRange
- C:452:EQ:PowerTransformerEnd.g:valueRange
- C:301:EQ:PowerTransformerEnd.r:valueRange
- C:301:EQ:PowerTransformerEnd.ratedS:valueRange
- C:301:EQ:PowerTransformerEnd.ratedS:valueRange2winding
- C:301:EQ:PowerTransformerEnd.ratedU:valueRange
- C:452:EQ:PowerTransformerEnd.x:PowerTransformerEndX
- C:452:EQ:PowerTransformerEnd.x:value
- C:452:EQ:PowerTransformerEnd:pu
- C:301:EQ:PowerTransformerEnd:secondWindingValues
- C:301:EQ:PowerTransformerEnd:terminalConsistency
- C:301:EQ:PowerTransformer:associationNotUsed

- C:301:EQ:TapChanger:multipleTypes
- C:301:EQ:TapChanger.highStep:valueRangePair
- C:301:EQ:TapChanger.ltcFlag:tapChangerControl
- C:301:EQ:TapChanger.neutralStep:valueRangePairFrom
- C:301:EQ:TapChanger.neutralStep:valueRangePairTo
- C:600:EQ:TapChanger.neutralU:ValueRangePair
- C:301:EQ:TapChanger.neutralU:
- C:301:EQ:TapChanger.normalStep:valueRangePairFrom
- C:301:EQ:TapChanger.normalStep:valueRangePairTo
- C:452:EQ:TapChangerControl:remoteQcontrol
- C:452:EQ:PhaseTapChanger:controlModeP
- C:452:EQ:RatioTapChanger:controlMode
- C:301:EQ:PhaseTapChangerAsymmetrical.windingConnectionAngle:valueRange

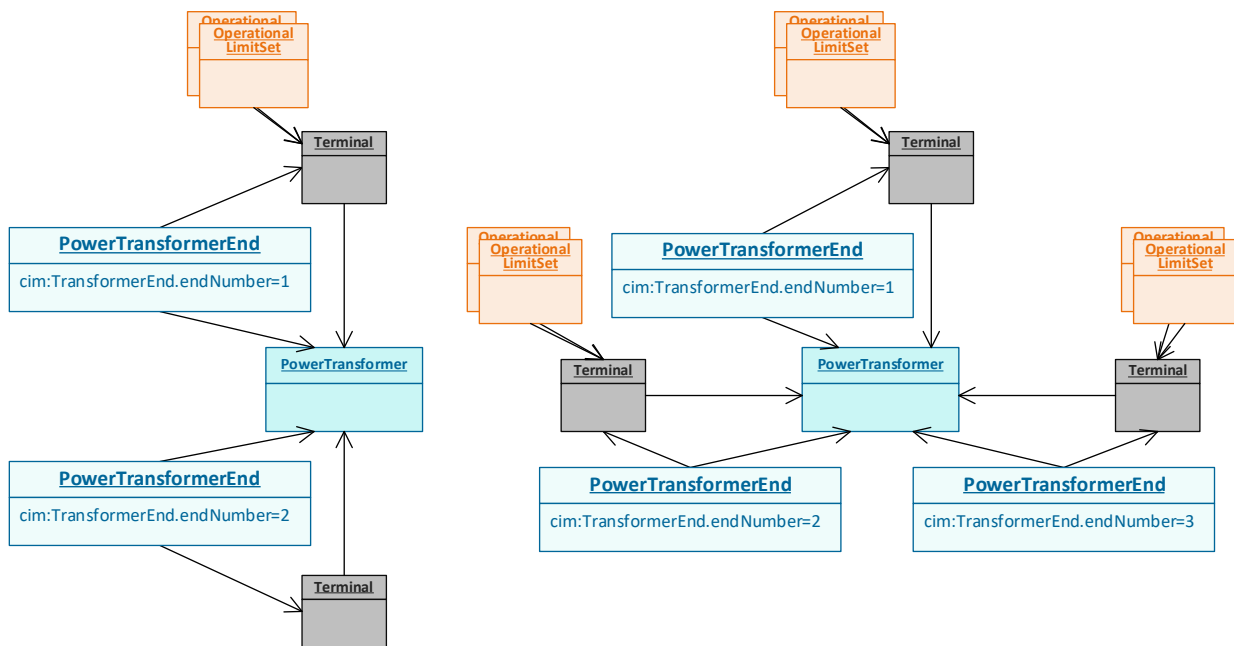
1.4.3.1.6 Transformer limits

In CIM, a transformer limit is modelled by a combination of a `cim:OperationalLimitSet` object and one or more `cim:ApparentPowerLimit` objects, each of which is associated with a `cim:OperationalLimitType`. The `cim:OperationalLimitSet` is associated with a `cim:Terminal` of a `cim:PowerTransformer`.



The following requirements apply to the modelling of transformer limits in the proposed LTDS grid model:

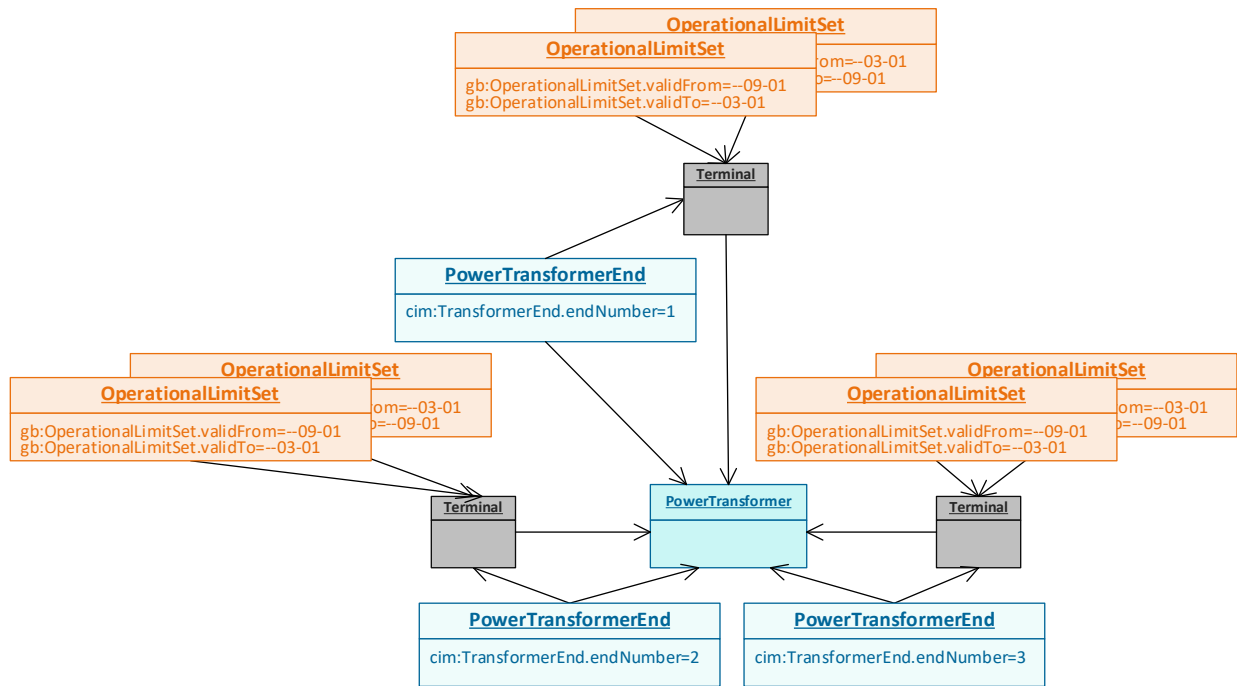
- Every `cim:PowerTransformer` has a minimum of two `cim:OperationalLimitSet` objects, one for winter and one for summer, both associated with the `cim:Terminal` of the winding with the highest voltage (i.e., the winding with `cim:TransformerEnd.endNumber=1`). For 3-winding transformers, two `cim:OperationalLimitSet` objects, one for winter and one for summer, are also associated with the `cim:Terminal` of each of the other windings (i.e., the windings with `cim:TransformerEnd.endNumber=2` and `cim:TransformerEnd.endNumber=3`).



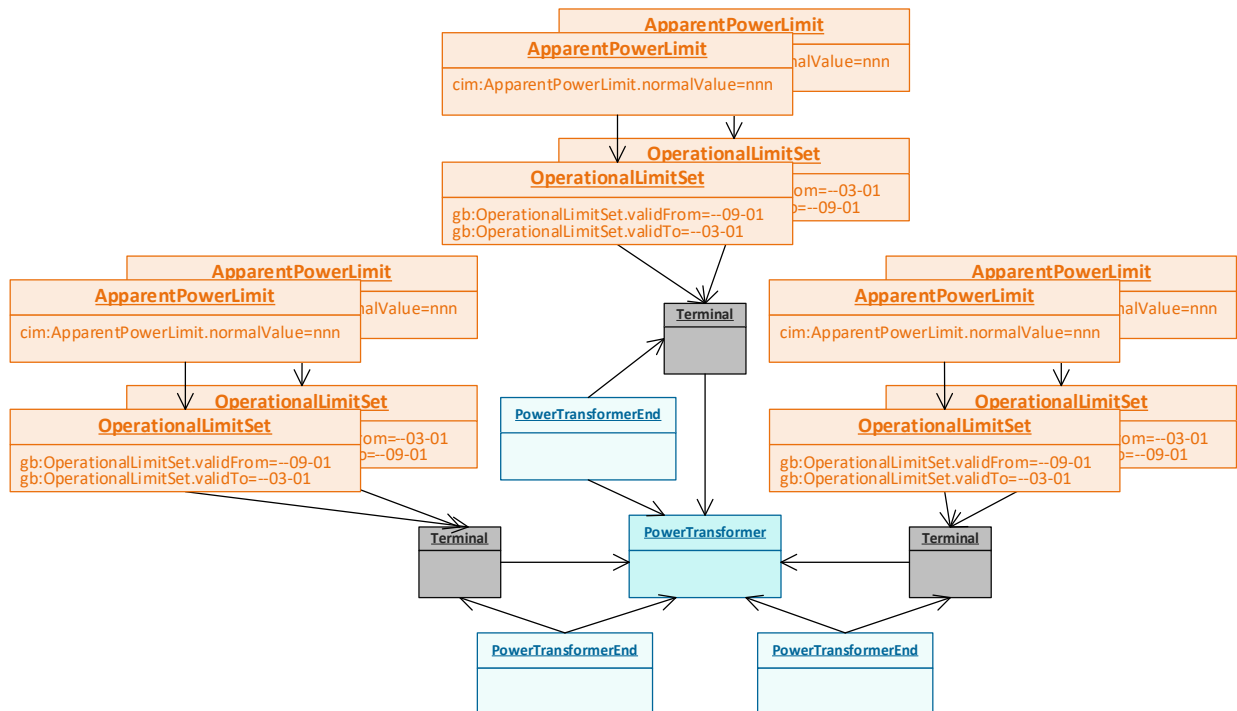
a) Two-winding transformer

b) Three-winding transformer

- Each `cim:OperationalLimitSet` has a period of validity. This period is specified using the `gb:OperationalLimitSet.validFrom` and `gb:OperationalLimitSet.validTo` attributes. There are no prescribed start/end dates for seasons, but the `gb:OperationalLimitSet.validFrom` and `gb:OperationalLimitSet.validTo` dates of the `cim:OperationalLimitSet` objects associated with a given `cim:Terminal` of the transformer describe periods which completely cover a calendar year in a non-overlapping fashion.



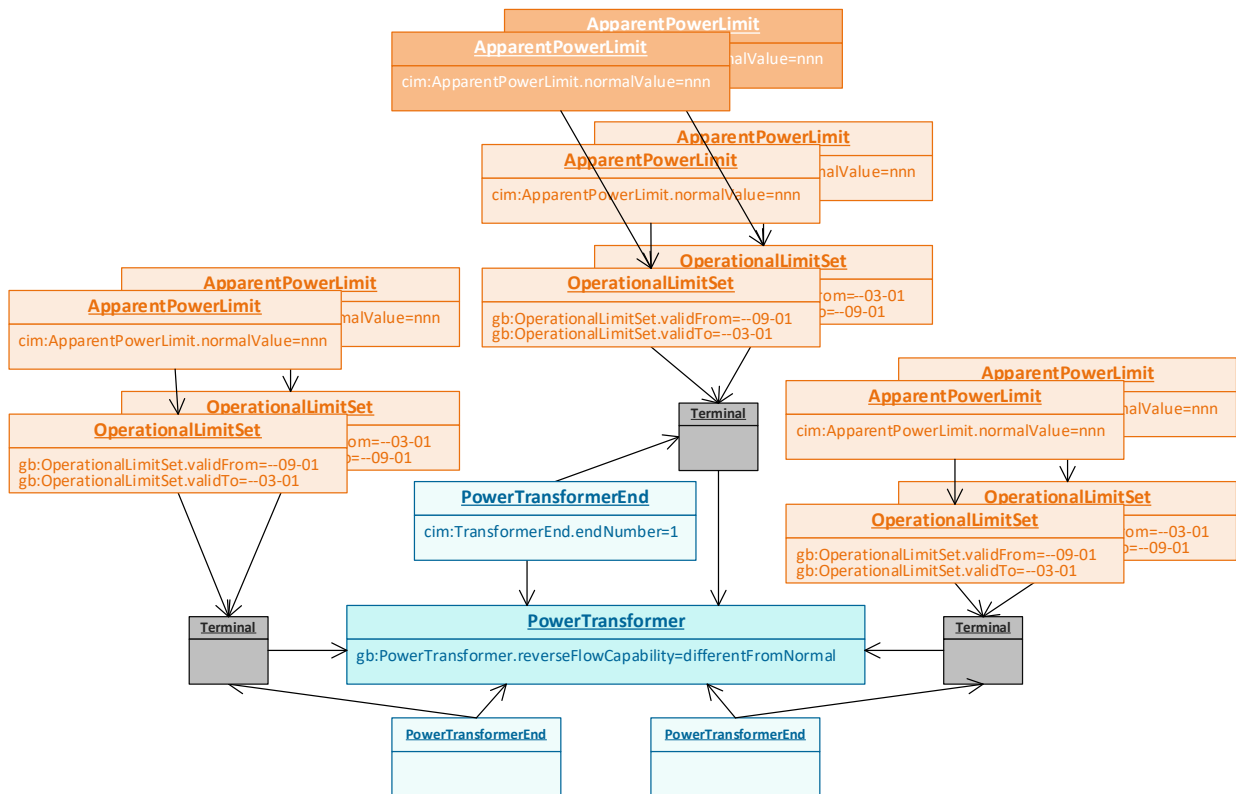
- Each `cim:OperationalLimitSet` associated with a `cim:PowerTransformer`'s `cim:Terminal` is associated with a `cim:ApparentPowerLimit` object whose `cim:ApparentPowerLimit.normalValue` attribute is populated with a value reflecting the MVA limit for the power flow in the normal direction that is typically used in DNO's planning and interconnection studies.



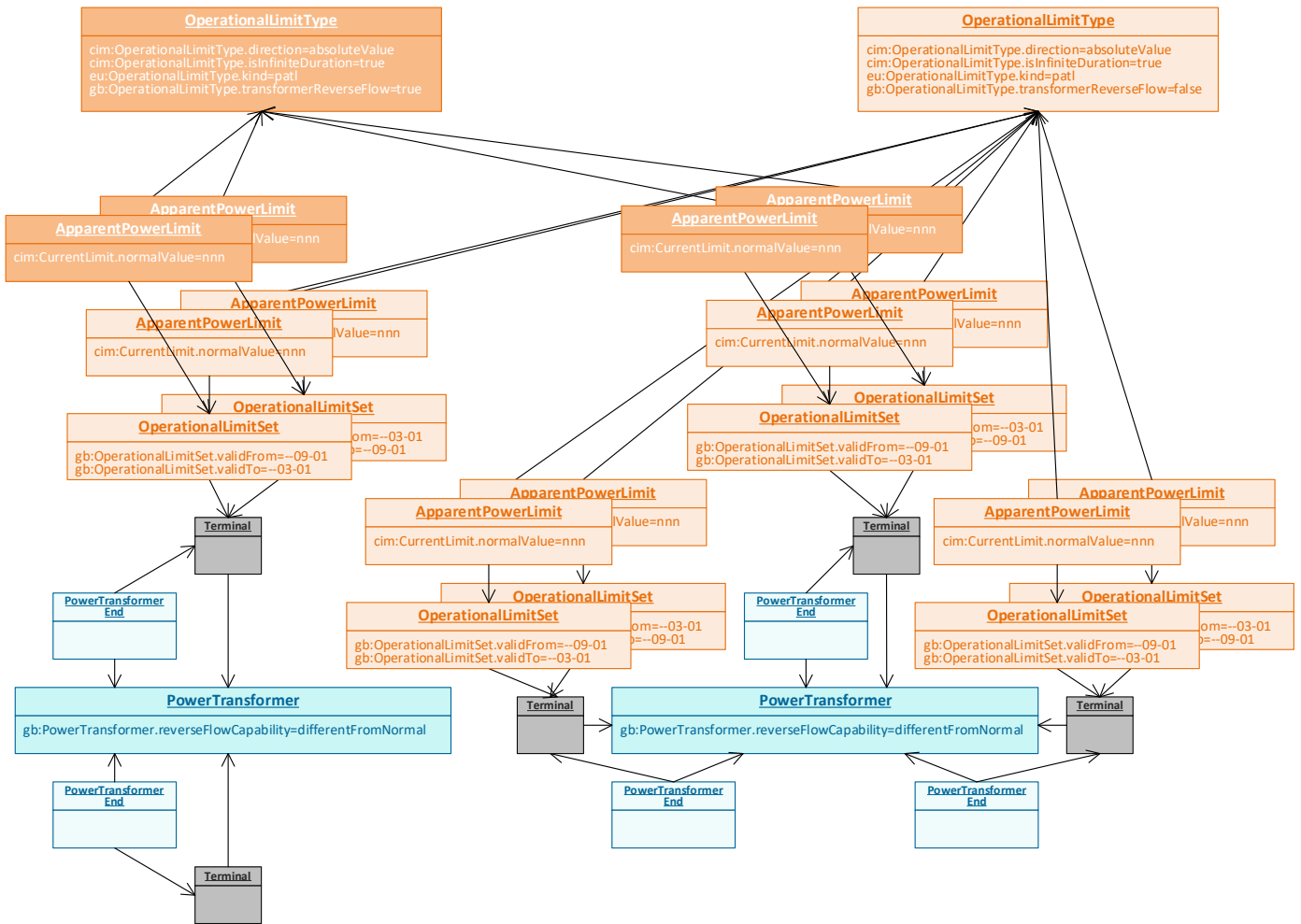
The standard approach used by the DNO in calculating its typically used transformer limits is documented by the DNO in its concurrently published *LTDS Overview* document. Any transformer-specific deviations from that standard

calculation approach are described in the `cim:IdentifiedObject.description` attribute of the `cim:ApparentPowerLimit`.

- If a `cim:PowerTransformer` object has `gb:PowerTransformer.reverseFlowCapability=differentFromNormal`, each `cim:OperationalLimitSet` associated with the `cim:Terminal` of the winding with `cim:TransformerEnd.endNumber=1` also has a `cim:ApparentPowerLimit` (shown in dark orange fill below), which represents the operating limit for the reverse direction of flow (i.e., low voltage to high voltage).



- Two `cim:OperationalLimitType` objects are included in a Full Model to support the typing of transformer `cim:ApparentPowerLimit` objects. The following types are defined:
 - Transformer MVA 'normal direction of flow' limits (light orange fill below)
 - Transformer MVA 'reverse direction of flow' limits (dark orange fill below)



two transformer-related cim:OperationalLimitType objects referenced by cim:ApparentPowerLimit objects associated with two transformers

Each of these two cim:OperationalLimitType objects have the following attribute values:

- cim:OperationalLimitType.direction=high
- cim:OperationalLimitType.isInfiniteDuration=true
- eu:OperationalLimitType.kind=patl

One cim:OperationalLimitType has the attribute gb:OperationalLimitType.transformerReverseFlow=true and the other has gb:OperationalLimitType.transformerReverseFlow=false.

The classes and attributes in the LTDS Equipment profile which support transformer limit modelling are:

OperationalLimitSet		
REQUIRED	OperationalLimitSet	validFrom
REQUIRED	OperationalLimitSet	validTo
ApparentPowerLimit		
REQUIRED	ApparentPowerLimit	normalValue
OperationalLimitType (two)		

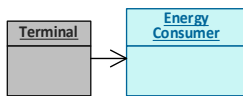
REQUIRED	OperationalLimitType	direction (must=high)
REQUIRED	OperationalLimitType	isInfiniteDuration (must=true)
REQUIRED	OperationalLimitType	kind (must=patl)
REQUIRED	OperationalLimitType	transformerReverseFlow (one must=true, one must=false)

Also refer to *Appendix 9 - Grid Data Constraints*:

- C:301:EQ:ApparentPowerLimit.normalValue:valueRange

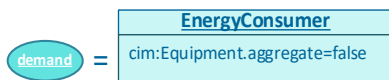
1.4.3.1.7 Load

In CIM, a load is modelled using a `cim:EnergyConsumer` object along with its associated `cim:Terminal`.

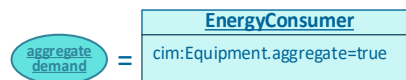


The following requirements apply to the modelling of load in the proposed LTDS grid model:

- The `cim:EnergyConsumer` object is used to represent both individual load and aggregate load. Individual load is indicated by `cim:Equipment.aggregate=false` in the `cim:EnergyConsumer` object. Aggregate load is indicated by `cim:Equipment.aggregate=true` in the `cim:EnergyConsumer` object.

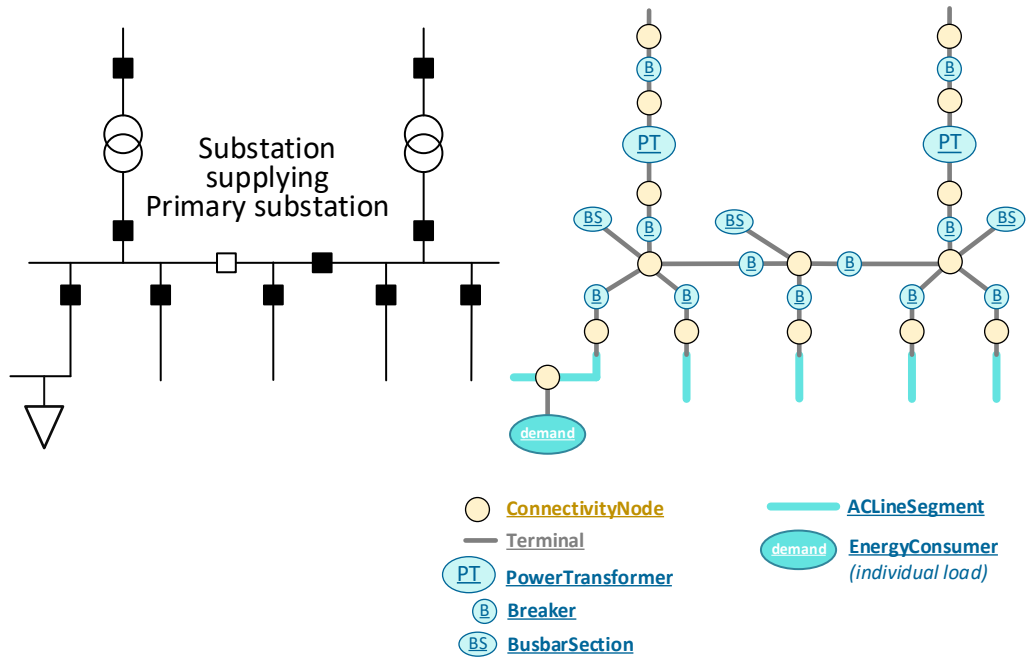


a) individual load

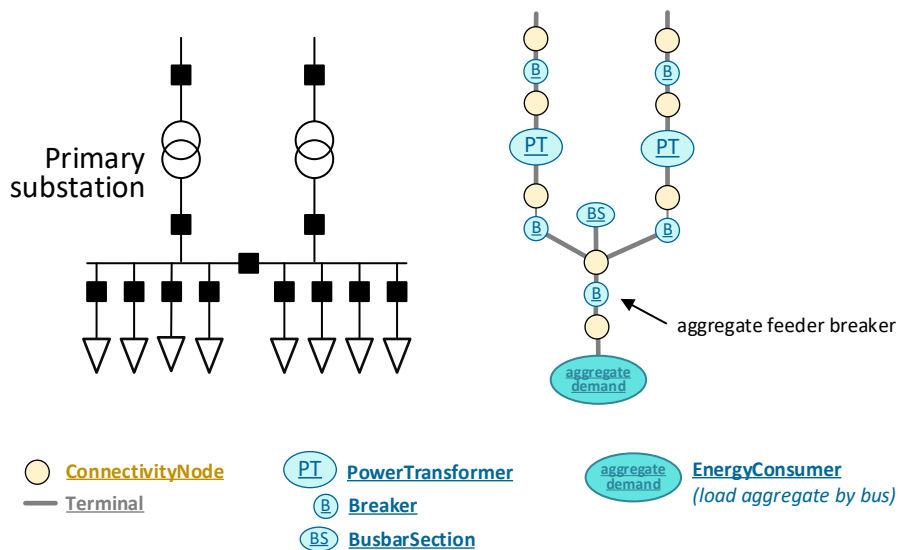


b) aggregate load

- Every load in scope which is connected to the grid at a voltage level above the lowest modelled voltage level is modelled as individual load at its grid location using a `cim:EnergyConsumer` object.



- All load connected to the grid outside the scope (i.e., at or below the lowest modelled voltage level) is modelled as aggregate load connected to the aggregate feeder breaker.



A note on assumed energy consumer load response:

- Since neither the cim:EnergyConsumer “fixed” attributes (.pfixed, .pfixedPct, .qfixed, qfixedPct) nor cim:LoadResponseCharacteristic are defined for LTDS, the assumption is that loads are modelled as constant power loads.

The classes and attributes in the LTDS Equipment profile which support load modelling are:

EnergyConsumer

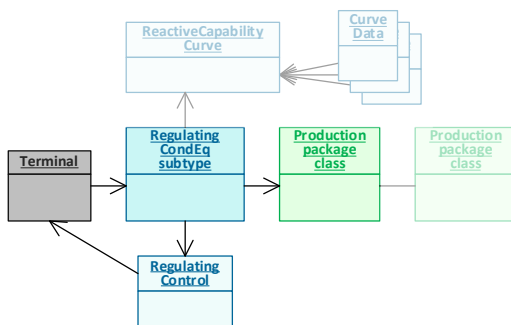
REQUIRED Equipment

aggregate

1.4.3.1.8 Generation

In CIM, generation is modelled using a combination of:

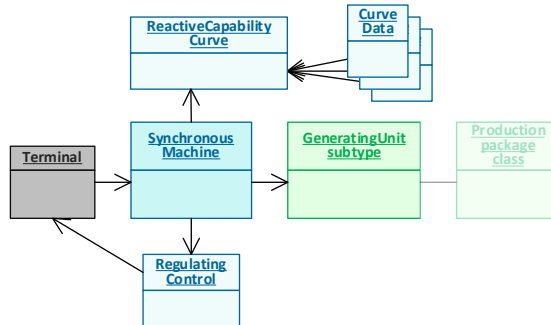
- A single `cim:RegulatingCondEq` subtype object (either a `cim:SynchronousMachine` object, a `cim:AsynchronousMachine` object, or a `cim:PowerElectronicsConnection` object) with
- An associated `cim:RegulatingControl` object and
- A primary `cim:Equipment` subtype object from the Production package of the CIM UML model (either a `cim:GeneratingUnit` subtype object or a `cim:PowerElectronicsConnection` subtype object).
- In certain cases, the following are also required:
 - Additional objects from the Production package
 - An associated `cim:ReactiveCapabilityCurve` object with its `cim:CurveData` objects.



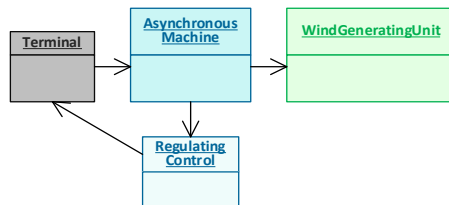
The following requirements apply to the modelling of generation in the proposed LTDS grid model:

- The fuel type of the generation determines the combination of objects modelled:
 - Generators powered by fuel of the following types:
 - Advanced Fuel
 - Biofuel
 - Fossil
 - Geothermal
 - Nuclear
 - Solar (non-inverter based)
 - Storage (other than battery)
 - Waste
 - Water
 - Other

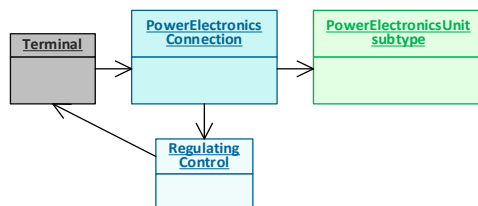
are modelled using a `cim:SynchronousMachine` object, a `cim:RegulatingControl` object, a `cim:ReactiveCapabilityCurve` object (plus its `cim:CurveData` objects) along with an appropriate `cim:GeneratingUnit` subtype object. Additional Production package objects may be required depending on the specific fuel type.



- Non-inverter-based wind generation is modelled with a `cim:AsynchronousMachine` object, a `cim:RegulatingControl` object, and a `cim:WindGeneratingUnit` object. No additional Production package objects are required.



- Generation that connects to the network using power electronics is modelled with a `cim:PowerElectronicsConnection` object, a `cim:RegulatingControl` object, and a `cim:PowerElectronicsUnit` subtype object. No additional Production package objects are required.

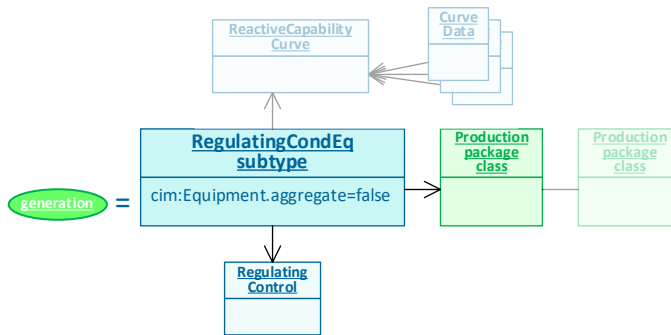


LTDS fuel types are based on the list of fuel types used by GC0139, augmented as necessary to fit with the CIM information model structure. The specific patterns of CIM objects for each generator fuel type are shown in Figure 2.

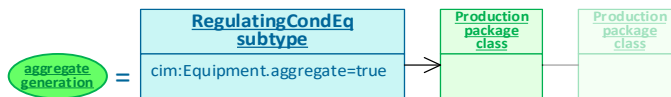
Figure 2: Generator modelling by fuel type using cim:RegulatingCondEq child objects and associated objects

GC0139 Fuel Type Report	Further Differentiation Required by CIM	Combination of CIM objects that indicates GC0139 fuel type			
		RegulatingCondEq subtype object	Equipment subtype object from Production package	further Production package object	attribute value required
Advanced Fuel (produced via gasification or pyrolysis of biofuel or waste)		SynchronousMachine	ThermalGeneratingUnit	OtherFuel <<GB>>	.otherFuelType=OtherFuelKind.advanced <<GB>>
Biofuel - Biogas from anaerobic digestion (excluding landfill & sewage)		SynchronousMachine	ThermalGeneratingUnit	BioFuel <<GB>>	.bioFuelType=BioFuelKind.anaerobicGas <<GB>>
Biofuel – Landfill gas		SynchronousMachine	ThermalGeneratingUnit	BioFuel <<GB>>	.bioFuelType=BioFuelKind.landfillGas <<GB>>
Biofuel – Sewage gas		SynchronousMachine	ThermalGeneratingUnit	BioFuel <<GB>>	.bioFuelType=BioFuelKind.sewageGas <<GB>>
Biofuel – Other		SynchronousMachine	ThermalGeneratingUnit	BioFuel <<GB>>	.bioFuelType=BioFuelKind.other <<GB>>
Biomass		SynchronousMachine	ThermalGeneratingUnit	BioFuel <<GB>>	.bioFuelType=BioFuelKind.biomass <<GB>>
Fossil – Brown coal/lignite		SynchronousMachine	ThermalGeneratingUnit	FossilFuel	.fossilFuelType=FuelType.brownCoalLignite
Fossil – Coal gas		SynchronousMachine	ThermalGeneratingUnit	FossilFuel	.fossilFuelType=FuelType.coalDerivedGas
Fossil – Gas		SynchronousMachine	ThermalGeneratingUnit	FossilFuel	.fossilFuelType=FuelType.gas
Fossil – Hard coal		SynchronousMachine	ThermalGeneratingUnit	FossilFuel	.fossilFuelType=FuelType.hardCoal
Fossil – Oil		SynchronousMachine	ThermalGeneratingUnit	FossilFuel	.fossilFuelType=FuelType.oil
Fossil – Oil shale		SynchronousMachine	ThermalGeneratingUnit	FossilFuel	.fossilFuelType=FuelType.oilShale
Fossil – Peat		SynchronousMachine	ThermalGeneratingUnit	FossilFuel	.fossilFuelType=FuelType.peat
Fossil – Other		SynchronousMachine	ThermalGeneratingUnit	FossilFuel	.fossilFuelType=FuelType.other
Geothermal		SynchronousMachine	GeothermalGeneratingUnit <<NC>>		
Hydrogen		PowerElectronicsConnection	PowerElectricalChemicalUnit <<NC>>		
Nuclear		SynchronousMachine	NuclearGeneratingUnit		
Solar	if inverter-based	PowerElectronicsConnection	PhotoVoltaicUnit		
	if non-inverter-based	SynchronousMachine	SolarGeneratingUnit		
Storage	if battery	PowerElectronicsConnection	BatteryUnit	CAESPlant	
	if compressed air	SynchronousMachine	ThermalGeneratingUnit		
	if flywheel	SynchronousMachine	FlywheelUnit <<GB>>		
	if pumped storage	SynchronousMachine	HydroGeneratingUnit		
Waste		SynchronousMachine	ThermalGeneratingUnit	OtherFuel <<GB>>	.otherFuelType=OtherFuelKind.waste <<GB>>
Water (flowing water or head of water)	if flowing water	SynchronousMachine	HydroGeneratingUnit	HydroPowerPlant	.hydroPlantStorageType=HydroPlantStorageKind.runOfRiver
	if head of water	SynchronousMachine	HydroGeneratingUnit	HydroPowerPlant	.hydroPlantStorageType=HydroPlantStorageKind.storage
Wind	if inverter-based	PowerElectronicsConnection	PowerElectronicsWindUnit		
	if non-inverter-based	AsynchronousMachine	WindGeneratingUnit		
Other		SynchronousMachine	GeneratingUnit		

- The combination of objects described in the table above is used to represent both individual generation and aggregate generation. Individual generation is indicated by `cim:Equipment.aggregate=false` in the `cim:RegulatingCondEq` subtype object. Aggregate generation is indicated by `cim:Equipment.aggregate=true` in the `cim:RegulatingCondEq` subtype object. Aggregate generation is modelled more simply (with fewer classes and attributes) than individual generation.



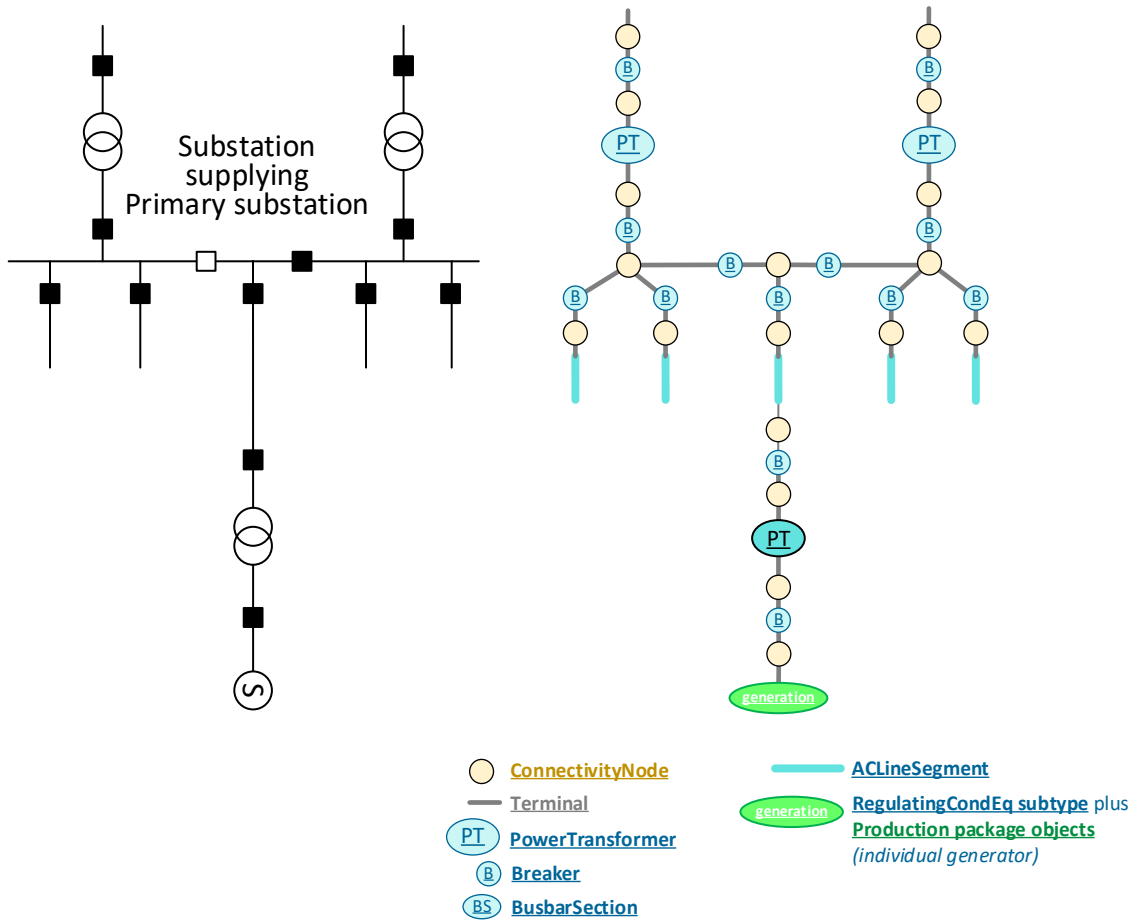
a) Individual generation



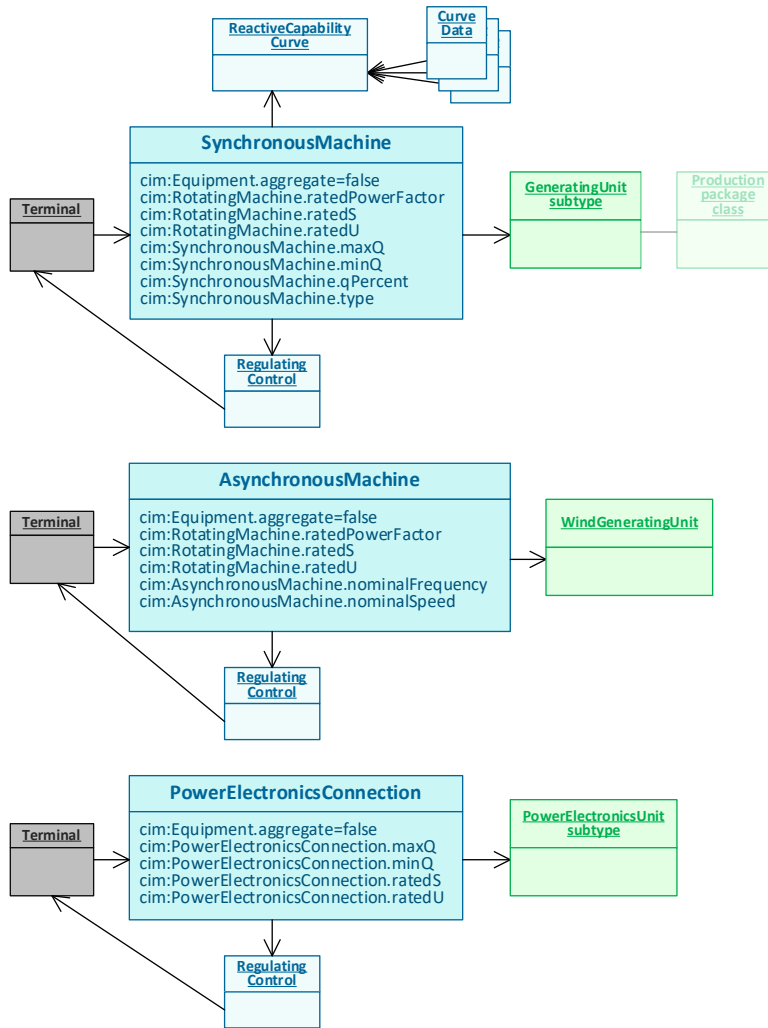
b) Aggregate generation

Individual generation

Every generator in scope which is connected at a voltage level above the lowest modelled voltage level is modelled as individual generation. For individual generation, basic modelling of the network between the generator and its grid connection point is provided. At the minimum, this consists of the step-up transformer and associated switching devices.



The `cim:RegulatingCondEq` subtype objects used to represent individual generation have the following attributes populated:



A note regarding power limits for individual generation represented by `cim:SynchronousMachine` or `cim:AsynchronousMachine`:

- There is one set of power limits defined in the Equipment profile. However, the Steady State Hypothesis profile allows the selection of an operating mode from among multiple options (each of which would have its own set of real-world limitations). Until this CIM shortcoming is corrected, special care needs to be taken that Equipment Models and Steady State Hypothesis Models published together as a case have coordinated information.

	Power limits defined in Equipment profile	Operating mode defined in Steady State Hypothesis profile
SynchronousMachine	GeneratingUnit.maxOperatingP GeneratingUnit.minOperatingP SynchronousMachine.maxQ SynchronousMachine.minQ	SynchronousMachine.operatingMode can be =generator, condenser or motor
AsynchronousMachine	GeneratingUnit.maxOperatingP GeneratingUnit.minOperatingP	AsynchronousMachine.asynchronousMachineType can be =generator or motor

The classes and attributes in the LTDS Equipment profile which support individual generation modelling are:

- RegulatingCondEq-related classes

SynchronousMachine		
REQUIRED	Equipment	aggregate
REQUIRED	RotatingMachine	ratedPowerFactor
REQUIRED	RotatingMachine	ratedS
REQUIRED	RotatingMachine	ratedU
REQUIRED	SynchronousMachine	maxQ
REQUIRED	SynchronousMachine	minQ
REQUIRED	SynchronousMachine	qPercent
REQUIRED	SynchronousMachine	type
ReactiveCapabilityCurve		
REQUIRED	Curve	curveStyle
REQUIRED	Curve	xUnit
REQUIRED	Curve	y1Unit
REQUIRED	Curve	y2Unit
CurveData		
REQUIRED	CurveData	xvalue
REQUIRED	CurveData	y1value
REQUIRED	CurveData	y2value
AsynchronousMachine		
REQUIRED	Equipment	aggregate
REQUIRED	RotatingMachine	ratedPowerFactor
REQUIRED	RotatingMachine	ratedS
REQUIRED	RotatingMachine	ratedU
REQUIRED	AsynchronousMachine	nominalFrequency
REQUIRED	AsynchronousMachine	nominalSpeed
PowerElectronicsConnection		
REQUIRED	Equipment	aggregate
REQUIRED	PowerElectronicsConnection	maxQ
REQUIRED	PowerElectronicsConnection	minQ
REQUIRED	PowerElectronicsConnection	ratedS
REQUIRED	PowerElectronicsConnection	ratedU
RegulatingControl		
REQUIRED	RegulatingControl	mode

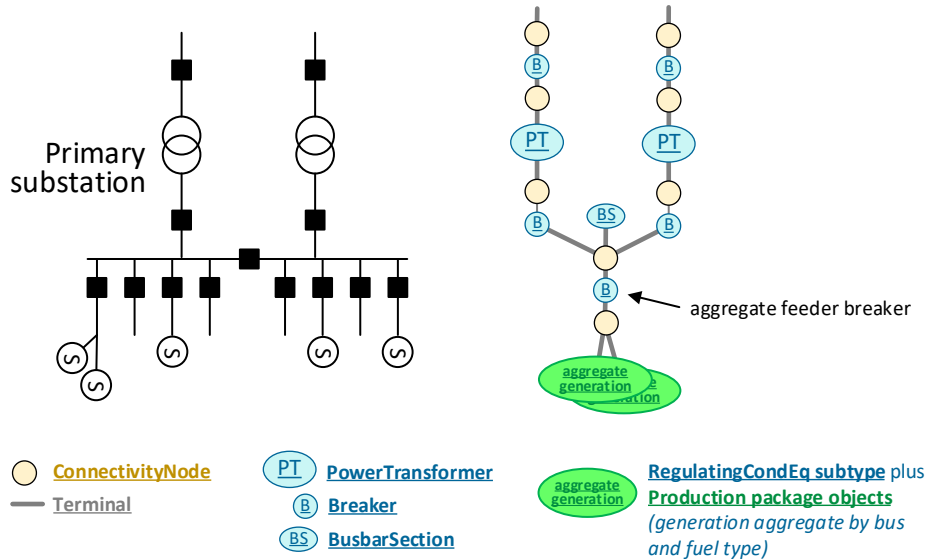
- Production package classes

GeneratingUnit		
REQUIRED	GeneratingUnit	maxOperatingP
REQUIRED	GeneratingUnit	minOperatingP
REQUIRED	GeneratingUnit	ratedNetMaxP
FlywheelUnit <<GB>>		
REQUIRED	GeneratingUnit	maxOperatingP
REQUIRED	GeneratingUnit	minOperatingP
REQUIRED	GeneratingUnit	ratedNetMaxP
REQUIRED	FlywheelUnit	energyStorageCapacity
GeothermalGeneratingUnit <<NC>>		

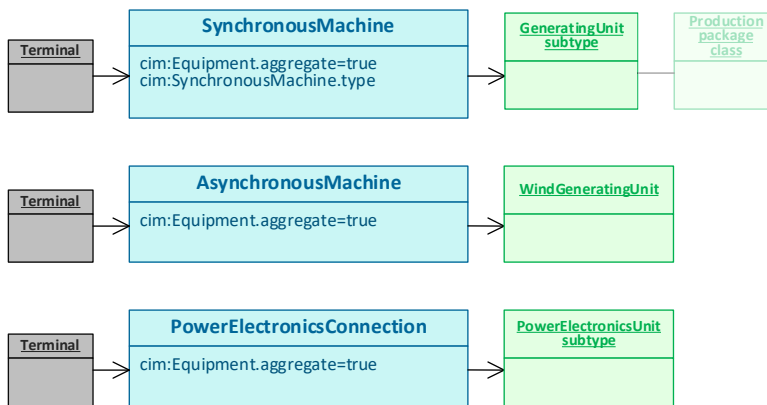
REQUIRED	GeneratingUnit	maxOperatingP
REQUIRED	GeneratingUnit	minOperatingP
REQUIRED	GeneratingUnit	ratedNetMaxP
HydroGeneratingUnit		
REQUIRED	GeneratingUnit	maxOperatingP
REQUIRED	GeneratingUnit	minOperatingP
REQUIRED	GeneratingUnit	ratedNetMaxP
HydroPowerPlant		
REQUIRED	HydroPowerPlant	hydroPlantStorageType
REQUIRED	HydroPowerPlant	energyStorageCapacity
NuclearGeneratingUnit		
REQUIRED	GeneratingUnit	maxOperatingP
REQUIRED	GeneratingUnit	minOperatingP
REQUIRED	GeneratingUnit	ratedNetMaxP
SolarGeneratingUnit		
REQUIRED	GeneratingUnit	maxOperatingP
REQUIRED	GeneratingUnit	minOperatingP
REQUIRED	GeneratingUnit	ratedNetMaxP
ThermalGeneratingUnit		
REQUIRED	GeneratingUnit	maxOperatingP
REQUIRED	GeneratingUnit	minOperatingP
REQUIRED	GeneratingUnit	ratedNetMaxP
BioFuel <<GB>>		
REQUIRED	BioFuel	bioFuelType
FossilFuel		
REQUIRED	FossilFuel	fossilFuelType
CAESPlant		
REQUIRED	CAESPlant	energyStorageCapacity
OtherFuel <<GB>>		
REQUIRED	OtherFuel	otherFuelType
WindGeneratingUnit		
REQUIRED	GeneratingUnit	maxOperatingP
REQUIRED	GeneratingUnit	minOperatingP
REQUIRED	GeneratingUnit	ratedNetMaxP
BatteryUnit		
REQUIRED	PowerElectronicsUnit	maxP
REQUIRED	PowerElectronicsUnit	minP
REQUIRED	BatteryUnit	ratedE
PhotoVoltaicUnit		
REQUIRED	PowerElectronicsUnit	maxP
REQUIRED	PowerElectronicsUnit	minP
PowerElectricalChemicalUnit <<NC>>		
REQUIRED	PowerElectronicsUnit	maxP
REQUIRED	PowerElectronicsUnit	minP
PowerElectronicsWindUnit		
REQUIRED	PowerElectronicsUnit	maxP
REQUIRED	PowerElectronicsUnit	minP

Aggregate generation

All generation (including behind-the-meter generation) connected to the grid outside the scope (i.e., at or below the lowest modelled voltage level) is modelled as aggregate generation connected to the aggregate feeder breaker.



Aggregate generation is modelled with less detail than individual generation and is aggregated by fuel type. Fuel type, as described above, is differentiated by the combination of objects used. The `cim:RegulatingCondEq` subtype objects used in the representation of aggregate generation have these attributes populated:



The classes and attributes in the LTDS Equipment profile which support aggregate generation modelling are:

- RegulatingCondEq-related classes

SynchronousMachine		
REQUIRED	Equipment	aggregate
REQUIRED	SynchronousMachine	type
AsynchronousMachine		
REQUIRED	Equipment	aggregate
PowerElectronicsConnection		
REQUIRED	Equipment	aggregate

- Production package classes

GeneratingUnit		
REQUIRED	GeneratingUnit	ratedNetMaxP
FlywheelUnit <<GB>>		
REQUIRED	GeneratingUnit	ratedNetMaxP
REQUIRED	FlywheelUnit	energyStorageCapacity
GeothermalGeneratingUnit <<NC>>		
REQUIRED	GeneratingUnit	ratedNetMaxP
HydroGeneratingUnit		
REQUIRED	GeneratingUnit	ratedNetMaxP
HydroPowerPlant		
REQUIRED	HydroPowerPlant	hydroPlantStorageType
REQUIRED	HydroPowerPlant	energyStorageCapacity
NuclearGeneratingUnit		
REQUIRED	GeneratingUnit	ratedNetMaxP
SolarGeneratingUnit		
REQUIRED	GeneratingUnit	ratedNetMaxP
ThermalGeneratingUnit		
REQUIRED	GeneratingUnit	ratedNetMaxP
BioFuel <<GB>>		
REQUIRED	BioFuel	bioFuelType
FossilFuel		
REQUIRED	FossilFuel	fossilFuelType
CAESPlant		
REQUIRED	CAESPlant	energyStorageCapacity
OtherFuel <<GB>>		
REQUIRED	OtherFuel	otherFuelType
WindGeneratingUnit		
REQUIRED	GeneratingUnit	ratedNetMaxP
BatteryUnit		
REQUIRED	PowerElectronicsUnit	maxP
REQUIRED	BatteryUnit	ratedE
PhotoVoltaicUnit		
REQUIRED	PowerElectronicsUnit	maxP
PowerElectricalChemicalUnit <<NC>>		
REQUIRED	PowerElectronicsUnit	maxP
PowerElectronicsWindUnit		
REQUIRED	PowerElectronicsUnit	maxP

Also refer to *Appendix 9 - Grid Data Constraints*:

- C:301:EQ:BatteryUnit.ratedE:valueRange
- C:452:EQ:CurveData.Curve:reactive
- C:301:EQ:ReactiveCapabilityCurve:yvalues
- C:600:EQ:ReactiveCapabilityCurve:units
- C:452:EQ:ReactiveCapabiltyCurve.CurveData:xvalue
- C:452:EQ:RegulatingControl:RegulatingEquipment
- C:452:EQ:SynchronousMachine:controlMode
- C:452:EQ:SynchronousMachine:reactiveLimits

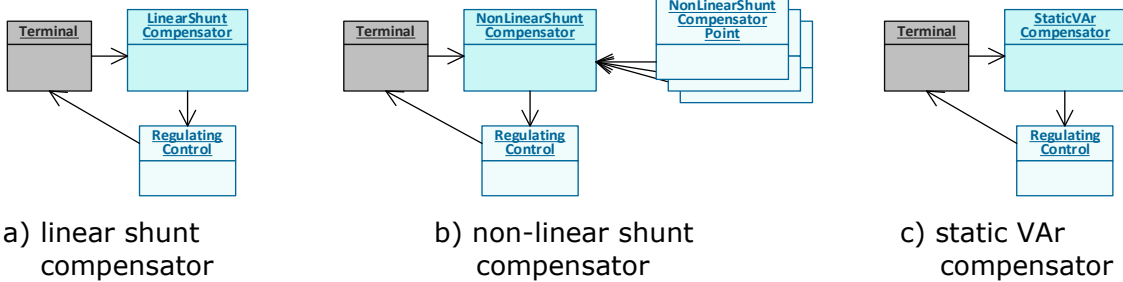
- C:301:EQ:GeneratingUnit.ratedNetMaxP:valueRange

1.4.3.1.9 Compensator

In CIM, a series compensator is modelled with a `cim:SeriesCompensator` object and two associated `cim:Terminal` objects.



A shunt compensator is modelled with a `cim:ShuntCompensator` subtype object (either a `cim:LinearShuntCompensator` or a `cim:NonLinearShuntCompensator`). A static VAR compensator is modelled with a `cim:StaticVarCompensator` object. Each of them has only one associated `cim:Terminal` object. Each of them has an associated `cim:RegulatingControl` object.



The following requirements apply to the modelling of compensators:

- All series compensators, shunt compensators and static VAR compensators in the LTDS grid model scope are modelled at their correct grid location.

The classes and attributes in the LTDS Equipment profile which support compensator modelling are:

SeriesCompensator		
REQUIRED	SeriesCompensator	r
REQUIRED	SeriesCompensator	x
LinearShuntCompensator		
OPTIONAL	ShuntCompensator	aVRDelay
OPTIONAL	ShuntCompensator	grounded
REQUIRED	ShuntCompensator	maximumSections
REQUIRED	ShuntCompensator	nomU
REQUIRED	ShuntCompensator	normalSections
OPTIONAL	ShuntCompensator	voltageSensitivity
REQUIRED	LinearShuntCompensator	bPerSection
REQUIRED	LinearShuntCompensator	gPerSection
NonLinearShuntCompensator		
OPTIONAL	ShuntCompensator	aVRDelay
OPTIONAL	ShuntCompensator	grounded

REQUIRED	ShuntCompensator	maximumSections
REQUIRED	ShuntCompensator	nomU
REQUIRED	ShuntCompensator	normalSections
OPTIONAL	ShuntCompensator	voltageSensitivity
NonLinearShuntCompensatorPoint		
REQUIRED	NonLinearShuntCompensatorPoint	b
REQUIRED	NonLinearShuntCompensatorPoint	g
REQUIRED	NonLinearShuntCompensatorPoint	sectionNumber
StaticVarCompensator		
REQUIRED	StaticVarCompensator	capacitiveRating
REQUIRED	StaticVarCompensator	inductiveRating
REQUIRED	StaticVarCompensator	slope
RegulatingControl		
REQUIRED	RegulatingControl	mode

Notes on OPTIONAL attributes:

- For all `cim:LinearShuntCompensator` and `cim:NonLinearShuntCompensator` objects,
 - `.aVRDelay` and `.voltageSensitivity` are populated at local discretion.
 - `.grounded` is populated for compensators with Yn or Zn connections to indicate if the neutral is solidly grounded.

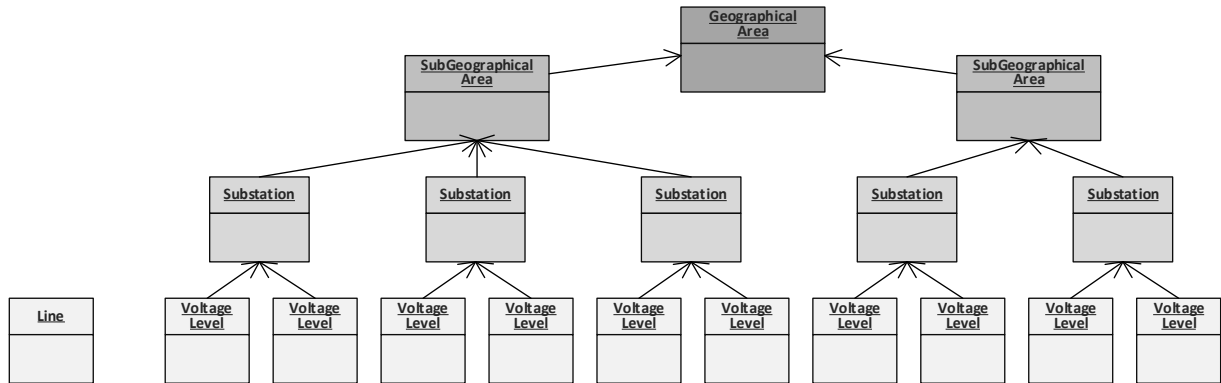
Also refer to [Appendix 9 - Grid Data Constraints](#):

- C:301:EQ:SeriesCompensator:numberOfTerminals
- C:452:EQ:ShuntCompensator:controlMode
- C:301:EQ:ShuntCompensator:numberOfTerminals
- C:301:EQ:ShuntCompensator.nomU:nominalVoltageDifference
- C:301:EQ:ShuntCompensator.normalSections:valueRangePair
- C:452:EQ:ShuntCompensator.voltageSensitivity:valueRange
- C:452:EQ:LinearShuntCompensator.gPerSection:valueRange
- C:301:EQ:NonlinearShuntCompensatorPoint:numberOfInstances
- C:452:EQ:NonlinearShuntCompensatorPoint.g:valueRange
- C:452:EQ:StaticVarCompensator:controlMode
- C:301:EQ:StaticVarCompensator.capacitiveRating:valueRange
- C:301:EQ:StaticVarCompensator.inductiveRating:valueRange
- C:301:EQ:StaticVarCompensator.slope:valueRange
- C:452:EQ:RegulatingControl:RegulatingEquipment

1.4.3.1.10 Containment

There are a number of CIM objects that are used together to describe the containment of grid objects. The purpose of CIM containment is not to define connectivity, but rather to

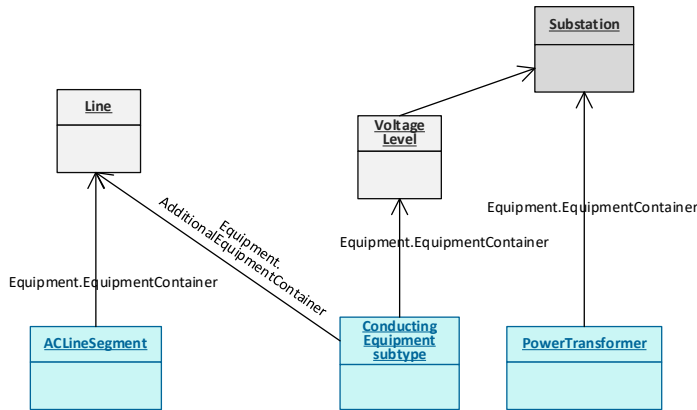
support object naming, display definition, and human navigation of models. Containment objects include `cim:Line`, `cim:VoltageLevel`, `cim:Substation`, `cim:SubGeographicalRegion` and `cim:GeographicalRegion`. A `cim:VoltageLevel` is contained in (has an association with) a `cim:Substation`. A `cim:Substation` is contained in a `cim:SubGeographicalRegion`. A `cim:SubGeographicalRegion` is contained in a `cim:GeographicalRegion`.



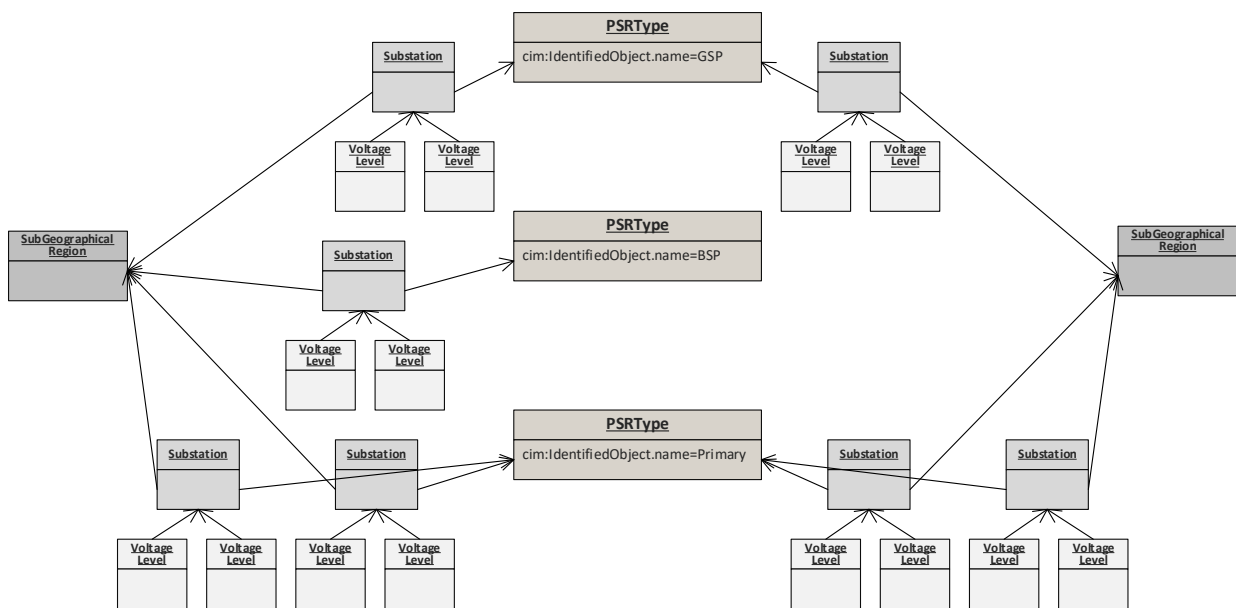
The following requirements apply to the modelling of containment in the proposed LTDS grid model:

- A single `cim:GeographicalArea` object represents the licence area.
- Every GSP in scope is modelled using a `cim:SubgeographicalArea` object which is associated with the `cim:GeographicalArea`.
- Every substation in scope is modelled as a `cim:Substation` object which is associated with the appropriate `cim:SubgeographicalArea`.
- Every grid voltage level within a substation is modelled with a `cim:VoltageLevel` object associated with the `cim:Substation`.
- Every device represented by a `cim:ConductingEquipment` subtype object is contained in one of the following:
 - A `cim:Line` object
 - A `cim:VoltageLevel` object or
 - A `cim:Substation` object.

Only `cim:PowerTransformer` objects are directly contained in a `cim:Substation`. A `cim:ConductingEquipment` subtype object contained in a `cim:VoltageLevel` may have a `cim:Equipment.AdditionalEquipmentContainer` association with a `cim:Line` (see [Circuit](#)).



- Three `cim:PSRType` objects are included in a Full Model to support the typing of `cim:Substation` objects. They have the following values for `cim:IdentifiedObject.name`:
 - `cim:IdentifiedObject.name=GSP`
 - `cim:IdentifiedObject.name=BSP`
 - `cim:IdentifiedObject.name=Primary`
 (Additional `cim:PSRType` objects may be defined to represent other types of substations with local importance.)
- Every substation containing a GSP has its `cim:Substation` object associated with the `cim:PSRType` object with `cim:IdentifiedObject.name=GSP`. Likewise, every substation containing a BSP has its `cim:Substation` object associated with the `cim:PSRType` with `cim:IdentifiedObject.name=BSP`. And every Primary substation has its `cim:Substation` object associated with the `cim:PSRType` with `cim:IdentifiedObject.name=Primary`.



The classes and attributes in the LTDS Equipment profile which support containment modelling are:

GeographicalRegion
SubGeographicalRegion
Substation
PSRType
VoltageLevel

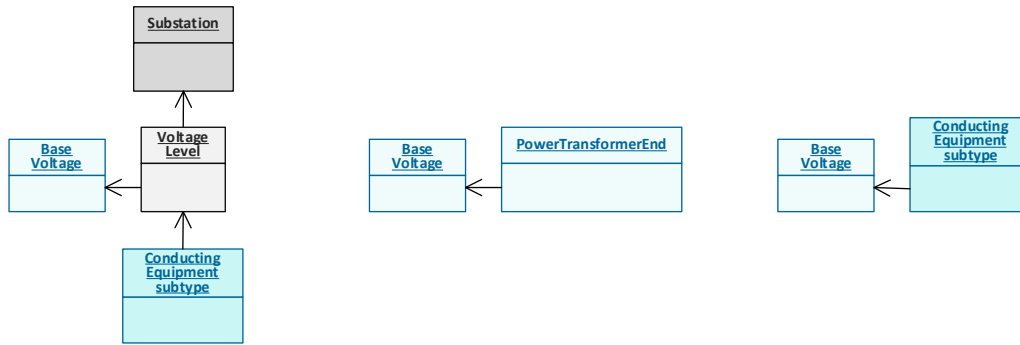
(Note that the only attributes of the containment classes are those inherited from cim:IdentifiedObject.)

Also refer to *Appendix 9 - Grid Data Constraints*:

- C:452:EQ:BusbarSection:containment
- C:452:EQ:Disconnecter:containment
- C:452:EQ:EnergyConnection:containment
- C:452:EQ:Fuse:containment
- C:600:EQ:GeographicalRegion:EQ__4
- C:452:EQ:GroundDisconnecter:containment
- C:452:EQ:PowerTransformer:containment
- C:452:EQ:ProtectedSwitch:containment
- C:452:EQ:SeriesCompensator:containment
- C:600:EQ:Substation:count

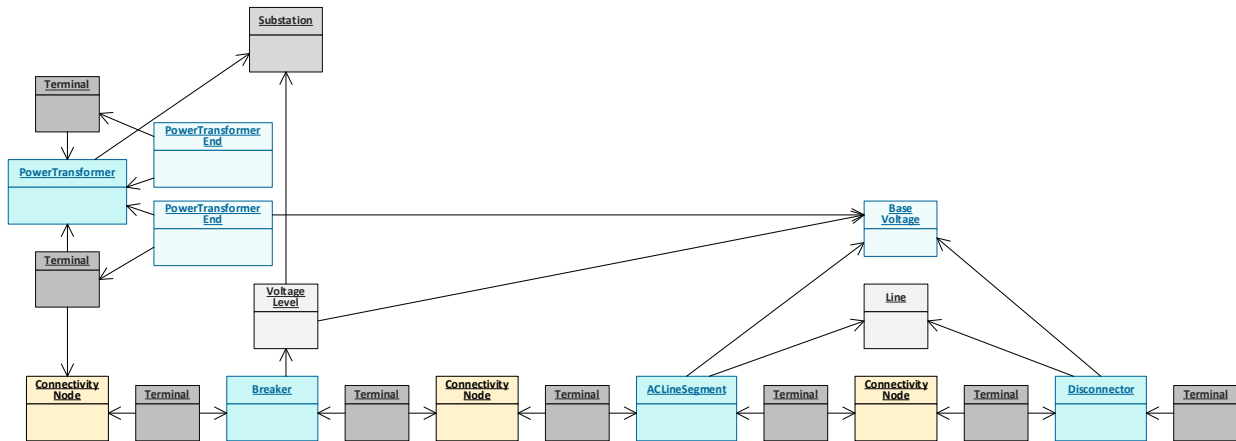
1.4.3.1.11 Nominal voltage level

In CIM, a nominal voltage level is modelled using a cim:BaseVoltage object. A cim:BaseVoltage object can be referenced by a cim:VoltageLevel object or by a cim:PowerTransformerEnd object. A cim:BaseVoltage object can also be referenced by a cim:ConductingEquipment subtype object, but only if the object is not a cim:PowerTransformer and is not contained in a cim:VoltageLevel.



- a) `cim:BaseVoltage` referenced by a `cim:VoltageLevel` subtype
- b) `cim:BaseVoltage` referenced by a `cim:PowerTransformerEnd`
- c) `cim:BaseVoltage` referenced by a `cim:ConductingEquipment` subtype not a `cim:PowerTransformer` and not contained in a `cim:VoltageLevel`

A single `cim:BaseVoltage` is referenced by multiple objects:



The following requirements apply to the modelling of base voltages in LTDS grid model:

- Each nominal voltage present in the LTDS grid model scope is modelled by a single `cim:BaseVoltage` object.

The classes and attributes in the LTDS Equipment profile which support containment modelling are:

BaseVoltage
REQUIRED BaseVoltage nominalVoltage

Also refer to *Appendix 9 - Grid Data Constraints*:

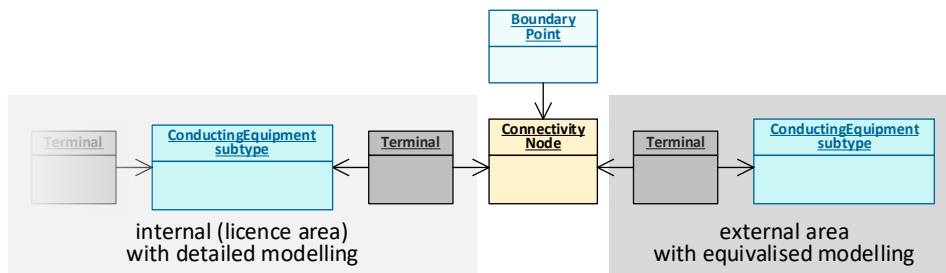
- C:301:EQ:BaseVoltage.nominalVoltage:valueRange
- C:301:EQ:ConductingEquipment.BaseVoltage:usage
- C:452:EQ:ConductingEquipment.BaseVoltage:whereRequired

1.4.3.1.12 External connection

In grid studies, simplified or equivalenced modelling is typically used for “external” portions of the grid – areas of the grid that are not the focus of the study, but are connected to and have power exchange with the internal portion. The best long-term CIM approach to managing the modelling of external portions of the grid is currently under discussion, with solutions being developed by both the CIM Working Groups and ENTSO-E.

For LTDS in CIM terms, a simple approach to external grid modelling is used that marks the boundary between the internal (licence area) grid and external (adjacent licence area or transmission) grids. Internal grid modelling is done in accordance with the detailed requirements outlined in this document. External grid modelling is an equivalent, modelled at a level of detail sufficient to support the *NETS Maximum Demand “solved case”* and the *NETS Minimum Demand “solved case”*.

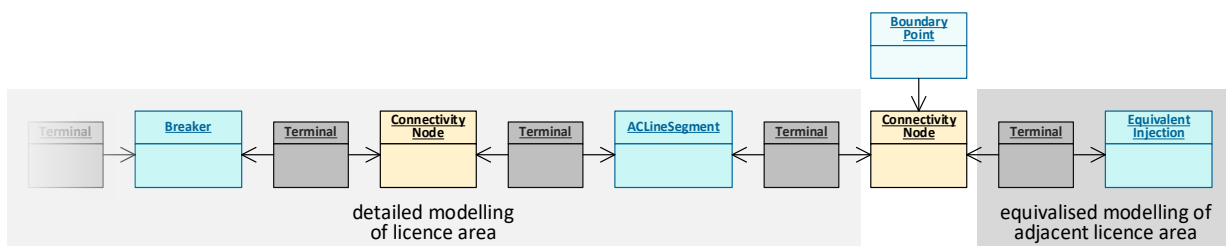
Each boundary between the internal (licence area) grid and an external grid is identified with an eu:BoundaryPoint object.



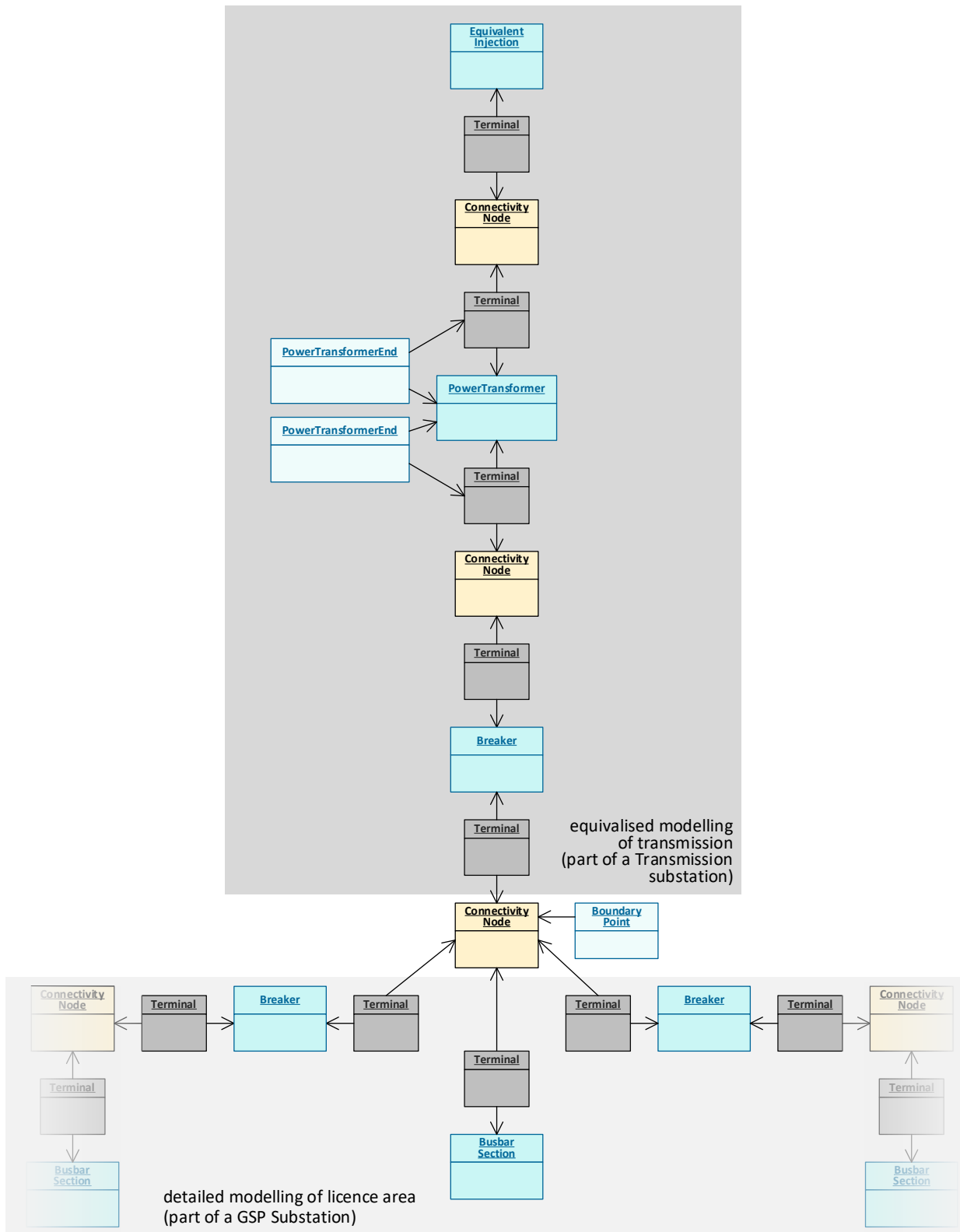
Simplified modelling of equipment and connectivity in the external area is done using the same types of CIM objects used for internal modelling. Load and generation injections in the external area are typically simplified and modelled using a single cim:EquivalentInjection.

The following examples illustrate very basic modelling of a connection to an adjacent licence area and a connection to the transmission system. More complex modelling of external areas will be required when flows between connection points in the external grid have impact.

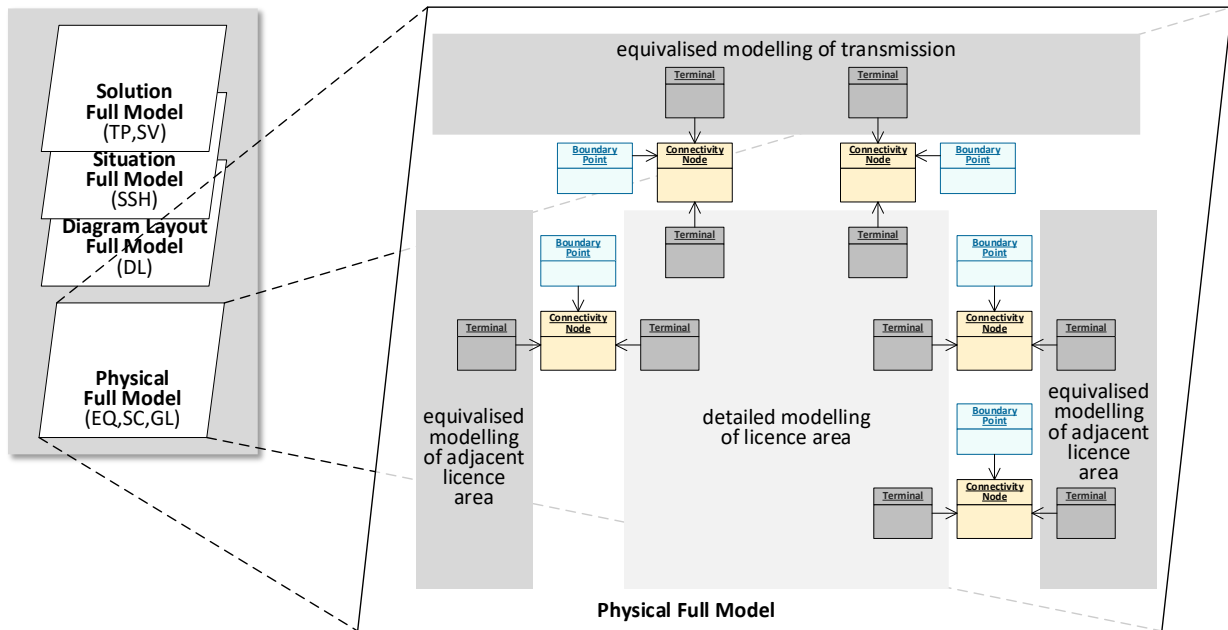
A circuit connecting to another licence area could be represented as shown below:



A connection at a GSP could be modelled in the following fashion:



It is important to note that the simple approach to external grid modelling taken by LTDS means that all modelling (of both the internal and external grids) is included in the Full Models supplied as part of the complete set of LTDS grid model data.



The classes and attributes in the LTDS Equipment profile which support external grid modelling are:

BoundaryPoint		
EquivalentInjection		
OPTIONAL	EquivalentInjection	maxP
OPTIONAL	EquivalentInjection	maxQ
OPTIONAL	EquivalentInjection	minP
OPTIONAL	EquivalentInjection	minQ
REQUIRED	EquivalentInjection	regulationCapability

Notes on OPTIONAL attributes:

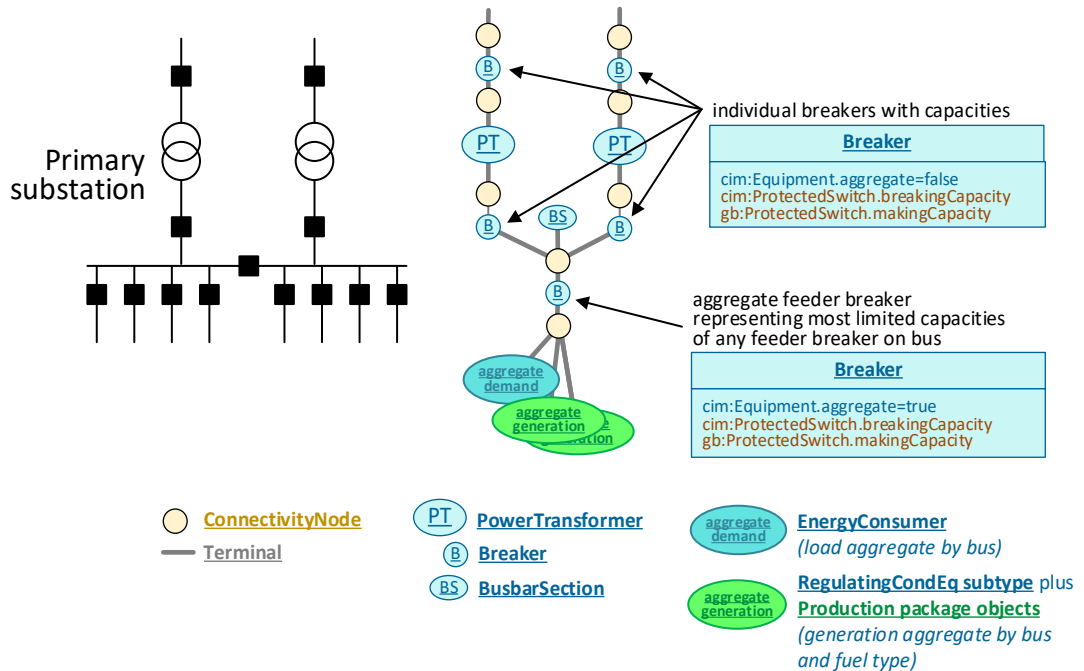
- For cim:EquivalentConnection objects used in representing the transmission grid, .maxP, .maxQ, .minP, and .minQ are populated.
- For cim:EquivalentConnection objects used in representing adjacent licence area grids, .maxP, .maxQ, .minP, and .minQ are populated at local discretion.

1.4.3.2 Short Circuit (SC) profile data

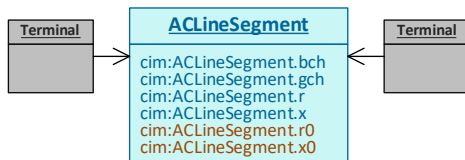
The Short Circuit profile describes equipment electrical behaviour characteristics essential to the execution of short circuit studies.

There is a very limited set of short circuit study input data in the proposed LTDS grid model. The required short circuit data is comprised of select attributes on a select set of classes. They are shown in the diagrams below in rust-coloured text.

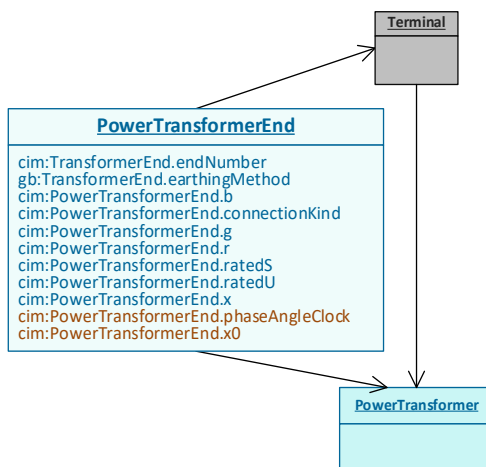
- Breaking and making capacity ratings are supplied for each `cim:Breaker`, including aggregate feeder breakers. The capacity ratings of the aggregate feeder breaker reflect those of the most limited of any of the feeder breakers associated with the bus.



- A `cim:ACLineSegment` has its zero sequence resistance and reactance supplied.



- A `cim:PowerTransformerEnd` has phase clock angle and zero sequence reactance supplied.



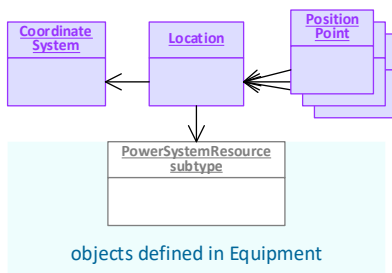
Also refer to Appendix 9 – Grid Data Constraints:

- C:301:SC:PowerTransformerEnd.phaseAngleClock:valueRange

1.4.3.3 Geographical Location (GL) profile data

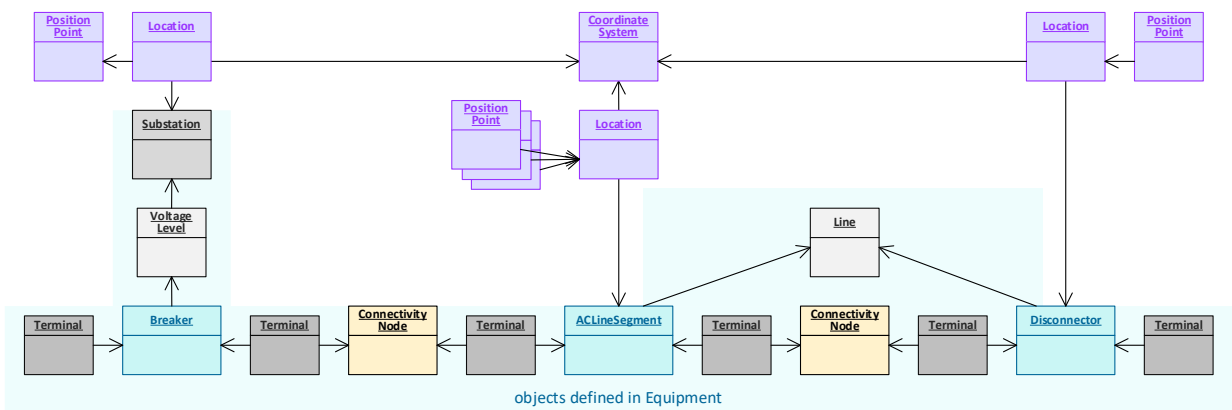
The Geographical Location profile describes the geospatial location of equipment, facilities, and load and generation.

In CIM, a geographical location is described using a `cim:Location` object, its `cim:PositionPoint` object or objects, along with a reference to a `cim:CoordinateSystem` object.



The following requirements apply to the modelling of geospatial locations in the proposed LTDS grid model:

- A `cim:Location` is associated with every `cim:Substation` object.
- A `cim:Location` is associated with every `cim:ConductingEquipment` subtype object that is not associated (directly or indirectly) with a `cim:Substation`.
- Typically, a `cim:Location` has one `cim:PositionPoint`, though multiple `cim:PositionPoint` objects may be used to accurately describe a `cim:Location` (for example, for a `cim:ACLineSegment`).



Classes and attributes in the LTDS Geographical Location profile which support location modelling:

Location	
PositionPoint	
OPTIONAL	sequenceNumber

REQUIRED	PositionPoint	xPosition
REQUIRED	PositionPoint	yPosition
OPTIONAL	PositionPoint	zPosition
CoordinateSystem		
REQUIRED	CoordinateSystem	crsUrn (must=urn:ogc:def:crs:EPSG::4326)

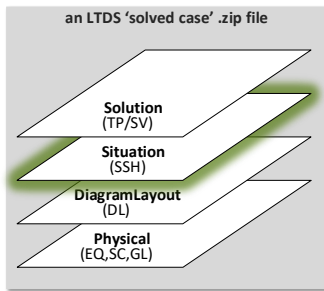
Notes on OPTIONAL attributes:

- For all cim:PositionPoint objects,
.sequenceNumber is populated only if multiple position points are associated with a cim:Location.
- For all cim:PositionPoint objects,
.zPosition is populated at local discretion.

Also refer to *Appendix 9 - Grid Data Constraints*:

- C:13:GL:CoordinateSystem.crsUrn:epsg

1.4.4 Situation modelling



Situation data describes a grid operating state and is used, in conjunction with foundational Physical data, as input to network analysis.

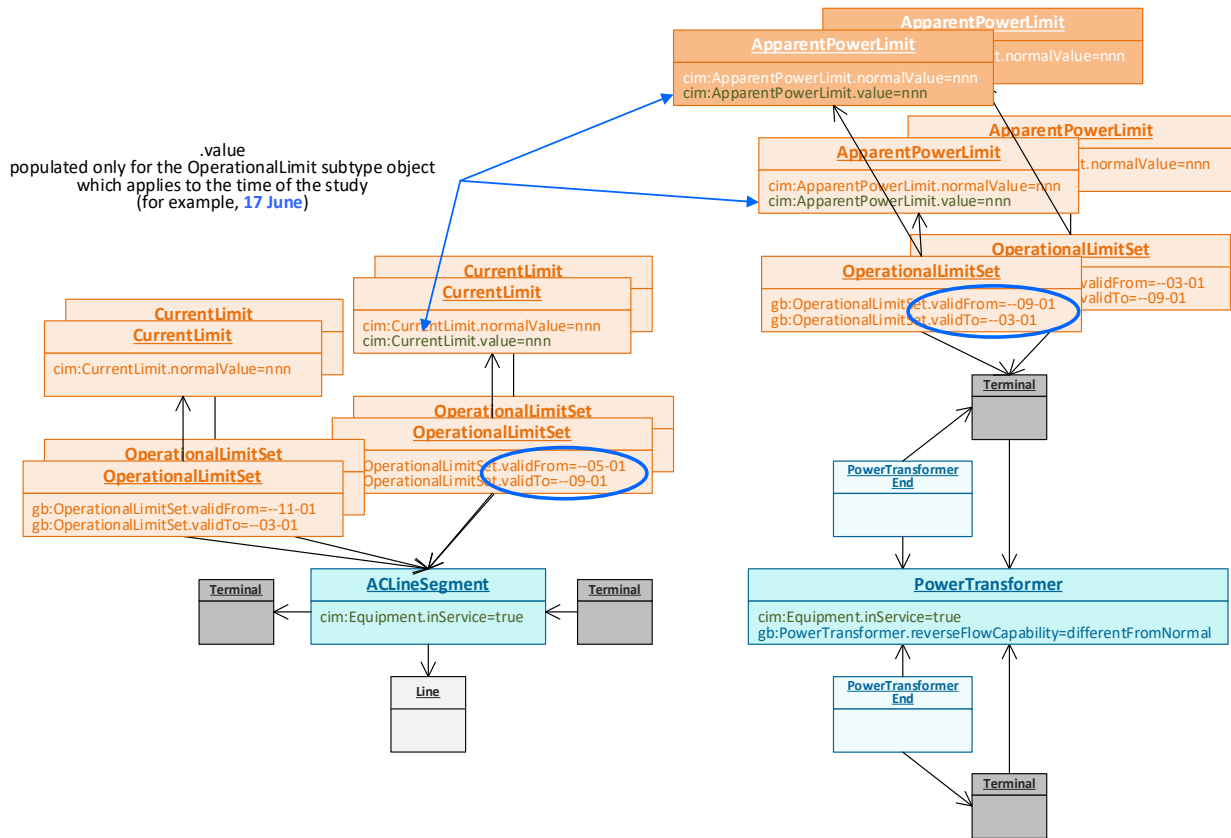
1.4.4.1 Steady State Hypothesis profile data

There is one profile – the Steady State Hypothesis profile – that defines the attributes that make up Situation data. These attributes represent load and generation injections, switching equipment states, control settings of equipment, etc. They augment the underlying grid model objects provided by the Physical profiles. Multiple sets of Situation profile data – multiple Steady State Hypothesis Full Models each describing a specific operating state – can “fit” on the same underlying set of Physical profile data (the same Physical Full Model).

In general, if an object exists in an underlying Full Model containing Equipment profile data, any Full Model containing Steady State Hypothesis profile data which is intended to “fit” with the underlying Full Model has its Steady State Hypothesis attributes populated. Many classes do not have any Steady State Hypothesis attributes, but the following do and objects of those classes have their attributes populated:

- All `cim:Equipment` subtype classes
- All `cim:TapChanger` subtype classes
- All `cim:RegulatingControl` subtype classes

The `cim:OperationalLimit` subtype classes are an exception to rule of required Steady State Hypothesis attribute population. A `cim:OperationalLimit` subtype object has its `cim:OperationalLimit.value` attribute populated only if it is associated with the `cim:OperationalLimitSet` whose period of validity includes the date being represented by the Steady State Hypothesis Full Model.



A note regarding the use of power transformer limits in determining power flow violations:

- The value of the `cim:ApparentPowerLimit.value` attribute must always be positive and solution flows are considered to be in alarm or violation when they exceed the specified limit. For transformers where the reverse flow limit is different from the normal flow limit, network analysis software is responsible for determining direction of flow through a transformer and using the appropriate `cim:ApparentPowerLimit`.

Note that an anomaly in CIM and CGMES profiling has left multiple Equipment subtype classes out of the Steady State Hypothesis UML profile. This oversight notwithstanding, in LTDS expressed in CIM terms, all Equipment subtype objects present in an underlying Full Model are expected to have corresponding subtype objects present, and their `cim:Equipment.inService` attribute populated, in any Situation Full Model intended to “fit” with the underlying Full Model. The table of attributes and classes below reflects this expectation.

The classes and attributes in the LTDS Steady State Hypothesis profile are:

Bus and bus group	
BusbarSection	
REQUIRED	Equipment inService

Switching device			
Disconnecter			
REQUIRED	Equipment		inService
REQUIRED	Switch		open
Fuse			
REQUIRED	Equipment		inService
REQUIRED	Switch		open
GroundDisconnecter			
REQUIRED	Equipment		inService
REQUIRED	Switch		open
Breaker			
REQUIRED	Equipment		inService
REQUIRED	Switch		open
DisconnectingCircuitBreaker			
REQUIRED	Equipment		inService
REQUIRED	Switch		open
LoadBreakSwitch			
REQUIRED	Equipment		inService
REQUIRED	Switch		open

Circuit			
ACLineSegment			
REQUIRED	Equipment		inService
CurrentLimit			
REQUIRED	CurrentLimit		value

Transformer			
PowerTransformer			
REQUIRED	Equipment		inService
ApparentPowerLimit			
REQUIRED	ApparentPowerLimit		value
Transformer Tap Changer			
PhaseTapChangerLinear			
REQUIRED	TapChanger		controlEnabled
REQUIRED	TapChanger		step
PhaseTapChangerAsymmetrical			
REQUIRED	TapChanger		controlEnabled
REQUIRED	TapChanger		step
PhaseTapChangerSymmetrical			
REQUIRED	TapChanger		controlEnabled
REQUIRED	TapChanger		step
PhaseTapChangerTabular			
REQUIRED	TapChanger		controlEnabled
REQUIRED	TapChanger		step
RatioTapChanger			
REQUIRED	TapChanger		controlEnabled
REQUIRED	TapChanger		step
TapChangerControl			
REQUIRED	RegulatingControl		discrete
REQUIRED	RegulatingControl		enabled

OPTIONAL	RegulatingControl	maxAllowedTargetValue
OPTIONAL	RegulatingControl	minAllowedTargetValue
OPTIONAL	RegulatingControl	targetDeadband
REQUIRED	RegulatingControl	targetValue
REQUIRED	RegulatingControl	targetValueUnitMultiplier

Load		
EnergyConsumer		
REQUIRED	Equipment	inService
REQUIRED	EnergyConsumer	p
REQUIRED	EnergyConsumer	q

Generation - individual and aggregate		
Generator electrical characteristics		
SynchronousMachine		
REQUIRED	Equipment	inService
REQUIRED	RegulatingCondEq	controlEnabled
REQUIRED	RotatingMachine	p
REQUIRED	RotatingMachine	q
REQUIRED	SynchronousMachine	operatingMode
REQUIRED	SynchronousMachine	referencePriority
AsynchronousMachine		
REQUIRED	Equipment	inService
REQUIRED	RegulatingCondEq	controlEnabled
REQUIRED	RotatingMachine	p
REQUIRED	RotatingMachine	q
REQUIRED	AsynchronousMachine	asynchronousMachineType
PowerElectronicsConnection		
REQUIRED	Equipment	inService
REQUIRED	RegulatingCondEq	controlEnabled
REQUIRED	PowerElectronicsConnection	p
REQUIRED	PowerElectronicsConnection	q
Controls		
RegulatingControl (not required for aggregate generation)		
REQUIRED	RegulatingControl	discrete
REQUIRED	RegulatingControl	enabled
OPTIONAL	RegulatingControl	maxAllowedTargetValue
OPTIONAL	RegulatingControl	minAllowedTargetValue
OPTIONAL	RegulatingControl	targetDeadband
REQUIRED	RegulatingControl	targetValue
REQUIRED	RegulatingControl	targetValueUnitMultiplier
Generator physical characteristics		
GeneratingUnit		
REQUIRED	Equipment	inService
REQUIRED	GeneratingUnit	normalPF
FlywheelUnit <<GB>>		
REQUIRED	Equipment	inService
REQUIRED	GeneratingUnit	normalPF
GeothermalGeneratingUnit <<NC>>		
REQUIRED	Equipment	inService
REQUIRED	GeneratingUnit	normalPF

HydroGeneratingUnit			
REQUIRED	Equipment		inService
REQUIRED	GeneratingUnit		normalPF
NuclearGeneratingUnit			
REQUIRED	Equipment		inService
REQUIRED	GeneratingUnit		normalPF
SolarGeneratingUnit			
REQUIRED	Equipment		inService
REQUIRED	GeneratingUnit		normalPF
ThermalGeneratingUnit			
REQUIRED	Equipment		inService
REQUIRED	GeneratingUnit		normalPF
WindGeneratingUnit			
REQUIRED	Equipment		inService
REQUIRED	GeneratingUnit		normalPF
BatteryUnit			
REQUIRED	Equipment		inService
REQUIRED	BatteryUnit		storedE
PhotoVoltaicUnit			
REQUIRED	Equipment		inService
PowerElectricalChemicalUnit <<NC>>			
REQUIRED	Equipment		inService
PowerElectronicsWindUnit			
REQUIRED	Equipment		inService

Compensator			
Series			
SeriesCompensator			
REQUIRED	Equipment		inService
Shunt			
LinearShuntCompensator			
REQUIRED	Equipment		inService
REQUIRED	RegulatingCondEq		controlEnabled
REQUIRED	ShuntCompensator		sections
NonLinearShuntCompensator			
REQUIRED	Equipment		inService
REQUIRED	RegulatingCondEq		controlEnabled
REQUIRED	ShuntCompensator		sections
StaticVarCompensator			
REQUIRED	Equipment		inService
REQUIRED	RegulatingCondEq		controlEnabled
REQUIRED	StaticVarCompensator		q
Controls			
RegulatingControl			
REQUIRED	RegulatingControl		discrete
REQUIRED	RegulatingControl		enabled
OPTIONAL	RegulatingControl		maxAllowedTargetValue
OPTIONAL	RegulatingControl		minAllowedTargetValue
OPTIONAL	RegulatingControl		targetDeadband
REQUIRED	RegulatingControl		targetValue

REQUIRED	RegulatingControl	targetValueUnitMultiplier
External connections		
EquivalentInjection		
REQUIRED	Equipment	inService
REQUIRED	EquivalentInjection	p
REQUIRED	EquivalentInjection	q
OPTIONAL	EquivalentInjection	regulationStatus
OPTIONAL	EquivalentInjection	regulationTarget

Notes on OPTIONAL attributes:

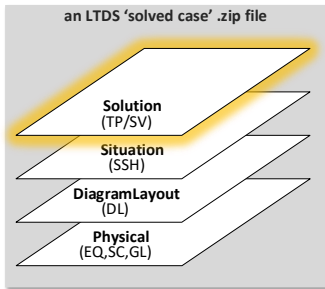
- For all `cim:TapChangerControl` objects, `.maxAllowedTargetValue`, `.minAllowedTargetValue`, and `.targetDeadband` are populated at local discretion.
- For all `cim:RegulatingControl` objects, `.maxAllowedTargetValue`, `.minAllowedTargetValue`, and `.targetDeadband` are populated at local discretion.
- For `cim:EquivalentConnection` objects with `cim:EquivalentConnection.regulationCapability=true`, `.regulationStatus` and `.regulationTarget` are populated.

Also refer to [Appendix 9 - Grid Data Constraints](#):

- C:301:SSH:ApparentPowerLimit.value:valueRange
- C:301:SSH:CurrentLimit.value:valueRange
- C:456:SSH:EnergyConsumer.p:ValueRange
- C:456:SSH:EnergyConsumer.q:ValueRange
- C:301:SSH:GeneratingUnit.normalPF:valueRange
- C:456:SSH:NA:singleActivePowerSlack
- C:301:SSH:RegulatingControl:requiredAttributes
- C:301:SSH:RegulatingControl.targetDeadband:applicability
- C:301:SSH:RegulatingControl.targetDeadband:targetDB
- C:301:SSH:RegulatingControl.targetDeadband:valueRange
- C:452:EQ:RegulatingControl.targetValue:tapChanger
- C:456:SSH:RegulatingControl.targetValue:value
- C:456:SSH:RotatingMachine:pAndQcapabilityCurve
- C:456:SSH:RotatingMachine:pAndQcapabilityCurve
- C:301:SSH:ShuntCompensator.sections:valueLinear
- C:301:SSH:ShuntCompensator.sections:valueNonLinear
- C:456:SSH:ShuntCompensator.sections:value
- C:301:SSH:ShuntCompensator.sections:valueRange

- C:301:SSH:TapChanger.step:valueRangePairFrom
- C:301:SSH:TapChanger.step:valueRangePairTo
- C:456:SSH:TapChanger.step:value
- C:301:SSH:TapChanger.step:valueType

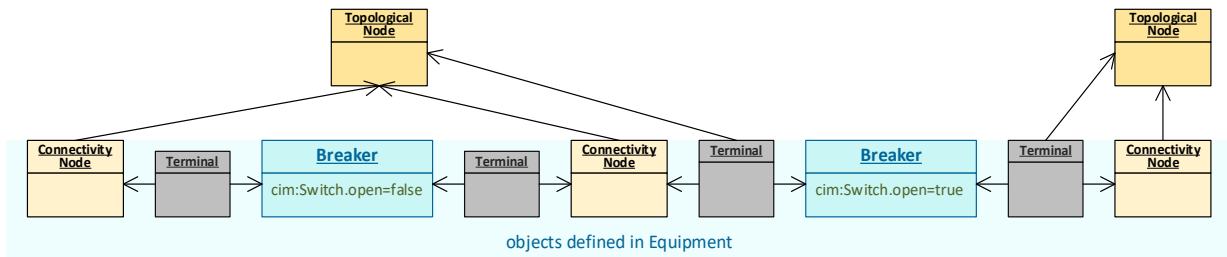
1.4.5 Solution modelling



Solution data describes the output resulting from a successful power flow execution. It is machine generated.

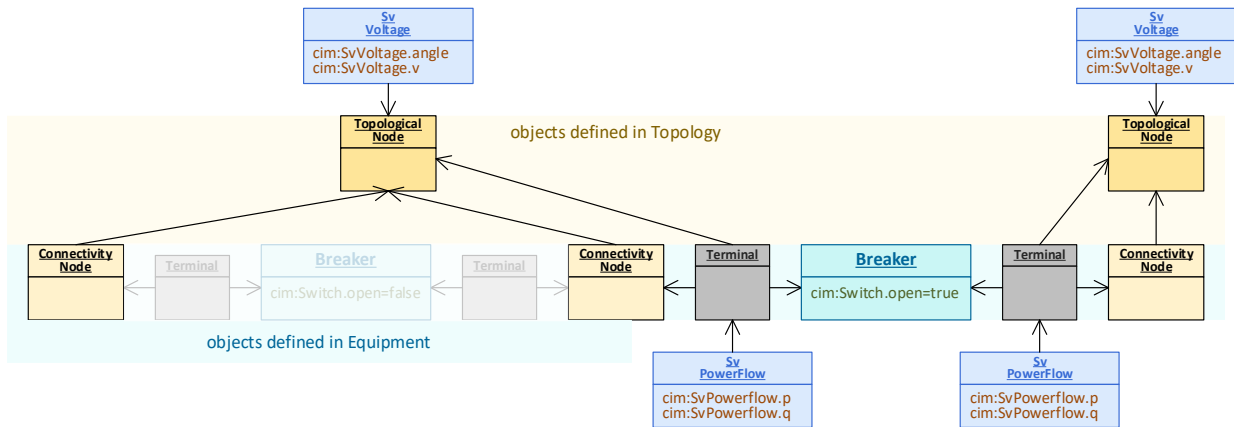
1.4.5.1 Topology profile data

The Topology profile describes the output of topology processing which uses data described by the Equipment and Steady State Hypothesis profiles as input. Topology processing creates `cim:TopologicalNode` objects eliminating closed switches and zero impedance branches.

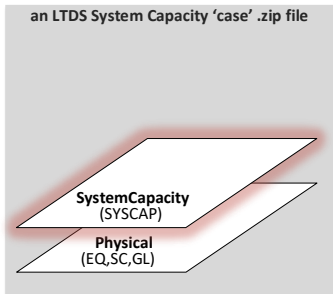


1.4.5.2 State Variables profile data

The State Variables profile describes the output of power flow calculation which uses data described by the Equipment, Steady State Hypothesis and Topology profiles as input. Power flow calculation creates `cim:SvVoltage` objects which describe node voltage and angle and `cim:SvPowerFlow` objects which supply active and reactive power flows.



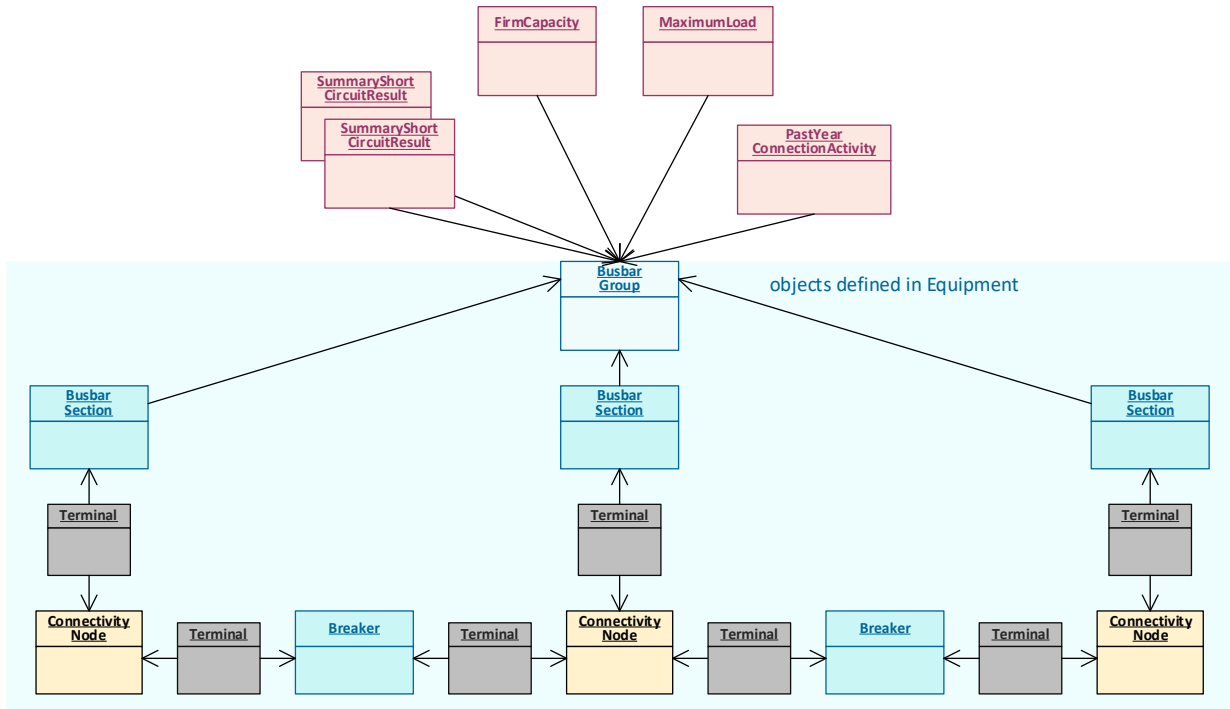
1.4.6 System capacity profile data



The System Capacity profile describes bus-related system information. It is an LTDS-defined extension profile.

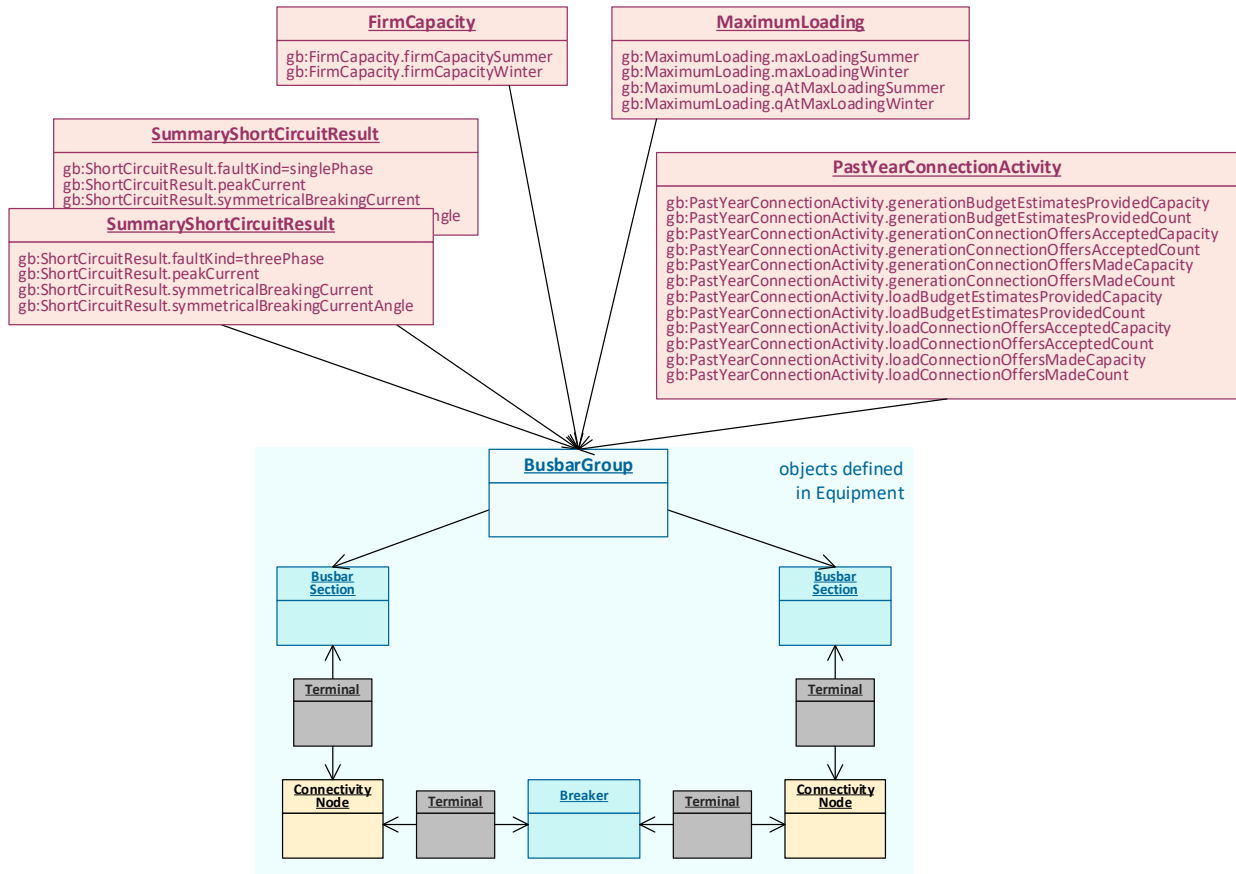
As described in the Bus section above, busbar groups represent sets of one or more connected busses normally operated as a single bus. In LTDS in CIM terms, a variety of information is associated with a busbar group:

- Three-phase and single-phase fault level information is provided by two gb:SummaryShortCircuitResult objects.
- Seasonal firm capacity information is supplied by a gb:FirmCapacity object.
- Seasonal non-coincident bus maximum loading information is provided by a gb:MaximumLoading object.
- Past year connection activity is described in the gb:PastYearConnectionActivity object.



Different sets of information are supplied for different types of LTDS cases.

- In the *Existing System Capacity* "case", all the sets of information are supplied (subject to the requirements outlined below the diagram).



Requirements

- Fault level information is supplied by two `gb:SummaryShortCircuitResult` objects associated with every `gb:BusbarGroup`, one representing single-phase faults, the other three-phase faults.

Calculated fault currents should include all relevant contributions from synchronous and induction machines as well as other parts of the distribution network and other connected networks (transmission and distribution). A clear definition of the method used to calculate fault currents (including a description of the application of engineering recommendation G74) are documented by the DNO in its concurrently published *LTDS Overview* document. Deviations from the standard calculation approach are described in the `cim:IdentifiedObject.description` attribute of the appropriate `gb:SummaryShortCircuitResult`.

A note on equivalent infeed impedance calculations: In the previous version of LTDS the positive and zero sequence impedance parameters ($R1$, $X1$, $R0$ and $X0$) were explicitly specified. In this proposed version of LTDS these values can be calculated using the single and three phase fault current magnitudes and angles. Equations used for these calculations are provided in [*Appendix 8 – Equivalent Infeed Impedance Calculations*](#).

- Summer and winter firm capacity information is provided by a `gb:FirmCapacity` object for every `gb:BusbarGroup` affiliated with busses at any BSP or lower voltage substation.

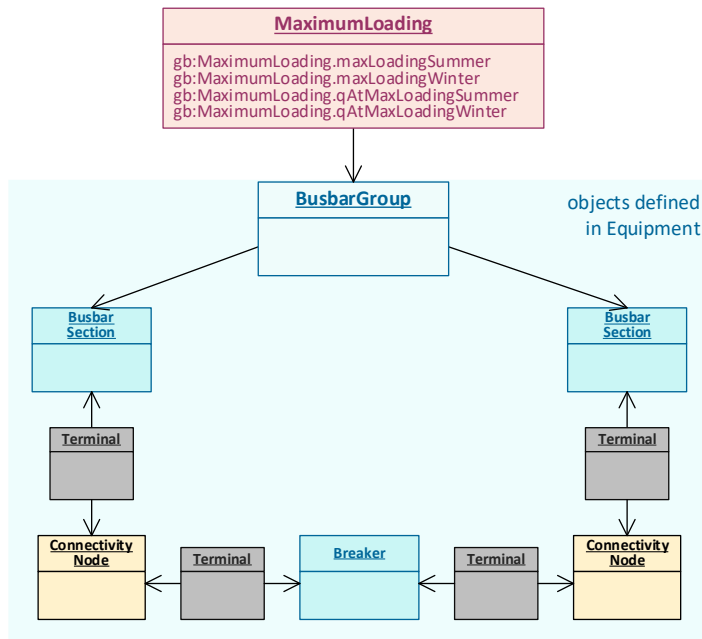
The standard approach used by the DNO in calculating firm capacities is documented by the DNO in its concurrently published *LTDS Overview* document. For connected busses where the calculation deviates from the standard, additional explanatory information to assist in user interpretation is documented in the `cim:IdentifiedObject.description` attribute of the connected bus's `gb:BusbarGroup`.

- The previous year's summer and winter non-coincident bus group maximum loadings are provided by a `gb:MaximumLoading` object for every `gb:BusbarGroup` affiliated with busses at any BSP or lower voltage substation.

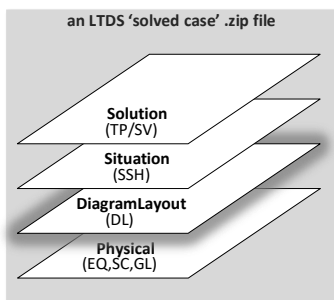
- Connection activity which has occurred over the past year is summarised using a `gb:PastYearConnectionActivity` object associated to any `gb:BusbarGroup` representing busses at which connection activity occurred. Connection activity is measured by the count of connection projects, related to the bus group, which have achieved a certain status over the previous year. The total capacity of the connections included in each count is also provided. Each transition from one status to the next is

counted (meaning, for example, that a load connection project which received both a budget estimate and a connection offer in the past year would appear in both `.loadBudgetEstimatesProvidedCount` and in `.loadConnectionOffersMadeCount` and its MW would be included in both `.loadBudgetEstimatesProvidedCapacity` and in `.loadConnectionOffersMadeCapacity`).

- In the *Future Year n System Capacity "case"*, forecast non-coincident bus group maximum loadings are supplied, using a `gb:MaximumLoading` object, for every `gb:BusbarGroup` affiliated with buses at any BSP or lower voltage substation.



1.4.7 Diagram layout profile data



The Diagram Layout profile describes the layout of CIM objects on a diagram. Diagram Layout data is typically populated by a diagram creation function of the tool used to maintain grid model instance data.

The following requirements apply to diagrams supplied as part of LTDS grid model data:

- The style and layout of diagrams is flexible.
- The following types of diagrams, with the specified content, are provided:
 - A licence area geographic diagram illustrating:
 - Licence area name and boundary
 - GSP substations and their names

- Lines between GSP substations and their names
- A GSP Schematic diagram for each GSP in the licence area illustrating:
 - All substations in the GSP and their names
 - Lines between substations and their names
- A schematic diagram for subsets of substations in each GSP. Each substation in the GSP appears in one diagram. Diagrams illustrate:
 - Substations and their names
 - Lines between substations and their names
 - All equipment (e.g., lines, transformers, loads and generators) in substations and their names
 - Switch normal positions
- Additional diagram layouts to aid in understanding may be provided.
- It is not necessary to include Steady State Hypothesis, Topology and State Variables profile data on displays, although it is allowed.
- Use of the `cim:VisibilityLayer` construct to improve the user experience is encouraged.

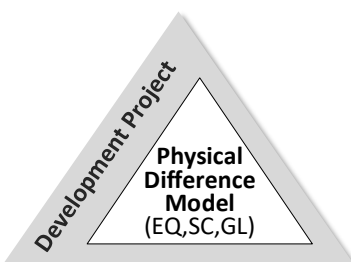
1.4.8 Project modelling

Prospective changes to the grid data contained a Full Model are described by Difference Models, which are comprised of two sets of grid model instance data:

- One set of objects, and their attributes and associations, define items to be added to an existing Full Model – these are the “forward differences”.
- A second set of objects, and their attributes and associations, define items to be deleted from an existing Full Model – these are “reverse differences”.

The objects making up the forward differences and reverse differences are CIM grid objects which conform to the class, attribute and association structure defined by one or more profiles, although they cannot, on their own, be expected to conform to the multiplicity rules specified by the profile. Thorough validation is only possible once a Difference Model is applied to a Full Model creating a new Full Model which should then conform to profile rules and constraints.

1.4.8.1 Development Project

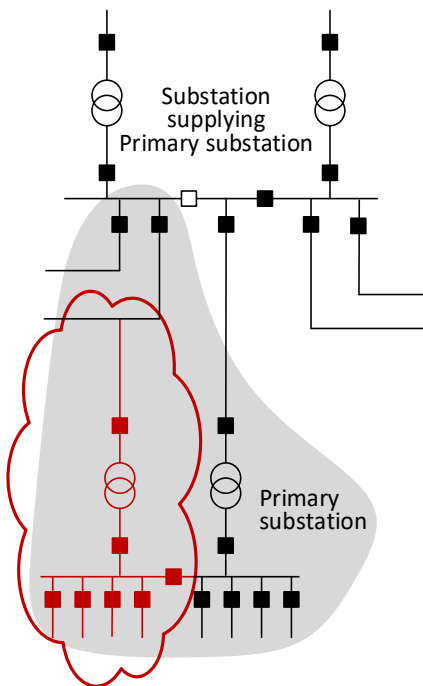


An LTDS Development Project describes a planned DNO grid development or reinforcement project within scope where finance has been secured (either within the company or from a third party) such that the project can be viewed as firm. The forward differences and reverse differences of a Development

Project can use any of the objects whose requirements were described in the Equipment (EQ) profile data section above and, once applied to an appropriate Full Model, the objects should satisfy the outlined data requirements.

The Development Project .zip file contains a single Difference Model that describes a single project. The header of the Difference Model provides information about the project’s estimated in-service time/date in its md:scenarioTime attribute. (Additional detail on the Difference Model header can be found in the *LTDS Data Exchange Specifications*.)

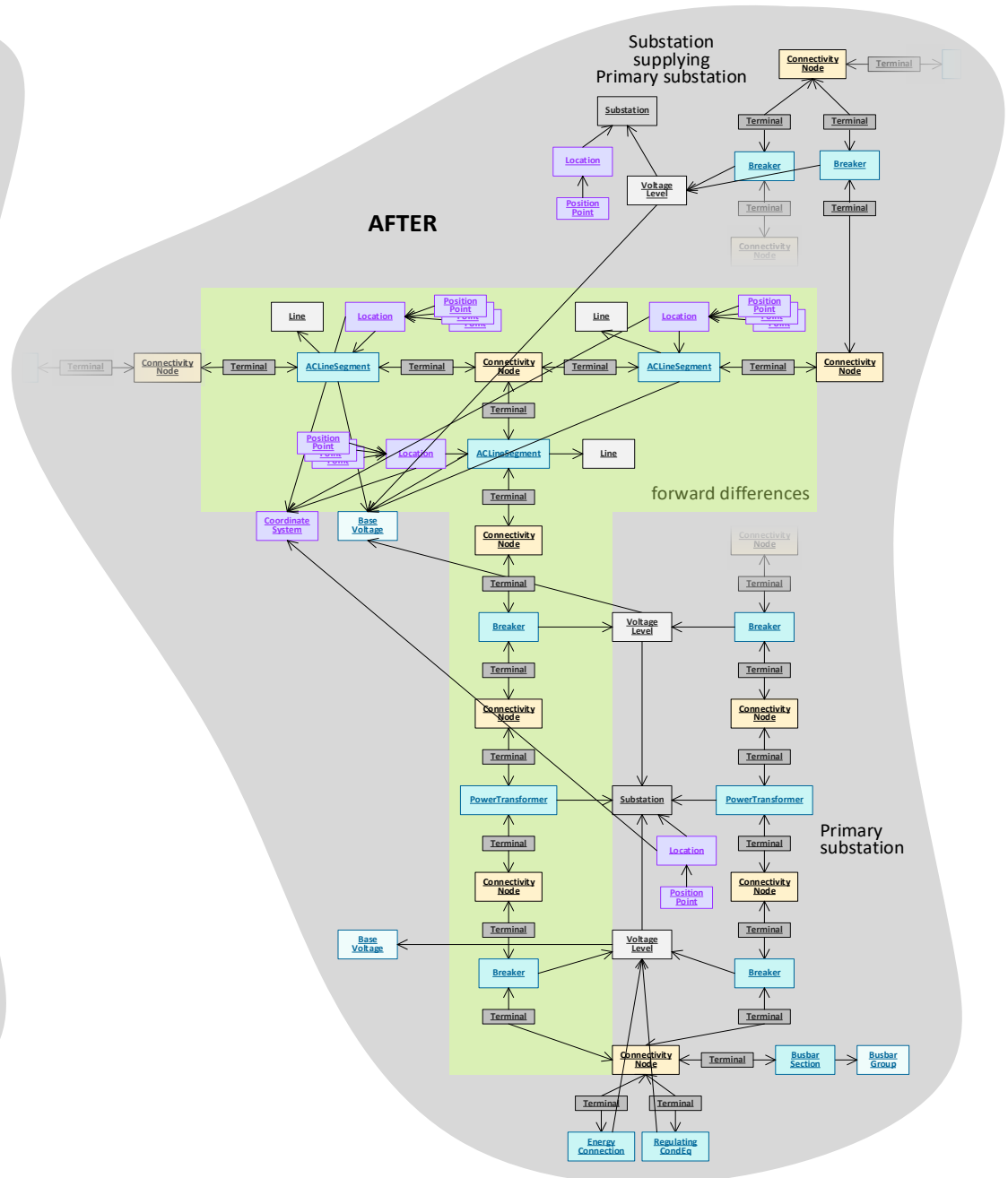
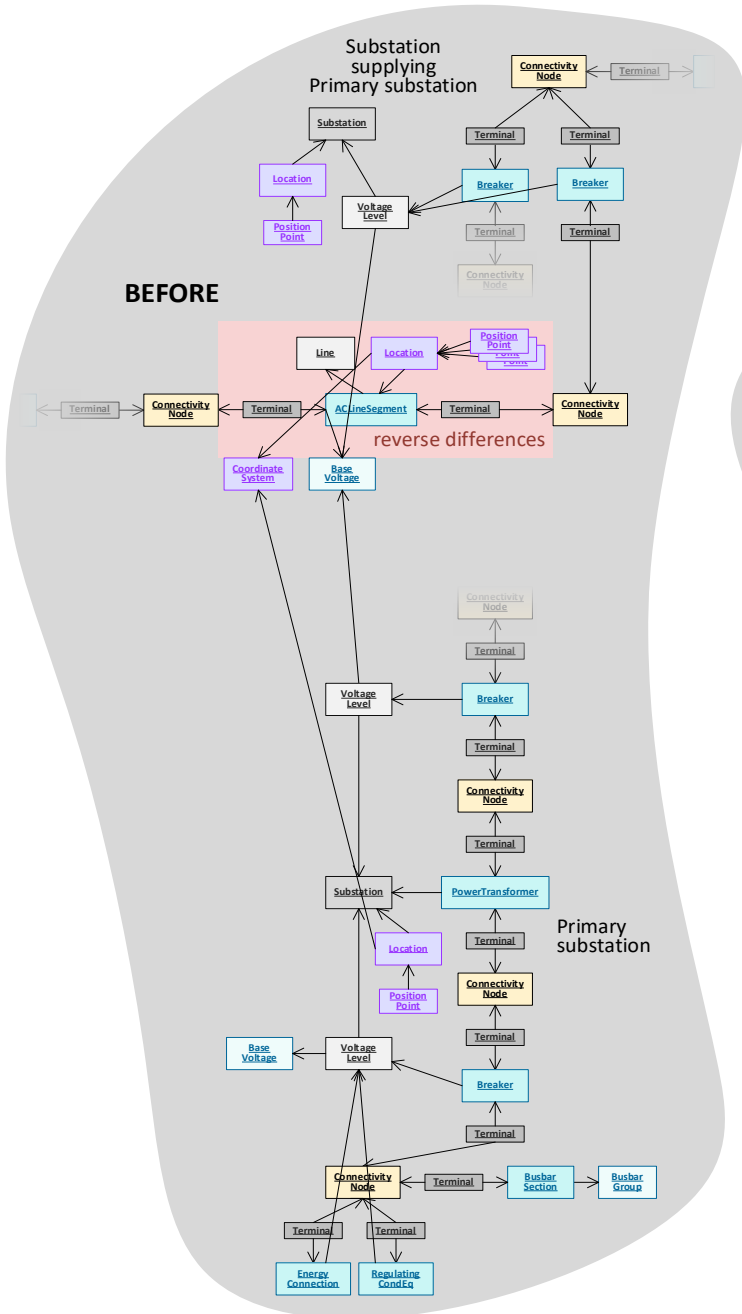
The use of grid objects making up a Development Project’s forward differences and reverse differences is illustrated by a means of a hypothetical project that taps an existing EHV circuit to feed a new HV bus at a Primary substation.



A “before” view and an “after” view of the portion of the grid model representing the grey area on the one-line diagram are shown below. (Note that modelling is simplified – no attributes are shown and numerous objects, particularly those related to the transformers, are eliminated.) The reverse differences (objects and associations to remove) are highlighted in the pink area of the “before” view. And the forward differences (objects and associations to add) are highlighted in the green area of the “after” view.

In the example, the existing cim:ACLineSegment and its associated cim:Line, cim:Location, and cim:Terminal objects are removed and two cim:ACLineSegment objects, separated by a cim:ConnectivityNode to support the tap, are added. The new circuit to the Primary substation along with the new transformer and substation breakers are represented by objects in the forward differences. Note that there are numerous associations in the forward

differences which reference existing objects (like `cim:CoordinateSystem`, `cim:BaseVoltage`, and `cim:VoltageLevel`) are defined.



1.5 Modelling aligned with CGMES v3.0 constraints

LTDS is a data exchange implementation which uses CGMES v3.0 as an underlying data exchange standard. If a DNO desires to use a single source model to provide grid models which conform to both LTDS and CGMES v3.0 exchange requirements, data beyond what is described above needs to be populated. In general, the additional data relates to generator behaviour, load forecasting, equipment short circuit parameters, and operational limits. A detailed description of each type of data required for CGMES 3.0 consumers will be supplied post-consultation after LTDS data modelling is finalised.

2 Data Confidentiality

Data Owners should ensure grid model data is subjected to Open Data Triage and find methods for the data to be shared in a secure fashion, as set out in Data Best Practice guidance.⁸ Grid model data provided in satisfaction of LTDS requirements shall be compliant with all relevant regulation, legislation and Security, Privacy and Resilience (SPaR) requirements.

⁸ [Decision on Data Best Practice Guidance and Digitalisation Strategy and Action Plan Guidance | Ofgem](#)

3 Terms, Definitions, and Abbreviated Terms

Common Grid Model Exchange Standard (CGMES)

The CGMES is a CIM-based profile and usage standards developed by the European Network Transmission System Operator for Electricity (ENTSO-E). Version 3.0 of CGMES (CGMES v3.0) is described by IEC 61970-600-1:2021 and IEC 61970-600-2:2021.

Common Information Model (CIM)

The CIM is an information model described by IEC 61970-301:2020 and expressed in UML. Its classes, attributes and associations provide the semantic model on which profiles are based.

Difference Model

A Difference Model is an instance of a dm:DifferenceModel. It describes an update to a Full Model. It is composed of

- a header which provides limited context information and
- two sets of CIM grid instance data, both of which conform to the same profile(s). One set describes objects/attributes/associations to be added, the other set describes objects/attributes/associations to be deleted.

Distribution Network Operator (DNO)

A DNO is a company that owns, operates, and maintains an electric distribution network in Great Britain.

Electric System Operator (ESO)

The ESO is the party with the responsibility for the minute-to-minute operation of Great Britain's system and transmission network, ensuring it is balanced and stable.

Full Model

A Full Model is an instance of a md:FullModel (which is a header which provides limited context information) along with a set of CIM grid instance data conforming to a profile or combination of profiles.

Grid Code 0139 (GC0139)

GC0139:Enhanced Planning-Data Exchange to Facilitate Whole System Planning.

Grid Supply Point (GSP)

A GSP is a Systems Connection Point at which the Transmission System is connected to a Distribution System in Great Britain.

High Voltage (HV)

HV is a range of nominal voltages over 1kV but less than 22kV.

International Electrotechnical Commission (IEC)

The IEC is an international standards organization that prepares and publishes international standards for electrical, electronic, and related technologies.

Long-Term Development Statement (LTDS)

The LTDS is a statement published by a DNO in Great Britain pursuant to provisions of paragraph 25.2 and 25.3 of the electricity distribution licence granted to it under section 6(1)(c) of the Electricity Act 1989.

Primary substation

A Primary substation is a substation with one or more HV busses, which:

- Are connected to the HV system and
- Are connected to transformers whose high-side voltages are above HV.

Profile

A profile is a non-overlapping subset of CIM classes, attributes and associations defined to support a data exchange.

4 List of LTDS Appendices

LTDS Information Model

- **Appendix 1:** LTDS Information Model and Profiles

This is the EnterpriseArchitect .eap file which includes LTDS information model and the profiles, both required and optional.

- **Appendix 2:** LTDS Information Model Diagrams and Descriptions

This is a Word document with machine-generated diagrams from .eap showing the relevant portions of the underlying information models (base CIM, European extensions, Network Code extensions, and Great Britain extensions) with definitions for all Great Britain extension classes, attributes, associations.

LTDS Profiles and Constraints

- **Appendix 3:** LTDS Profile Classes and Attributes

This is an Excel spreadsheet summarizing:

- Classes and attributes used by LTDS
- LTDS vs CGMES profile classes and enumerations.

- **Appendix 4:** LTDS Layered Profiles

This is a Word document with machine-generated content from .eap with diagrams showing each LTDS deviation and extended profile and including version information for each profile.

- **Appendix 5:** Short Circuit Result Profile

This is a Word document with machine-generated content from .eap including diagrams and description of classes, attributes and associations of the short circuit result optional profile.

- **Appendix 6:** LTDS Profiles in RDFS

This is machine-generated information which represents the RDF schemas of all profiles. RDFS is generated for individual profiles i.e., LTDS deviation profiles and LTDS extended profiles as well as for merged profiles where the resulting RDFS is a merge of CGMES v3.0 RDFS, LTDS deviation profile and LTDS extended profile.

- **Appendix 7:** LTDS Constraints in SHACL

This is machine-generated information of SHACL based constraints. These constraints are validating cardinalities of associations, attributes, their datatypes and relationship. SHACL constraints are generated only for the merged profiles.

- **Appendix 8:** Equivalent Infeed Impedance Calculations

In the previous version of LTDS the positive and zero sequence impedance parameters (R1, X1, R0 and X0) were explicitly specified. In this version of LTDS these values can be calculated using the single and three phase fault current magnitudes and angles. This appendix is a Word document which describes the equations to calculate impedances.

- **Appendix 9:** LTDS Constraint Descriptions

This is a Word document containing tables with descriptions of:

- Relevant CGMES v3.0 constraints