European Network of
Transmission System Operators
for Electricity

BOUNDARY AND REFERENCE DATA EXCHANGE APPLICATION SPECIFICATION

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APPROVED DOCUMENT
VERSION 1.0

This document is maintained by the ENTSO-E CIM WG. Comments or remarks are to be provided at cim@entsoe.eu

NOTE CONCERNING WORDING USED IN THIS DOCUMENT

The force of the following words is modified by the requirement level of the document in which they are used.

- SHALL: This word, or the terms “REQUIRED” or “MUST”, means that the definition is an absolute requirement of the specification.
- SHALL NOT: This phrase, or the phrase “MUST NOT”, means that the definition is an absolute prohibition of the specification.
- SHOULD: This word, or the adjective “RECOMMENDED”, means that there may exist valid reasons in particular circumstances to ignore a particular item, but the full implications must be understood and carefully weighed before choosing a different course.
- SHOULD NOT: This phrase, or the phrase “NOT RECOMMENDED”, means that there may exist valid reasons in particular circumstances when the particular behaviour is acceptable or even useful, but the full implications should be understood and the case carefully weighed before implementing any behaviour described with this label.
- MAY: This word, or the adjective “OPTIONAL”, means that an item is truly optional.

Revision History

Version	Release	Date	Paragraph	Comments
0.1	0	2022-01-31		Initial version
0.2	0	2023-02-15		Version for CIM WG review
1.0	1.0	2023-03-01		Approved document

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1 Introduction

Boundary datasets use the definitions of boundary profiles (Equipment boundary, EQBD and Topology boundary, TPBD) defined in previous IEC CGMES versions. Starting with CGMES v3.0 of 2021, the TPBD profile has been discontinued, while the EQBD profile has been only deprecated – to allow for smooth transition to its new counterpart: simply the Core Equipment (Core EQ) profile. In other words, Core EQ profile is to be used as governing profile for boundary datasets for new developments, as it is covering a wider set of use cases, while the deprecated EQBD profile can still be used for a transition period.

There are additional needs for header and metadata information to support the addition Network Code services as Coordinated Security Analysis (CSA), Coordinated Capacity Calculation (CCC) and Outage Planning Coordination (OPC) that require usage of Common Grid Model (CGM). Therefore, ENTSO-E approved “Metadata and document header data exchange specification” to extend both CGMES v3 and IEC 61970-552:2016 (header part of the standard).

As part of the Network Code profile the Equipment Reliability are also included as part of the governing profiles for the boundary dataset.

In general, addition to the IEC standards (such as e.g. CGMES 3.0) or ENTSO-E specifications (such as, e.g., CSA profiles), there are three types of documents that should be considered when implementing these profiles.

- “Metadata and document header data exchange specification” (nickname “Header”) is an ENTSO-E specification describing the metadata and header data, which complements Network codes profiles (also sometimes referred to as CSA profiles)
- “Boundary and Reference data specification” (nickname “Boundary”) is this document, which extends CGMES (IEC 61970-600-1:2021 and IEC 61970-600-2:2021). It is at present an ENTSO-E specification, but will be integrated in the next edition of IEC CGMES standard, e.g. v3.1. It refers to “Metadata and document header data exchange specification” and it is to be applied in all CGMES v3 applications that need to support CGM process (perhaps TYNDP as well).
- Each business process, such as CSA, CC, OPC or TYNDP, creates Implementation guide (IG) that refers to header and boundary documents and describes how to use them for their own process. However, IG can only constrain and shall not extend or contradict other documents. The IGs are reviewed and agreed by CGMES SG and recommended to CIM WG.

The following figure illustrated the main documents.

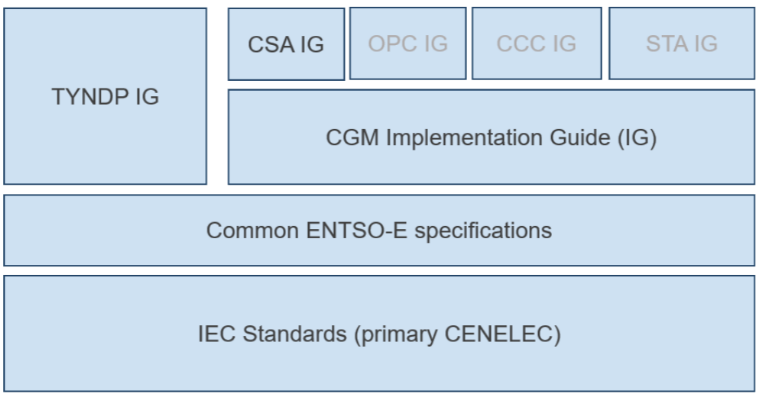


Figure 1 Hierarchy of specifications and implementation guides.

1.1 Implementation in standards

This document contains specification and guidance related to boundary data and reference data. The intention is that the content is included in next revision of related standards. However, the standardisation process may take 1-2 years. Therefore, in the meantime, the approved version of this specification can be implemented and will be referenced from various implementation packages, e.g. a package that contains all relevant document for the implementation of processes such as CGM building process or TYNDP process.

In case an application (software) is used in multiple business processes which may require support of boundary datasets that are exchanged either in one or many instance files, this application should support all different ways specified in this document. This is also recommended practice to be able to transition to the new way of handling boundaries and reference data.

2 Scope

This document specifies improved handling of boundary and reference data. It defines the business constraints related to them. Therefore, it assumes that readers are familiar with related data exchange standards and either have or plan to have applications conform to data exchange standards prior implementing business constraints defined in this document.

3 Normative references

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

- IEC 61970-600-1:2021 Energy management system application program interface (EMS-API) - Part 600-1: Common Grid Model Exchange Standard (CGMES) - Structure and rules;
- IEC 61970-600-2:2021 Energy management system application program interface (EMS-API) - Part 600-2: Common Grid Model Exchange Standard (CGMES) - Exchange profiles specification.
- IEC 60633 Edition 2.1 Terminology for high-voltage direct current (HVDC) transmission

4 Terms and definitions

4.1

dataset
RDF(S)/OWL file that contains individuals that comply with the classes as specified by ontologies

[SOURCE: ISO 21597-1:2020, 3.1.10]

4.2

model
collection of data describing instances, objects or entities, real or computed. In the context of CIM the semantics of the data is defined by profiles. Hence a model can contain equipment data, power flow initial values, power flow results etc.

Note 1 to entry: In power system analysis, a model is a set of static data describing the power system. Examples of Models include the Static Network Model, the Topology Solution, and the Network Solution produced by a power flow or state estimator application.

[SOURCE: IEC 61970-552:2016, 3.8]

4.3

modelling authority set

an abstract entity which is attributed to an agent (modelling authority). The modelling authority set is versioned by the agent.

4.4

modelling authority set version

a specialization of the modelling authority set which is attributed to an agent. A version of the modelling authority set can be seen as an envelop for models which conform to different profiles.

4.5

model exchange

the storing, accessing, transferring, and archiving of models

4.6

profile

schema that defines the structure and semantics of a model that may be exchanged

Note 1 to entry: A Profile is a restricted subset of the more general CIM.

[SOURCE: IEC 61970-552:2016, 3.9]

4.7

profile document

collection of profiles intended to be used together for a particular business purpose

[SOURCE: IEC 61970-552:2016, 3.10]

5 Abbreviated terms

CIM	Common Information Model (electricity)
CGMES	Common Grid Model Exchange Standard
CGM	Common Grid Model
DSO	Distribution System Operator
ENTSO-E	European Network of Transmission System Operators for Electricity
IEC	The International Electrotechnical Commission
IGM	Individual Grid Model
SO	System Operator
MAS	Model Authority Set
NC	Network codes
RDF	Resource Description Framework
RDFS	RDF Schema
SHACL	Shapes Constraint Language
TSO	Transmission System Operator
URI	Uniform Resource Identifier

6 Boundary datasets specification

6.1 Requirements

IGMs and CGMs need to support multiple processes which requires the following additional information and general terms:

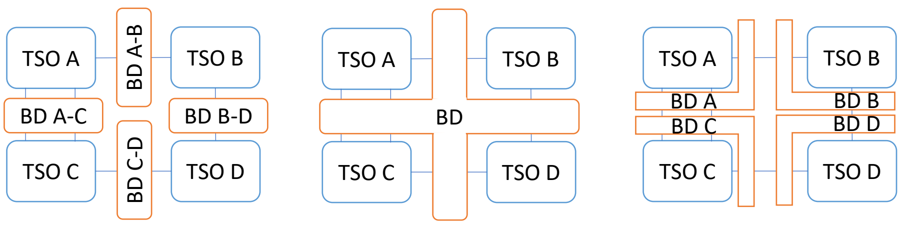
- usage of reference data;
- support of boundary point in a substation which also needs to take into account boundary point setup for HVDC interconnections;
- full coverage of TSO-DSO data exchange which requires new boundary considerations.

6.2 General concept

The following additional requirements are defined:

- Boundary datasets are bilateral, i.e. agreed between entities connected or responsible for the boundary elements between them. Boundary datasets can be exported:
  - per two MAS (e.g. TSO) border,
  - per MAS (e.g. TSO),
  - per region (e.g. Continental Europe, Nordic, pan-European, etc).

The following figure is illustrating different split options for the boundary dataset. In option a) there are four boundary instance files for each of the borders; in option b) there is one boundary set which covers all borders; in option c) each TSO has separate boundary dataset. There is no overlap between boundary information in option a) and b), while in option c) the boundary information between two MAS (TSOs) is duplicated. Option c) is only useful when for instance TSO A exchanges its boundary with the DSOs. However, this can also be achieved in similar manner using option a).



Option a) per border   Option b) per region   Option c) per TSO

- The versioning of the boundary sets is per collection, i.e. a set of per two MAS border, per MAS (e.g. TSO) or mixed exports of boundary datasets. There could be duplications between boundaries part of the set (export), but all boundary information shall be consistent and provided as a package or one or many datasets, i.e. it is not allowed for a package to include different versions of boundary datasets, e.g. pan-European boundary set valid for Jan 2023 cannot be package together with pan-European boundary set valid for Jan 2021.
- The tools shall be able to import multiple boundaries as a set (the package of which is versioned).

- A boundary dataset shall contain all containers that are shared between two neighbouring MAS. Therefore, SubGeographicalRegion and GeographicalRegion shall be defined in the reference data and shall not be redefined in a boundary set.

- No individual instance dataset can include duplicates. Network model management tools and merging tools shall support duplicates existing in IGMs coming from (also defined in) boundary and reference data. If there are duplicates, they shall be defined in reference or boundary data. Duplication of any other non-boundary related information is not allowed.

- Merged instance dataset shall not have any duplicates that were there for the purpose of a pre-merge process. However, the application may need to keep track on the duplications in order to be able to support disassembling process.

- BoundaryPoint-s shall be kept in a merged model to support disassembly.

- Each HVDC Pole has two BoundaryPoint-s. Depending on the HVDC modelling the following exports/imports shall be supported:

    - An exporting party shall support one or more of injection models in their AC IGM and may also export DC IGMs.

    - An importing party shall support all the injection models in the AC IGMs and may also support import of DC IGMs.

- The modelling authority governing the boundary dataset and the version of the modelling authority set providing the boundary dataset depends on the scope of the exchange supported by the boundary dataset. In some cases, the modelling authority can be an organisation like ENTSO-E and in other cases it could be an entity (e.g. system operator) that manages a local boundary dataset, e.g. boundary dataset between a TSO and DSOs.

6.3 Data content

6.3.1 Header

The document “Metadata and document header data exchange specification” describes the header that accompanies the boundary datasets as well as the packaging and linking the data via a manifest instance file.

6.3.2 Main data content

6.3.2.1 Amendments to IEC 61970-600-1:2021

The following amendments are applied to existing rules and constraints in CGMES v3:

- The standard shall specify that:

    - Equipment profile data can be exchanged together with Equipment Reliability profile (part of NC profiles) in one instance file.

    - Steady State Hypothesis profile data can be exchanged together with Steady State Instructions profile (part of the NC profiles) in one instance file.

- In addition, the following table provides some detailed changes.

Reference	Old text	New text	Status, justification
EQBD2	The equipment boundary profile defines which instance data represents types or voltages which are agreed for the CGMES based exchanges. Therefore, individual grid models shall refer to the equipment boundary instance file to use declared EnergySchedulingType-s, GeographicalRegion-s (EQ__4 does not apply for equipment boundary profile and instance data) and BaseVoltage-s. This does not limit different model authorities when it comes to defining additional types or voltages in their instance files (distribution), although there shall not be an overlap of data values between equipment boundary files and individual grid model instance files.	Left blank intentionally.	deleted as reference data instance is not included in the boundary dataset
FILX3	One zip file may only contain the following types of files: – A single instance file (distribution) of the following types: equipment (EQ), equipment boundary (EQBD), topology (TP), steady state hypothesis (SSH), state variables (SV), dynamics (DY), diagram layout (DL), geographical location (GL). – Combinations of equipment, topology, steady state hypothesis, state variables, dynamics, diagram and geographical instance files which are allowed by the CGMES and are related to one MAS only.	One zip file may only contain the following types of files: – A single XML instance file (distribution). – Multiple XML instance files that are related to one or more MAS. – Difference XML files of one or more MAS. – Boundary MAS XML instance files (full or difference) - Reference instance data – one or many XML instance files	

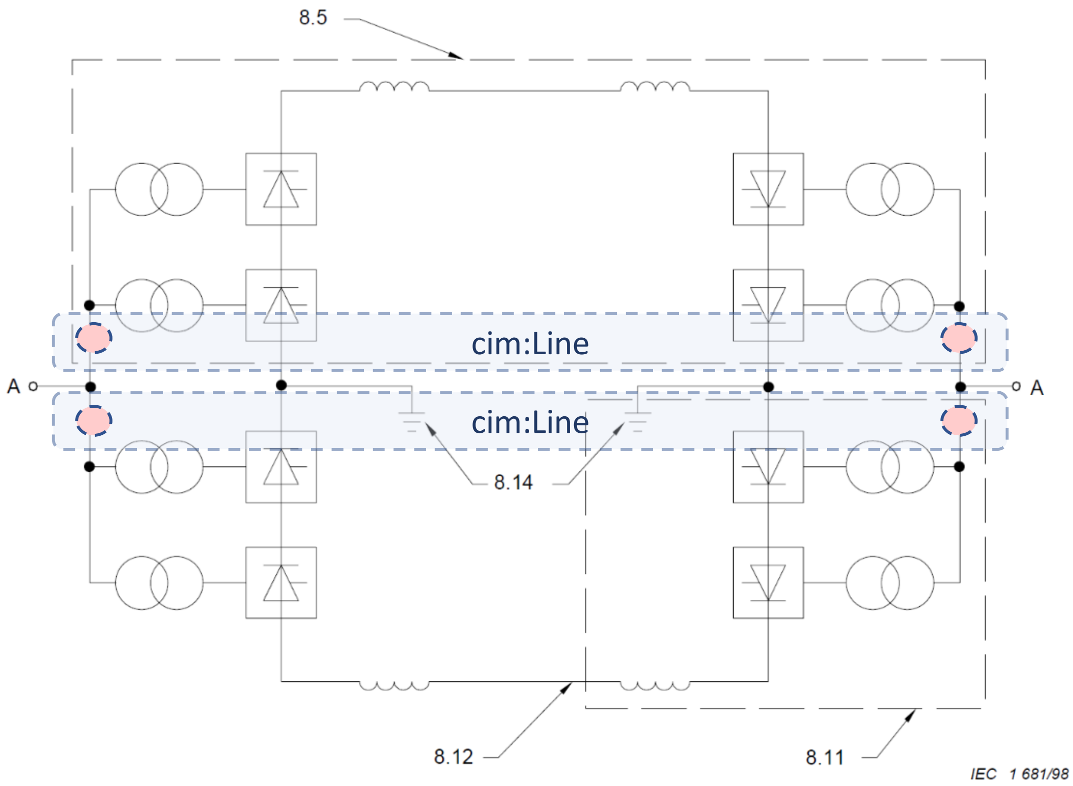
	– Difference files of one MAS. – Equipment, topology, steady state hypothesis, state variables, dynamics, diagram and geographical files per MAS for an merged model. – Difference files per MAS for an merged model. – Boundary MAS instance files (full or difference if the merged model is expressed with difference files) shall always be included in the zip file containing an merged model		
BPPL5	There are two main representations/exchanges of an HVDC link which are supported by the CGMES: – Simplified exchange (no exchange of the AC/DC part of the HVDC interconnections. A HVDC link is represented with two radial AC lines). – Detailed exchange (AC/DC part of HVDC links is exchanged).	replaced by the information in section “HVDC modelling alternatives”	
BBPL6	In the simplified exchange of an HVDC link the net interchange between the MAS is represented by EquivalentInjection classes referring to each common coupling node (CC).	For an HVDC link (modelled as simplified or detailed) the net interchange between the MAS-s is represented by EquivalentInjection classes referring to each common coupling node (CC), i.e. the BoundaryPoint.	Modified. The point of common coupling for an ACDCConverter is a Terminal connected to the BoundaryPoint.
BPPL8	In the detailed exchange of an HVDC link the HVDC grid shall be exchanged as a MAS: – Separate instance files (EQ, TP, SSH, SV) are	In the detailed exchange of an HVDC link the HVDC grid shall be exchanged as a MAS: – Separate instance files (EQ, TP, SSH, SV) are included in an HVDC MAS, or	Modified. It is allowed business processes to restrict detailed HVDC MAS to be exchanged separately also if it is part of

	included in a HVDC MAS, or – In case one system operator (TSO or DSO) is responsible for the HVDC, the HVDC model is included in the system operator MAS (EQ, TP, SSH, SV).	– In case one system operator (TSO or DSO) is responsible for the HVDC, the HVDC model can be included in the system operator MAS (EQ, TP, SSH, SV).	internal to the MAS grid.
BPPL9	In case of a detailed exchange of an HVDC link, the HVDC MAS shall refer to the common coupling points (ConnectivityNode) included in the Boundary set.	In case of a detailed exchange of an HVDC link, the HVDC MAS shall refer to the common coupling points (ConnectivityNode) associated with a BoundaryPoint. ACDCConverter.PccTerminal shall be a Terminal that is connected to a BoundaryPoiint	Modified
BPPL12	The objective of this version of the CGMES is to enable a possibility to make a bilateral agreement based on the EQ profile vocabulary. The reason for this is that the content of the boundary can be different among different business processes. The recommendation is that the agreement is as minimalistic as possible preferably just a ConnectivityNode. For instance, the boundary data set of IEC 61970-600-2 are considered to meet this requirement. **It is recommended that model parts intended for model assembly do not contain boundary information, i.e. no overlap of data between model parts and boundary instance files.**	The objective of this version of the CGMES is to enable a possibility to make a bilateral agreement based on the EQ profile vocabulary. The reason for this is that the content of the boundary can be different among different business processes. The recommendation is that the agreement is as minimalistic as possible preferably just a ConnectivityNode. For instance, the boundary dataset of IEC 61970-600-2 are considered to meet this requirement.	
PROF10	CGMES instance file (distribution) dependency shall be declared by md:Model.DependentOn in the header according to Figure 1 and the associated rules.	CGMES instance file (distribution) dependency shall be declared by md:Model.DependentOn (**prov:Model.wasInfluencedBy in the new header)** in the header according to Figure 1 and the associated rules.	

	Rules: • Diagram Layout [DL] shall be associated with one or more in {Core Equipment [EQ], Topology [TP], Dynamics [DY]} • Geographical Location [GL] shall be associated with one or more in {Equipment Boundary [EQBD], Core Equipment [EQ]} • Topology [TP] shall be associated with one or more Steady State Hypothesis [SSH]. The cardinalities of dependencies shown in Figure 1 are the minimum requirement. It is allowed, but not required, to include indirect references (references made by the referred instance file). It is expected that by including all instance files defined in the DependentOn references and the referred files DependentOn there shall not be any dangling references (e.g. no object is pointing to a non-existing object in the assembled or merged model).	Rules: • Diagram Layout [DL] shall be associated with one or more in {Core Equipment [EQ], Topology [TP], Dynamics [DY]} • Geographical Location [GL] shall be associated with one or more in {Equipment Boundary [EQBD], Core Equipment [EQ]} • Topology [TP] shall be associated with one or more Steady State Hypothesis [SSH]. • **References to used reference data shall be provided.** The cardinalities of dependencies shown in Figure 1 are the minimum requirement. It is allowed, but not required, to include indirect references (references made by the referred instance file). It is expected that by including all instance files defined in the DependentOn references and the referred files DependentOn there shall not be any dangling references (e.g. no object is pointing to a non-existing object in the assembled or merged model).	

6.3.2.2 Boundary point for HVDC interconnection

The concept of an HVDC Pole is defined in IEC 60633 and is shown in Figure 2.



Key

A	AC system	8.12	HVDC transmission line
8.5	HVDC system pole	8.14	Earth electrodes
8.11	Substation pole		

Figure 2 Definitions as defined in IEC 60633

In this document item 8.5 “HVDC system pole” in Figure 2 is called an “HVDC Pole", not an “HVDC system pole”. Each HVDC Pole has a boundary point at each side which means two boundary points per HVDC Pole as shown by the red circles in Figure 2. Figure 2 also shows the point of common coupling (PCC) at “A” but the branches from the PCC to the HVDC Poles is not shown with enough detail to indicate the locations of the PccTerminals. The PccTerminal is shown in Figure 3, which illustrates the connection mechanism of IGMs via boundary points that follows the process defined in CGMES.

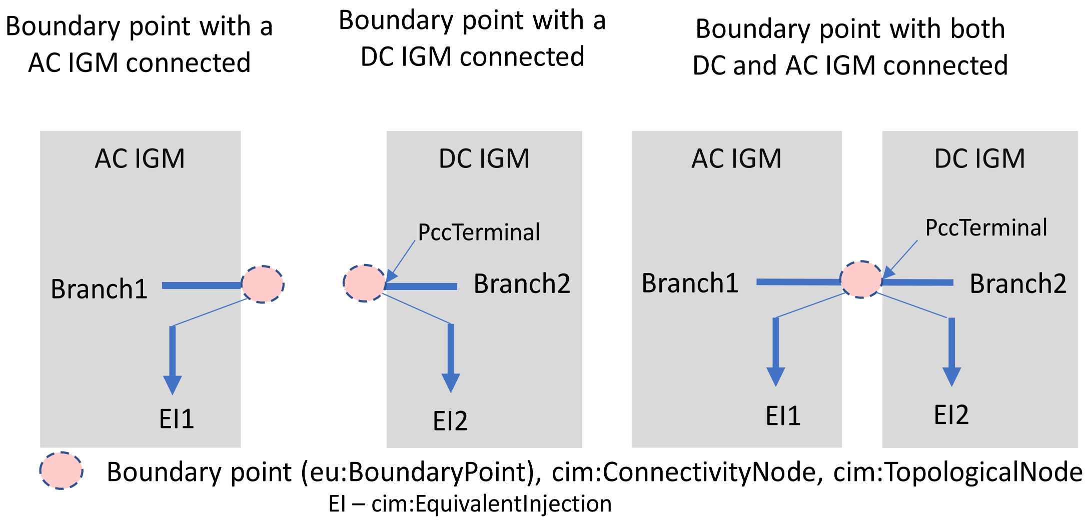


Figure 3 Boundary point connection cases

The left case in Figure 3 shows an AC IGM that is not connected to the DC IGM at the other side. The middle case shows a DC IGM that is not connected to the AC IGM at the other side, this happens when a DC IGM has HVDC Poles with only one end connected. The right case shows a situation where the DC and AC IGMs are connected.

Figure 4 illustrates an HVDC Bipole, where the upper part in the figure shows an external HVDC Link between TSOs and the lower - an internal HVDC Link.

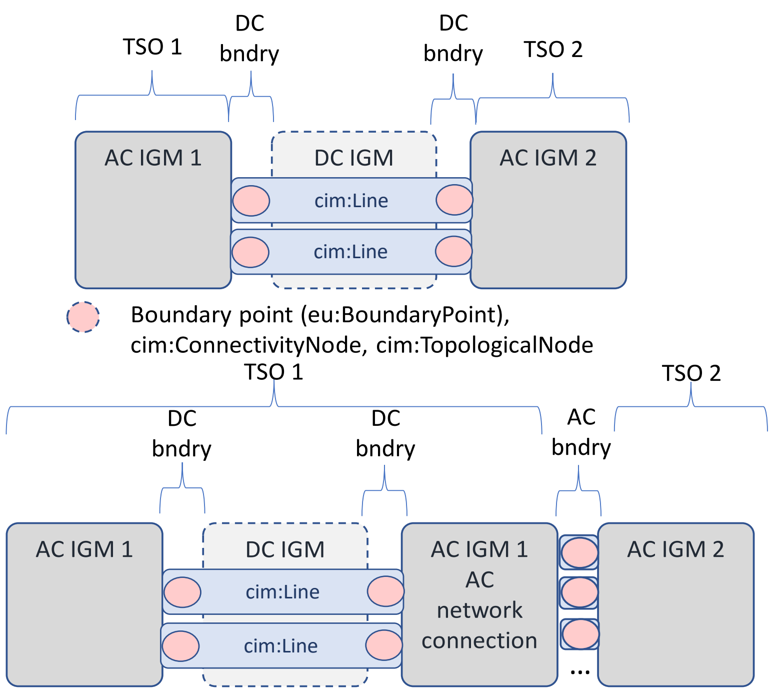


Figure 4 Boundaries for internal and external HVDC Links

A consequence of having the filters in the AC IGM is that the shunts and filters will be described in two different AC IGMs for an external HVDC Link. In case the TSO responsible for the link would like to manage the filters at both sides of the HVDC Link, all filters can be moved into the AC IGM of the TSO managing the HVDC Link. This is accomplished by making the HVDC Link internal to the TSO IGM and introducing an AC boundary as shown to the right in Figure 4.

Detailed models for HVDC Links embedded in an AC IGM may be provided by the responsible TSO as a service to other TSOs or RCCs. Using detailed HVDC models means including DC IGMs in the assembly of a CGM.

All BoundaryPoint-s are defined for the AC part of the grid even if they need to be used for connecting with DC IGM.

6.3.2.3 Boundary connectivity

6.3.2.3.1 Incomplete connectivity at boundary

In case boundary information is not duplicated in an IGM, this IGM is incomplete and a power flow cannot be computed with an IGM alone. By assembling an IGM with the boundary, the IGM becomes complete and power flow can be computed. This boundary situation is shown in Figure 5.

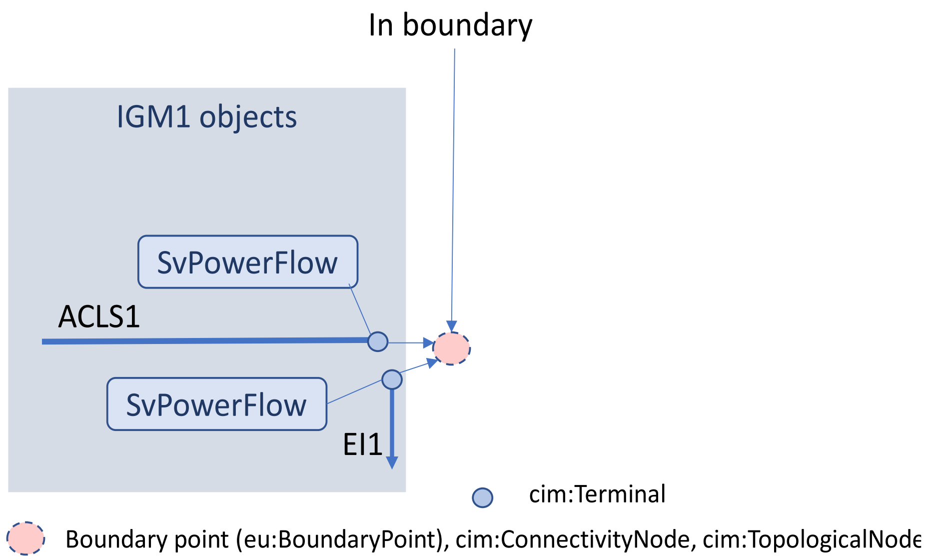


Figure 5 Boundary with a single IGM, no duplication of boundary information

The IGM connects to a TopolocicalNode and a ConnectivityNode with a Terminal belonging to one branch, typically a ACLineSegment, and one EquivalentInjection in case of AC interconnection on a Line. The EquivalentInjection's Terminal has a SvPowerFlow.

6.3.2.3.2 Complete connectivity at boundary

A model having two IGMs connecting at a boundary is shown in Figure 6.

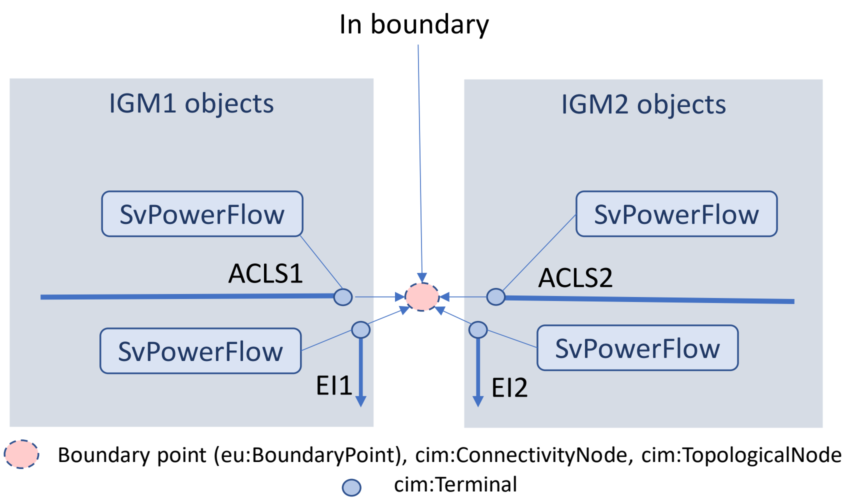


Figure 6 Boundary with two IGMs connected

Each IGM connects to the Boundary (TopologicalNode and ConnectivityNode) using the Terminal-s of the related equipment. In case of AC interconnection on a Line as shown in Figure 6, a ACLineSegment and one EquivalentInjection. The EquivalentInjection's Terminal has a SvPowerFlow.

The sum of the power flows in EquivalentInjection-s (EI1 and EI2) are supposed to be equal with different signs but as this typically is not the case at initial IGM delivery, they shall be aligned as part of the CGM creation process.

6.3.2.4 Control area conventions

When a tie line, e.g. a ACLineSegment, is connected to a boundary which is also a boundary for a ControlArea of type interchange (ControlArea.type equals ControlAreaTypeKind.Interchange) it may have a TieFlow. If a tie line is included in transfer capacity trade it shall have a TieFlows as shown in Figure 7.

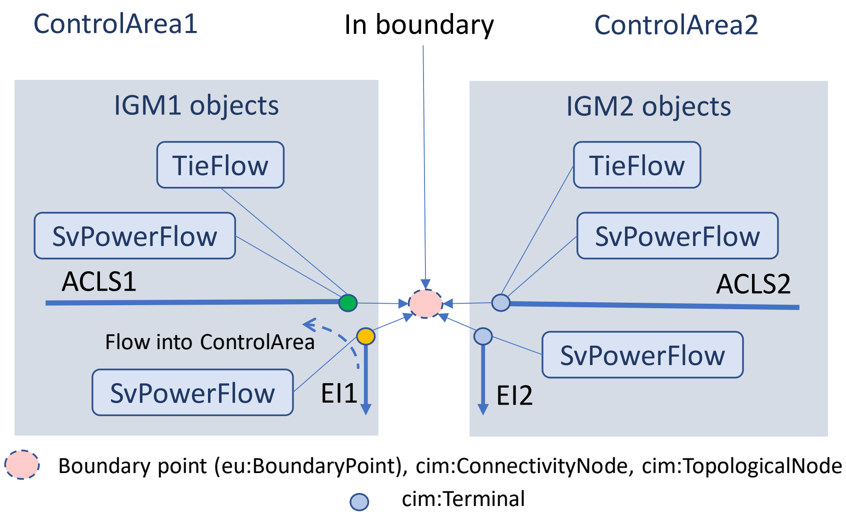


Figure 7 Transfer capacity trade at boundary with two IGMs

The flows at Terminal-s (e.g. SvPowerFlow) follow the load sign convention, i.e. flow from the TopologicalNode into the Terminal is positive. This means that a power flow at a tie line connected to a boundary TopologicalNode (TN) is a flow into the ControlArea. Figure 7 shows an example where the dashed arrow represents a flow into the ControlArea and the ACLS1 Terminal, shown with green in Figure 7, has a positive flow which is the same sign convention as for ControlArea.netinterchange.

The calculated power flow for the tie line is updated at the SvPowerFlow at the EquivalentInjection. Figure 7 shows a SvPowerFlow linked to the EI1 Terminal, yellow in Figure 7. The flow at the EI1 Terminal is into the TN which is the negated value of the tie line flow.

The flag TieFlow.positiveFlowIn is true if the flow from the TN into the tie line Terminal, green in Figure 7, is also a flow into the ControlArea. But with the conventions in Figure 7 where the TieFlow is located at the tie line end towards the boundary and the SvPowerFlow is at EquivalentInjection the TieFlow.positiveFlowIn being located at the tie line Terminal has lost its meaning.

For trade with an IGM not included in the CGM a TieFlow is still present at the boundary TopologicalNode / ConnectivityNode but no tie line will be connected for the not included IGM, see Figure 8.

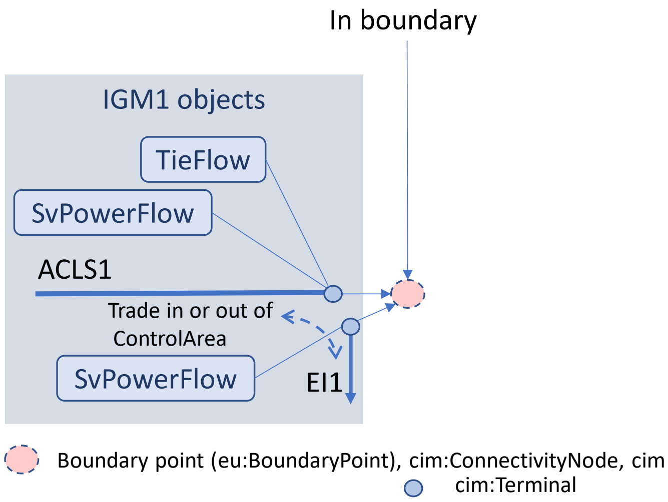


Figure 8 Trade with at a boundary with single IGM

The EquivalentInjection.p value, see dashed double arrow in Figure 8, describes the flow to or from the not included IGM and must have a realistic value which is the reasoning in case of partial merge for scaling the boundary injections (of the tie lines which are only defined on one side and for which a TieFlow exists) to match the net interchanges.

6.3.2.5 HVDC modelling alternatives

6.3.2.5.1 Injection models without the DC IGM

The injections models without DC IGM apply to the AC IGMs only.

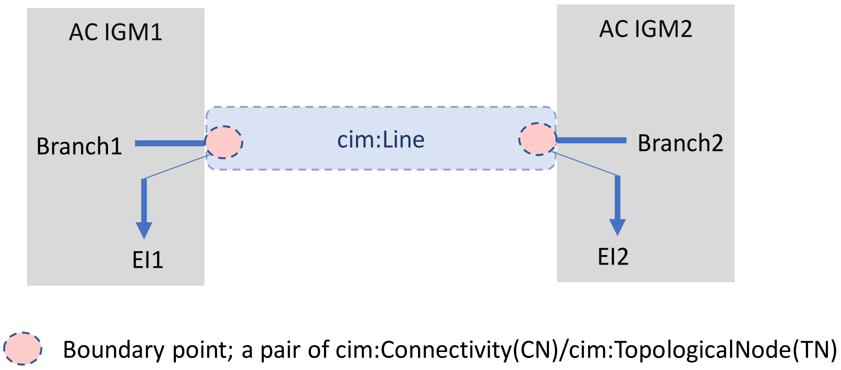


Figure 9 Injection model boundary with AC IGMs

Figure 9 shows how two AC IGMs connect with an HVDC Link. At each side there is one cim:EquivalentInjection, EI1 and EI2, that describe the power flow into the HVDC Pole represented by the cim:Line. Note that cim:DCLine cannot be used as the cim:DCLIne can only contain DC elements.

6.3.2.5.2 PQ Injection model without voltage control

Each side of an HVDC Pole is described by a cim:EquivalentInjection without voltage control (constant PQ element) in an AC IGM and without filters and shunts. It is used with CSC. This is a simplified HVDC model that shall not be combined with a DC IGM as the filters are missing and shall only be used if the intent is to never assemble the AC IGM with a matching DC IGM.

The reactive power in cim:EquivalentInjection.q corresponds to the reactive power consumed by the converter when the case was set up and changes in active power transfer due to contingencies is not reflected by a change in cim:EquivalentInjection.q.

6.3.2.5.3 PV Injection model with voltage control

Each side of an HVDC Pole is described by a cim:EquivalentInjection (EI) with voltage control in an AC IGM. This is a simplified HVDC model that can be assembled with a matching DC IGM.

The model uses simplified HVDC without shunts or filters. The voltage control gives a continuous response that does not match the discrete response of the shunts and filters from a CSC but describes the behaviour of a VSC well. As the cim:EquivalentInjection may also have a reactive capability curve it is used to describe the reactive power capability.

When this alternative is used at least the cim:EquivalentInjection.minQ and cim:EquivalentInjection.maxQ limits must be provided and the limit values shall match the reactive capability available at the active power flow specified in cim:EquivalentInjection.p.

This option can be used for

- simplified model of CSC where the shunts and filters are not modelled in the AC IGM. Instead, the cim:EquivalentInjection in the AC IGM has voltage control enabled to describe the absent filters. This model is not allowed as it is not representing the behaviour of the filter correctly. If a DC IGM exists use option 6.3.2.5.4.
- simplified model of VSC. This model can be assembled with a DC IGM as the cim:EquivalentInjection-s are replaced by the VSC in the DC IGM.

6.3.2.5.4 PQ Injection model with shunts and filters for voltage control

Each side of an HVDC Pole is described by a cim:EquivalentInjection without voltage control in an AC IGM and with shunts and filters in the AC IGM doing voltage control. It is used with CSC and is a simplified HVDC model that can be assembled with a matching DC IGM.

The filters not used for harmonics are available for voltage control. The cim:EquivalentInjection is a constant PQ element.

A change in the active power transfer is handled as follows:

- cim:EquivalentInjection.p is updated.
- cim:EquivalentInjection.q may be updated to reflect the change in active power transfer, e.g. by using the simple formula Q=P/2 or Q=0.6*P according to some references. The choice shall be based on the specific converter characteristics.
- The shunts and filters not used for harmonics filtering are available for voltage control.

This option supports DC IGMs with CSCs that are assembled into a CGM but can also be used without the DC IGM.

6.3.2.5.5 Detailed representation with DC IGM

A DC IGM has a detailed model that describes the converters (CSC or VSC) for all HVDC Poles in one HVDC Link. A TSO exporting a DC IGM will also export an AC IGM that connects with at least one end of the HVDC Poles in the DC IGM. The other end of the HVDC Poles shall also connect to an AC IGM.

As a DC IGM on its own is meaningless, an importing party must create a CGM including both DC and AC IGMs. For a party importing a DC IGM this means that at least one AC IGM, that connects with the HVDC Poles in the DC IGM, shall also be imported.

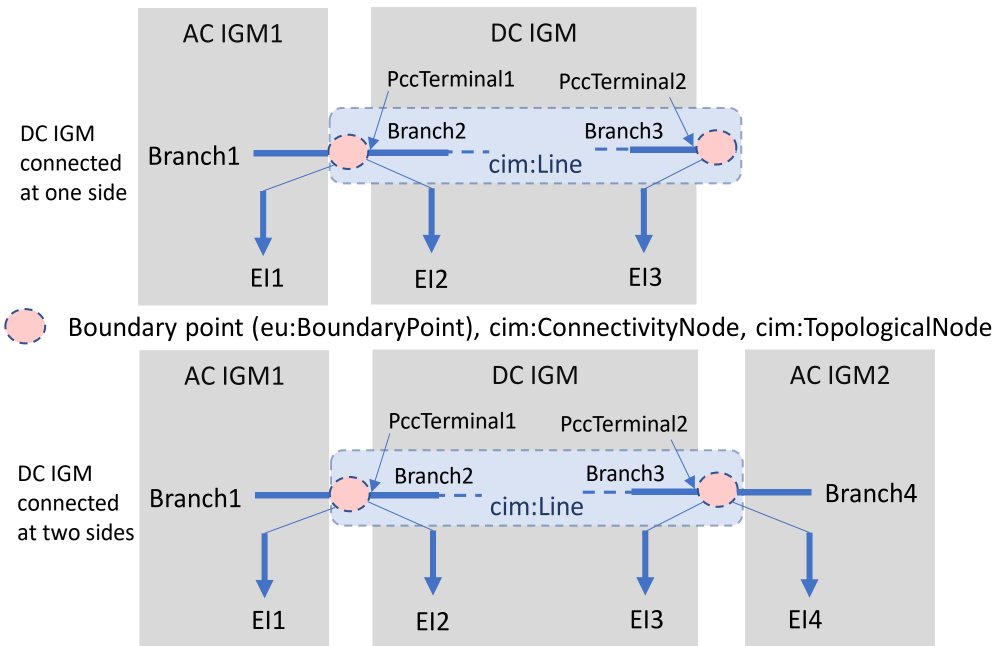


Figure 10 Boundary for a DC IGM and AC IGMs in a CGM or a partial CGM

Figure 10 shows two cases, the upper where the DC IGM is connected at one end of an HVDC Pole and the lower where both ends of an HVDC Pole is connected to AC IGMs.

For an external link between two TSOs, an importing party shall include the AC IGM at least at one end of the HVDC Poles in the DC IGM. With one end of the HVDC Poles connected to an AC IGM and the other end not connected corresponds to the upper part of Figure 10. This is useful when the CGM or a partial CGM is used in studies where active power losses are considered but the voltage at the open end is not considered. In system studies where the voltage is a concern as well as the power flow in a larger region the AC IGMs at both ends of the HVDC Poles shall be included in the CGM or a partial CGM which corresponds to the lower part of Figure 10.

In case of a CSC the filters shall be represented by the AC IGMs at both ends of the HVDC Poles.

6.3.2.6 Boundary point in a tie-line

Figure 11 shows the setup in case of BoundaryPoint in a tie-line.

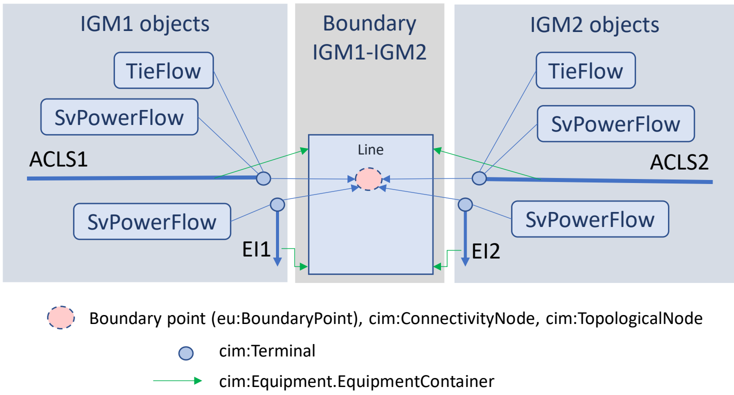


Figure 11 Boundary in a tie-line

In the case of boundary point located in a tie-line, the container is a Line. The Line, the ConnectivityNode, EquivalentInjection-s and the ACLineSegment-s (ACLS1 and ACLS2) are included in the boundary.

6.3.2.7 Boundary point in a substation

Figure 12 shows the setup in case of BoundaryPoint in a substation.

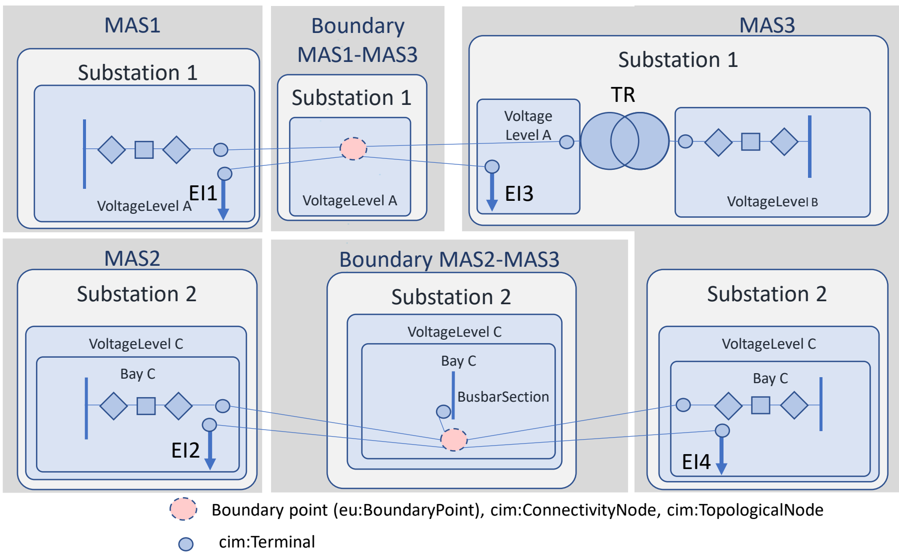


Figure 12 Boundary point in a substation

There are three MAS-es representing IGMs and two boundary parts, one between MAS1 and MAS3 (MAS1-MAS3) and another one between MAS2 and MAS3 (MAS2-MAS3). Following the principle of duplicating data between IGM MAS and Boundary MAS defined in this document, the voltage levels, substation objects and any other common objects are included in the boundary MAS and neighbouring MAS-es. For instance, EI4 (EquivalentInjection), switches and disconnectors in MAS3 are contained in Bay C and VoltageLevel C and Substation 2. The BusbarSection, the BoundaryPoint, in Boundary MAS2-MAS3 are also contained in Bay C, VoltageLevel C and Substation 2. The same for EI2 and related switches and disconnectors in MAS2.

In case of more complex boundary additional elements can be included and if necessary additional boundary points are defined.

Note that not all terminals are shown in the figure illustrating boundary point in a substation.

6.4 Data validation

SHACL based constraints are used for the validation of boundary datasets. The constraints cover cardinality of attributes, datatypes, and any other complex dependencies.

The following constraints are defined in addition to other boundary related constraints:

- C:600:EQ:BoundaryPoint:HVDC

  In case BoundaryPoint-s of an HVDC interconnection have to be modelled as BoundaryPoint-s in an AC Line instead of in a Substation, the two BoundaryPoint-s shall be contained in a single AC Line.

- C:600:EQ:BoundaryPoint:HVDCbipole

  HVDC Bipole shall be modelled with four boundary points and each of the two HVDC Poles are modelled by an AC Line in cases where another container is not existing. Each HVDC Pole in an HVDC Bipole will have its own pair of PccTerminal-s.

7 Reference datasets specification

7.1 Requirements

When exchanging data there is a need to refer to common objects that are relevant for multiple data exchange processes. Having a mechanism to use a set or different sets of reference data would optimize the data exchange. For instance, CGMES equipment profile is defining BaseVoltage class and it is allowed that a given MAS is either referring to an instance of BaseVoltage defined by the MAS or by the Boundary MAS. However, Boundary profiles are deprecated in CGMES v3.0 and in addition there are new profiles that can benefit by using other reference data. Therefore, there should be a specification how to define and maintain reference data and how to include it in an exchange process.

7.2 General concept

The following specification is defined for supporting reference data:

- Reference data uses W3C ontologies such as
  - DCAT (W3C Data Catalog Vocabulary) is an RDF vocabulary designed to facilitate interoperability between data catalogs published on the Web. By using DCAT to describe datasets in catalogs, publishers increase discoverability and enable applications to consume metadata from multiple catalogs. It enables decentralized publishing of catalogs and facilitates federated dataset search across catalogs. Aggregated DCAT metadata can serve as a manifest file to facilitate digital preservation.

- SKOS (W3C Simple Knowledge Organization System) designed for representation of thesauri, classification schemes, taxonomies, subject-heading systems, or any other type of structured controlled vocabulary. SKOS is part of the Semantic Web family of standards built upon RDF and RDFS, and its main objective is to enable easy publication and use of such vocabularies as linked data.
- CIM profiles that define classes that can be used for instantiating reference data.

- Reference data will be published following the principles of linked data, but in order to manage the transition smoothly, sets of reference data can be made available for data exchange processes and the implementation of this needs to be elaborated.
- In contrast to the current practice, reference datasets are packaged in separate, non-boundary sets. These reference datasets are referenced from different models. For instance, an IGM will need access to reference data for BaseVoltage, region definitions, detail information on metadata, etc. Boundary Set will also need access to reference data for elements that are common.
- The dependencies and packaging of the reference data is described in a manifest that uses DCAT, see “Metadata and document header data exchange specification”.

7.3 Data content

Reference datasets can be grouped in two main categories:

- Datasets that include definitions of SKOS and DCAT vocabularies
- Datasets that do not include SKOS and DCAT vocabularies and are only based on parts of the CIM model.

It is expected that at later stage all reference data will include elements of SKOS and DCAT vocabularies which is also the way European Commission is publishing authority tables. Therefore, depending on the development stage different datasets can have different content that is gradually aligned helping the transition to fully aligned reference data.

This section explains different options on the content of reference datasets and rules that are used when converting the data from various sources. The explanation is mainly done using examples.

7.3.1 Header

The document “Metadata and document header data exchange specification” describes the header that accompanies the reference data as well as the packaging and linking the data via a manifest instance file.

7.3.2 Main data content

Different instances of reference data build the main content of the dataset. Due to agreed concepts at European level the current reference datasets distributions include only one skos:ConceptScheme. For instance, if the dataset defines the reference data for BaseVoltage the instance file which is a distribution of this dataset contains only one skos:ConceptScheme rdf:about=http://energy.referencedata.eu/BaseVoltage.

The content of the skos:ConceptScheme provides the main information on the reference dataset. The skos:ConceptScheme of reference power flow settings is provided for illustration.

```
<skos:ConceptScheme rdf:about="http://energy.referencedata.eu/PowerFlowSettings">
  <rdf:type rdf:resource="http://www.w3.org/ns/dcat#Dataset"/>
  <dcterms:modified>2022-09-16T13:18:37.985254</dcterms:modified>
  <dcat:version>1</dcat:version>
```

```
    <skos:prefLabel>PowerFlowSettings</skos:prefLabel>
    <dcterms:identifier>urn:uuid:aaed01a1-fff7-49aa-a5f2-df07c05e16a9</dcterms:identifier>
    <dcat:keyword>PFS</dcat:keyword>
    <skos:definition xml:lang="en">List of commonly used Power Flow Settings</skos:definition>
  </skos:ConceptScheme>
```

In fact the skos:ConceptScheme is describing the list, the group of reference data type. skos:Concept is used to define individual members of the list. The usage of SKOS allows to make relation between different skos:Concept-s which is necessary in some case. For instance a property like skos:exactMatch indicates that there is exact match between the skos:Concept defined in this dataset and another skos:Concept defined in another dataset. The example below shows the exact match relationship between the reference data on confidentiality level Sensitive which is defined by ENTSO-E and by the European Commission. Using this approach ENTSO-E can define a list of allowed confidentiality levels based on internal security related agreements and for some of confidentiality levels can reuse already defined levels by the EC, e.g. “Sensitivity”.

```
  <skos:Concept rdf:about="http://energy.referencedata.eu/Confidentiality/c28079e4-02ba-4a08-
9093-8247ebe57f21">
    <dcterms:identifier>urn:uuid:c28079e4-02ba-4a08-9093-8247ebe57f21</dcterms:identifier>
    <skos:prefLabel>Sensitive</skos:prefLabel>
    <skos:definition xml:lang="en">Sensitive non-classified (SNC) information, information
whose unauthorised disclosure could cause damage to the Commission or other interested parties
such as businesses, companies, intellectual property or personal data but which is not EU
classified information.</skos:definition>
    <skos:inScheme rdf:resource="http://energy.referencedata.eu/Confidentiality"/>
    <skos:topConceptOf rdf:resource="http://energy.referencedata.eu/Confidentiality"/>
    <skos:exactMatch rdf:resource="http://publications.europa.eu/resource/authority/access-
right/SENSITIVE"/>
  </skos:Concept>
```

In general skos:Concept rdf:about shall be a resolvable URL. ENTSO-E is in transition to ensure this. There are two ways how the resolvable URL are formatted:

- {the URL for the ConceptScheme}/{the name of the Concept}

```
<skos:Concept rdf:about="http://energy.referencedata.eu/StandardBusinessTypeList/A01">
```

- {the URL for the ConceptScheme}/{the identifier of the Concept}

```
<skos:Concept    rdf:about="http://energy.referencedata.eu/Confidentiality/c28079e4-02ba-4a08-
9093-8247ebe57f21">
```

Or

```
<skos:Concept
rdf:about="http://energy.referencedata.eu/BaseVoltage/6d63ed36bf6842f3b98995e04eed3dd0">
```

In most of the cases this is done to ensure a level of backwards compatibility. The general rule is that the URI used as rdf:about shall not be understood as a coded string from which information is derived. The purpose is to provide a reference to the data. Individual information is collected from the properties of the skos:Concept. The following instance of BaseVoltage reference data illustrates this.

```
  <skos:Concept
rdf:about="http://energy.referencedata.eu/BaseVoltage/7891a026ba2c42098556665efd13ba94">
    <rdf:type rdf:resource="http://iec.ch/TC57/CIM100#BaseVoltage"/>
    <cim:BaseVoltage.nominalVoltage>220</cim:BaseVoltage.nominalVoltage>
    <cim:IdentifiedObject.name>AC-220</cim:IdentifiedObject.name>
    <cim:IdentifiedObject.description>Base voltage defined by ENTSO-E 220
kV</cim:IdentifiedObject.description>
    <dcterms:identifier>urn:uuid:7891a026ba2c42098556665efd13ba94</dcterms:identifier>
    <skos:prefLabel>AC-220</skos:prefLabel>
    <skos:definition xml:lang="en">Base voltage defined by ENTSO-E 220 kV</skos:definition>
    <skos:inScheme rdf:resource="http://energy.referencedata.eu/BaseVoltage"/>
```

```
    <skos:topConceptOf rdf:resource="http://energy.referencedata.eu/BaseVoltage"/>
  </skos:Concept>
```

Here skos:Concept includes properties that are native for the skos:Concept as well as CIM attributes native to the cim:BaseVoltage. The class with rdf:about http://energy.referencedata.eu/BaseVoltage/7891a026ba2c42098556665efd13ba94 has two rdf:type-s skos:Concept and cim:BaseVoltage. Information is duplicated between some of the properties CIM, SKOS, DCAT in order to facilitate transition period. After all systems transition to be able to use SKOS and DCAT properties, the CIM properties can be removed.

The properties skos:inScheme and skos:topConceptOf are necessary to link the skos:Concept to skos:ConceptScheme. skos:topConceptOf is a property that is used by the European Commission in various tooling to help representing hierarchy of the skos:Concept. Therefore skos:topConceptOf should be seen as part of the long term plan to align with EU Commission Data Publication office practices and this is needed for VockBench (Tool that Data Publication office is using) to show and display data in a correct way.

Note that the UUID “7891a026ba2c42098556665efd13ba94” is missing the “-” part of the formatting, which is not correct. Also it would not be correct if the UUID is ”urn:uuid:_7891a026ba2c42098556665efd13ba94” as in this option is “_” should not be used. The correct dcterms:identifier is:

```
<dcterms:identifier>urn:uuid:7891a026-ba2c-4209-8556-665efd13ba94</dcterms:identifier>
```

ENTSO-E CIM WG agreed to add additional entries of reference data with correct IDs that will replace entries with not valid IDs. This is done in order to ensure transition.

7.3.3 Linkage between reference data instances and other data instances

There are two ways how to reference (link) to reference data.

- By using the identifier (dcterms:identifier)
- By using the complete URI/URL defined in the rdf:about of the skos:Concept

In Network Codes profiles approved by ENTSO-E and in CGMES, references on class level are using rdf:resource as illustrated below.

```
  <cim:ACLineSegment rdf:ID="_17086487-56ba-4979-b8de-064025a6b4da">
    <cim:IdentifiedObject.name>BE-Line_1</cim:IdentifiedObject.name>
    …
    <cim:ConductingEquipment.BaseVoltage rdf:resource="#_a7f1d8de-d658-428a-821b-3a5ae5965fd1"
/>
    <cim:Conductor.length>22</cim:Conductor.length>
    …
    <cim:IdentifiedObject.mRID>17086487-56ba-4979-b8de-
064025a6b4da</cim:IdentifiedObject.mRID>
  </cim:ACLineSegment>
```

In general RDF/XML allows further abbreviating IRIs (Internationalized Resource Identifier[1]) in XML attributes in two ways. The XML infoset provides a base URI attribute xml:base that sets the base URI for resolving relative IRIs, otherwise the base URI is that of the document. The base URI applies to all RDF/XML attributes that deal with IRIs which are rdf:about, rdf:resource, rdf:ID and rdf:datatype. The rdf:ID attribute on a node element (not property element, that has another meaning) can be used instead of rdf:about and gives a relative IRI equivalent to “#” (i.e. denotes URI fragment) concatenated with the rdf:ID attribute value. So for example if rdf:ID="http://iec.ch/TC57/CIM100#_17086487-56ba-4979-b8de-064025a6b4da", that would be equivalent to rdf:about="#_17086487-56ba-4979-b8de-064025a6b4da". rdf:ID provides an additional check since the same name can only appear once in the scope of an xml:base value (or document, if none is given), so is useful for defining a set of distinct, related terms relative

[1] Internationalized Resource Identifiers (IRIs) are a new protocol element, a complement to URIs [RFC2396]. An IRI is a sequence of characters from the Universal Character Set (Unicode/ISO10646). There is a mapping from IRIs to URIs, which means that IRIs can be used instead of URIs where appropriate to identify resources.

to the same IRI. Both forms require a base URI to be known, either from an in-scope xml:base or from the URI of the RDF/XML document.

In CIMXML the “#” sign also replaces the base declared by xml:base but the instance files do not include declaration of xml:base. Therefore, parsers will assign local path as xml:base and the result could be something like this rdf:ID="C:\Temp_17086487-56ba-4979-b8de-064025a6b4da".

In addition, current CIMXML exchanges separate between rdf:ID and rdf:about. rdf:ID is used when a class is created and rdf:about is used when additional instance data is added to the same entity. As stated in IEC 61970-600-1:2021, there is a proposal to change this in the future versions and only rdf:about to be used.

Same URI concept is applied to rdf:resource. Currently rdf:resource="#_a7f1d8de-d658-428a-821b-3a5ae5965fd1" is a reference to a class with rdf:ID "_a7f1d8de-d658-428a-821b-3a5ae5965fd1” or cim:IdentifiedObject.mRID "a7f1d8de-d658-428a-821b-3a5ae5965fd1” and it is assumed that this class can be found locally as there is no xml:base declared. This approach will work for linking with reference data as the identifier is part of the data for each skos:Concept class, e.g. dcterms:identifier.

However, more direct linkage can also be used and it conforms to CIMXML as the same approach is used when referring to enumerated values. An example of same ACLineSegment class is provided below where the reference to the BaseVoltage class is not abbreviated and “#” sign is not used.

```
<cim:ACLineSegment rdf:ID="_17086487-56ba-4979-b8de-064025a6b4da">
    <cim:IdentifiedObject.name>BE-Line_1</cim:IdentifiedObject.name>
    …
    <cim:ConductingEquipment.BaseVoltage
rdf:resource="http://energy.referencedata.eu/BaseVoltage/_a7f1d8de-d658-428a-821b-
3a5ae5965fd1" />
    <cim:Conductor.length>22</cim:Conductor.length>
    …
    <cim:IdentifiedObject.mRID>17086487-56ba-4979-b8de-
064025a6b4da</cim:IdentifiedObject.mRID>
  </cim:ACLineSegment>
```

7.4 Data validation

SHACL based constraints are used for the validation of reference datasets. The constraints cover cardinality of associations and attributes, datatypes, and any other complex dependencies.

7.5 Data publication

Reference data is published under the domain[2]: http://energy.referencedata.eu. Different systems should be able to automatically retrieve the data (using APIs or other techniques) in order to keep local copies up to date.

7.6 Data serialisation

Currently CIMXML that conforms to IEC 61970-552 is used for serialisation of XML documents. The standard that is published by IEC has issues and implementation of this standard take some assumptions. Both CGMES v2.4 and CGMES v3.0 are using the same CIMXML serialisation. Note that old profiles (CGMES v3.0 and prior versions) use file header specified by IEC 61970-552, while new profile such as NC profiles use the header specified in the ENTSO-E “Metadata and document header data exchange specification”.

7.6.1 Data serialisation outlook

In general, the serialisation of reference data can follow the same CIMXML serialisation. However, many IT services are using JSON and this becomes a preferred serialisation. Therefore, community is working to clarify how JSON-LD serialisation (similar to JSON, but

[2] Note that there is ongoing process of data publication and not all reference data is available at this location at the time of the publication of this document.

adapted for linked data) should be applied to CIM and reference data related to CIM based data exchanges. A separate specification will be provided to specify this. In addition, W3C serialisation- Turtle is used for explanation of different approaches as this serialisation is more human readable.

JSON-LD (A JSON-based Serialization for Linked Data, W3C Recommendation 16 July 2020) is defined here: [JSON-LD 1.1 (w3.org)](). Specific usage for CIM based data exchanges will be defined at later stage together with a transition plan.

7.7 Data packaging

The document "Metadata and document header data exchange specification" describes the header that accompanies the reference data as well as the packaging and linking the data via a manifest instance file.

8 Implementation guidance

8.1 General

In the previous versions of boundary specification, the boundary dataset could contain only non-overlapping datasets. Starting with this version, it is allowed to have CIM objects belonging to a boundary dataset duplicated between the boundary dataset and the IGMs or whatever applicable dataset, with following implications:

- Existing tooling is not required to be changed in the usual case of TSO-TSO merge as it can still operate without duplicates. However, in cases for boundary point in substation, including cross-border connection through a transformer and TSO-DSO data exchanges, duplication is applied and shall be supported. In these cases, business processes need to ensure transition period.
- For enabling BoundaryPoint in substation (the HVDC use case) the reference data and boundary set need to be published/updated. No changes in CGMES profiles.
- When a system operator, e.g. a TSO needs to manage boundary and reference data related to exchanges between the TSO and DSOs, special attention should be paid on the common data such as GeographicalRegion, SubGeographicalRegion-s, BaseVoltage-s, Substation-s, VoltageLevel-s, etc. Already existing reference data shall be used and extended using the same concept in order to cover local needs.
- Mixing boundary and reference data should be discouraged and as reference data gets published and updated different projects shall plan transition to new approaches.

8.2 Examples on boundary datasets and reference datasets

The following examples illustrate the implementation of the boundary and reference data.

8.2.1 Complete set which includes reference data

This is the current way of describing boundary information. Necessary reference data such as BaseVoltage instances are included in the Equipment profile describing boundary set instance.

An example is available in the Test Configurations included in the CGMES Conformity Assessment Scheme v3.0.

8.2.2 Separate boundary and reference datasets

In this way of exchange, the pure boundary information which relates to the boundary points and their containment is separate for reference data.

An example is available here: https://extra.entsoe.eu/Board/DC/CIM/CIM%20CGMES/BusinessProcess/Boundary/RefDoc/BoundaryTestSample/SeparateBoundaryAndRefData.zip

8.2.3 Modular boundary set per MAS border and separate reference dataset

In this way of exchange, the boundary dataset is split per MAS (e.g. TSO) border and the reference data is separated. This gives more flexibility for system operators to reuse the borders that are necessary for different merged models and local references when exchanging with DSOs. In addition, it is expected that there will be improved stability of the boundary dataset and change of one interconnection would not have impact on the instance data dependency of a MAS that it is not making use of the changed interconnection.

An example is available here: https://extra.entsoe.eu/Board/DC/CIM/CIM%20CGMES/BusinessProcess/Boundary/RefDoc/BoundaryTestSample/ModularBoundaryPerMasBorderSeparateRefData.zip

9 Bibliography

- ENTSO-E Metadata and document header data exchange specification, v2.1, Sep 2022.

10 Annex A: Boundary point issue background

Boundary point placed in substation was designed in 2013 in CGMES 2.4.15. However, CGMES 2.4.15 EQBD and TPBD had issues which prevented the utilization of this. In CGMES v3.0 boundary point in substation was revised. Recent activities related to development of test configurations for CGMES v3.0 revealed some issues.

IEC 61970-456 only states this: “A boundary network part may also have a Substation instead of a Line as shown in Figure 10. In this case the Substation, a VoltageLevel and a ConnectivityNode is in the boundary network part while the rest of the Substation equipment is defined within the regional network parts.”

In the context of CGMES v3.0 and BoundaryPoint class this means the following:

- In the Boundary MAS the following elements are defined: ConnectivityNode, BoundaryPoint, VoltageLevel, Substation, SubGeographicalRegion (because there is required association end Substation.Region), GeographicalRegion (because there is required association end SubGeographicalRegion.Region)
- All elements that belong to MAS of an IGM are exchanged in the instance files of MAS IGM 1, but are contained in regions and in Substation/VoltageLevel (for the elements the boundary substation) defined in boundary MAS. The same logic for MAS IGM 2. EquivalentInjection-s related to BoundaryPoint will also be contained in the respective MAS.

Therefore, in order to model boundary point in a substation, the boundary substation and related containers need to be defined in the boundary MAS in a similar way as the Line is defined in Boundary MAS for a case of BoundaryPoint placed on a tie-line.

The use cases for boundary point in substation are:

- TSO-DSO boundaries, not only within one country/control area, but also in case of cross-border connection via a transformer.

- TSO-TSO boundary in cases where the border crosses in a substation (on a transformer)
- DSO-DSO and TSO-SGU and DSO-SGU, and MV – LV if they are managed by different system by the utility.
- In back-to-back HVDC interconnections, where the two boundary points are placed in a substation
- In detailed modelling of HVDC interconnection, where the two boundary points are placed in a substation

Guidance/specification on the following points is needed:

- Vendors need to decouple GeographicalRegion (or SubGeographicalRegion) and MAS concepts, i.e. it should be possible to serialize in respective MAS the equipment independently of where it is contained.
- If the BoundaryPoint is in a substation the boundary substation (no matter how big it is) should be part of the boundary MAS. Here some guidance should be given as people need to also distinguish on asset level. It is most probably the case that MAS IGM 1 and MAS IGM 2 may have its own substations that contain their assets. That looks fine at the first sight, but there are rules that block e.g. switch between 2 substations.
- With this setup many elements in MAS IGM 1 that are contained in the substation defined in boundary as shared container will also belong to the boundary regions. Note in case of a big substation that it could also contain generation or loads. Here it is important to see what explanation is needed in case there is a generator in the boundary substation contained in e.g. ENTSO-E region, but exchanged in MAS IGM 1 (e.g. BE) and considered as part of BE. The bigger the substation the more questions like this would appear. A related question here is what role in the setup ControlArea and TieFlows play here and if they would need to be treated differently in the case of BoundaryPoint in a Substation
- In case of a substation busbar being designated as a boundary point there will be many elements (more than 2 branches and potentially single terminal devices) connected to it. Depending on what belongs to MAS IGM 1 and what to MAS IGM 2 there should be a logic in the tools that the flow via elements that belong to MAS IGM 1 is summed as p,q of the EquivalentInjection that would represent the flow exchange for MAS IGM 1. Same for MAS IGM 2. Therefore, the logic is more complex compared to a single line which ends are connected to two different regions (in case of tie line boundary).
- There should be a statement that the boundary substation cannot be defined in MAS IGM 1 as this will break many other rules e.g. boundary set would be dependent on MAS IGM 1, MAS IGM 2 equipment will need to point to containers in MAS IGM 1 which is also forbidden. Alternative way is to allow duplications for elements that are defined in a boundary set.
- Need to discuss if the association end Substation.Region should remain required or be optional like the Line. Or be optional only in cases the boundary point is in substation. It is not necessary that we need to touch here, but some discussion is necessary to confirm.
- Some of the rules in section 5.7 in IEC 61970-600-1 may need clarification depending on the discussion on this issue. At the first sight it seems there is no controversial things, but some of the figures there may confusing.
- With the fact that potentially many elements will be part of the boundary substation that is not part of MAS IGM 1. The reporting on flows and other statistics between regions,

sub regions, substations might be somewhat complicated. Some guidance is needed here to suggest some directions.