Making a positive difference for energy consumers

Long Term Development Statement (LTDS)

Grid Modelling Annex 1: Grid Modelling Guidelines

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This document overviews the grid modelling approach and details the grid model data requirements for data supplied under the Grid Modelling section of the Long Term Development Statement (LTDS) Form of Statement.

1 Contents

2 Introduction

This document provides the detailed requirements 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.

3 Grid Modelling 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 the International Electrotechnical (IEC) 61970 family of standards provide the basis for the structure of the LTDS grid model data. The information model described in IEC 61970-301:2022[1] forms the foundation and IEC 61970-600-1:2021[2] and IEC 61970-600-2:2021[3] - together known as CGMES v3.0 (Common Grid Model Exchange Standard version 3.0) - describe CIM usage and profiles.

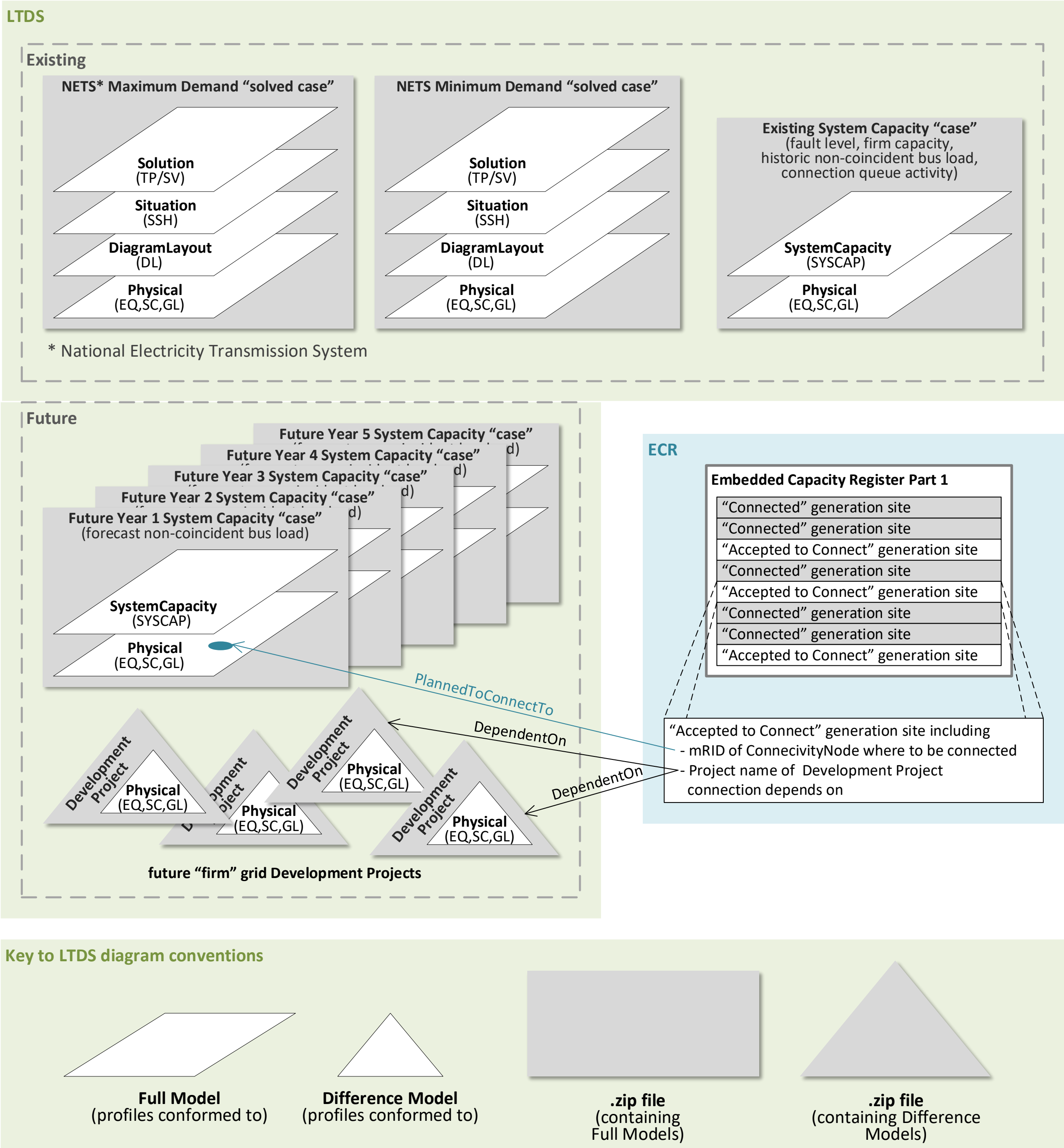
The CIM and its related IEC standards provide several basic constructs for the high-level organisation of grid model data. They are:

- 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.

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 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.

[1] IEC 61970-301:2020+AMD1:2022 CSV | IEC Webstore IEC 61970-301:2020+AMD1:2022 CSV | IEC Webstore
[2] IEC 61970-600-1:2021 | IEC Webstore
[3] IEC 61970-600-2:2021 | IEC Webstore

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 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 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.

LTDS grid model data exchange, like 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, the CGMES v3.0 standards, and 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 *LTDS Grid Modelling Annex 2 - Data Exchange Specifications*.

Instead of including information on future generation connections within LTDS grid modelling, information from the Embedded Capacity Register (ECR) is leveraged. Two types of references within ECR allow its information to be correlated to LTDS grid models:

- One type specifies the grid location of the future connection by means of a reference to the cim:IdentifiedObject.mRID of the appropriate LTDS cim:ConnectivityNode.

- The other type identifies licensee development projects on which the future connection is dependent by reference to the project identifiers from the appropriate *Development Project* .zip file names

4 Grid Data Representation

This document is concerned with the content of the Full Models and Difference Models referenced in 3 Grid Modelling Data Organisation above. Its focus is the grid model data itself. It describes the CIM modelling structures used to represent grid equipment, its characteristics and its connectivity and sets out the LTDS grid data population requirements. The requirements are organised as follows:

- First, data requirements related to the three main CIM profile groups are outlined:
  - The **Physical profile group** (whose data requirements are addressed in 4.3 Physical modelling) 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 4.4 Situation modelling) 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 4.5 Solution modelling) 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 related to 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 and LTDS

requirements related to its data are detailed in 4.6 System capacity profile data.
  - The Diagram Layout profile describes the layout of CIM objects for visualisation on a display. LTDS requirements related to its data are detailed in 4.7 Diagram layout profile data.

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. *Grid Modelling Appendix 5 – LTDS Merged Profile Class and Attribute List* and the LTDS layered profiles in UML section of the *LTDS Grid Modelling Annex 2 - 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. *Grid Modelling Appendix 7 – LTDS Subset of CGMES Constraints Descriptions* contains detail on each constraint.

As described in **3 Grid Modelling Data Organisation** above, the LTDS grid model data provides both existing/previous year information and future information. The same CIM data structures are 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**
NETS Maximum Demand "solved case" .zip file *NETS Minimum Demand "solved case" .zip file*		
	Physical Full Model	4.3 Physical modelling
	Diagram Layout Full Model	4.7 Diagram layout profile data
	Situation Full Model	4.4 Situation modelling
	Solution Full Model	4.5 Solution modelling
Existing System Capacity "case" *Future Year n System Capacity "case"*		
	Physical Full Model	4.3 Physical modelling
	System Capacity Full Model	4.6 System capacity profile data
Development Project		
	Difference Model	5.1 Development Project

LTDS Grid Data Requirements

4.1 CIM conventions used in requirements definition

The 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 association's 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 or attribute 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 61970-301[4].
- 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"[5].
- gb: means the class/attribute/association is defined in specific extensions for Great Britain. These extensions are described in *Grid Modelling Appendix 2 - LTDS Information Model Extension Definitions and Diagrams*.

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 applies to all five of the subtypes of cim:GeneratingUnit the text will refer to "all cim:GeneratingUnit subtype objects".

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.

[4] IEC 61970-301:2020+AMD1:2022 | IEC Webstore

[5] https://www.entsoe.eu/Documents/CIM_documents/Grid_Model_CIM/NetworkCodes_Related_Cannonical_Extensions_v2.2.pdf

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.

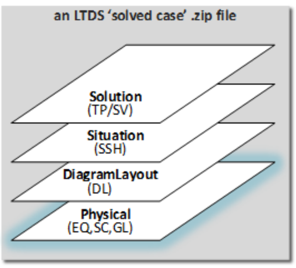
Profile	IdentifiedObject .mRID	IdentifiedObject .name	IdentifiedObject .description
Equipment	required	required	optional
Short Circuit	required		
Geographical Location	required	optional	
Diagram Layout	required	optional	optional
Steady State Hypothesis	required		
Topology	required	optional	optional
State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

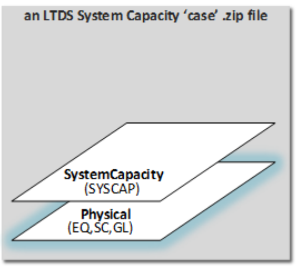
4.2 General

The LTDS grid model scope includes from the 132kV network (EHV in Scotland) down to the lower voltage busbars of primary substations. It also includes details of any interconnectors at lower voltages between primary substations needed to assess the capability of the higher voltage networks.

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

4.3 Physical modelling





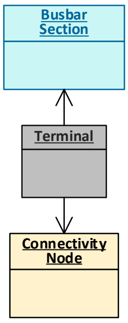
Physical data describes the grid itself. It provides information about the behaviour, connectivity, and geographic location of the equipment that makes up the electrical system.

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.

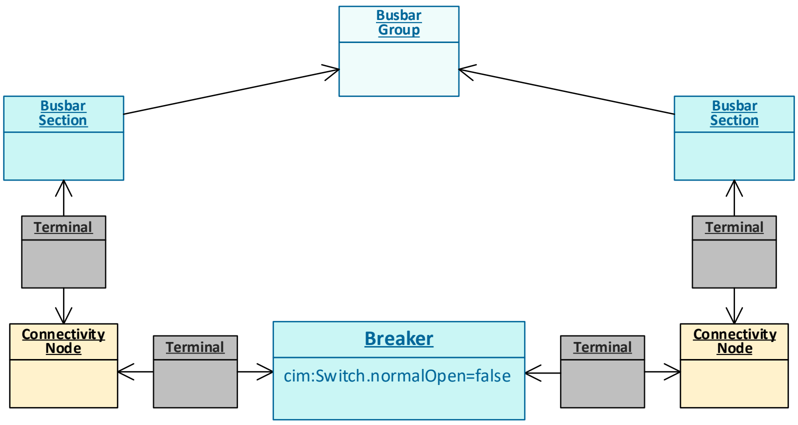
4.3.2 Bus and bus group

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 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.

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

BusbarSection
BusbarGroup

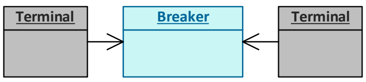
(Note that in this list – and all similar lists throughout this document – the cim:IdentifiedObject attributes required by the Equipment profile are not shown. Their requirements are described, at the profile level, in 4.1 CIM conventions used in requirements definition.)

Also refer to *Grid Modelling Appendix 7 – LTDS Subset of CGMES Constraints Descriptions*:

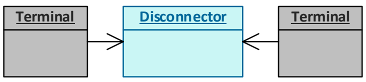
- C:301:EQ:BusbarSection:numberOfTerminals

4.3.2.1 Switching device

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



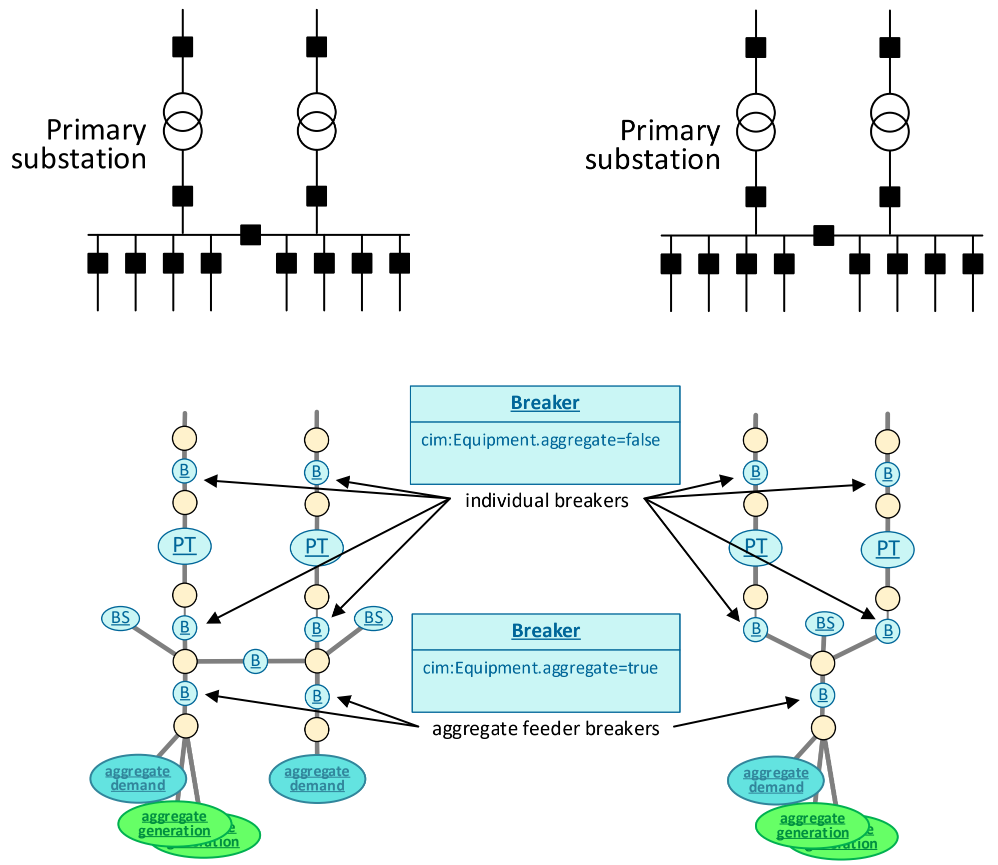
A non-breaker switching device, e.g., a disconnector, is modelled using a cim:Disconnector object.



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

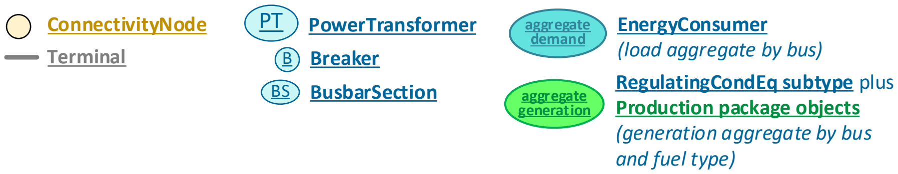
- Every circuit breaker in scope is modelled, with the exception of normally closed bus coupling breakers connecting busses at the lowest modelled voltage level. These breakers are optionally modelled.
- Other switching devices are modelled as necessary to allow every circuit, transformer, busbar, generator, 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.



a) connected busses at lowest voltage level modelled as two busses

b) connected busses at lowest voltage level modelled as a single bus



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

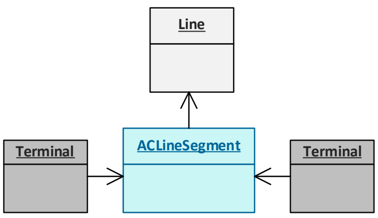
Disconnector		
REQUIRED	Switch	normalOpen
REQUIRED	Switch	ratedCurrent
Fuse		
REQUIRED	Switch	normalOpen
REQUIRED	Switch	ratedCurrent
GroundDisconnector		
REQUIRED	Switch	normalOpen
REQUIRED	Switch	ratedCurrent
Breaker		
REQUIRED	Equipment	aggregate
REQUIRED	Switch	normalOpen
REQUIRED	Switch	ratedCurrent
DisconnectingCircuitBreaker		
REQUIRED	Switch	normalOpen
REQUIRED	Switch	ratedCurrent
LoadBreakSwitch		
REQUIRED	Switch	normalOpen
REQUIRED	Switch	ratedCurrent

Also refer to *Grid Modelling Appendix 7 – LTDS Subset of CGMES Constraints Descriptions*:

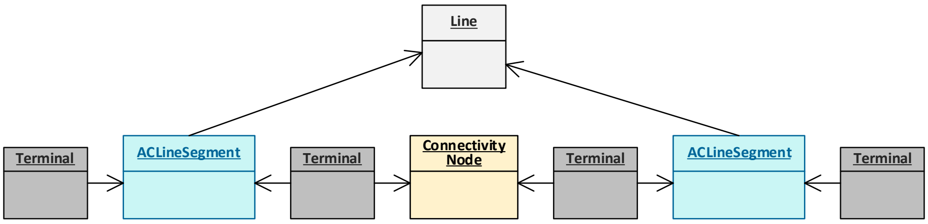
- C:452:EQ:Switch:connection
- C:301:EQ:Switch:numberOfTerminals
- C:301:EQ:Switch.ratedCurrent:valueRange

4.3.2.2 Circuit

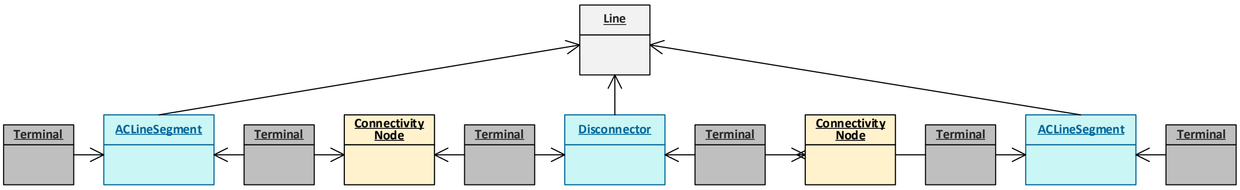
A circuit is modelled using a cim:Line object containing at least one cim:ACLineSegment object.



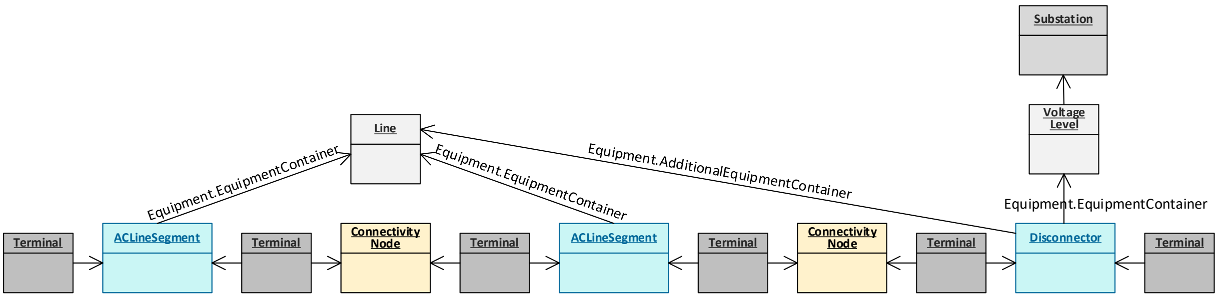
A cim:Line may contain multiple cim:ACLineSegment objects.



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



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 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

Notes on OPTIONAL attributes:

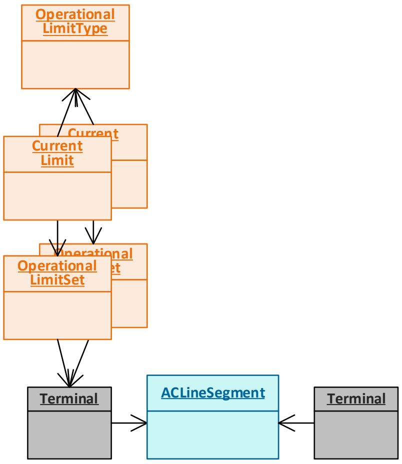
- For all cim:ACLineSegment objects,
  .gch is populated at local discretion.

Also refer to *Grid Modelling Appendix 7 – LTDS Subset of CGMES Constraints Descriptions*:

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

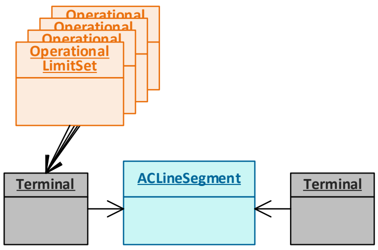
4.3.2.3 Circuit limits

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).

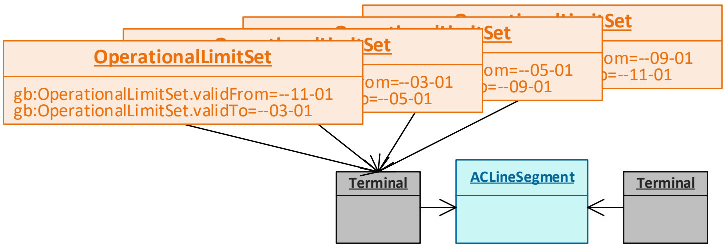


The following requirements apply to the modelling of circuit limits in the LTDS grid model:

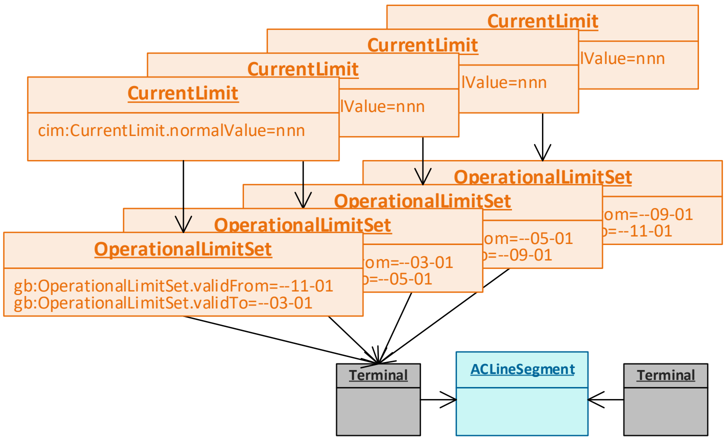
- Every cim:ACLineSegment has at least one cim:OperationalLimitSet object associated with one of its two cim:Terminal objects and can have as many as necessary to accurately reflect the licensee's 'seasonal' limit philosophies.



- 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.

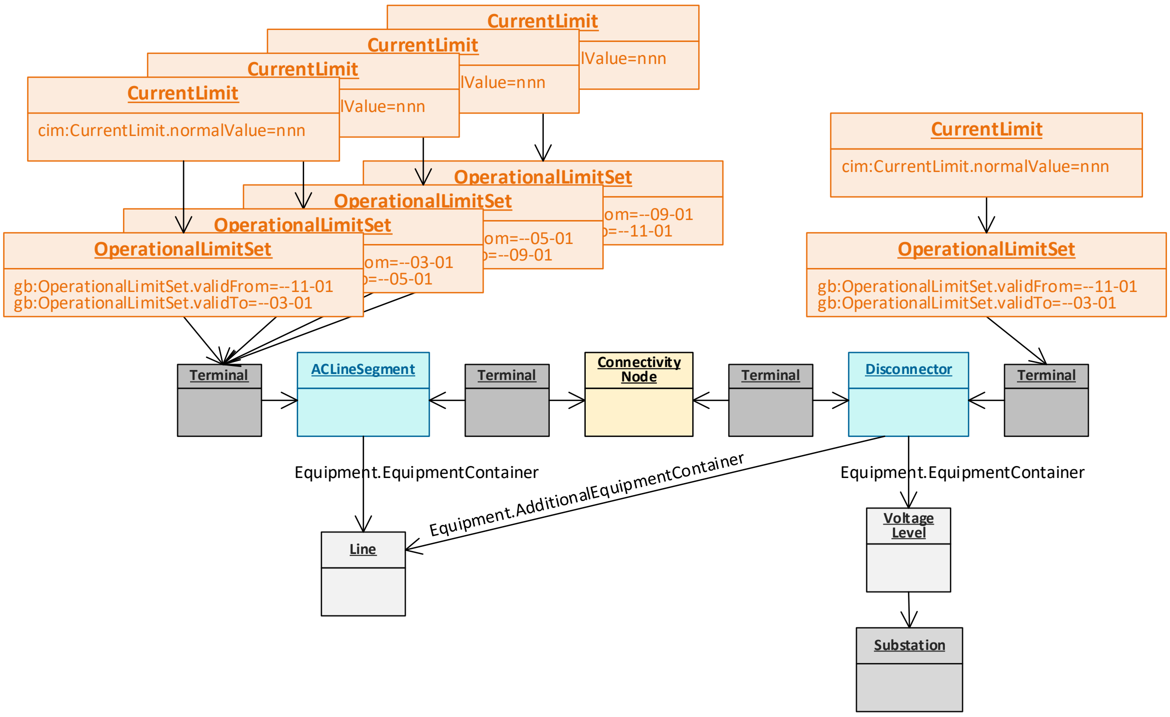


- Each cim:OperationalLimitSet associated with a cim:ACLineSegment's cim:Terminal is associated with a cim:CurrentLimit object whose cim:CurrentLimit.normalValue attribute is populated with a value reflecting the seasonal conductor ampere limit typically used in licensee planning and interconnection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

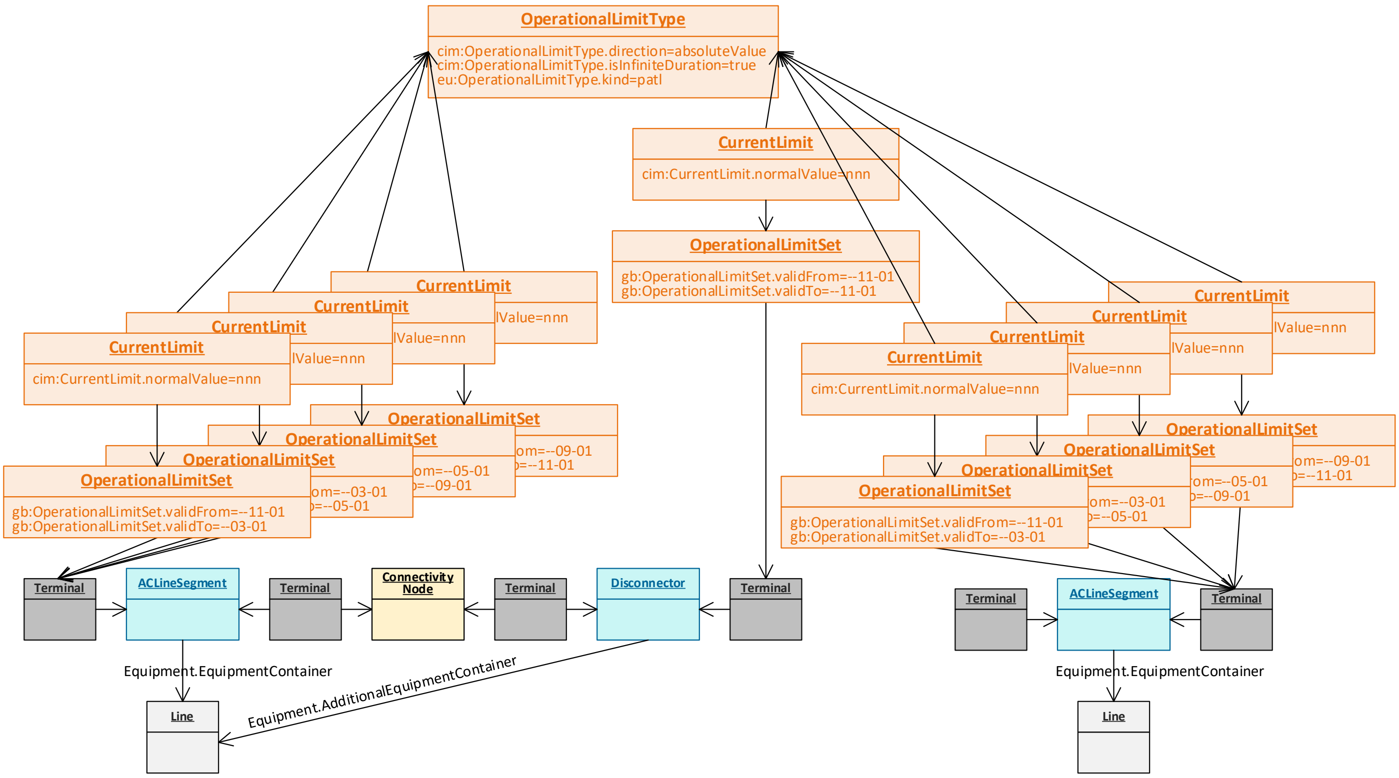


The standard approach used by the licensee in calculating circuit-related limits is to be documented in the Summary Information section of the licensee's LTDS publication. Deviations from the standard calculation approach and additional explanatory information to assist in user interpretation are described 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:

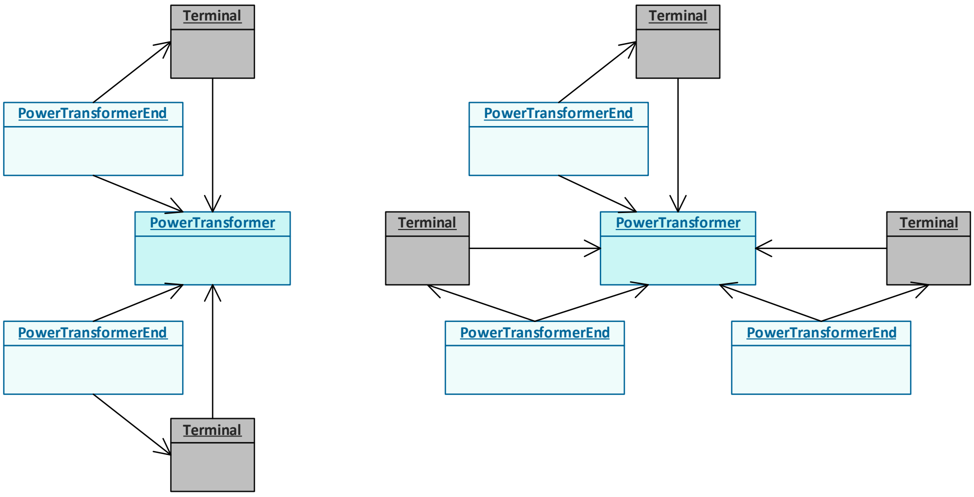
OperationalLimitSet		
REQUIRED	OperationalLimitSet	validFrom
REQUIRED	OperationalLimitSet	validTo
CurrentLimit		
REQUIRED	CurrentLimit	normalValue
OperationalLimitType (one)		
REQUIRED	OperationalLimitType	direction (must=absoluteValue)
REQUIRED	OperationalLimitType	isInfiniteDuration (must=true)
REQUIRED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

Also refer to *Grid Modelling Appendix 7 – LTDS Subset of CGMES Constraints Descriptions*:

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

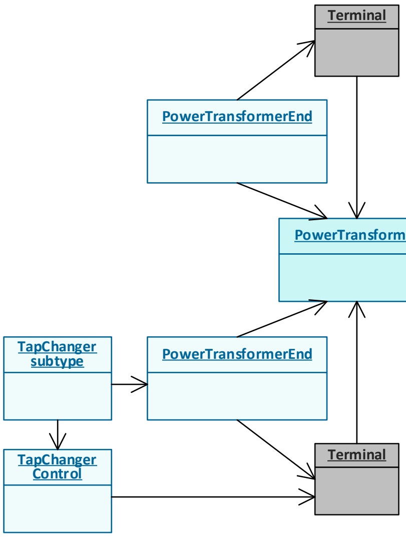
4.3.2.4 Transformer

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.

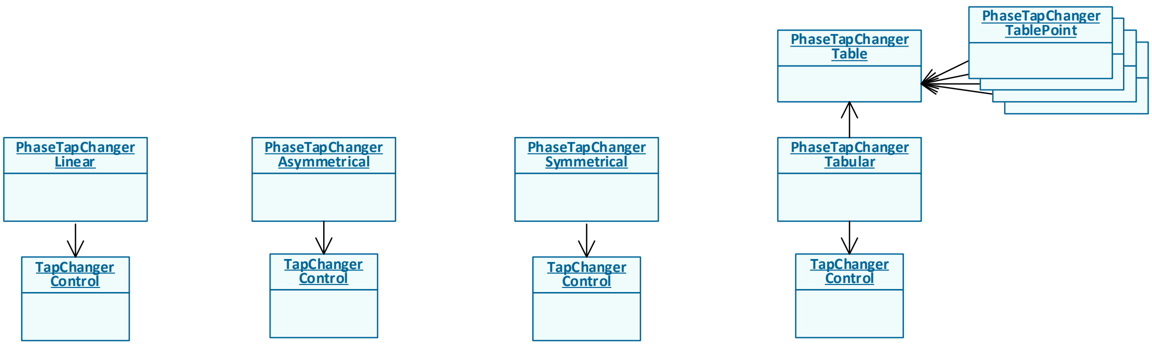


a) two-winding transformer b) three-winding transformer

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 LTDS grid model:

- Every GSP-related and every licensee-owned transformer in scope is modelled, including its control functions, if present. For any transformer with unusual characteristics, its manufacturer and an explanation of its characteristics are provided in the cim:IdentifiedObject.description attribute of the cim:PowerTransformer.

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.

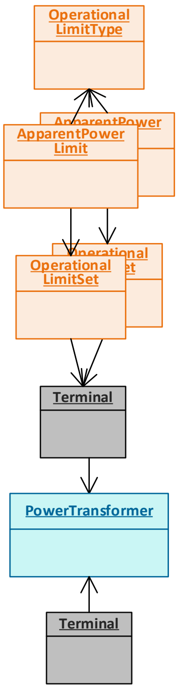
Also refer to <u>*Grid Modelling Appendix 7 – LTDS Subset of CGMES Constraints Descriptions*</u>:

- 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

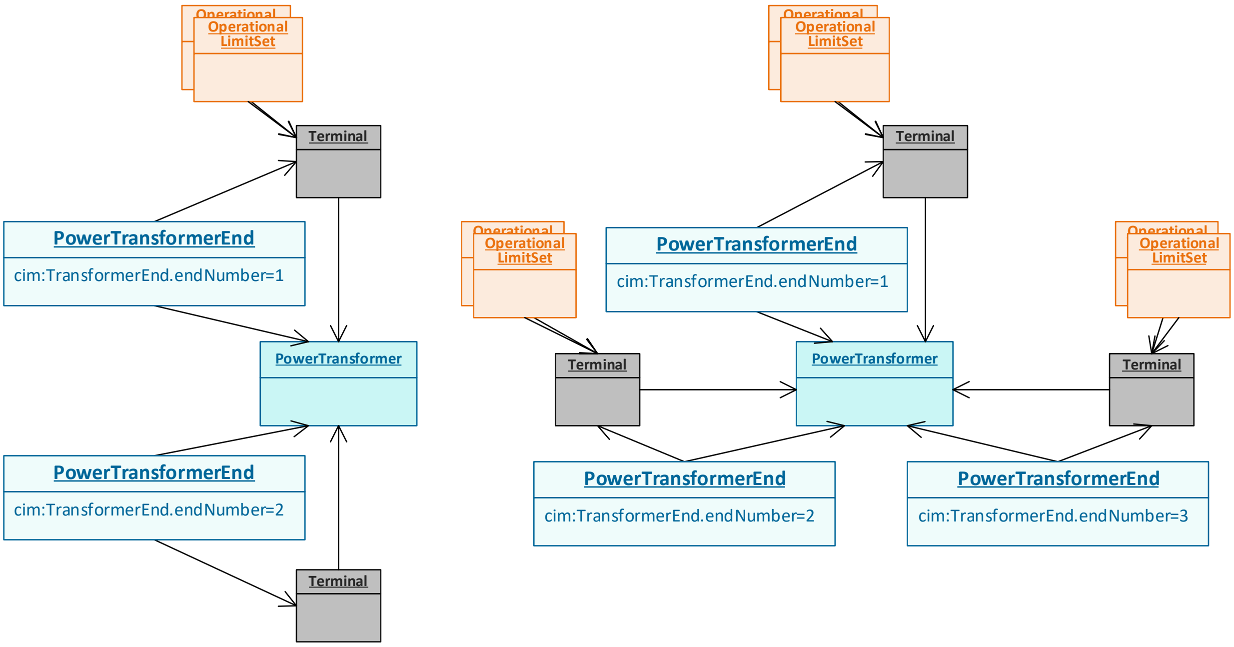
4.3.2.5 Transformer limits

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.



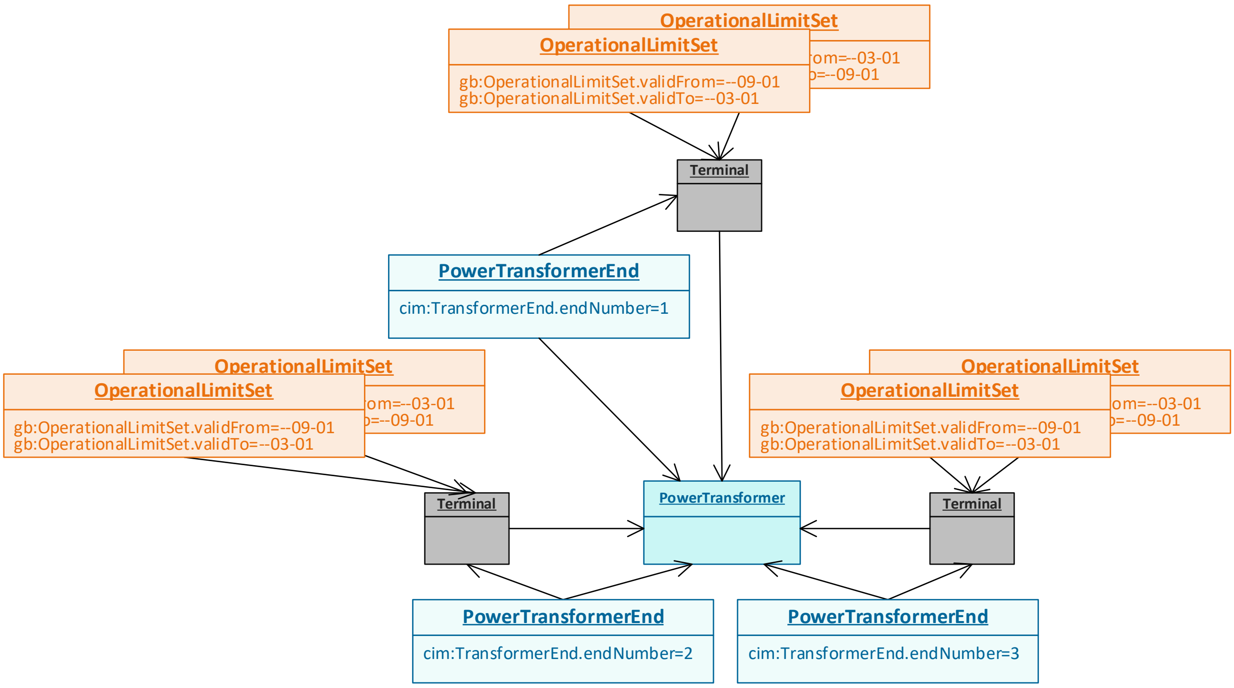
The following requirements apply to the modelling of transformer limits in the LTDS grid model:

- 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).

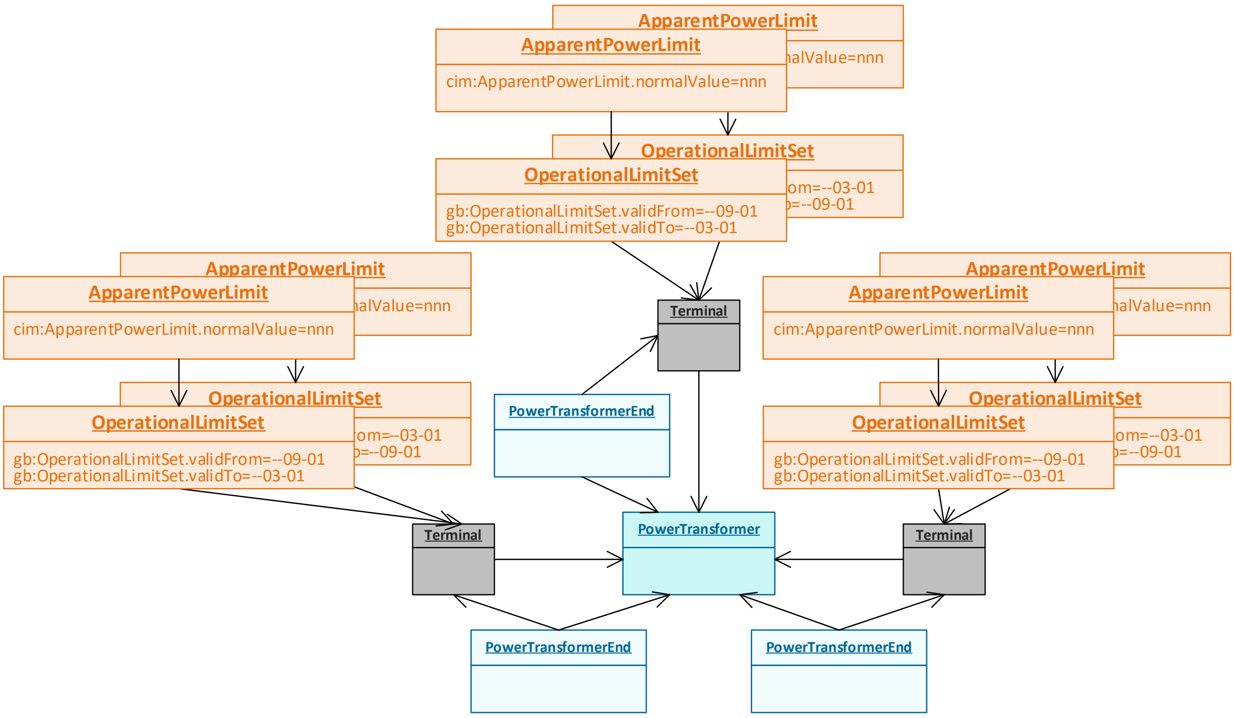


a) two-winding transformer b) three-winding transformer

- 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.

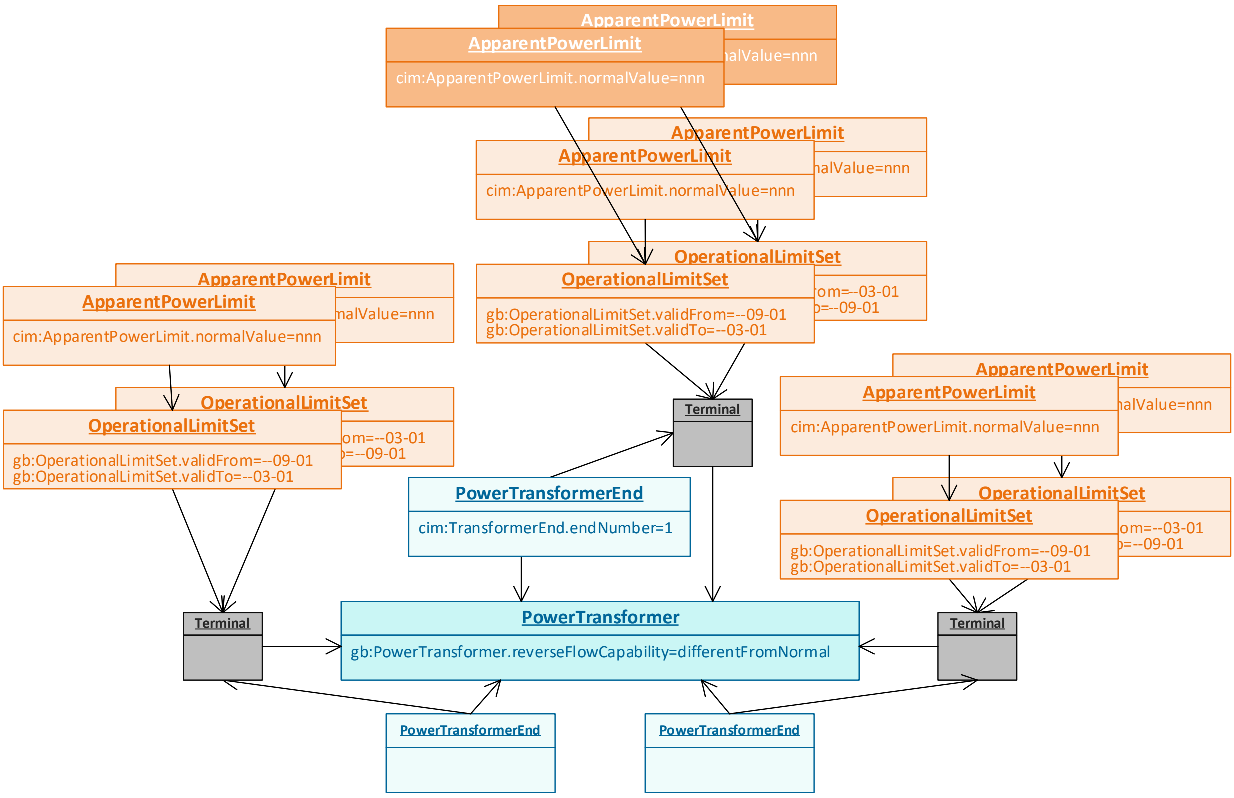


- Each cim:OperationalLimitSet associated with a cim:PowerTransformer's cim:Terminal is associated with a cim:ApparentPowerLimit object whose cim:ApparentPowerLimit.normalValue attribute is populated with a value reflecting the MVA limit for the power flow in the normal direction that is typically used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

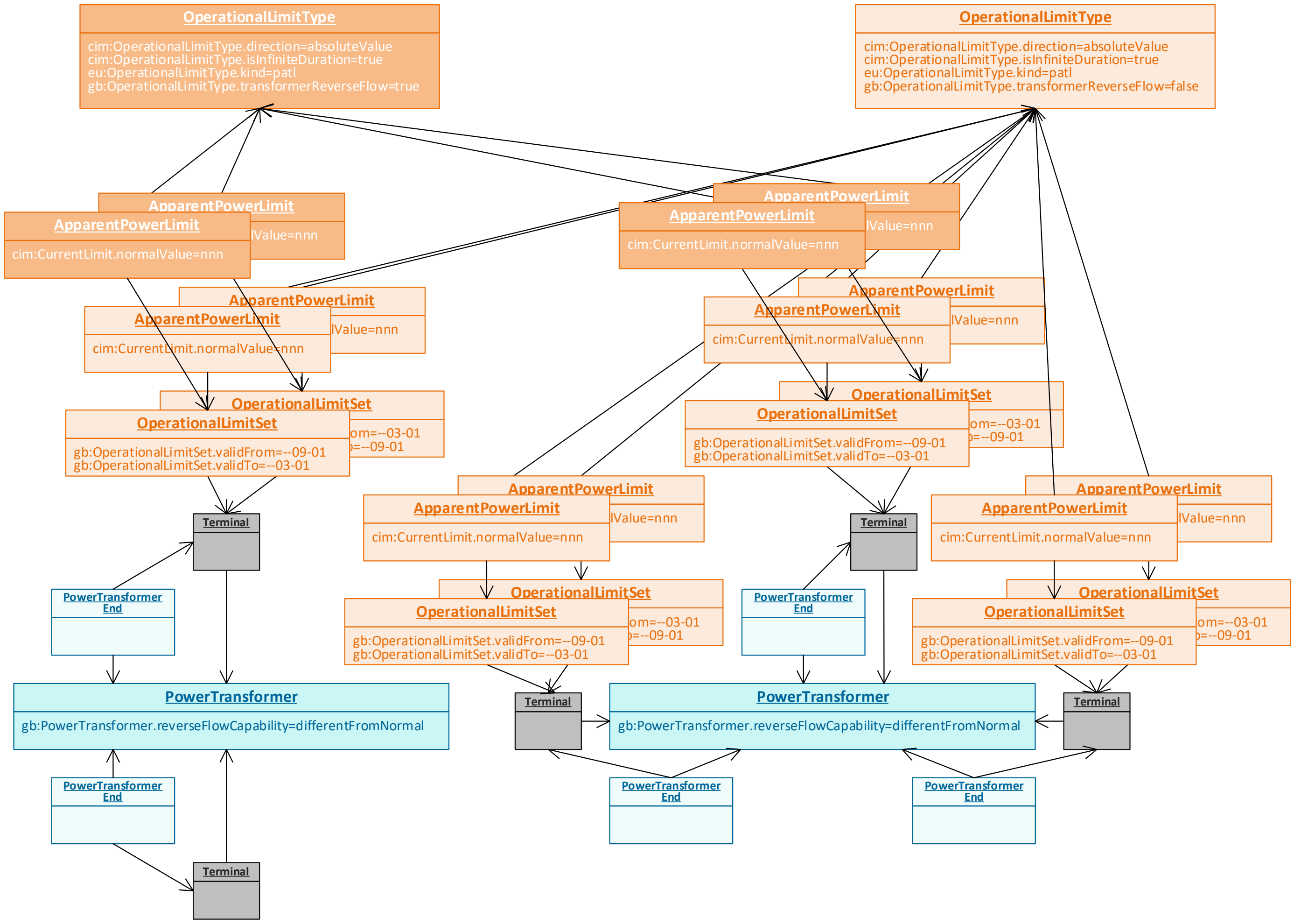


The standard approach used by the licensee in calculating its typically used transformer limits is to be documented in the Summary Information section of the licensee's LTDS publication. Any transformer-specific deviations from that standard calculation approach are described in the cim:IdentifiedObject.description 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)		

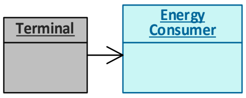
REQUIRED	OperationalLimitType	direction (must=high)
REQUIRED	OperationalLimitType	isInfiniteDuration (must=true)
REQUIRED	OperationalLimitType	kind (must=patl)
REQUIRED	OperationalLimitType	transformerReverseFlow (one must=true, one must=false)

Also refer to *Grid Modelling Appendix 7 – LTDS Subset of CGMES Constraints Descriptions*:

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

4.3.2.6 Load

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

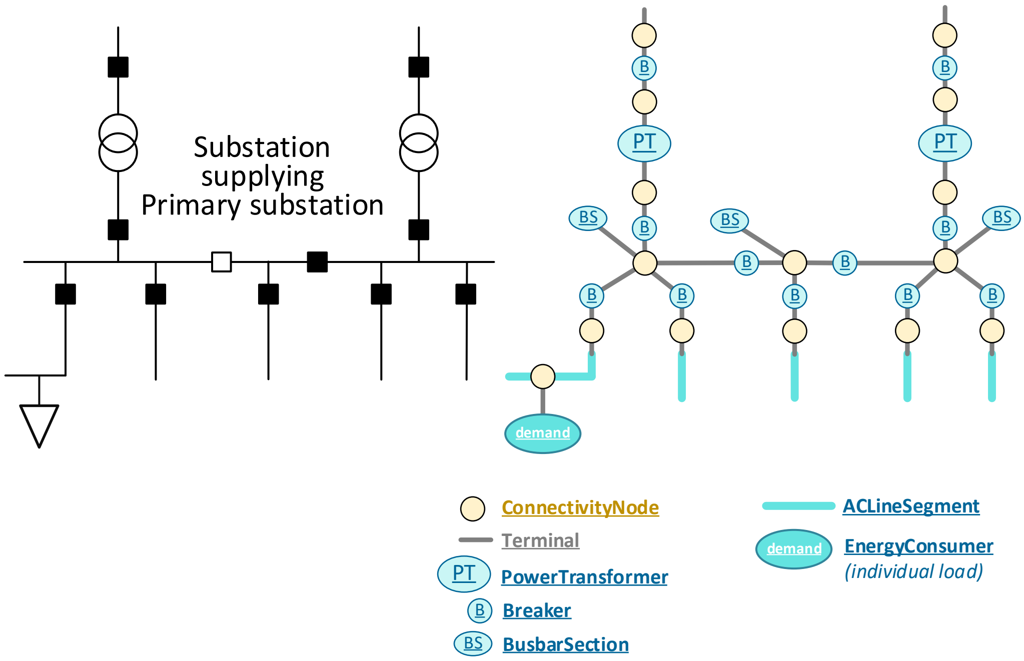


The following requirements apply to the modelling of load in the LTDS grid model:

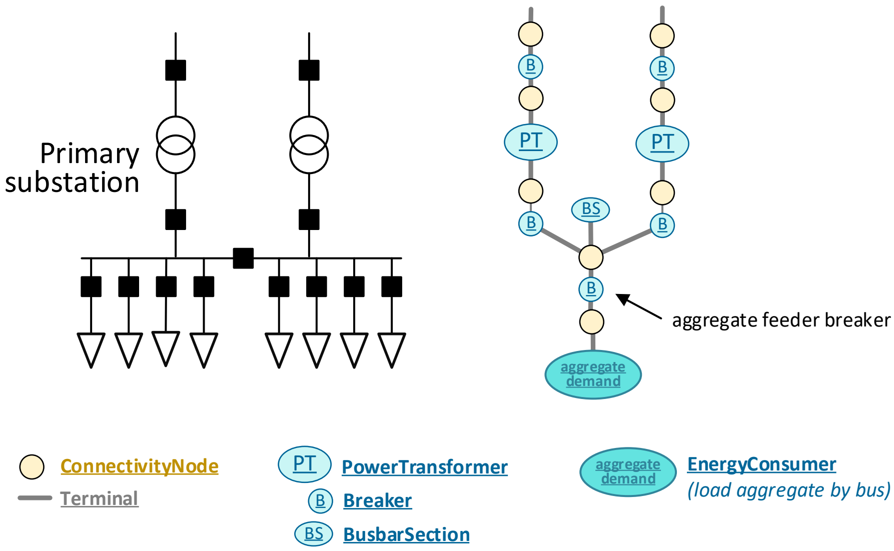
- The cim:EnergyConsumer object is used to represent both individual load and aggregate load. Individual load is indicated by cim:Equipment.aggregate=false in the cim:EnergyConsumer object. Aggregate load is indicated by cim:Equipment.aggregate=true in the cim:EnergyConsumer object.

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.

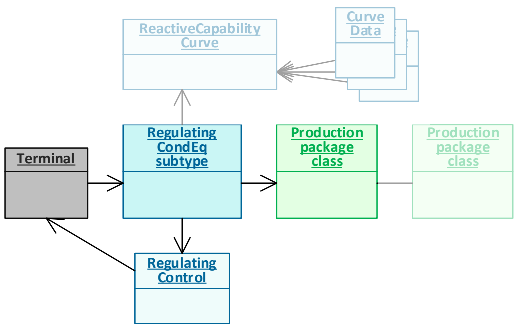
The classes and attributes in the LTDS Equipment profile which support load modelling are:

EnergyConsumer			
	REQUIRED	Equipment	aggregate

4.3.2.7 Generation

In CIM, generation is modelled using a combination of:

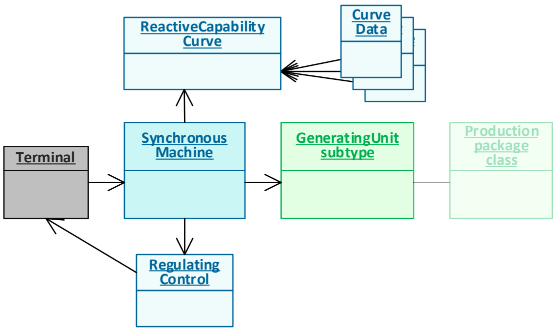
- A single cim:RegulatingCondEq subtype object (either a cim:SynchronousMachine object, a cim:AsynchronousMachine object, or a cim:PowerElectronicsConnection object) with
- An associated cim:RegulatingControl object and
- A primary cim:Equipment subtype object from the Production package of the CIM UML 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.



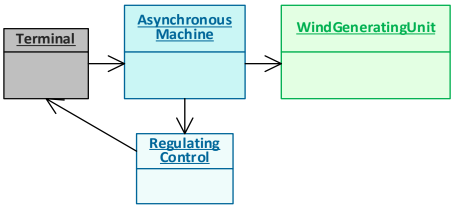
The following requirements apply to the modelling of generation in the LTDS grid model:

- 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

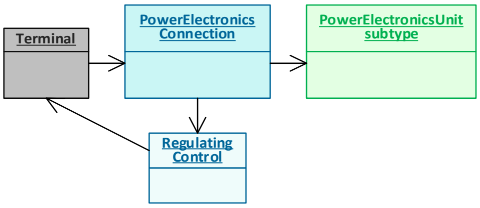
are modelled using a cim:SynchronousMachine object, a cim:RegulatingControl object, a cim:ReactiveCapabilityCurve object (plus its cim:CurveData objects) along with an appropriate cim:GeneratingUnit subtype object. Additional Production package objects may be required depending on the specific fuel type.



- 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.

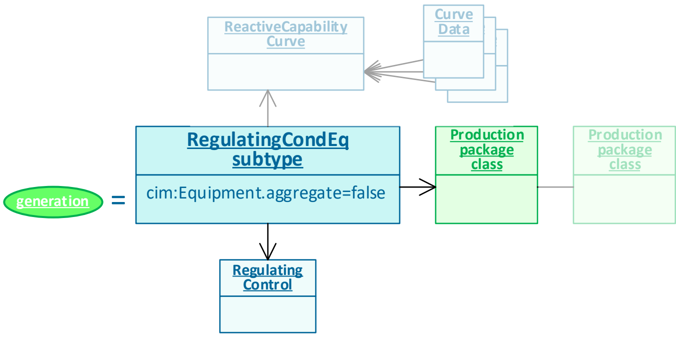


LTDS fuel types are based on the list of fuel types used by GC0139, augmented as necessary to fit with the CIM information model structure. The specific patterns of CIM objects for each generator fuel type are shown in Figure 2.

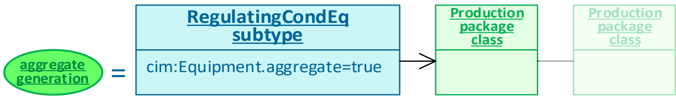
Figure 2: Generator modelling by fuel type using cim:RegulatingCondEq child objects and associated objects

GC0139 Fuel Type	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		
	if compressed air	SynchronousMachine	ThermalGeneratingUnit	CAESPlant	
	if flywheel	SynchronousMachine	FlywheelUnit <<GB>>		
	if pumped storage	SynchronousMachine	HydroGeneratingUnit	HydroPowerPlant	.hydroPlantStorageType=HydroPlantStorageKind.pumpedStorage
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.



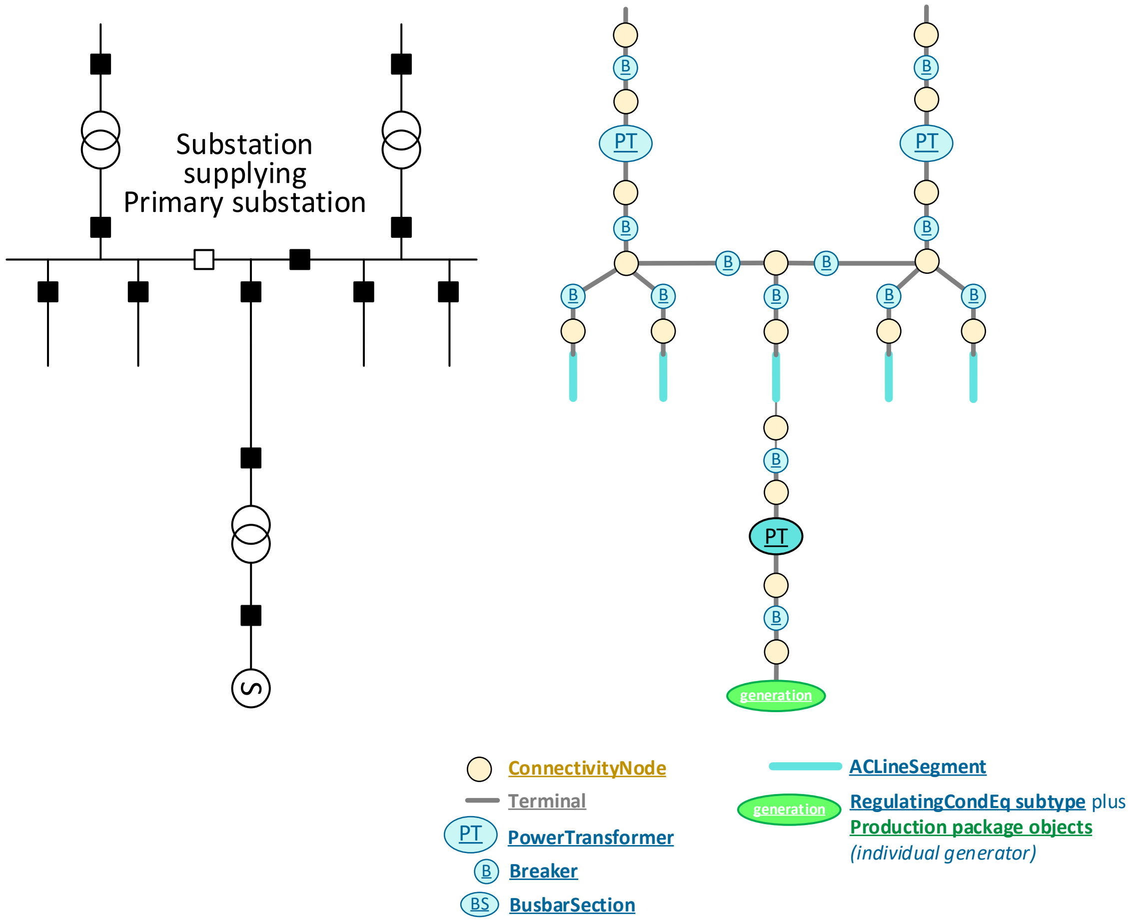
a) individual generation



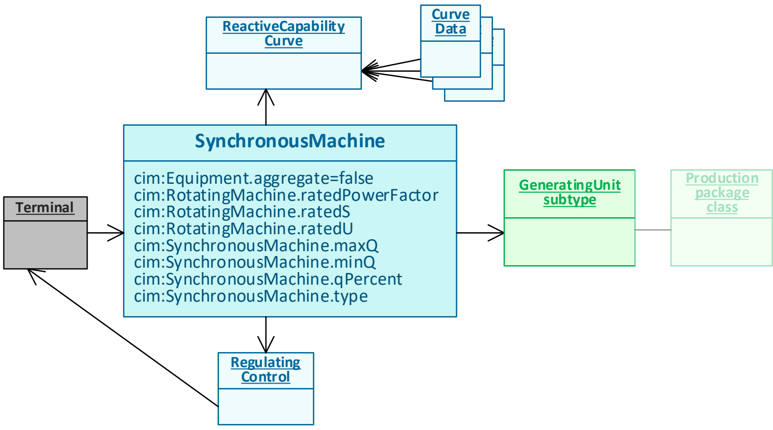
b) aggregate generation

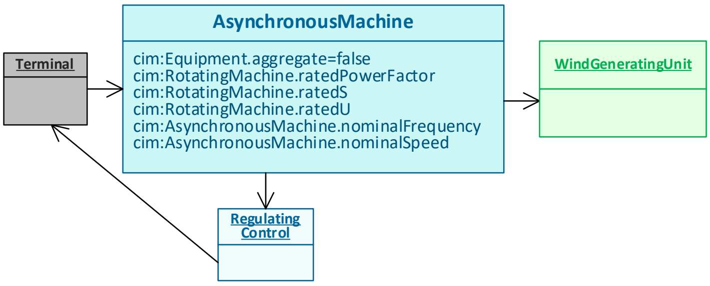
<u>Individual generation</u>

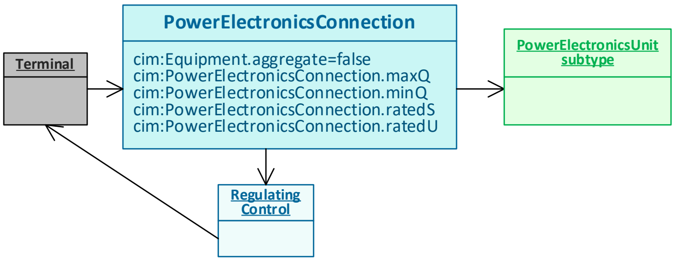
Every generator in scope which is connected at a voltage level above the lowest modelled voltage level is modelled as individual generation. For individual generation, basic modelling of the network between the generator and its grid connection point is provided. At the minimum, this consists of the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

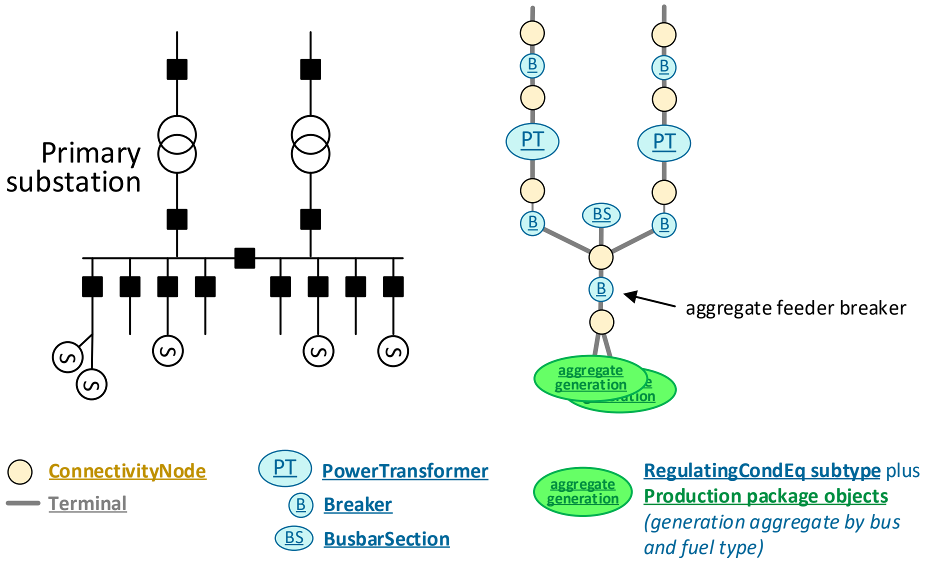
- Production package classes

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>>		

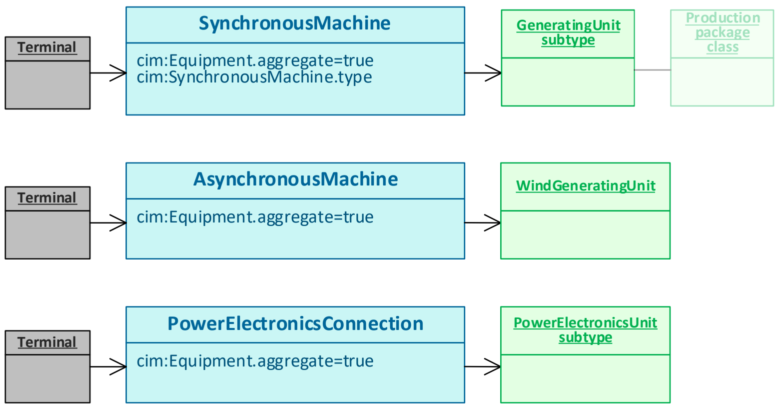
REQUIRED	GeneratingUnit	maxOperatingP
REQUIRED	GeneratingUnit	minOperatingP
REQUIRED	GeneratingUnit	ratedNetMaxP
HydroGeneratingUnit		
REQUIRED	GeneratingUnit	maxOperatingP
REQUIRED	GeneratingUnit	minOperatingP
REQUIRED	GeneratingUnit	ratedNetMaxP
HydroPowerPlant		
REQUIRED	HydroPowerPlant	hydroPlantStorageType
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

<u>Aggregate generation</u>

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 *Grid Modelling Appendix 7 – LTDS Subset of CGMES Constraints Descriptions*:

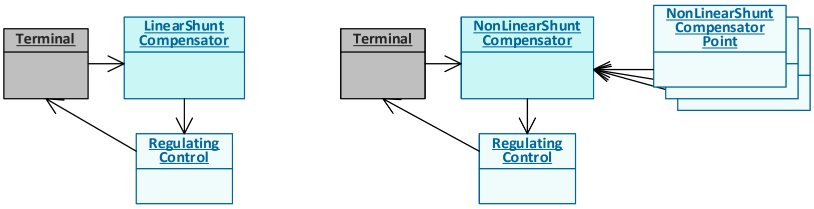
- C:301:EQ:BatteryUnit.ratedE:valueRange
- C:452:EQ:CurveData.Curve:reactive
- C:301:EQ:ReactiveCapabilityCurve:yvalues
- C:600:EQ:ReactiveCapabilityCurve:units
- C:452:EQ:ReactiveCapabiltyCurve.CurveData:xvalue
- C:452:EQ:RegulatingControl:RegulatingEquipment
- C:452:EQ:SynchronousMachine:controlMode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

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

4.3.2.8 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.



a) linear shunt compensator

b) non-linear shunt compensator

c) static VAr compensator

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 .voltageSensitivty are populated at local discretion.

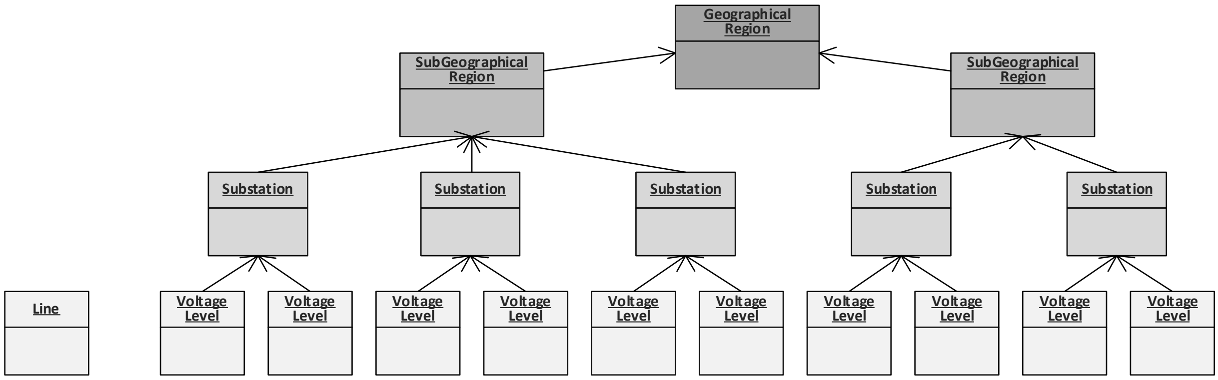
  .grounded is populated for compensators with Yn or Zn connections to indicate if the neutral is solidly grounded.

Also refer to *Grid Modelling Appendix 7 – LTDS Subset of CGMES Constraints Descriptions*:

- 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

4.3.2.9 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.



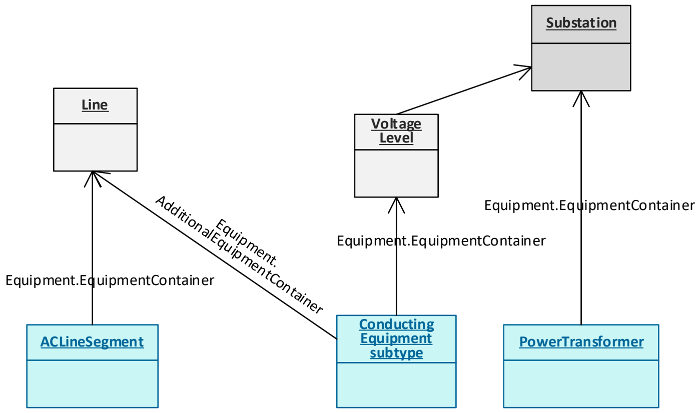
The following requirements apply to the modelling of containment in the LTDS grid model:

- A single cim:GeographicalRegion object represents the licence area.
- Every GSP in scope is modelled using a cim:SubgeographicalRegion object which is associated with the cim:GeographicalRegion.
- Every substation in scope is modelled as a cim:Substation object which is associated with the appropriate cim:SubgeographicalRegion.
- 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 associated with a cim:Line object, a cim:VoltageLevel object or a cim:Substation object, in accordance with the following limitations:

cim:ConductingEquipment object	**Can be contained in:**		
	cim: Voltage Level	**cim: Substation**	**cim: Line**
cim:PowerTransformer		Y	
cim:ProtectedSwitch or subtype (cim:Breaker)	Y		
cim:BusbarSection	Y		
cim:EnergyConnection or subtype (cim:EnergyConsumer or cim:RegulatingCondEq)	Y		
cim:Conductor or subtype (cim:ACLineSegment)			Y
cim:ConductingEquipment subtypes not listed above	Y		Y

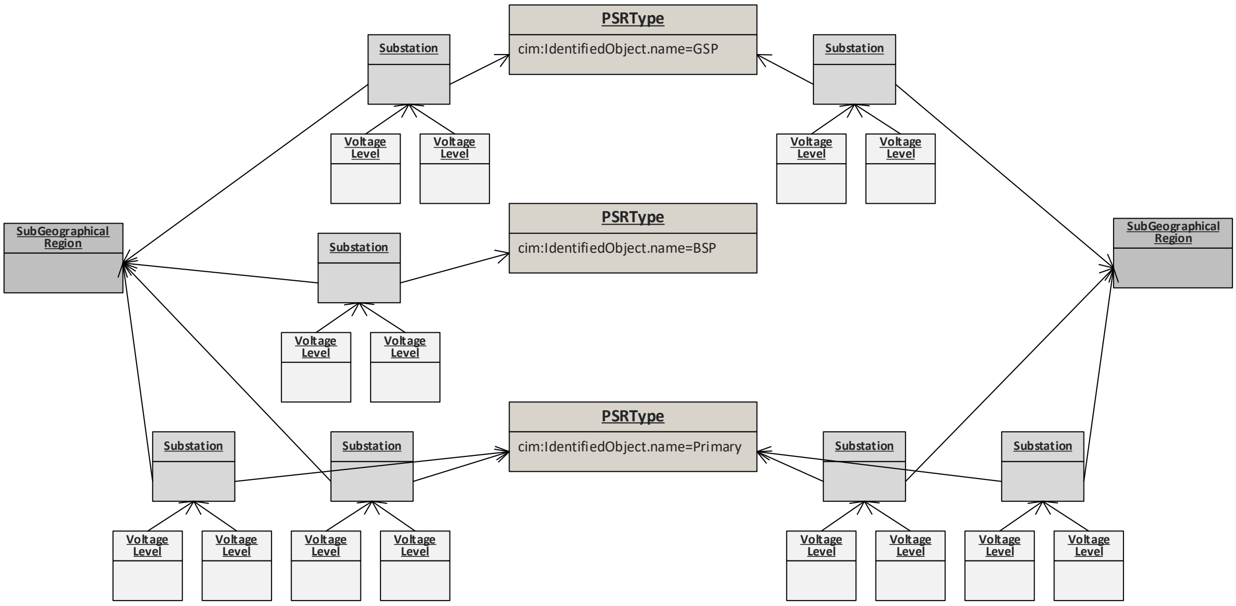
Note: The above limitations are in conformance with CGMES v3.0 constraints. cim:Bay and cim:DCConverterUnit are not mentioned as they are not defined in LTDS.

- A cim:ConductingEquipment subtype object associated with a cim:VoltageLevel may have a cim:Equipment.AdditionalEquipmentContainer association with a cim:Line (see Circuit).



- Every cim:GeneratingUnit subtype object and every cim:PowerElectronicsUnit subtype object have an association with a cim:Substation.
- Every cim:ConnectivityNode object is associated with a cim:ConnectivityNodeContainer subtype object (cim:Line, cim:VoltageLevel or cim:Substation). The specific object is one associated with one of the cim:ConductingEquipment subtype objects associated to the cim:ConnectivityNode via a cim:Terminal. For example, if a cim:PowerTransformer and a cim:Breaker were associated to a cim:ConnectivityNode via their cim:Terminals, the cim:ConnectivityNode would be associated with either the cim:PowerTransformer's cim:Substation object or the cim:Breaker's cim:VoltageLevel object. There is no preference as to which.
- 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

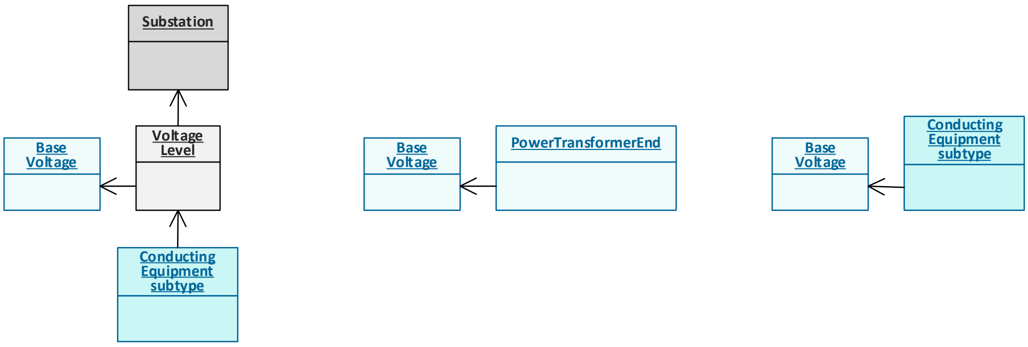
(Note that the only attributes of the containment classes are those inherited from cim:IdentifiedObject.)

Also refer to *Grid Modelling Appendix 7 – LTDS Subset of CGMES Constraints Descriptions*:

- C:452:EQ:BusbarSection:containment
- C:452:EQ:ConnectivityNode:containment
- C:452:EQ:Disconnector:containment
- C:452:EQ:EnergyConnection:containment
- C:452:EQ:Fuse:containment
- C:600:EQ:GeographicalRegion:EQ__4
- C:452:EQ:GroundDisconnector:containment
- C:452:EQ:PowerTransformer:containment
- C:452:EQ:ProtectedSwitch:containment
- C:452:EQ:SeriesCompensator:containment
- C:600:EQ:Substation:count

4.3.2.10 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.

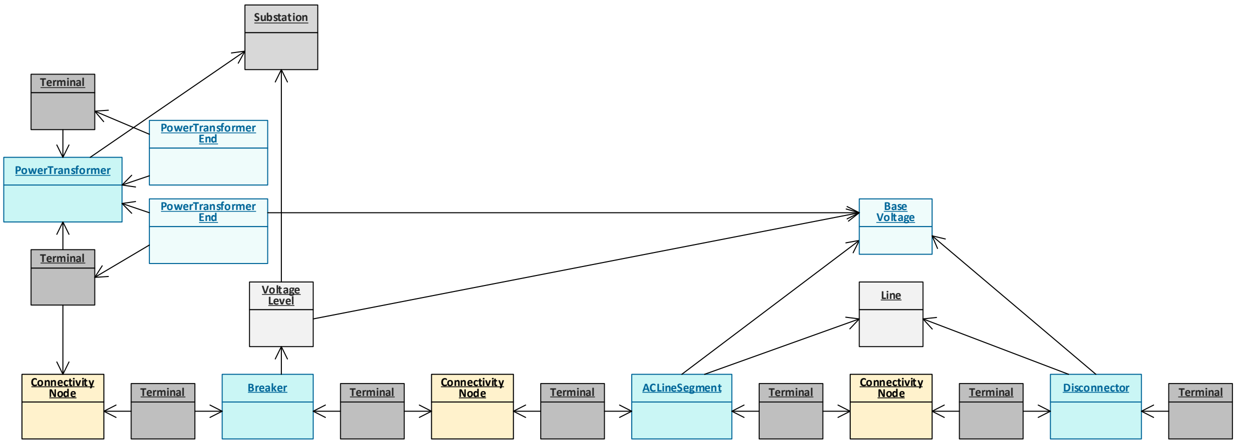


a) cim:BaseVoltage referenced by a cim:VoltageLevel subtype

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 *Grid Modelling Appendix 7 – LTDS Subset of CGMES Constraints Descriptions*:

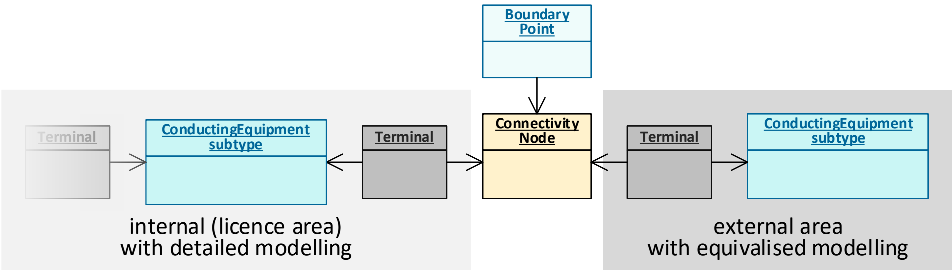
- C:301:EQ:BaseVoltage.nominalVoltage:valueRange
- C:301:EQ:ConductingEquipment.BaseVoltage:usage
- C:452:EQ:ConductingEquipment.BaseVoltage:whereRequired

4.3.2.11 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"*.

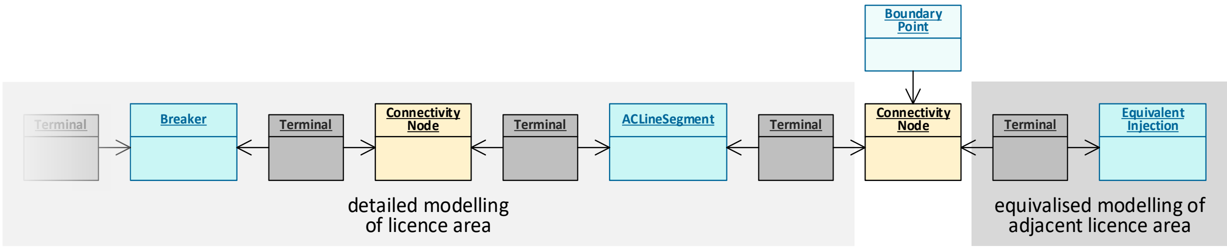
Each boundary between the internal (licence area) grid and an external grid is identified with an eu:BoundaryPoint object.



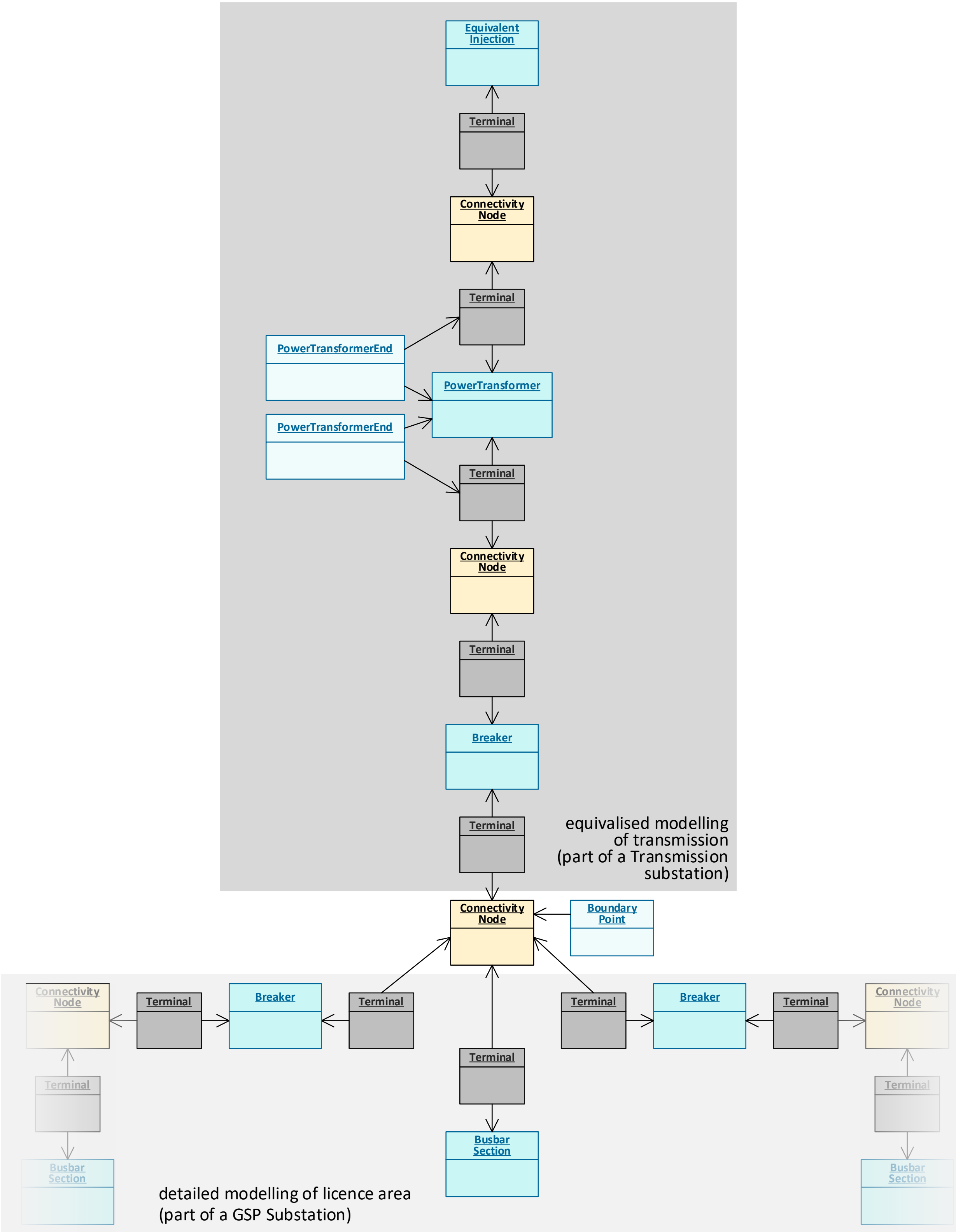
Simplified modelling of equipment and connectivity in the external area is done using the same types of CIM objects used for internal modelling. Load and generation injections in the external area are typically simplified and modelled using a single cim:EquivalentInjection.

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 is required when flows between connection points in the external grid have impact.

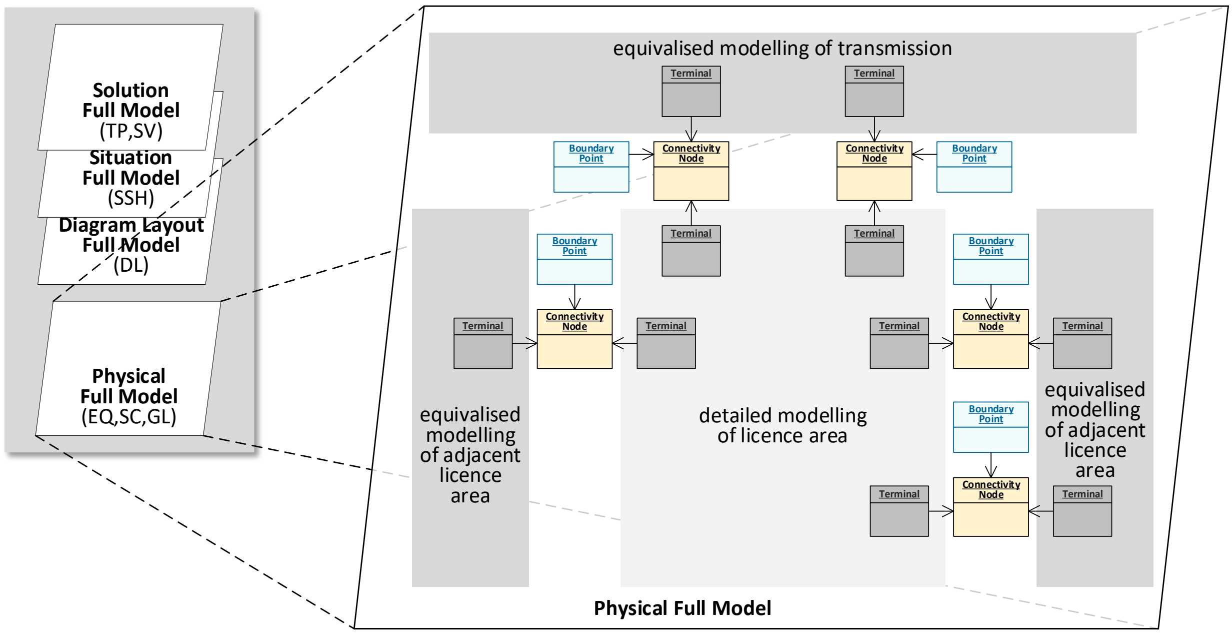
A circuit connecting to another licence area could be represented as shown below:



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:

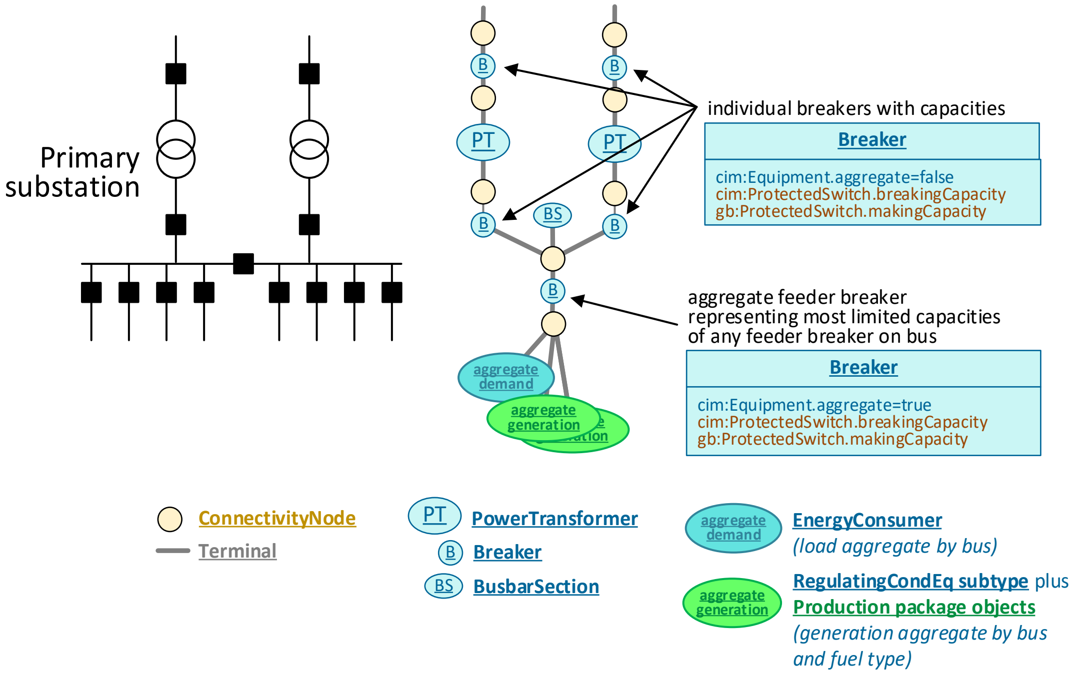
- For cim:EquivalentConnection objects used in representing the transmission grid,
  .maxP, .maxQ, .minP, and .minQ are populated.
- For cim:EquivalentConnection objects used in representing adjacent licence area grids,
  .maxP, .maxQ, .minP, and .minQ are populated at local discretion.

4.3.3 Short Circuit (SC) profile data

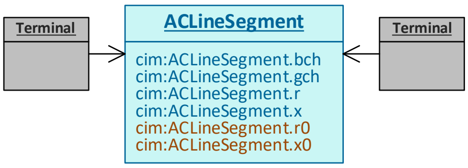
The Short Circuit profile describes equipment electrical behaviour characteristics essential to the execution of short circuit studies.

There is a very limited set of short circuit study input data in the 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.

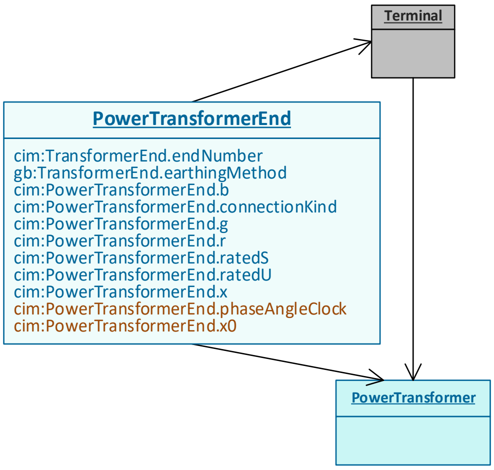
- Breaking and making capacity ratings are supplied for each cim:Breaker, including aggregate feeder breakers. Typically, rms break currents should be decremented to the expected protection operation time, however, undecremented rms break current may be provided if documented in an explanatory note in the cim:IdentifiedObject.description attribute of the cim:Breaker. 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.



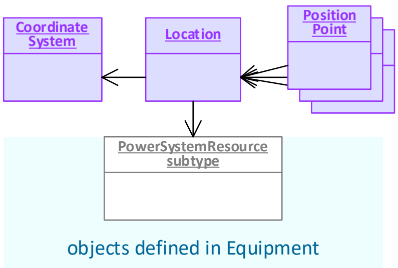
Also refer to *Grid Modelling Appendix 7 – LTDS Subset of CGMES Constraints Descriptions*:

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

4.3.4 Geographical Location (GL) profile data

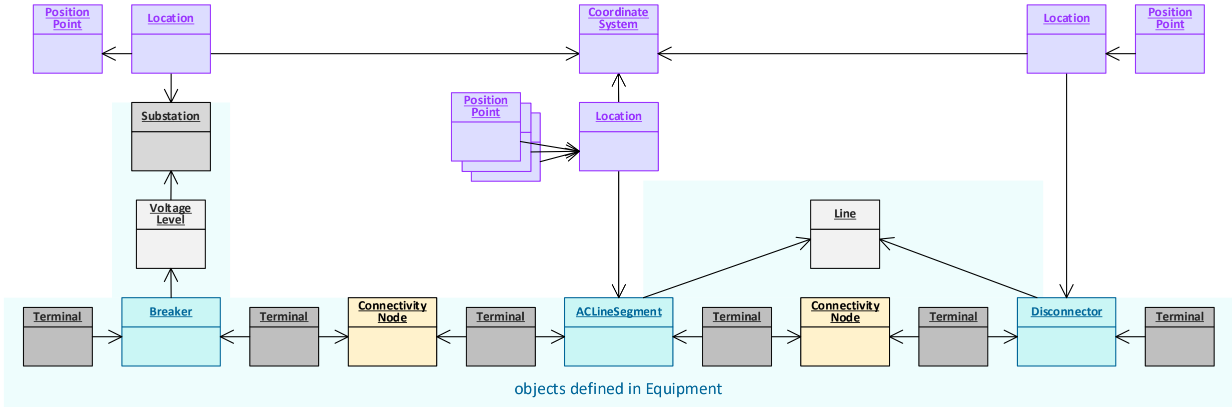
The Geographical Location profile describes the geospatial location of equipment, facilities, and load and generation.

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

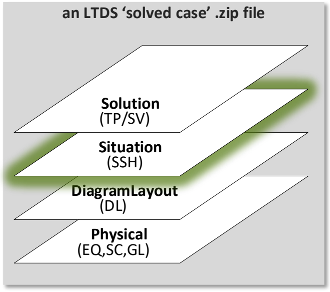
Notes on OPTIONAL attributes:

- 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 *Grid Modelling Appendix 7 – LTDS Subset of CGMES Constraints Descriptions*:

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

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.

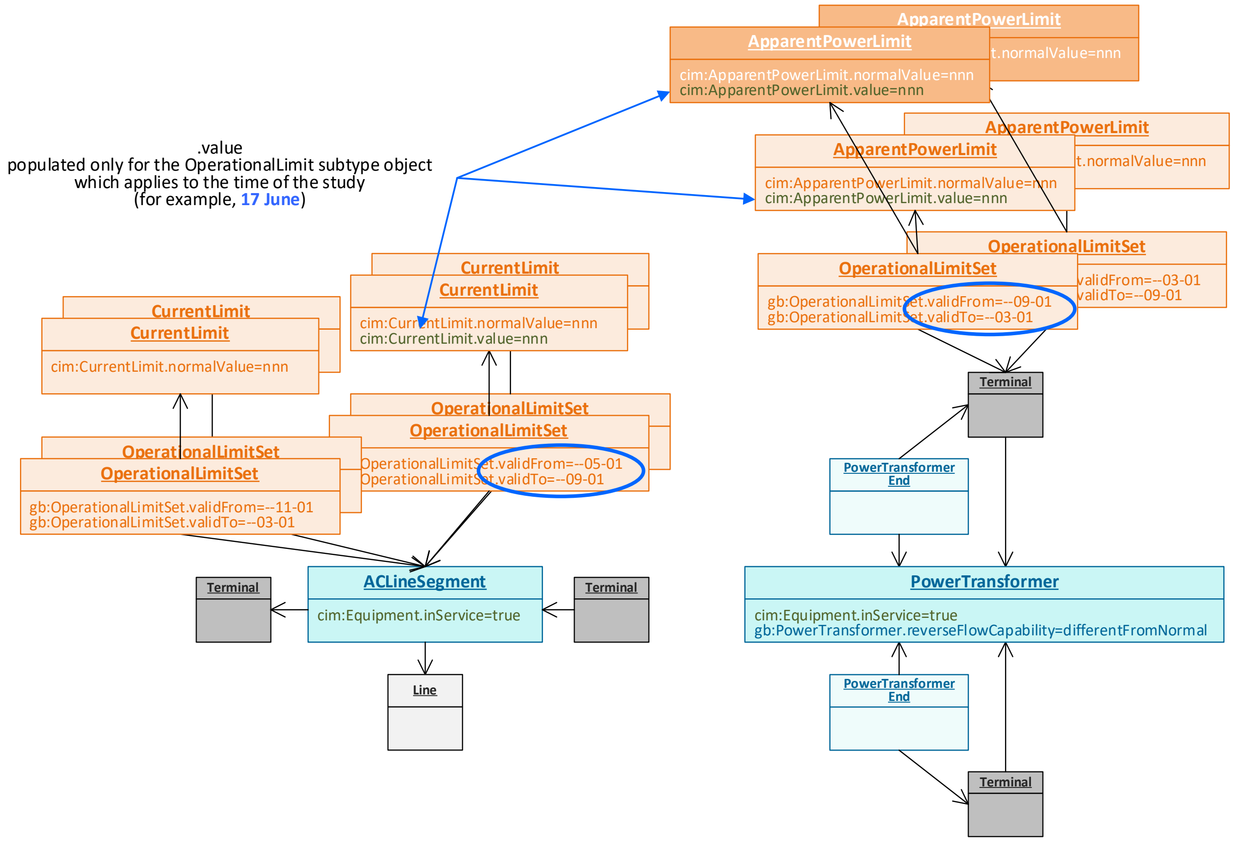
4.4.1 Steady State Hypothesis profile data

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			
Disconnector			
	REQUIRED	Equipment	inService
	REQUIRED	Switch	open
Fuse			
	REQUIRED	Equipment	inService
	REQUIRED	Switch	open
GroundDisconnector			
	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:

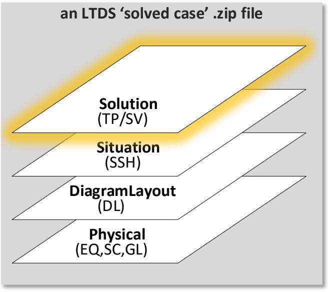
- For all cim:TapChangerControl objects,
  .maxAllowedTargetValue, .minAllowedTargetValue, and .targetDeadband are populated at local discretion.
- For all cim:RegulatingControl objects,
  .maxAllowedTargetValue, .minAllowedTargetValue, and .targetDeadband are populated at local discretion.
- For cim:EquivalentConnection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

Also refer to *Grid Modelling Appendix 7 – LTDS Subset of CGMES Constraints Descriptions*:

- 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

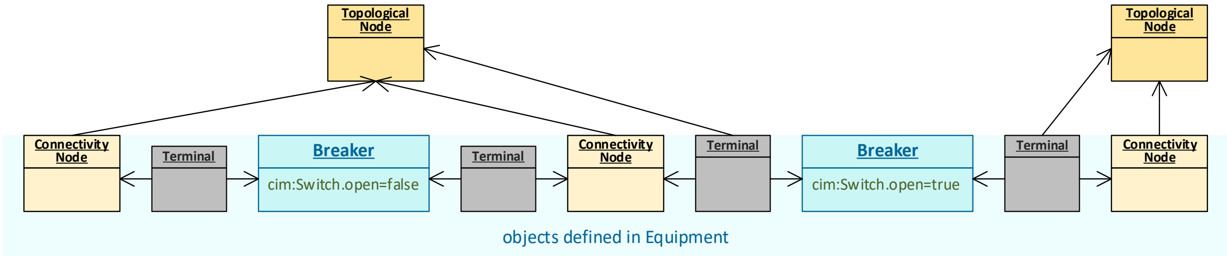
4.5 Solution modelling



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

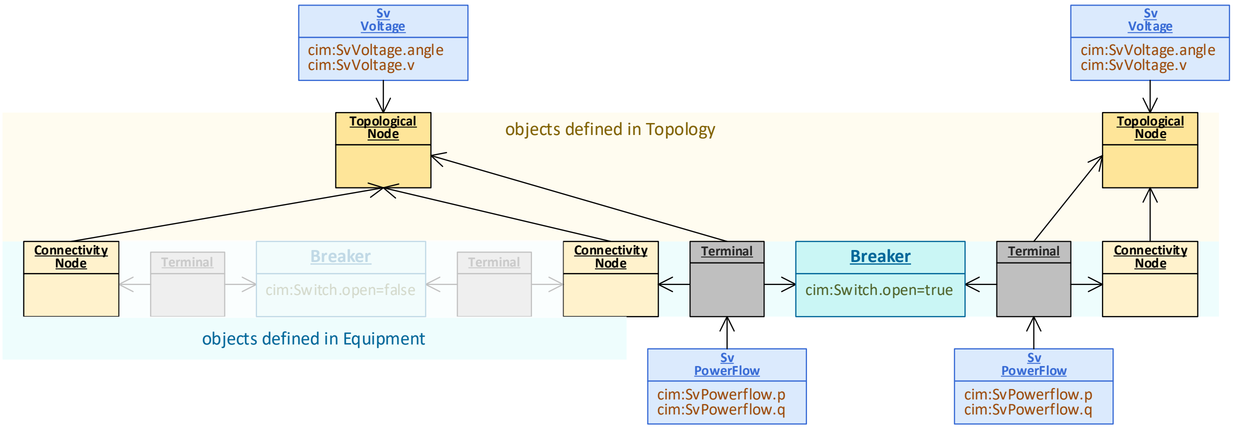
4.5.1 Topology profile data

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.

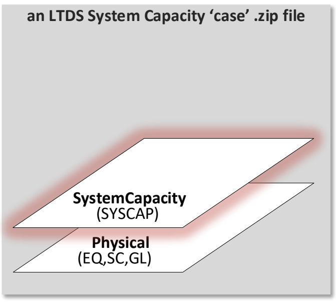


4.5.2 State Variables profile data

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.



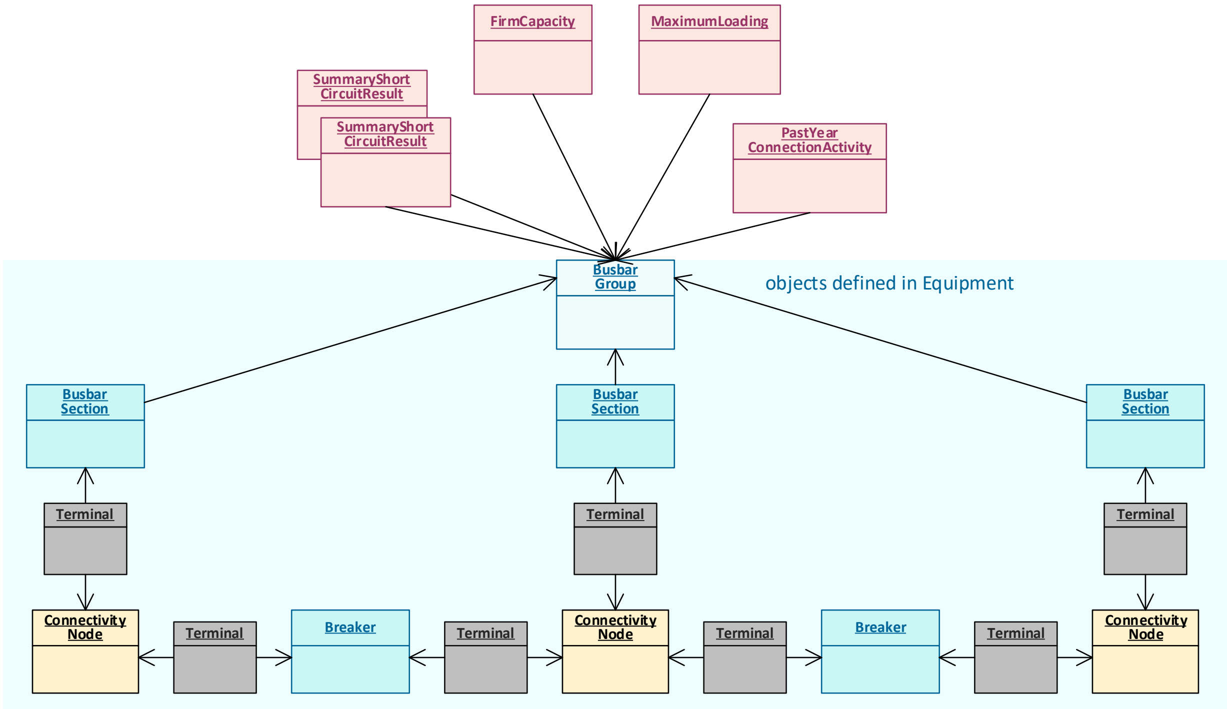
4.6 System capacity profile data



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

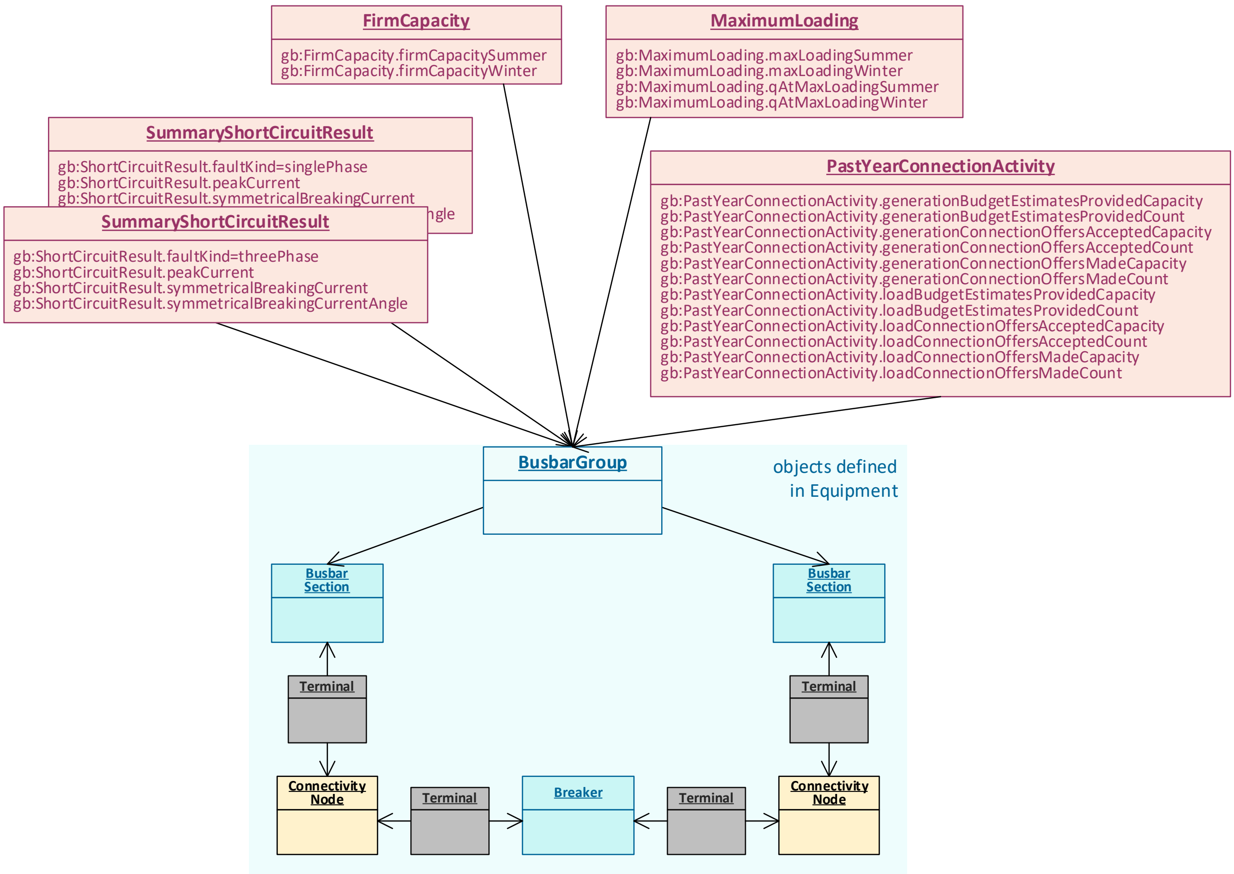
As described in the Bus section above, busbar groups represent sets of one or more connected busses normally operated as a single bus. In LTDS in CIM terms, a variety of information is associated with a busbar group:

- 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.

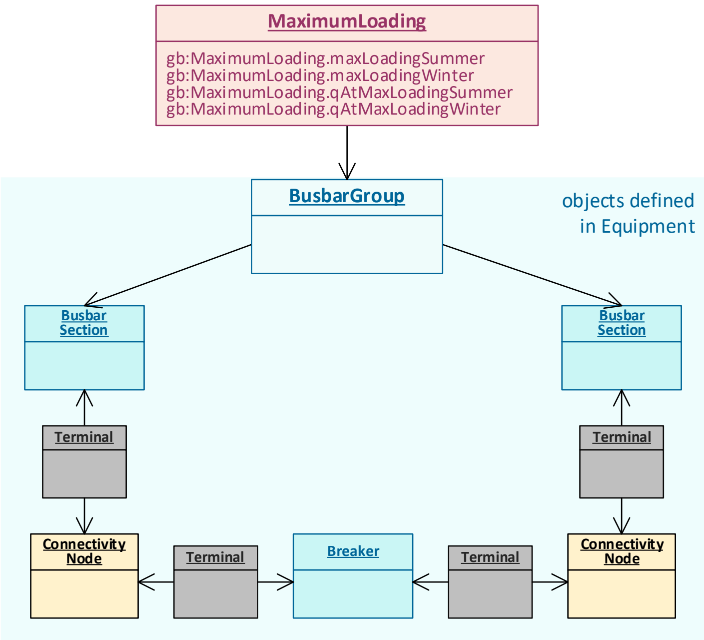
  Calculated fault currents should include all relevant contributions from synchronous and induction machines as well as other parts of the distribution network and other connected networks (transmission and distribution). A clear definition of the method used to calculate fault currents (including a description of the application of engineering recommendation G74) is to be documented in the Summary Information section of the licensee's LTDS publication. 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 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 7 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.

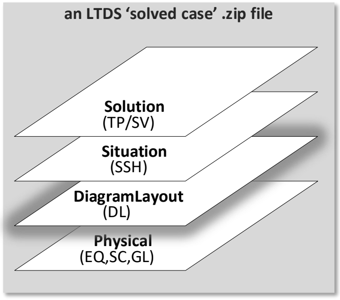
  The standard approach used by the licensee in calculating firm capacities is to be documented in the Summary Information section of the licensee's LTDS publication. For connected busses where the calculation deviates from the standard, additional explanatory information to assist in user interpretation is documented in the cim:IdentifiedObject.description attribute of the appropriate gb:FirmCapacity.
- 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 and represent peak load on the bus group under normal grid operating conditions.
- 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 busses at any BSP or lower voltage substation. The factors typically considered in determining forecast maximum loadings are to be documented in the Summary Information section of the licensee's LTDS publication. Special conditions or assumptions for a given bus group are described in the cim:IdentifiedObject.description attribute of the appropriate cim:MaximumLoading. Where forecast loadings apply to a single customer, then the distribution code submission (or equivalent) from the customer should be used.



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.

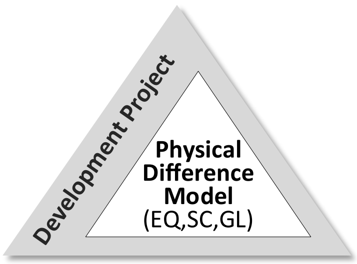
5 Project Modelling

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.

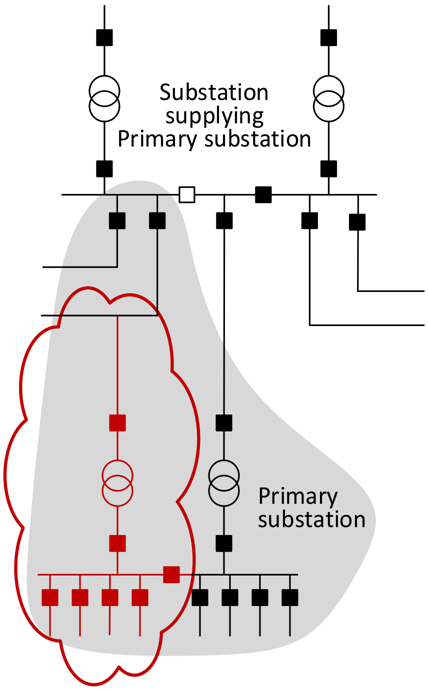
5.1 Development Project



An LTDS Development Project describes a planned licensee 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 4.3.1 Equipment (EQ) profile data, 4.3.3 Short Circuit (SC) profile data, or 4.3.4 Geographical Location (GL) profile data above. It is understood that in their early stages, development projects may be more simply described than the existing grid is and may not, if applied to an appropriate Full Model, fully satisfy the data requirements outlined above.

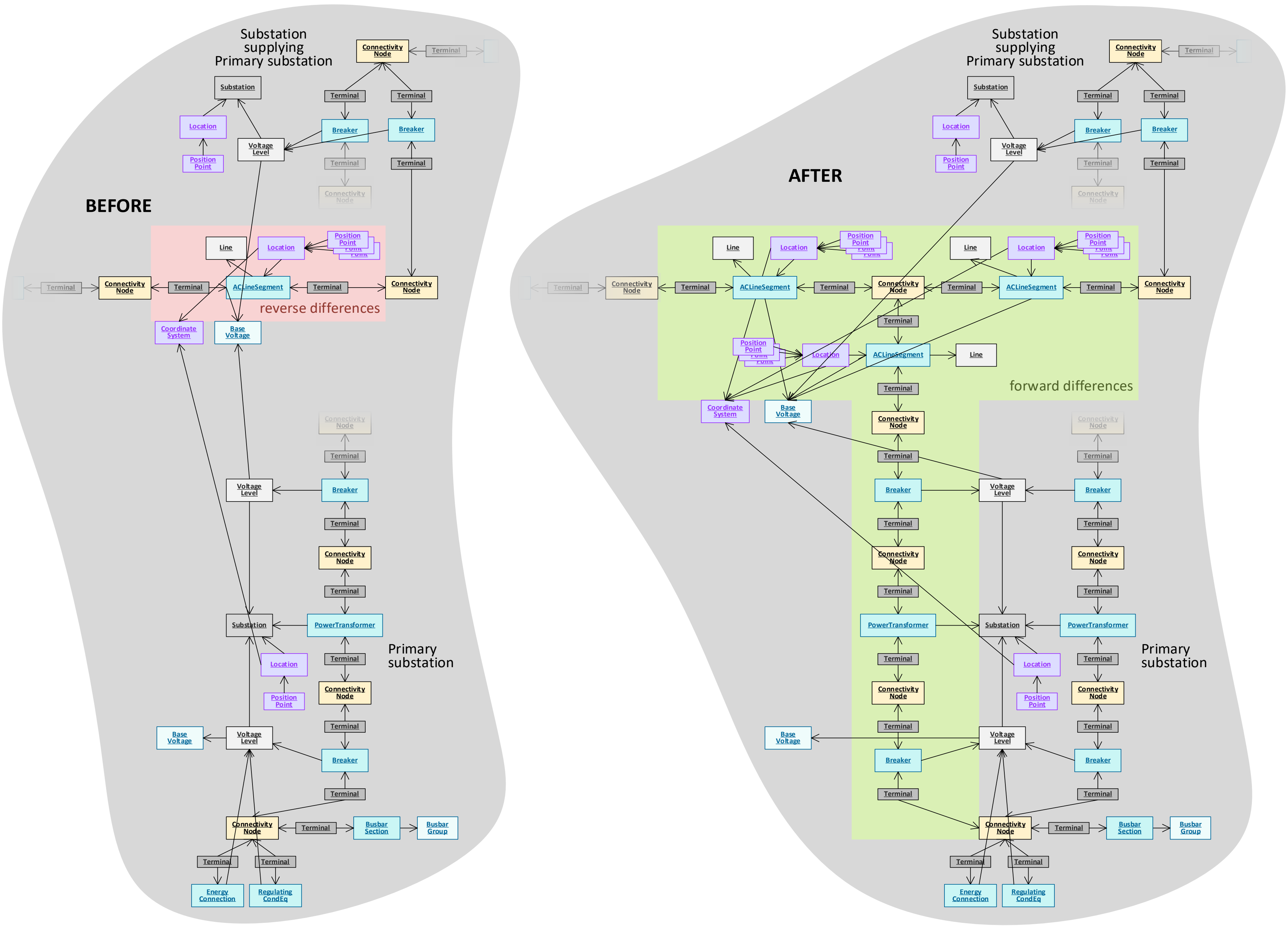
The Development Project .zip file contains a single Difference Model that describes a single project. The header of the Difference Model provides information about the project's estimated in-service time/date in its md:scenarioTime attribute. (Additional detail on the Difference Model header can be found in *LTDS Grid Modelling Annex 2 - 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.


BEFORE
Substation supplying Primary substation
reverse differences
Primary substation
AFTER
Substation supplying Primary substation
forward differences
Primary substation

6 LTDS and CGMES v3.0 Dual-Purpose Models

LTDS data exchange definitions use CGMES v3.0 as an underlying base. If a licensee desires to create a dual-purpose model to provide grid modelling which conforms to both LTDS and CGMES v3.0 exchange requirements, data beyond what is described above needs to be populated.

Machine-readable CIM-based data exchanges are described using both RDFS profiles and SHACL-based constraints. RDFS profiles define the structure of the exchanged data (i.e. the vocabulary) - classes, attributes, associations, and cardinalities. SHACL-based constraints (SHACL constraints) define rules related to the data content - more complex requirements which describe allowed or required instances, values and patterns. (See the 3.4 Constraints section of *LTDS Grid Modelling Annex 2 - Data Exchange Specifications* for more detail on the differences between profiles and constraints.) The sections below describe the additional information required in dual-purpose models as a consequence of RDFS profile and SHACL constraint differences between CGMES v3.0 and LTDS. The additional data requirements caused by RDFS profile differences are considered first, profile by profile. The subsequent section considers the consequences of differences in SHACL constraints.

6.1 Additional data required by CGMES v3.0 RDFS profiles

Attributes required to be added to LTDS profile-conformant models to make them CGMES v3.0 profile-conformant are shown in the tables below, along with guidance on their population, where appropriate. Attributes appear in the table if they are required by CGMES v3.0 and are "not defined" or "optional" in LTDS. Such attributes are present only in the EQ, SC and SSH profiles – none exist in the GL, DL, TP, or SV profiles.

There is also one, and only one, association difference between CGMES v3.0 and LTDS: in the TP profile, CGMES v3.0 requires that there be at least one cim:Terminal instance associated to a cim:TopologicalNode. LTDS does not have a similar requirement. (Note that the association was not included in LTDS because IEC CIM WG13 has decided that the association will not be included in future TP profiles.)

Attributes are listed in the tables below by the class in which they are defined. It's important to keep in mind that they apply equally to all subtype classes of the listed class. For instance, the cim:Switch.retained attribute which is identified as CGMES-required in the table below would also be required for all of cim:Switch's subtype classes (cim:Disconnector, cim:Fuse, cim:GroundDisconnector, cim:ProtectedSwitch, cim:Breaker, cim:DisconnectingCircuitBreaker, cim:LoadBreakSwitch).

Table of EQ profile attributes required by CGMES v3.0 but not by LTDS

Attributes listed in this table are required in the CGMES v3.0 EQ profile, while they are not defined in the LTDS EQ profile. These attributes must be populated in a dual-purpose model.

Class				
.attribute	**CIM/CGMES v3.0 definition**	**Attribute in LTDS**	**Attribute in CGMES v3.0**	**Information population guidance**
cim:BoundaryPoint				
.fromEndIsoCode	The ISO code of the region which the "From" side of the Boundary point belongs to or it is connected to. The ISO code is a two-character country code as defined by ISO 3166 (http://www.iso.org/iso/country_codes). The length of the string is 2 characters maximum.	not defined	**required**	GB
.fromEndName	A human readable name with length of the string 64 characters maximum. It covers the following two cases: -if the Boundary point is placed on a tie-line, it is the name (IdentifiedObject.name) of the substation at which the "From" side of the tie-line is connected to. -if the Boundary point is placed in a substation, it is the name (IdentifiedObject.name) of the element (e.g. PowerTransformer, ACLineSegment, Switch, etc.) at which the "From" side of the Boundary point is connected to	not defined	**required**	<Substation.name of this license area substation>
.fromEndNameTso	Identifies the name of the transmission system operator, distribution system operator or other entity at which the “From” side of the interconnection is connected to. The length of the string is 64 characters maximum.	not defined	**required**	<this licence area abbreviation> {EELC, EMEB, LOND, MANW, MIDE,NEEB, NORW, HYDE, SPOW, SEEB, SOUT, SWAE, SWEB, YELG}

.toEndIsoCode	The ISO code of the region which the “To” side of the Boundary point belongs to or is connected to. The ISO code is a two-character country code as defined by ISO 3166 (http://www.iso.org/iso/country_codes). The length of the string is 2 characters maximum.	not defined	**required**	GB
.toEndName	A human readable name with length of the string 64 characters maximum. It covers the following two cases: -if the Boundary point is placed on a tie-line, it is the name (IdentifiedObject.name) of the substation at which the “To” side of the tie-line is connected to. -if the Boundary point is placed in a substation, it is the name (IdentifiedObject.name) of the element (e.g. PowerTransformer, ACLineSegment, Switch, etc.) at which the “To” side of the Boundary point is connected to.	not defined	**required**	<Substation.name of substation in adjacent licence area (transmission or distribution) >
.toEndNameTso	Identifies the name of the transmission system operator, distribution system operator or other entity at which the "To" side of the interconnection is connected to. The length of the string is 64 characters maximum.	not defined	**required**	NGET, SPTL or SHETL (if adjacent licence area is transmission) or EELC, EMEB, LOND, MANW, MIDE, NEEB, NORW, HYDE, SPOW, SEEB, SOUT, SWAE, SWEB, or YELG (if adjacent licence area is distribution)
cim:GeneratingUnit				
.maxOperatingP	This is the maximum operating active power limit the dispatcher can enter for this unit.	optional	**required**	
.minOperatingP	This is the minimum operating active power limit the dispatcher can enter for this unit.	optional	**required**	

cim:PhaseTapChangerLinear				
.xMin <<deprecated>>	The reactance depends on the tap position according to a "u" shaped curve. The minimum reactance (xMin) appears at the mid tap position. PowerTransformerEnd.x shall be consistent with PhaseTapChangerLinear.xMin and PhaseTapChangerNonLinear.xMin. In case of inconsistency, PowerTransformerEnd.x shall be used.	not defined	**required**	
cim:PhaseTapChangerNonLinear				
.xMin <<deprecated>>	The reactance depend on the tap position according to a "u" shaped curve. The minimum reactance (xMin) appear at the mid tap position. PowerTransformerEnd.x shall be consistent with PhaseTapChangerLinear.xMin and PhaseTapChangerNonLinear.xMin. In case of inconsistency, PowerTransformerEnd.x shall be used.	not defined	**required**	
cim:Switch				
.retained	Branch is retained in the topological solution. The flow through retained switches will normally be calculated in power flow.	not defined	**required**	<provides guidance to consuming application’s topology processor, so setting should reflect consumer requirements. if all switches are retained this can cause numerical issues in the power flow computation due to excessive presence of zero impedance connections, therefore it is advised to minimise the number of cim:Switch objects with .retained=true. >
cim:WindGeneratingUnit				
.windGenUnitType	The kind of wind generating unit.	not defined	**required**	

Table of SC profile attributes required by CGMES v3.0 but not by LTDS

Attributes listed in this table are required in the CGMES v3.0 SC profile, while they are not defined in the LTDS SC profile. These attributes must be populated in a dual-purpose model.

Class				
.attribute	**CIM/CGMES v3.0 definition**	**Attribute in LTDS**	**Attribute in CGMES v3.0**	**Information population guidance**
cim:ACLineSegment				
.b0ch	Zero sequence shunt (charging) susceptance, uniformly distributed, of the entire line section.	not defined	**required**	
.g0ch	Zero sequence shunt (charging) conductance, uniformly distributed, of the entire line section.	not defined	**required**	
.shortCircuitEndTemperature	Maximum permitted temperature at the end of SC for the calculation of minimum short-circuit currents. Used for short circuit data exchange according to IEC 60909.	not defined	**required**	
cim:AsynchronousMachine				
.converterFedDrive	Indicates whether the machine is a converter fed drive. Used for short circuit data exchange according to IEC 60909.	not defined	**required**	
.efficiency	Efficiency of the asynchronous machine at nominal operation as a percentage. Indicator for converter drive motors. Used for short circuit data exchange according to IEC 60909.	not defined	**required**	
.ialrRatio	Ratio of locked-rotor current to the rated current of the motor (Ia/Ir). Used for short circuit data exchange according to IEC 60909.	not defined	**required**	
.polePairNumber	Number of pole pairs of stator. Used for short circuit data exchange according to IEC 60909.	not defined	**required**	
.ratedMechanicalPower	Rated mechanical power (Pr in IEC 60909-0). Used for short circuit data exchange according to IEC 60909.	not defined	**required**	

.reversible	Indicates for converter drive motors if the power can be reversible. Used for short circuit data exchange according to IEC 60909.	not defined	**required**	
cim:EquivalentInjection				
.r	Positive sequence resistance. Used to represent Extended-Ward (IEC 60909). Usage : Extended-Ward is a result of network reduction prior to the data exchange.	not defined	**required**	
.r0	Zero sequence resistance. Used to represent Extended-Ward (IEC 60909). Usage : Extended-Ward is a result of network reduction prior to the data exchange.	not defined	**required**	
.r2	Negative sequence resistance. Used to represent Extended-Ward (IEC 60909). Usage : Extended-Ward is a result of network reduction prior to the data exchange.	not defined	**required**	
.x	Positive sequence reactance. Used to represent Extended-Ward (IEC 60909). Usage : Extended-Ward is a result of network reduction prior to the data exchange.	not defined	**required**	
.x0	Zero sequence reactance. Used to represent Extended-Ward (IEC 60909). Usage : Extended-Ward is a result of network reduction prior to the data exchange.	not defined	**required**	
.x2	Negative sequence reactance. Used to represent Extended-Ward (IEC 60909). Usage : Extended-Ward is a result of network reduction prior to the data exchange.	not defined	**required**	
cim:LinearShuntCompensator				
.b0PerSection	Zero sequence shunt (charging) susceptance per section.	not defined	**required**	

.g0PerSection	Zero sequence shunt (charging) conductance per section.	not defined	**required**	
cim:NonlinearShuntCompensatorPoint				
.b0	Zero sequence shunt (charging) susceptance per section.	not defined	**required**	
.g0	Zero sequence shunt (charging) conductance per section.	not defined	**required**	
cim:PowerTransformer				
.isPartOfGeneratorUnit	Indicates whether the machine is part of a power station unit. Used for short circuit data exchange according to IEC 60909. It has an impact on how the correction factors are calculated for transformers, since the transformer is not necessarily part of a synchronous machine and generating unit. It is not always possible to derive this information from the model. This is why the attribute is necessary.	not defined	**required**	
cim:PowerTransformerEnd				
.b0	Zero sequence magnetizing branch susceptance.	not defined	**required**	
.g0	Zero sequence magnetizing branch conductance (star-model).	not defined	**required**	
.r0	Zero sequence series resistance (star-model) of the transformer end.	not defined	**required**	
cim:SeriesCompensator				
.r0	Zero sequence resistance.	not defined	**required**	
.varistorPresent	Describe if a metal oxide varistor (mov) for over voltage protection is configured in parallel with the series compensator. It is used for short circuit calculations.	not defined	**required**	
.x0	Zero sequence reactance.	not defined	**required**	
cim:SynchronousMachine				
.earthing	Indicates whether or not the generator is earthed. Used for short circuit data exchange according to IEC 60909.	not defined	**required**	
.r	Equivalent resistance (RG) of generator. RG is considered for the calculation of all currents, except for the calculation of the peak	not defined	**required**	

	current ip. Used for short circuit data exchange according to IEC 60909.			
.r0	Zero sequence resistance of the synchronous machine.	not defined	**required**	
.r2	Negative sequence resistance.	not defined	**required**	
.satDirectSubtransX	Direct-axis subtransient reactance saturated, also known as Xd"sat.	not defined	**required**	
.x0	Zero sequence reactance of the synchronous machine.	not defined	**required**	
.x2	Negative sequence reactance.	not defined	**required**	
cim:TransformerEnd				
.grounded	(for Yn and Zn connections) True if the neutral is grounded.	not defined	**required**	

Table of SSH profile attributes required by CGMES v3.0 but not by LTDS

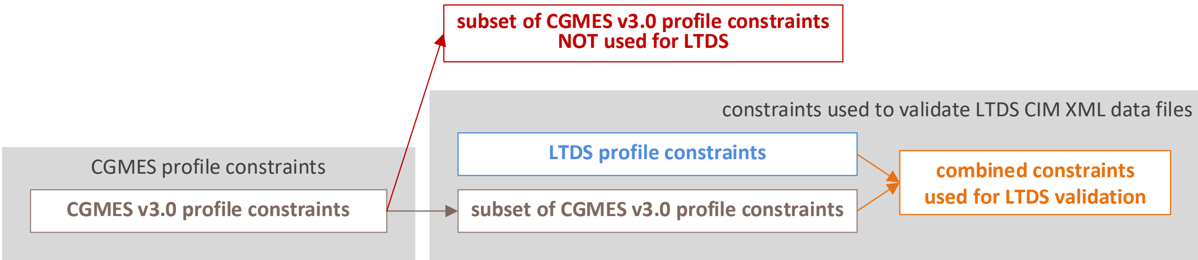
Attributes listed in this table are required in the CGMES v3.0 SSH profile, while they are not defined in the LTDS SSH profile. These attributes must be populated in a dual-purpose model.

Class				
.attribute	**CIM/CGMES v3.0 definition**	**Attribute in LTDS**	**Attribute in CGMES v3.0**	**Information population guidance**
cim:ACDCTerminal				
.connected	The connected status is related to a bus-branch model and the topological node to terminal relation. True implies the terminal is connected to the related topological node and false implies it is not. In a bus-branch model, the connected status is used to tell if equipment is disconnected without having to change the connectivity described by the topological node to terminal relation. A valid case is that conducting equipment can be	not defined	**required**	true

	connected in one end and open in the other. In particular for an AC line segment, where the reactive line charging can be significant, this is a relevant case.			
cim:BatteryUnit				
.batteryState	The current state of the battery (charging, full, etc.).	optional	**required**	
cim:Switch				
.locked	If true, the switch is locked. The resulting switch state is a combination of locked and Switch.open attributes as follows: • locked=true and Switch.open=true. The resulting state is open and locked; • locked=false and Switch.open=true. The resulting state is open; • locked=false and Switch.open=false. The resulting state is closed.	not defined	**required**	

6.1.1 Additional data required by SHACL constraints

SHACL constraints describe rules that relate to the content of exchanged data. There are more than 2000 CGMES v3.0 SHACL constraints. LTDS relies on a subset of them as a base which it augments with LTDS-specific constraints. (The CGMES subset is documented in *Grid Modelling Appendix 7 – LTDS Subset of CGMES Constraints Descriptions*. The LTDS-specific constraints will be documented during the LTDS in CIM implementation phase.) It is the subset of CGMES v3.0 constraints which are not used by LTDS (shown in red in the diagram below) that need to be considered in creating dual-purpose models.



The subset of CGMES v3.0 constraints not used for LTDS describes content-related rules that are either:

- Not relevant to LTDS (like constraints which relate to classes, attributes and associations which are not defined in LTDS) or
- In conflict with LTDS content-related rules (like, for example, the differing requirements related to OperationalLimitType instances).

There is little that can be done in a dual-purpose model to accommodate for latter case, where CGMES constraints conflict with LTDS constraints. It should be possible, however, to create modelling which satisfies most occurrences of the former case, where CGMES constraints pertain to classes, attributes and associations which are undefined by LTDS.

The aim of this section is to simply identify classes and attributes present in CGMES profiles – which might have SHACL constraints associated with them – which are not defined in LTDS. The analysis of the specific constraints in the subset of CGMES v3.0 constraints not used by LTDS and their applicability to specific classes, attributes or associations is beyond the scope of this document. It is suggested that producers of dual-purpose models validate them utilising the complete set of CGMES v3.0 SHACL constraints and a suitable SHACL-based validation tool.

It is worth noting that, depending on the grid being represented, it may not be possible to create a dual-purpose model that is simultaneously able to satisfy both the full set of CGMES v3.0 constraints and the LTDS constraints.

Table of EQ profile classes included in CGMES v3.0 but not defined by LTDS

An X in the table indicates a class which is defined in a CGMES v3.0 profile but is not defined in the corresponding LTDS profile. It is possible that CGMES v3.0-specific SHACL constraints exist which would require that instances of these classes be added to an LTDS model to create a dual-purpose model.

Class	EQ profile	SC profile	GL profile	SSH profile	TP profile	SV profile
ACDCConverter	X			X		X
ACDCConverterDCTerminal	X			X	X	
ACDCTerminal		X		X		
ActivePowerLimit	X			X		
AsynchronousMachine		X				
AuxiliaryEquipment	X			X		
BasicIntervalSchedule	X					
Bay	X					
BusbarSection		X				
BusNameMarker	X					
Clamp	X			X		
CogenerationPlant	X					
CombinedCyclePlant	X					
ConductingEquipment		X				
Conductor		X				
ConformLoad	X			X		
ConformLoadGroup	X					
ConformLoadSchedule	X					
Connector		X				
ControlArea	X			X		
ControlAreaGeneratingUnit	X					
CsConverter	X			X		X
CurrentTransformer	X			X		
Cut	X			X		
DayType	X					
DCBaseTerminal	X			X	X	
DCBreaker	X			X		
DCBusbar	X			X		
DCChopper	X			X		
DCConductingEquipment	X			X		
DCConverterUnit	X					
DCDisconnector	X			X		
DCEquipmentContainer	X				X	
DCGround	X			X		
DCLine	X					
DCLineSegment	X			X		
DCNode	X				X	

DCSeriesDevice	X			X		
DCShunt	X			X		
DCSwitch	X			X		
DCTerminal	X			X	X	
DCTopologicalIsland						X
DCTopologicalNode					X	X
EarthFaultCompensator	X	X		X		
EnergyArea	X					
EnergyConnection		X				
EnergySchedulingType	X					
EnergySource	X	X		X		
Equipment		X				
EquivalentBranch	X	X		X		
EquivalentEquipment		X				
EquivalentInjection		X				
EquivalentNetwork	X					
EquivalentShunt	X			X		
ExternalNetworkInjection	X	X		X		
FaultIndicator	X			X		
GrossToNetActivePowerCurve	X					
Ground	X			X		
GroundingImpedance	X	X		X		
HydroPump	X			X		
IdentifiedObject		X				
Jumper	X			X		
Junction	X			X		
LinearShuntCompensator		X				
LoadArea	X					
LoadGroup	X					
LoadResponseCharacteristic	X					
MutualCoupling		X				
NonConformLoad	X			X		
NonConformLoadGroup	X					
NonConformLoadSchedule	X					
NonlinearShuntCompensatorPoint		X				
StreetAddress <<Compound>>			X			
PetersenCoil	X	X		X		
TownDetail <<Compound>>			X			
PostLineSensor	X			X		
PotentialTransformer	X			X		
PowerSystemResource		X				
PowerTransformer		X				
RegularIntervalSchedule	X					
RegularTimePoint	X					
RegulatingCondEq		X				

RegulationSchedule	X					
ReportingGroup	X					
RotatingMachine		X				
Season	X					
SeasonDayTypeSchedule	X					
Sensor	X			X		
SeriesCompensator		X				
ServiceLocation			X			
ShuntCompensator		X				
SolarPowerPlant<<European>>	X					
StationSupply	X			X		
StreetDetail <<Compound>>			X			
Status <<Compound>>			X			
SubLoadArea	X					
SurgeArrester	X			X		
SwitchSchedule	X					
SynchronousMachine		X				
TapSchedule	X					
Terminal		X		X	X	
TieFlow	X					
TransformerEnd		X				
VoltageLimit	X			X		
VsCapabilityCurve	X					
VsConverter	X			X		X
WaveTrap	X			X		
WindPowerPlant<<European>>	X					
WorkLocation			X			

Table of EQ profile attributes optional in CGMES v3.0 but not defined by LTDS

The classes shown in this table are defined in both the CGMES v3.0 EQ profile and in the LTDS EQ profile and have attributes listed which are optional in the CGMES v3.0 EQ profile and are not defined in LTDS. While not populating these attributes would not cause CGMES v3.0 profile validation errors, it is possible that CGMES v3.0-specific SHACL constraints may exist which would require these attributes be populated in dual-purpose models. As in the profiles section above, attributes in this table are listed based on the class in which they are defined and apply equally to all subtype classes of the listed class.

Class	
.attribute	**CIM/CGMES v3.0 definition**
cim:BoundaryPoint	
.isDirectCurrent	If true, this boundary point is a point of common coupling (PCC) of a direct current (DC) interconnection, otherwise the interconnection is AC (default).
.isExcludedFromAreaInterchange	If true, this boundary point is on the interconnection that is excluded from control area interchange calculation and consequently has no related tie flows. Otherwise, the interconnection is included in control area interchange and a TieFlow is required at all sides of the boundary point (default).
cim:EnergyConsumer	
.pfixed	Active power of the load that is a fixed quantity and does not vary as load group value varies. Load sign convention is used, i.e. positive sign means flow out from a node.
.pfixedPct	Fixed active power as a percentage of load group fixed active power. Used to represent the time-varying components. Load sign convention is used, i.e. positive sign means flow out from a node.
.qfixed	Reactive power of the load that is a fixed quantity and does not vary as load group value varies. Load sign convention is used, i.e. positive sign means flow out from a node.
.qfixedPCT	Fixed reactive power as a percentage of load group fixed reactive power. Used to represent the time-varying components. Load sign convention is used, i.e. positive sign means flow out from a node.
cim:Equipment	
.normallyInService	Specifies the availability of the equipment under normal operating conditions. True means the equipment is available for topology processing, which determines if the equipment is energized or not. False means that the equipment is treated by network applications as if it is not in the model.
cim:GeneratingUnit	
.genControlSource	The source of controls for a generating unit. Defines the control status of the generating unit.

.governorSCD	Governor Speed Changer Droop. This is the change in generator power output divided by the change in frequency normalized by the nominal power of the generator and the nominal frequency and expressed in percent and negated. A positive value of speed change droop provides additional generator output upon a drop in frequency.
.longPF	Generating unit long term economic participation factor.
.maximumAllowableSpinningReserve	Maximum allowable spinning reserve. Spinning reserve will never be considered greater than this value regardless of the current operating point.
.nominalP	The nominal power of the generating unit. Used to give precise meaning to percentage based attributes such as the governor speed change droop (governorSCD attribute). The attribute shall be a positive value equal to or less than RotatingMachine.ratedS.
.ratedGrossMaxP	The unit's gross rated maximum capacity (book value). The attribute shall be a positive value.
.ratedGrossMinP	The gross rated minimum generation level which the unit can safely operate at while delivering power to the transmission grid. The attribute shall be a positive value.
.shortPF	Generating unit short term economic participation factor.
.startupCost	The initial startup cost incurred for each start of the GeneratingUnit.
.startupTime	Time it takes to get the unit on-line, from the time that the prime mover mechanical power is applied.
.totalEfficiency	The efficiency of the unit in converting the fuel into electrical energy.
.variableCost	The variable cost component of production per unit of ActivePower.
cim:HydroGeneratingUnit	
.dropHeight	The height water drops from the reservoir mid-point to the turbine.
.energyConversionCapability	Energy conversion capability for generating.
.turbineType	Type of turbine.
cim:IdentifiedObject	
.energyIdentCodeEic	The attribute is used for an exchange of the EIC code (Energy identification Code). The length of the string is 16 characters as defined by the EIC code. For details on EIC scheme please refer to ENTSO-E web site.
.shortName	The attribute is used for an exchange of a human readable short name with length of the string 12 characters maximum.
cim:StaticVarCompensator	
.sVCControlMode	SVC control mode.

.voltageSetPoint	The reactive power output of the SVC is proportional to the difference between the voltage at the regulated bus and the voltage setpoint. When the regulated bus voltage is equal to the voltage setpoint, the reactive power output is zero.
cim:VoltageLevel	
.highVoltageLimit	The bus bar's high voltage limit. The limit applies to all equipment and nodes contained in a given VoltageLevel. It is not required that it is exchanged in pair with lowVoltageLimit. It is preferable to use operational VoltageLimit, which prevails, if present.
.lowVoltageLimit	The bus bar's low voltage limit. The limit applies to all equipment and nodes contained in a given VoltageLevel. It is not required that it is exchanged in pair with highVoltageLimit. It is preferable to use operational VoltageLimit, which prevails, if present.

Table of SC profile attributes optional in CGMES v3.0 but not defined by LTDS

The classes shown in this table are defined in both the CGMES v3.0 SC profile and in the LTDS SC profile and have attributes which are optional in the CGMES v3.0 SC profile and are not defined in LTDS. While not populating these attributes would not cause CGMES v3.0 profile validation errors, it is possible that CGMES v3.0-specific SHACL constraints may exist which would require these attributes be populated in dual-purpose models. As above, attributes in this table are listed based on the class in which they are defined and apply equally to all subtype classes of the listed class.

Class	
.attribute	**CIM/CGMES v3.0 definition**
cim:AsynchronousMachine	
.rxLockedRotorRatio	Locked rotor ratio (R/X). Used for short circuit data exchange according to IEC 60909.
cim:BusbarSection	
.ipMax	Maximum allowable peak short-circuit current of busbar (Ipmax in IEC 60909-0). Mechanical limit of the busbar in the substation itself. Used for short circuit data exchange according to IEC 60909.
cim:PowerTransformer	
.beforeShCircuitHighestOperatingCurrent	The highest operating current (Ib in IEC 60909-0) before short circuit (depends on network configuration and relevant reliability philosophy). It is used for calculation of the impedance correction factor KT defined in IEC 60909-0.

.beforeShCircuitHighestOperatingVoltage	The highest operating voltage (Ub in IEC 60909-0) before short circuit. It is used for calculation of the impedance correction factor KT defined in IEC 60909-0. This is worst case voltage on the low side winding (3.7.1 of IEC 60909:2001). Used to define operating conditions.
.beforeShortCircuitAnglePf	The angle of power factor before short circuit (phib in IEC 60909-0). It is used for calculation of the impedance correction factor KT defined in IEC 60909-0. This is the worst case power factor. Used to define operating conditions.
.highSideMinOperatingU	The minimum operating voltage (uQmin in IEC 60909-0) at the high voltage side (Q side) of the unit transformer of the power station unit. A value well established from long-term operating experience of the system. It is used for calculation of the impedance correction factor KG defined in IEC 60909-0.
.operationalValuesConsidered	It is used to define if the data (other attributes related to short circuit data exchange) defines long term operational conditions or not. Used for short circuit data exchange according to IEC 60909.
cim:SeriesCompensator	
.varistorRatedCurrent	The maximum current the varistor is designed to handle at specified duration. It is used for short circuit calculations and exchanged only if SeriesCompensator.varistorPresent is true. The attribute shall be a positive value.
.varistorVoltageThreshold	The dc voltage at which the varistor starts conducting. It is used for short circuit calculations and exchanged only if SeriesCompensator.varistorPresent is true.
cim:SynchronousMachine	
.earthingStarPointR	Generator star point earthing resistance (Re). Used for short circuit data exchange according to IEC 60909.
.earthingStarPointX	Generator star point earthing reactance (Xe). Used for short circuit data exchange according to IEC 60909.
.ikk	Steady-state short-circuit current (in A for the profile) of generator with compound excitation during 3-phase short circuit. - Ikk=0: Generator with no compound excitation. - Ikk<>0: Generator with compound excitation. Ikk is used to calculate the minimum steady-state short-circuit current for generators with compound excitation. (4.6.1.2 in IEC 60909-0:2001). Used only for single fed short circuit on a generator. (4.3.4.2. in IEC 60909-0:2001).
.mu	Factor to calculate the breaking current (Section 4.5.2.1 in IEC 60909-0). Used only for single fed short circuit on a generator (Section 4.3.4.2. in IEC 60909-0).

.satDirectSyncX	Direct-axes saturated synchronous reactance (xdsat); reciprocal of short-circuit ration. Used for short circuit data exchange, only for single fed short circuit on a generator. (4.3.4.2. in IEC 60909-0:2001).
.satDirectTransX	Saturated Direct-axis transient reactance. The attribute is primarily used for short circuit calculations according to ANSI.
.shortCircuitRotorType	Type of rotor, used by short circuit applications, only for single fed short circuit according to IEC 60909.
.voltageRegulationRange	Range of generator voltage regulation (PG in IEC 60909-0) used for calculation of the impedance correction factor KG defined in IEC 60909-0. This attribute is used to describe the operating voltage of the generating unit.
cim:TransformerEnd	
.rground	(for Yn and Zn connections) Resistance part of neutral impedance where 'grounded' is true.
.xground	(for Yn and Zn connections) Reactive part of neutral impedance where 'grounded' is true.

7 Equivalent Infeed Impedance Calculations

7.1 Introduction

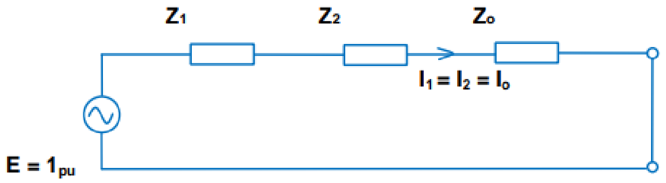
In place of explicitly specified positive and zero sequence impedance parameters (R1, X1, R0 and X0), Grid Modelling requires single and three phase fault current magnitudes and angles to be supplied. They can be used to calculate the impedance parameters and the equations for doing so are presented below.

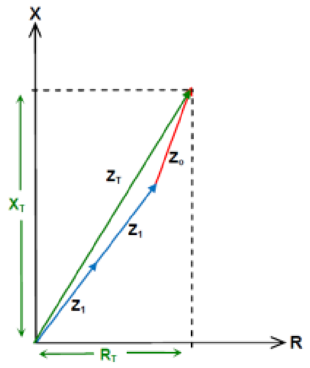
Note that the equations can produce negative zero sequence parameters. This is acceptable as the zero sequence parameters are not used in isolation, they are always combined with at least the positive sequence impedance in sequence networks analysis.

The following parameters are used by the equations:

- $I_{3\emptyset}$ – three phase fault current magnitude, in kA (exchanged using gb:ShortCircuitResult.symmetricalBreakingCurrent for gb:ShortCircuitResult.faultKind with value gb:ShortCircuitFaultKind.threePhase)
- $\theta_{3\emptyset}$ – three phase fault current angle, in degrees (exchanged using gb:ShortCircuitResult.symmetricalBreakingCurrentAngle for gb:ShortCircuitResult.faultKind with value gb:ShortCircuitFaultKind.threePhase)
- $I_{1\emptyset}$ – single phase fault current magnitude, in kA (exchanged using gb:ShortCircuitResult.symmetricalBreakingCurrent for gb:ShortCircuitResult.faultKind with value gb:ShortCircuitFaultKind.singlePhase)
- $\theta_{1\emptyset}$ – single phase fault current angle, in degrees (exchanged using gb:ShortCircuitResult.symmetricalBreakingCurrentAngle for gb:ShortCircuitResult.faultKind with value gb:ShortCircuitFaultKind.singlePhase)

7.2 Three phase fault





The following equations apply for three phase fault:

$$Z_1 = \frac{E}{I_1} \quad where\ I_1 = I_{3\emptyset(pu)} = \frac{I_{3\emptyset}}{I_B}\ ;\ I_B = \frac{MVA_B}{\sqrt{3}.V_L};\ MVA_B\ is\ base\ MVA;\ V_L\ is\ the\ line\ to\ line\ voltage$$

$$I_1 = \frac{I_{3\emptyset}}{\frac{MVA_B}{\sqrt{3}.V_L}} = \frac{\sqrt{3}.V_L.I_{3\emptyset}}{MVA_B};\ Z_1 = \frac{1}{\frac{\sqrt{3}.V_L.I_{3\emptyset}}{MVA_B}};$$

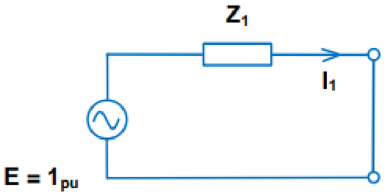
$$Z_{1(pu)} = \frac{MVA_B}{\sqrt{3}.V_L.I_{3\theta}};$$

$$Z_1 = R_1 + jX_1 = \frac{E\angle 0^o}{I_1\angle\theta_{3\emptyset}} = Z_1\angle(-\theta_{3\emptyset});$$

$$R_{1(pu)} = \frac{MVA_B}{\sqrt{3}.V_L.I_{3\emptyset}}cos(\theta_{3\emptyset});$$

$$X_{1(pu)} = \frac{MVA_B}{\sqrt{3}.V_L.I_{3\emptyset}}sin(-\theta_{3\emptyset});$$

7.3 Single phase fault



The following equations apply for single phase fault:

$$I_1 = \frac{E}{Z_1 + Z_2 + Z_3}; \quad I_1 = I_2 = I_0 = \frac{1}{3} I_{1\emptyset(pu)};$$

$$Assume\ Z_1 = Z_2, i.e. positive\ and\ negative\ sequence\ impedance\ are\ equal$$

$$I_{1\emptyset(pu)} = \frac{3E}{2Z_1 + Z_0} = \frac{3E}{Z_T}; \quad Z_T = \frac{3E}{I_{1\emptyset(pu)}}; \quad I_{1\theta(pu)} = \frac{I_{1\emptyset}}{I_B} = \frac{\sqrt{3}.V_L.I_{1\emptyset}}{MVA_B}; \quad I_B = \frac{MVA_B}{\sqrt{3}.V_L}$$

$$Z_T = \frac{3MVA_B}{\sqrt{3}.V_L.I_{1\emptyset}};$$

$$R_T = \frac{3MVA_B}{\sqrt{3}.V_L.I_{1\emptyset}} cos(\emptyset_{1\emptyset});$$

$$X_T = \frac{3MVA_B}{\sqrt{3}.V_L.I_{1\emptyset}} sin(-\emptyset_{1\emptyset});$$

$$R_0 = R_T - 2R_1;$$

$$X_0 = X_T - 2X_1;$$

$$R_{0(pu)} = \frac{3MVA_B}{\sqrt{3}.V_L.I_{1\emptyset}} cos\emptyset_{1\emptyset} - \frac{2MVA_B}{\sqrt{3}.V_L.I_{3\emptyset}} cos\emptyset_{3\emptyset} = \frac{MVA_B}{\sqrt{3}.V_L}\left[\frac{3cos\emptyset_{1\emptyset}}{I_{1\emptyset}} - \frac{2cos\emptyset_{3\emptyset}}{I_{3\emptyset}}\right];$$

$$Similarly,$$

$$X_{0(pu)} = \frac{MVA_B}{\sqrt{3}.V_L}\left[\frac{3\sin(-\emptyset_{1\emptyset})}{I_{1\emptyset}} - \frac{2sin(-\emptyset_{3\emptyset})}{I_{3\emptyset}}\right]$$

8 Terms, Definitions, and Abbreviated Terms

Common Grid Model Exchange Standard (CGMES)

The CGMES is a CIM-based profile and usage standard 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.

Extra High Voltage (EHV)

Extra High Voltage (EHV) refers to the extra high voltage infrastructure on distribution networks. These are distribution network assets with nominal voltages of at least 22kV.

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.

9 List of Grid Modelling Appendices

Grid Modelling Information Model

- *Grid Modelling Appendix 1 – LTDS Information Model and Profiles in UML*
  This is the Enterprise Architect .eap file which includes LTDS information model and the profiles, both required and optional.

- *Grid Modelling Appendix 2 – LTDS Information Model Extension Definitions and Diagrams*
  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.

Grid Modelling Profiles

- *Grid Modelling Appendix 3 – 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.

- *Grid Modelling Appendix 1 – LTDS Information Model and Profiles in UML*
  This is the Enterprise Architect .eap file which includes LTDS information model and the profiles, both required and optional.

- *Grid Modelling Appendix 4 – LTDS Difference Profile Definitions and Diagrams*
  This is a Word document with machine-generated content from .eap with diagrams explaining each LTDS deviation and extended profile (visually and in words) along with version information for each profile.

- *Grid Modelling Appendix 5 – LTDS Merged Profile Class and Attribute Lists*
  This is an Excel spreadsheet summarising:
    - Classes and attributes used by LTDS
    - LTDS vs CGMES profile classes and enumerations.

Grid Modelling Constraints

- *Grid Modelling Appendix 6 – LTDS Subset of CGMES 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.

- *Grid Modelling Appendix 7 – LTDS Subset of CGMES Constraints Descriptions*
  This is a Word document containing tables with descriptions of the relevant CGMES v3.0 constraints.

Additional CIM profile developed in conjunction with LTDS revision, but not required by Form of Statement

- *General Appendix 1 – Short Circuit Result Profile Definitions and Diagrams*
  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.