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Energy management system application program interface (EMS-API) – Part 600-1: Common Grid Model Exchange Standard (CGMES) – Structure and rules

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IEC Central Office
3, rue de Varembé
CH-1211 Geneva 20
Switzerland

Tel.: +41 22 919 02 11
info@iec.ch
www.iec.ch

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ENERGY MANAGEMENT SYSTEM APPLICATION PROGRAM INTERFACE (EMS-API) –

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FOREWORD

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International Standard IEC 61970-600-1 has been prepared by IEC technical committee 57: Power systems management and associated information exchange.

This first edition cancels and replaces IEC TS 61970-600-1 published in 2017. This edition constitutes a technical revision.

This edition includes the following significant technical changes with respect to IEC TS 61970-600-1:2017:

- Terms and definitions were updated.
- The "Type" column in all tables was deleted to increase readability of the document as all the rules are considered required, hence categorisation is not necessary.
- Requirement HGEN4 was added to define additional rules to the file header compared to IEC 61970-552:2016.

- Annex B on “Summary of specific rules for naming conventions” is deleted as the information was either integrated in the UML or considered outdated.
- Annex D referring to the PST modelling is deleted as it will be fully integrated in IEC 61970-301:2020+AMD1[1].
- Annex E “Implementation guide” is deleted as all rules and implementation guidance is or will be integrated in either Clause 5 of this document or IEC 61970-301:2020 (and its future Amendment 1) or IEC 61970-452 or IEC 61970-456 as referenced by this document. Note that former Subclause E.11.2 on ConformLoadGroup and NonConformLoadGroup was implemented differently due to another issue, please refer to IEC 61970-600-2:2020.
- Rules GENC17, GENC18, GENC19, EQ__4, EQ__5, SV__4, BPPL12, BPPL13, MVAL5, EXCH9, TP__4 and MARP12 were added.
- Rules GENC3, GENC6, PROF2, PROF4, PROF5, PROF8, PROF9, EXCH5, EXCH6, EXCH7, MAS_4, MAS_6, MAS_9, MAS_10, MAS_11, MAS_13, EQ__1, HREF2, HREF3, HREF5, MVAL3, TPBD1, TPBD2, BPPL10, NAMC12 and NAMC13 are deleted as they are considered not relevant due to other changes.
- The following rules were modified: GENC1, GENC2, GENC4, GENC5, GENC7, GENC8, GENC9, GENC10, GENC16, EQBD2, BPPL11, EXCH2, EXCH3, EXCH8, FBOD3, FBOD5, PROF10, PROF11, MAS_1, MAS_8, HGEN3, HREF1,EEXT1, EQ__2, TP__1, TP__2, TP__3, MARP10, MARP11, NAMC1, NAMC4, NAMC11, NAMC14, BPPL1, BPPL2 and BPPL3.
- Explicit equipment boundary profile definition (EQBD) has been deprecated (refer to Subclause 4.6.5 of IEC 61970-301:2020 and future Amendment 1 for details on deprecations) in this edition in favour of using its full profile counterpart (EQ) for exchange of boundary datasets. The topology boundary profile (TPBD) is not included in the CGMES as TP is considered output and therefore it is no need to exchange Topology information part of the boundary model authority set.
- Annex F has been deleted.

The text of this International Standard is based on the following documents:

FDIS	Report on voting
57/2366/FDIS	57/2382/RVD

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

The language used for the development of this International Standard is English.

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, available at www.iec.ch/members_experts/refdocs. The main document types developed by IEC are described in greater detail at www.iec.ch/standardsdev/publications.

A list of all parts in the IEC 61970 series, published under the general title *Energy management system application program interface (EMS-API)*, can be found on the IEC website.

1 An amendment to IEC 61970-301:2020 is currently under consideration.

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

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

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

INTRODUCTION

The purpose of this document is to define the Common Grid Model Exchange Standard (CGMES) based on Common Information Model (CIM) standards defined in IEC 61970-series, IEC 61968-series and IEC 62325-series and to address requirements defined by the European legislation. However, the document is not limited to the European legislation requirements and business processes, it is created to support data exchange between applications that support power system model management and analysis. The data exchange can be between internal applications or between applications at System Operators (SO) and Reginal Coordination Centre (RCC). This covers DSO-DSO, DSO-TSO, TSO-TSO, TSO-RCC/ISO/RTO and RCC-RCC interfaces, but not limited to these.

The CGMES is created to address the information exchange requirements provided in Common Grid Model methodologies (CGMm) in accordance with the legal requirements stated in various European network codes guidelines. The CGMES applies to applications dealing with power system data management, as well as applications supporting the following analyses:

- power flow and contingency analyses,
- short circuit calculations,
- market information and transparency,
- capacity calculation for capacity allocation and congestion management, and
- dynamic security assessment.

The conformity of applications used for system operation and system development data exchanges with the CGMES is crucial for the needed interoperability of these applications. This document provides the grouping of all principle requirements for the CGMES Conformity Assessment Framework and the guiding principles for assessing applications' CGMES conformity. The description of the CGMES Conformity Assessment Process is currently not part of the IEC 61970-600-series, but it is planned to be included as an international standard in order to validate that the CGMES is correctly implemented by suppliers of the applications used by system operators (ISO/TSO/DSO etc) and for Regional Coordination Centres (RCCs).

ENERGY MANAGEMENT SYSTEM APPLICATION PROGRAM INTERFACE (EMS-API) –

Part 600-1: Common Grid Model Exchange Standard (CGMES) – Structure and rules

1 Scope

This part of IEC 61970, which covers the definition of Common Grid Model Exchange Standard (CGMES), defines the main rules and application's requirements to meet business requirements for assembled and merged model to fit relevant business services. This document does not define the business requirements, business processes nor how applications are implemented. This document defines how relevant Common Information Model (CIM) standards work together so that specific business requirements can be resolved.

It also includes extensions to the Common Information Model (CIM). The current extensions are defined in IEC 61970-301:2020 and will be covered in its future Amendment 1, but additional extensions can be defined in other standards in the IEC 61970-600-series. The extensions can be used to define additional profiles or to expand IEC 61970-450-series or IEC 61968-13 profiles. However, primary CGMES includes additional constraints on existing profiles and validation of assembled and merged models that is based on existing profiles. This can be done by making optional attributes and associations mandatory (required).

In addition, this document includes the specification of the serialisation that must be supported by referring to an existing standard defined in IEC 61970-550-series, e.g., IEC 61970-552, and making relevant constraints related to it.

The goal is to achieve interoperability between applications using CGMES in a high-performance environment with combined minimum effort so that relevant business processes are satisfied.

An overview of IEC 61970-600 series is provided in the following table, which also presents identified needs that are not yet addressed.

Part	Description	Scope
61970-600-1	Structure and rules. This part defines the structure of the series of standard and the rules that needs to be applied on the assembled and merged models that are defined by the different profile standards.	In the scope
61970-600-2	Exchange profiles specification. This part defines the IEC 61970-450-series and IEC 61968-13 related profiles that are included in CGMES. It includes the references to published standards and additional constraints defined to the relevant standard. If the relevant edition of a standard is not published, it also includes the profile definition and the standard's constraints.	In the scope
to be defined (TBD)	Information extension. This part defines additional information model that is not included in the relevant edition of IEC 61970-301, IEC 61970-302 or IEC 61968-11 that is needed to meet business requirement.	Identified as a need and not yet addressed neither in this document nor in IEC 61970-600 series
to be defined (TBD)	Extended exchange profiles specification. This part defines additional profiles that is not included in IEC 61970-450-series and IEC 61968-13 that is needed to meet business requirement.	
to be defined (TBD)	Conformity Assessment Scheme (CAS). This part defines the Conformity Assessment Scheme (CAS) including test use cases and references to test configurations to evaluate if an application tool conforms to the CGMES.	

Clause 4, Data exchange context, describes the context the CGMES is developed to support.

Clause 5, Specifications and functionalities, defines the rules that shall be applied for validating a model part, an assembled and a merged model. When the rule is defined in the relevant profile it will include a refence to the rule.

Clause 6, CGMES governance, defines the governance of CGMES and the version strategy.

Annex A is left blank.

Annex B (normative), File header guidelines, explains the usage of the file header that is defined in IEC 61970-552.

2 Normative references

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

IEC 61970-552:2016, *Energy management system application program interface (EMS-API) – Part 552: CIMXML Model exchange format*

IEC 61970-301:2020, *Energy management system application program interface (EMS-API) – Part 301: Common information model (CIM) base*

IEC 61970-302:2018, *Energy management system application program interface (EMS-API) – Part 302: Common information model (CIM) dynamics*

3 Terms, definitions and abbreviated terms

For the purposes of this document, the following terms, definitions and abbreviated terms apply.

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

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

NOTE For definitions which are not specified in the CGMES the definitions in the IEC 61970 standard series shall be applied.

3.1 Terms and definitions

3.1.1
assembled model
model of a Model Authority Set with internal references resolved

3.1.2
boundary point
BP
connection point between two Model Authority Sets, that has been agreed on by both relevant Model Authority

3.1.3
boundary set
set containing all boundary points necessary for a merge model

3.1.4
CIM XML document/distribution
instance file which is serialised according to IEC 61970-552

3.1.5
distribution
specific representation of a dataset. A dataset might be available in multiple serializations that may differ in various ways, including natural language, media-type or format, schematic organization, temporal and spatial resolution. The level of detail in the distribution is defined by one or more profiles that the dataset conforms to

3.1.6
Common Grid Model Exchange Standard
CGMES
collection of standards defined in IEC 61970-600 series that support the exchange of power system models (e.g. individual grid model or common grid model) between model authorities (TSOs, DSOs, etc.) for the purpose of coordinated set of services to be performed on the same model according to legislation or general data exchanges in the frame of system operation, system development or utilities' projects

3.1.7
European extensions
collection of classes, attributes and associations, which either extend or are defined in the standard IEC CIM model (IEC 61970-300 series, IEC 91968-11 and IEC 62325-300 series). The European extensions aim at satisfying requirements by the European legislation hence not necessarily applicable to other continents. The worldwide adoption of these extensions may not be exactly the same as the defined extension

3.1.8
external references resolved
no dangling references are present across the models of Model Authority Sets

3.1.9
header references resolved
references defined in model header are resolved

3.1.10
internal references resolved
no dangling references are present within the model of a Model Authority Set

3.1.11
merged model
model that is a union of different assembled models with external and header references resolved

3.1.12
profile
data model to describe instance file for exchange of CIM data. A profile is a subset of classes, associations and attributes needed to accomplish a specific type of interface and based upon a CIM data model. Profiles may impose stricter rules on original classes and associations. A profile is usually converted to schema (XSD, RDF, OWL, etc.) that can be used to create, read and validate instance files for data exchange

Note 1 to entry: This term may be used to define either the semantic model for an instance data payload or the syntactic schema for an instance data payload. A profile may be expressed in XSD, RDF, and/or OWL files. An instance data conforming to a profile can be tested in exchanges between applications. A profile is necessary in order to “use” the canonical model.

3.1.13
solved model
model containing instance of State Variables (SV)

3.2 Abbreviated terms

BP	Boundary point
CIM	Common Information Model (electricity)
CGMES	Common Grid Model Exchange Standard
DL	Diagram Layout profile
DSO	Distribution System Operator
DY	Dynamics profile
ENTSO-E	European Network of Transmission System Operators for Electricity
EQ	Core Equipment profile
EQBD	Equipment Boundary profile
GL	Geographical Location profile
HVDC	High Voltage Direct Current
IEC	The International Electrotechnical Commission, headquartered in Geneva
IOP	Interoperability Test
ISO	Independent System Operator
MAS	Model Authority Set
mRID	CIM Master Resource Identifier
OCL	Object Constraint Language

OP	Operation profile
OWL	Web Ontology Language
RCC	Regional Coordination Centres
RDF	Resource Description Framework
RDFS	RDF Schema
SC	Short-Circuit profile
SHACL	Shapes Constraint Language
SSH	Steady State Hypothesis profile
SV	State Variables profile
TP	Topology profile
TSO	Transmission System Operator
URI	Uniform Resource Identifier
UUID	Universally Unique Identifier
XML	Extensible Markup Language
XSD	XML Schema Definition

4 Data exchange context

There are various levels at which an exchange of power system data/models is necessary. A pan-European model exchange level covers the territory of all system operators (TSOs and DSOs). Regional model exchanges can be realised between different TSOs in one or more synchronous areas. A model exchange on the national level includes interfaces between TSOs (in case there are multiple TSOs on a national level) as well as between different DSOs.

The purpose of model exchanges is not only to exchange the data from one authority to another but also to satisfy the ultimate goal, namely, to perform common studies using shared data. All parties involved in the process should be able to perform the same types of studies and share project tasks between different parties which are using different power system analysis applications. Indeed, the interoperability between different applications used in the exchange process is therefore crucial in both reaching seamless data exchange and obtaining comparable study results when using this data.

The CGMES covers these European and system operators (TSOs and DSOs) business processes by defining the following main types of exchanges valid for a particular study or process:

- Exchange of boundary set: An exchange of a boundary Set is necessary to prepare an exchange of an internal system operator model and to merge a common grid model. E.g. the ENTSO-E Network Modelling Database (NMD) is used to maintain the Boundary Set covering the pan-European area where all TSOs negotiate and agree on the boundary information.

- Exchange of an internal TSO model, i.e. individual grid model (IGM[2]): A number of business processes require each TSO to provide models of its internal territory. To describe its internal territory in a single stand-alone exchange, a TSO is treated as a single model authority set and shall be able to exchange datasets complying with profiles defined in the CGMES. The TSO prepares its internal model in such a way that it is easily and unambiguously combined with other TSO internal models to make up complete models for analytical purposes. This type of exchange can also be applied for the interface between a TSO and a DSO, where models covering transmission or distribution parts of the power system can be exchanged based on a mutual agreement between the TSOs and the DSOs. In this case, and if a TSO requests a DSO model, the DSO would provide its model in accordance with CGMES definitions.
- Exchange of a common grid model: A common grid model refers to the concept of having one model which can be used for multiple purposes. The specification describes what is needed to create a merge model of multiple TSOs' Individual Grid Models (IGM) of their responsible territory into a regional or pan-European model. Various business processes will require specific implementation of the profiles part of the CGMES and the exchange of respective instance files to meet interoperability inside the business process. The Common Grid Model meta-model description will ensure interoperability across the business process.

Business processes (e.g. system development planning, protection planning, operational planning, operation, fault study/simulation, market operation, etc.) are, of course, more complex than these operations, but what is important to note is that all processes are supported using only these basic kinds of interoperation. In addition, business processes shall define or precise, where necessary, the content of the data exchange within the scope of the defined profiles. For instance, OperationalLimitSet can be used to constraint any conducting equipment. It is up to the business process to define if any equipment is mandatory to have operational limits.

Note that each power system model normally consists of multiple datasets (distribution) as defined in CIM standards and further specified by CGMES.

The CGMES supports node-breaker (NB) and bus-branch (BB) model exchanges.

NOTE 1 A network model representation including the connectivity details of all the switching equipment and bays in substations and other equipment containers. Switching equipment is normally not retained, except for those carrying power flow that needs to be monitored, e.g. coupler bays. In order to be used in steady-state analysis calculations, this model representation usually requires topology processing, to produce a BB representation.

NOTE 2 A network model using a simplified representation of a network, typically resulting from topology processing (where the detailed switching equipment and bays get reduced to typically single bus per voltage level in a substation). The only switching equipment used shall be flagged as retained. This model representation is ultimately used in steady-state analysis calculations.

Moving forward the procedures of the model exchanges using the CGMES, it is expected that equipment and steady state hypothesis data (EQ and SSH distribution) will be the input source data for all processes. This type of model should be the fully detailed model with all disconnectors/breakers, etc. Any configuration changes will be made by changing switch statuses.

2 IGM: EU Regulation 2015/1222 Article 2
https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32015R1222.

ID	Specification
EXCH1.	The CGMES defines equipment and steady state hypothesis profiles as an input to power flow, meaning that all results, whether topology or state variables profiles distribution, shall refer to the equipment and steady state hypothesis objects. Therefore, in the case that both equipment and steady state hypothesis instance files are available for a node-breaker model representation, there is no need to exchange topology or state variables instance files in order to obtain a power flow solution.
EXCH2.	For node-breaker model exchanges the TopologicalNode-s represent the output from a topology processing on the detailed input source operational data. These may be optionally exchanged to be used by tools which have an interest in the computed buses.
EXCH3.	For node-breaker model exchanges mRID (rdf:ID in serialisation, see GENC1) of the TopologicalNode-s are not required to be persistent.
EXCH4.	For CGMES exchanges a Topology profile distribution is not exchanged using a difference file. In CGMES Topology profile distribution is only exchanged as full model.
EXCH5.	Left blank intentionally.
EXCH6.	Left blank intentionally.
EXCH7.	Left blank intentionally.
EXCH8.	An application supporting CGMES shall meet the following requirements and constraints: – Model exchange containing node-breaker, bus-branch and hybrid (mixed bus-branch and node-breaker) model representations; – One model authority set containing modelling parts representing different granularity, i.e. different subsets of the model can be modelled in detail as a node-breaker model while other subsets can be with bus-branch level of detail; – ConnectivityNode object instances shall be included in Core Equipment profile instance; – TopologicalNode object instances are representing a given result of a topology processing (EXCH1, EXCH2) or a designed topology; – The association end Terminal.ConnectivityNode is optional in the Core Equipment profile instance. However, a model including topology requires Terminals to have an association to either ConnectivityNode, TopologyNode or both; – The association end ConnectivityNode.TopologicalNode is required in the Topology profile distribution; – The association end Terminal.TopologicalNode is optional, while at least one instance of TopologicalNode.Terminal is required; – The association end Terminal.TopologicalNode is required in cases where a RegulatingControl is associated with a Terminal; Justification and consequence: – ConnectivityNode is a required class in Core Equipment instance data. Therefore, all model representations are built with ConnectivityNode-s; Historically there is assumption that ConnectivityNode-s are for node-breaker style modelling only (whereas TopologicalNode-s are for bus-branch modelling, typically resulting from topology processing on node-breaker models, with buses used to construct the admittance matrix for power flow). ConnectivityNode-s can actually be used for both modelling styles, which is the prescribed way of describing electrical connectivity of ConductingEquipment. For pure bus-branch models, this will mean one additional object (ConnectivityNode) per existing TopologicalNode. – The header information provided in the attribute Model.profile does not give any information about the model authority set model representation (bus-branch, node-breaker or hybrid).

ID	Specification
EXCH9.	CGMES recognises the following main cases of model exchange and model part assembly that application shall support: – Case 1: Exchange of node-breaker, bus-branch or hybrid models **without** topology processing result (**so, inherently without** power flow solution); – Case 2: Exchange of node-breaker, bus-branch or hybrid models **with** topology processing result, **but without** power flow solution; – Case 3: Exchange of node-breaker, bus-branch or hybrid models **with** topology processing result **and with** power flow solution; – Case 4: Merge of models containing same or different model representation **with** an execution of a topology processing; – Case 5: Merge of models containing same or different model representation **without** an execution of a topology processing; Cases 1, 2 and 3 are related to how the data is exchanged while cases 4 and 5 are related to how the models are merged. To provide consistency in the model parts it is recommends that within an exchange, if all models are exchanged according to: – Case 1, the merge process Case 4 is applied; – Case 2 or 3, the merge process Case 5 is applied. In general, within an exchange process where the deliverable is a merged model, the topology and state variables information can be used to ensure possibility of pre-merge validation of different model parts for conformity with exchange standard or procedures.

5 Specifications and functionalities

5.1 General constraints

The following rules are general in nature or involve multiple classes. Additional rules are defined in the notes to the individual classes in the profiles part of the CGMES.

ID	Specification
GENC1.	All IdentifiedObject-s shall have a persistent and globally unique identifier (Master Resource Identifier – mRID).
GENC2.	Name related attributes (name, shortName, description, etc. inherited by many classes from the abstract class IdentifiedObject) shall never be used as persistent identifiers for referencing purpose, but contain human readable text without additional embedded information that would need to be parsed. This implies that names can be changed without impacting the consistency of the dataset. (R:452:ALL:IdentifiedObject.name:rule)
GENC3.	Left blank intentionally.
GENC4.	IEC 61970-301 strongly recommends to use UUID, as specified in RFC 4122, for the .mRID. CGMES requires the usage of UUID.
GENC5.	(deprecated) A requirement to ensure transition until all systems and entities fully comply with GENC4. The CGMES defines the identifier as a non-case sensitive string which conforms to W3C (ISO 8859-1:1998, *Information technology — 8-bit single-byte coded graphic character sets — Part 1: Latin alphabet No. 1*, http://www.w3.org/MarkUp/html3/specialchars.html). A prefix may be added, if necessary, to ensure global uniqueness. The rdf:ID is the mRID plus an underscore "_" added in the beginning of the string. The maximum character limit of the string is 60 characters (including an underscore and a prefix, if any).
GENC6.	Left blank intentionally.
GENC7.	Each model authority is responsible for ensuring that the mRID is globally unique. The role of entities such as regional authorities is limited to coordination and harmonisation of the approaches used in different data exchanges and which shall conform to GENC4 and GENC5.
GENC8.	mRIDs shall be kept persistent between series of exchanges for all objects in all profiles with the following exceptions: – objects created in the Topology profile dataset when it represents the result of topological processing as part of a node-breaker model. – objects created in the State Variable profile dataset that are dependent Topology profile created object, e.g. SvPowerFlow, SvVoltage, etc. – objects created in the Diagram Layout profile dataset, e.g. DiagramObjectPoint and DiagramObject (in some cases, see DL__1).
GENC9.	Some objects in profiles define additional attributes to objects defined in other profiles, e.g. SSH extends objects defined in EQ profile. In profile definition these classes are tagged with "Description" stereotype. The objects of these classes shall be serialised using rdf:about with the additional attributes. Related requirements are MVAL4 and MVAL5.
GENC10.	Instance files shall be encoded according to UTF-8. UTF-16 is currently not supported.
GENC11.	Instance data (distribution) to be exchanged shall make use of the most detailed class possible within a profile, i.e. using sub-typed classes rather than general classes e.g. NuclearGeneratingUnit instead of GeneratingUnit. MAS_7 describe an exception.
GENC12.	Optional and required attributes and associations must be imported and exported if they are in the distribution prior to import. (R:452:ALL:NA:exchange)
GENC13.	If an optional attribute does not exist in the imported file, it does not have to be exported in case exactly the same data set is exported, i.e. the tool is not obliged to automatically provide this attribute. If the export is resulting from an action by the user performed after the import, e.g. data processing or model update the export can contain optional attributes. (R:452:ALL:NA:exchange1)
GENC14.	In most of the profiles the selection of optional and required attributes is made so as to ensure a minimum set of required attributes without which the exchange does not fulfil its basic purpose. Business processes governing different exchanges can require mandatory exchange of certain optional attributes or associations. Optional and required attributes and associations shall therefore be supported by applications which claim conformance with certain functionalities of the CGMES. This provides flexibility for the business processes to adapt to different business requirements and base the exchanges on CGMES compliant applications. (R:452:ALL:NA:exchange2)
GENC15.	Breakers represent busbar couplers in a bus-branch model exchange. In this case, breakers are only included if they are to be retained. In case of a node-breaker model exchange the rules defined in IEC 61970-452 and in the CGMES profiles shall be applied.

ID	Specification
GENC16.	Roles and multiplicity: The direction of the associations in the profiles part of the CGMES is defined in the profiles. All associations are bidirectional in the canonical CIM, but an association instance is specified only at one end in the instance files. The documentation of the profiles, which is part of the CGMES, describes the association with the end user. It is permissible to include both ends of an association in the XML, although only the end designated by the profile is required. The following two examples present two options which can be seen in the CGMES profiles: – Example 1: The names “ConductingEquipment.Terminals” and “Terminal.ConductingEquipment” specify opposite ends of the association between the ConductingEquipment class and the Terminal class. In a one-to-many association, the association reference is included with the data of the “many side” class. Therefore, a ConductingEquipment may be associated with up to two Terminals, whereas a Terminal shall be associated with one and only one ConductingEquipment. Consequently, the XML element corresponding to the ConductingEquipment class is not expected to contain any “ConductingEquipment.Terminals” elements. However, the XML element corresponding to the Terminal class is required to contain appropriate “Terminal.ConductingEquipment” elements. – Example 2: The names “TopologicalIsland. TopologicalNode-s ” and “TopologicalNode.TopologicalIsland” specify opposite ends of the association between the TopologicalIsland class and the TopologicalNode class. The XML element corresponding to the TopologicalNode class is not required to contain any “TopologicalNode.TopologicalIsland” elements. However, the XML element corresponding to the TopologicalIsland class is expected to contain appropriate “TopologicalIsland. TopologicalNode-s ” elements.
GENC17.	Attribute and role values (i.e. numerical values, string values, object references and enumeration values) appearing in a CIMXML document shall have a value, i.e. empty elements or attributes are not allowed..
GENC18.	Decimal character for floating point numbers shall only be a full stop. This constraint is necessary because local (regional) settings may select either comma or full stop and a particular local settings do not support both comma and full stop. The mix of comma and full stop prevents interoperability: hence one must be selected.
GENC19.	The Equipment boundary profile (EQBD) is deprecated. The requirements and constraints related EQBD applies to EQ in cases where it is used for an exchange of boundary information.
GENC20.	The implementation of CGMES is supported by machine-readable documentation which shall, as minimum, include Resource Description Framework Schema (RDFS) that conforms to IEC 61970-501. In addition, other machine-readable documentation such as W3C Shapes Constraint Language (SHACL) and Object Constraint Language (OCL) can be provided.

5.2 Model authority sets (MAS)

The CIM concept of Model Authority Sets is applied to enable the assembly and merging of model. It can also identify the source MAS when the merged model is referring to the original input model. Model Authority Sets allow an interconnection model to be divided into disjointed sets of objects, which in turn allows different parties to take responsibility for different parts of a common grid model.

ID	Specification
MAS_1.	All model object instance include a unique identification that confirms to UUID and identifies the Model Authority Set (MAS) version
MAS_2.	Across all models, including model with different MAS, the model object instance which represents a given real world equipment (line, transformer, etc.) shall always have the same mRID.
MAS_3.	A CIM functional representation is given by CIM classes defined in CGMES UML. Within any one model, object mRIDs are unique, since the same element shall not be represented twice.
MAS_4.	Left blank intentionally.
MAS_5.	In the case of upgrading from one version of CIM to another the mRID shall be kept persistent for the same functional representation in the new CIM given by a new CIM class. For instance, the change from CIM 15 to CIM 16 allows for a functional representation identified by the mRID for a ShuntCompensator which is changed to the newly introduced class NonLinearShuntCompensator with the same mRID.
MAS_6.	Left blank intentionally.
MAS_7.	A new mRID is generated in case there is a need to change the class (e.g. GeneratingUnit is changed to ThermalGeneratingUnit in a sequence of exchanges in a process). If a physical unit given by mRID in the asset part of the CIM needs to be represented simultaneously as GeneratingUnit and ThermalGeneratingUnit (a given specialisation) it must have different mRIDs for GeneratingUnit and ThermalGeneratingUnit. If different business processes are required to support both types (GeneratingUnit and ThermalGeneratingUnit), the applications should maintain two mRIDs and in both cases support difference file exchange.
MAS_8.	Only one representation (the main class or its specialisation, see MAS_7 and GENC11) shall be present in a given instance file (distribution).
MAS_9.	Left blank intentionally.
MAS_10.	Left blank intentionally.
MAS_11.	Left blank intentionally.
MAS_12.	Each Model Authority manages one or more Model Authority Set in its area of responsibility. The Model Authority is also responsible for assigning and maintaining object mRIDs for all Model Authority Set governed.
MAS_13.	Left blank intentionally.

5.3 File header

The following rules apply to all headers:

ID	Specification
HGEN1.	The definition of file header is specified in IEC 61970-552:2016.
HGEN2.	Each type of instance file (full and difference) shall have a file header. (IEC 61970-552:2016, Subclause 5.1)
HGEN3.	The header section shall always be the first element in a CIMXML document. (IEC 61970-552:2016, Subclause 5.2)
HGEN4.	Applications shall comply with the following additions (compared to IEC 61970-552:2016, Table 2) to the header definition amended by CGMES: Model.created – It is the time of the serialization. The format is an extended format according to ISO 8601-2005. European exchanges shall refer to UTC. Model.scenarioTime – This is the date and time that this model represents, i.e. for which the model is valid. The format is an extended format according to the ISO 8601-2005. European exchanges shall refer to UTC.

The following rules are applied to the model ID (rdf:about) in the file header:

ID	Specification
HREF1.	New ID is generated for new instance files only when the context of instance data (distribution) changes. An export done on the imported instance data (distribution) without any changes should have the same model ID reference in the header. Rearrangements of classes and attributes in the instance file (distribution) are allowed and does not require new ID.
HREF2.	Left blank intentionally.
HREF3.	Left blank intentionally.
HREF4.	The dependency reference in the header shall be used as guidance and shall not restrict the possibility of importing profiles which are exported based on a previous version of a depending profile instance file. The standard does not prevent the tools from exchanging files where the file reference does not match. Unresolved or missing references shall be reported to the user. In general, users are free to combine files on an ad-hoc basis and tooling shall identify and optionally resolve all unresolved references.
HREF5.	Left blank intentionally.

5.4 File body

ID	Specification
FBOD1.	The IEC 61970-552:2016 specification is used to format a file-based distribution, although the instance file shall contain only the objects from one Model Authority Set.
FBOD2.	An instance file (distribution) could contain instance data of more than one profile from the CGMES only if all profile URIs are defined in the file header and as long as the instance data belongs to one MAS. All profile URIs are defined in the file header even if one profile is a superset of another, i.e. both URIs should be included.
FBOD3.	Instance files (distribution) may contain objects with associations to objects which will be packaged in a different instance file. This situation means that the instance file by itself is not self-contained – it may have dangling references and may not be used except when combined with one or more other instance file as specified in the file header dependencies. For example, validation of TP instance data requires the EQ and boundary instance data in order to fulfil the dangling references validation. This could be reported as errors in the validating cardinalities across profile associations. In addition, there can be missing or more data in the dependent profile instance data, e.g. Terminal in EQ that is not included in TP or Terminal in TP that is not included in EQ. Therefore, the result of model instance data validation is conclusive only if all dangling references are resolved. Constraints or cardinality violations should be reported by validation tools when validating individual instance data. However, if the violations are due to dangling references they shall not be considered as non-compliance to the standard.
FBOD4.	The CGMES requires that at the receiving end of the exchange all references in the instance files pointing to instance files from other profiles which are part of the exchange should be satisfied. Therefore, the complete set of instance files necessary for the grid model shall have fulfilled references (no dangling references are allowed).
FBOD5.	A difference model shall not be created in cases where the numeric differences are outside the accuracy of the attributes' numerical declaration, e.g. a xsd:float is considered to only have 7-digit accuracy. It is up to the application to define a suitable tolerance value when creating difference files. (R:600:ALL:NA:float)

5.5 Profiles and instance file types

5.5.1 General

This subclause defines some specific rules for the profiles and their instance files so that the model exchange can be performed correctly.

5.5.2 CGMES profiles' properties

The profiles which are part of the CGMES are based on IEC CIM UML and maintained in a UML environment.

<table>
<tr><th>ID</th><th>Specification</th></tr>
<tr><td>PROF1.</td><td>The UML namespace, namespaces of the profiles, European extensions, profiles versions as well as the identification of the versions of the UML and profiles are defined in an Ontology class for each profile of the CGMES. These properties shall be used as a primary source for file header information.</td></tr>
<tr><td>PROF2.</td><td>Left blank intentionally.</td></tr>
<tr><td>PROF3.</td><td>Only instances of concrete classes are used in actual exchanges (instance files). Those concrete classes may inherit attributes or associations from abstract classes.</td></tr>
<tr><td>PROF4.</td><td>Left blank intentionally.</td></tr>
<tr><td>PROF5.</td><td>Left blank intentionally.</td></tr>
<tr><td>PROF6.</td><td>Classes/attributes/associations which were introduced as European extensions and are marked with a stereotype "European".</td></tr>
<tr><td>PROF7.</td><td>Any classes/attributes/associations which are defined by the CGMES profiles can be used in grid model exchanges. The authority governing a given business process and related data exchange process shall specify all required attributes/classes/associations to be exchanged. An optional attribute can be required, while a required attribute as defined in the CGMES cannot be changed to optional without modification of the version of the profile. Applications and tools should be able to deal with this complexity and support all classes and attributes depending on the tools' functionalities, i.e. at least they should be able to host the data and transfer with no change in case the tool is not able to use the data.</td></tr>
<tr><td>PROF8.</td><td>Left blank intentionally.</td></tr>
<tr><td>PROF9.</td><td>Left blank intentionally.</td></tr>
<tr><td>PROF10.</td><td>CGMES instance file (distribution) dependency shall be declared by md:Model.DependentOn in the header according to Figure 1 and the associated rules.

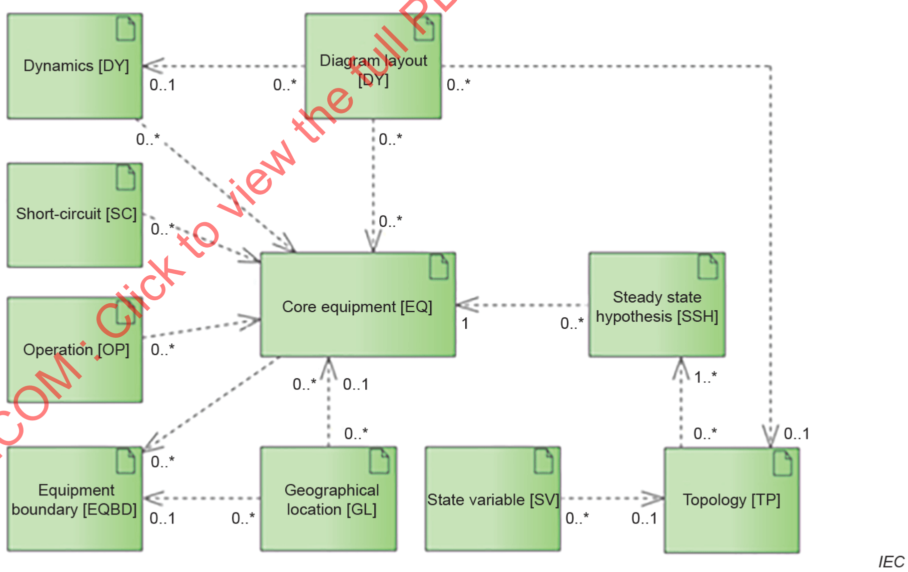


Figure 1 – CGMES instance file dependency

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).</td></tr>
</table>

ID	Specification
PROF11.	The respective profile URI shall be declared in the file header. If the profile URI is not included in the header, all classes/attributes/associations part of the undeclared profile are considered optional. Therefore, the profile references in the file header specify which profiles validation the instance file data is valid for. The instance data file (distribution) can contain data from multiple profiles (such as Short-Circuit or Operation) without being declared in the header profile references. However, the data belonging to non-declared profiles does not need to be imported and re-exported as the profiles are not defined in the file header. The user shall be informed if the data is not imported. (refer also to R:452:ALL:NA:exchange3 and R:452:ALL:NA:exchange4)

5.5.3 CGMES extensions

Due the complexity and specificity of the European data exchange requirements and TSOs' business processes, the CIM version used to create the profiles of the CGMES has been extended.

ID	Specification
EEXT1.	European extensions part of CGMES profiles shall be supported to conform to CGMES.
EEXT2.	All extension shall be an addition to an existing standard (CGMES of IEC CIM standards). European extensions which are part of the CGMES are extensions of the IEC CIM. When extending the canonical CIM it is permitted to create a restriction which does not prevent the validity of the CGMES. While an optional attribute or association can be made required as a part of the profiling work, a required attribute or association may not be made optional as part of an extension.
EEXT3.	Declaring the European extension URI and the corresponding alias: The European extension URI and the namespace alias shall be declared at the topmost element of the CIM/XML file along with CIM and other URI. Example (URI of the European CIM extension and the namespace alias): *<?xml version="1.0" encoding="utf-8"?>* *<rdf:RDF xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#"* *xmlns:cim="http://iec.ch/TC57/CIM100#* …. ***xmlns:eu="http://iec.ch/TC57/CIM100-EuropeanExtension/1/0#">*** **….** *</rdf:RDF>*

ID	Specification
EEXT4.	Using Extension namespace alias to declare the extended data is illustrated in the following examples. In the first example the attribute IdentifiedObject.shortName is declared as an extended attribute and prefixed with the namespace alias “eu”. Example (declaring an extended attribute): *<cim:ACLineSegment rdf:ID="_f732688e-bace-4ece-bc2b-5d9792608092">* *<cim:IdentifiedObject.name>DFG-THY 1</cim:IdentifiedObject.name>* ***<eu:IdentifiedObject.shortName>Brussels</eu:IdentifiedObject.shortName>*** *<cim:ACLineSegment.bch>4.61157E-05</cim:ACLineSegment.bch>* *<cim:ACLineSegment.r>1.06601</cim:ACLineSegment.r>* *<cim:ACLineSegment.x>34.28535</cim:ACLineSegment.x>* *<cim:Conductor.length>45</cim:Conductor.length>* *<cim:Equipment.aggregate>false</cim:Equipment.aggregate>* *<cim:ConductingEquipment.BaseVoltage rdf:resource=* *"#_4852044a-e072-441b-bc3c-dc7b00de7e5e" />* *</cim:ACLineSegment>* In the second example, if an instance of the extended class is declared as extension, then the extended class, i.e. ExtendedClass, and the extended attribute ExtendedClass.extendedAttribute must be prefixed with the extension namespace alias “eu”. Example (declaring an extended instance or object): ***<eu:ExtendedClass rdf:ID="_21d3bbfb-0aec-4e44-8db0-ae2e064b22e2">*** *<cim:IdentifiedObject.name>EX11</cim:IdentifiedObject.name>* ***<eu:ExtendedClass.extendedAttribute>20</eu:ExtendedClass.extendedAttribute >*** *….* *</eu:ExtendedClass >* The third example illustrates the addition of an association, namely European extension. Example (declaring an extended association): *<cim:ACLineSegment rdf:ID="_9cdc68b4-3953-c88a-24de-820873445a59">* *<cim:ACLineSegment.bch>0.000157</cim:ACLineSegment.bch>* *<cim:ACLineSegment.gch>0</cim:ACLineSegment.gch>* *<cim:ACLineSegment.r>1.04001</cim:ACLineSegment.r>* *<cim:ACLineSegment.x>12</cim:ACLineSegment.x>* ***<eu:ConductingEquipment.ExtendedClass rdf:resource="#_9cf549dc-2453-d994-976a-c2ea44773145" />*** *<cim:Conductor.length>30</cim:Conductor.length>* *<cim:IdentifiedObject.name>B1X3</cim:IdentifiedObject.name>* *</cim:ACLineSegment>*
EEXT5.	The same principle related to extensions applies to any other extensions. Therefore, if an instance file produced by a given application/software contains some extensions specific to vendors' internal applications, the same method to declare such extended data shall be used.
EEXT6.	An instance file (distribution) which contains classes, associations and attributes not defined in the CGMES shall be processed by the receiving application which would ignore the extensions left undefined by the CGMES and make use of the rest of the data.
EEXT7.	Extending an enumerator has to be done by adding a new enumerator which includes the additional values. Both the extended and the standard enumerator have to comply with the profile, i.e. if the standard enumerator is mandatory, it shall be included in addition to the new (extended) enumerator.

5.5.4 Equipment profile and instance file

An equipment profile instance file (distribution) is based on the IEC 61970-452 CIM static transmission network model profiles.

ID	Specification
EQ__1.	Left blank intentionally.
EQ__2.	An assembled EQ is the union of Core equipment (EQ), Short-Circuit (SC) and Operation (OP) that is included in an exchange describes the equipment in the power system model covered by a MAS.
EQ__3.	An equipment instance file would not normally change in case of frequent data exchange process. It can be updated with difference file exchange.
EQ__4.	Only one GeographicalRegion shall be exchanged per MAS. In case multiple Model Authority have a need to have the same GeographicalRegion (i.e. multiple TSOs in a country) the class GeographicalRegion shall be present in all Model Authority models and shall have different rdf:ID, but can have same name/description. There is no specific naming convention defined. Note that this is mainly applicable for exchanging transmission data. Additional clarifications when dealing with distribution data are not defined currently.
EQ__5.	SubGeographicalRegion is normally a TSO or sub-area of a TSO. There is no specific naming convention defined. Note that this is mainly applicable for exchanging transmission data. Additional clarifications when dealing with distribution data are not defined currently.

5.5.5 Topology profile and instance file

A topology profile instance file (distribution) is based on the IEC 61970-456 Solved power system state profiles.

ID	Specification
TP__1.	A topology instance file (distribution) of a merged model contains topology objects for all model authority sets being part of the merged model. These topology objects get referenced by the corresponding equipment describing how equipment is electrically connected.
TP__2.	A topology instance file (distribution) is the result of a network topology processing analysis. Because of this the topology instance file is considered as an output from the topology processing.
TP__3.	A topology instance file (distribution) is always exchanged in full.
TP__4.	A topology instance file (distribution) for source MAS shall contain: • topology objects for individual MAS, and • the TolopogicalNode-s related to the ConnectivityNode-s associated with BoundaryPoint-s because topology profile is not instantiated for boundary MAS. However, the topology instance file (distribution) cannot be merged with another assembled model's topology instance file (distribution) using the TopologyNode-s. The merge needs to use the boundary ConnectivityNode-s to link the result from the assembled models. The output of topology processing on a merged model will result in one Topology instance data file (distribution) where all TopologicalNode-s will get potentially new mRID-s.

5.5.6 Steady state hypothesis profile and instance file

A steady state hypothesis profile instance file (distribution) is based on the IEC 61970-456 Solved power system state profiles.

ID	Specification
SSH_1.	A steady state hypothesis instance file (distribution) contains input on the operational point (load, generation, border transits, switch and tap positions, generation set-points, operational limits, etc.) required to be able to perform power flow simulations.
SSH_2.	A steady state hypothesis instance file (distribution) is in CGMES always exchanged in full. Due to the nature of the SSH profile, all objects in a steady state hypothesis instance file shall have persistent mRIDs and rdf:IDs.

5.5.7 State variables profile and instance file

A state variable profile instance file (distribution) is based on the IEC 61970-456 Solved power system state profiles.

ID	Specification
SV__1.	A state variable instance file (distribution) contains all objects required to describe a steady-state solution.
SV__2.	A state variables instance file (distribution) is always exchanged in full.
SV__3.	A state variables instance file of a merged model contains state variables related objects for all model authority sets being part of the merged model.
SV__4.	All state variables shall be instantiated in the SV instance file (distribution) for all energized elements part of a TopologicalIsland independently of the regulating status of the elements (e.g. for a shunt compensator that is not regulating the SvShuntCompensatorSections.sections shall be the same as ShuntCompensator.sections). All instances shall be representing computed values obtained from a power flow calculation. For SvPowerFlow instances refer to profile constraint on the SvPowerFlow class.

5.5.8 Equipment boundary profile and instance file

ID	Specification
EQBD1.	An equipment boundary instance file (distribution) contains all objects defined in the equipment boundary profile and includes data for boundary information relating to a given exchange.
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.
EQBD3.	Equipment boundary instance files (distribution) can be updated using difference file exchange.

5.5.9 Topology boundary profile and instance file

This chapter has been left empty on purpose since instance file (distribution) of TPDB will no longer be exchanged.

ID	Specification
TPBD1.	Left blank intentionally.
TPBD2.	Left blank intentionally.

5.5.10 Diagram layout profile and instance file

A diagram instance file (distribution) is based on the IEC 61970-453 Diagram layout profile standard and contains data necessary for the model diagram.

ID	Specification
DL__1.	A full Diagram (non-difference instance file) represents a new drawing of the diagram. Data may change from one system drawing to another, e.g. two diagrams with the same mRID of the classes in the instance files (distribution) do not need to be identical. The purpose of the Diagram layout profile is to support the understanding of the equipment data. If a diagram generated by one system is updated by another the file does not need to be identical, with the exception of the edited changes. However, the updated and exported diagram instance file shall include all the same relevant information and must have the same layout rendering in the new destination system (old source) as the original, with the exception of the changes. The expected behaviour is that a diagram may have a new layout with the same Diagram mRID as well as DiagramObject mRID. Persistence of Diagram and DiagramObject mRIDs is required if difference updates are supported.
DL__2.	The objects in the equipment of the Diagram layout instance are identified by the DiagramObject.IdentifiedObject.
DL__3.	The diagram layout profile supports exchange of more than one diagram, e.g. detailed substation diagram, single line diagram, etc. in one instance file of DL profile.
DL__4.	A Diagram layout instance file (distribution) is normally exchanged in full.

5.5.11 Geographical location profile and instance file

A geographical location profile instance file (distribution) is based on the IEC 61968-13 CIM RDF Model exchange format for distribution.

ID	Specification
GL__1.	A geographical data instance file contains GIS data according to IEC 61968-13.
GL__2.	A geographical data instance file (distribution) is exchanged in full, although it could be updated using difference file exchange.

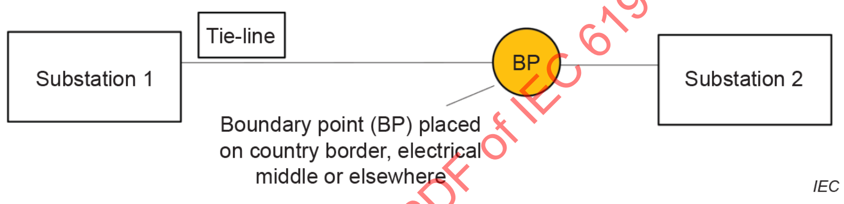
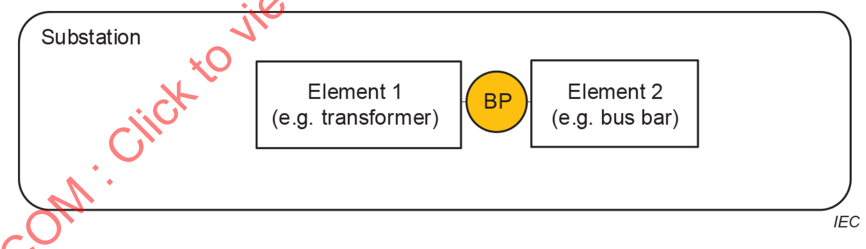
5.5.12 Dynamics profile and instance file

ID	Specification
DY_1.	A dynamics instance file (distribution) represents the parameters necessary to model dynamic behaviour of the power system, e.g. transient and subtransient reactances of synchronous machines, parameters of the control block diagrams of excitation systems, turbine, governors, power system stabilisers, etc.
DY_2.	A dynamics instance file (distribution) would not normally change in case of frequent data exchange processes. It may be updated using difference file exchange.

5.6 File exchange

ID	Specification
FILX1.	A given exchange consists of multiple files. The CGMES defines that instance files that belong to a given logical exchange shall be either zipped together or zipped individually. The tools shall use zip files directly when importing and exporting in order to minimise users' effort.
FILX2.	The CGMES defines no naming convention applied to the .xml or .zip file names. Although different business processes may define such a file naming convention, the applications shall rely solely on the information provided in the file headers in order to process the instance files.
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. – 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
FILX4.	The zip file shall not contain folders. It is only a container of *.xml files.
FILX5.	The hierarchy and model dependency shall be respected when exchanging models. The number of files and the type of the files (full or difference) depends on the requirements set by the business process. The following examples show some possible situations: – If the equipment file is changed, all files (depending on the requirements of the exchange: equipment, topology, steady state hypothesis, state variables, dynamics, diagram and geographical files) shall be sent as part of any exchange. – If only the steady state hypothesis file is changed, only the steady state hypothesis file shall be sent as part of any exchange if there is no requirement to exchange the solved power system model. – If only the state variables file is changed, only the state variables file shall be sent as part of any exchange. – If only the dynamics file is changed, only the dynamics file shall be sent as part of any exchange. – If only the diagram file is changed, only the diagram file shall be sent as a part of any exchange. – If only the geographical file is changed, only the geographical file shall be sent as a part of any exchange.
FILX6.	It is not permitted to exchange a topology file, a steady state hypothesis file, a state variables file, a dynamics file, a diagram file or a geographical file from one model and an equipment file from another model (or from an entity which has changed the equipment file) and attempt to merge all files into one merge model.
FILX7.	In case difference files are exchanged, the same dependencies as for full model exchange are followed. The difference file (e.g. equipment, topology or dynamics) should refer to the base model, which is subject of an update. Dependencies are listed in the file header of each file which is exchanged.

5.7 Boundary point – properties and location

ID	Specification
BPPL1.	EquivalentInjection classes are used to represent the power flow exchanges through Boundary points. These classes are included in the individual model MAS (e.g. Model Authority MAS) and refer to the Boundary points (ConnectivityNode-s) in the Boundary set. The SvInjection class is not used for this purpose.
BPPL2.	In case the use cases require the exchange of multiple SSH, TP, SV, etc. instance files (distribution) which are dependent on an EQ instance file, this EQ shall always include an instance of EquivalentInjection per Boundary point. Therefore, in a multi MAS (among TSOs, DSOs or mixed) exchange a Boundary point shall always have two EquivalentInjections per Boundary point which are contained in different MAS connecting to the Boundary point. mRIDs of those EquivalentInjections are kept persistent.
BPPL3.	A ConnectivityNode representing a Boundary point may connect various branches. Most common are ACLineSegment, PowerTransformer and subtypes of Switch. There are two options related to the location of the Boundary point (BP) in a network model representing the AC grid only: Boundary point placed on a tie-line (see Figure 2): The CGMES does not fix the position of the Boundary point on a tie-line. The Boundary point may be placed on a country border, at the electrical middle of the tie-line, or elsewhere based on mutual agreement between the two neighbouring MAS.  **Figure 2 – Boundary point placed on a tie-line** Boundary point placed in a substation (see Figure 3): The CGMES allows a Boundary point to be placed in a substation. The two neighbouring MAS shall agree between which two elements in a substation the Boundary point is placed.  **Figure 3 – Boundary point placed in a substation**

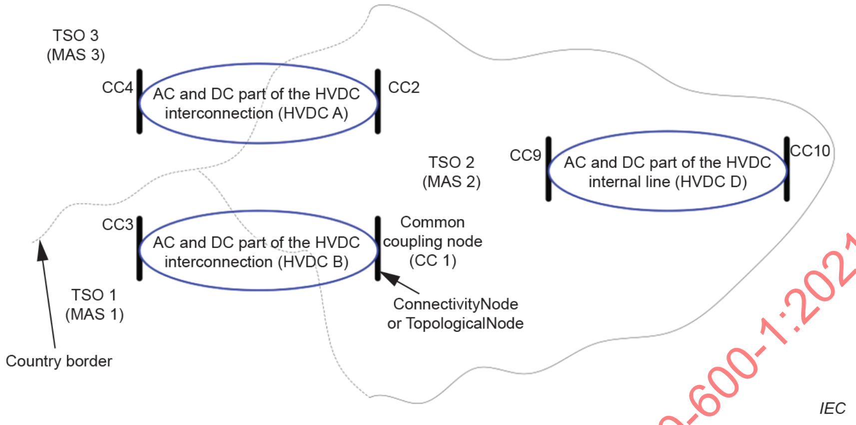
<table>
<tr><th>ID</th><th>Specification</th></tr>
<tr><td>BPPL4.</td><td>The CGMES supports HVDC modelling for a detailed representation of HVDC interconnections, system operator (TSO or DSO) internal HVDC links and HVDC grid. Figure 4 and Figure 5 illustrate different cases.


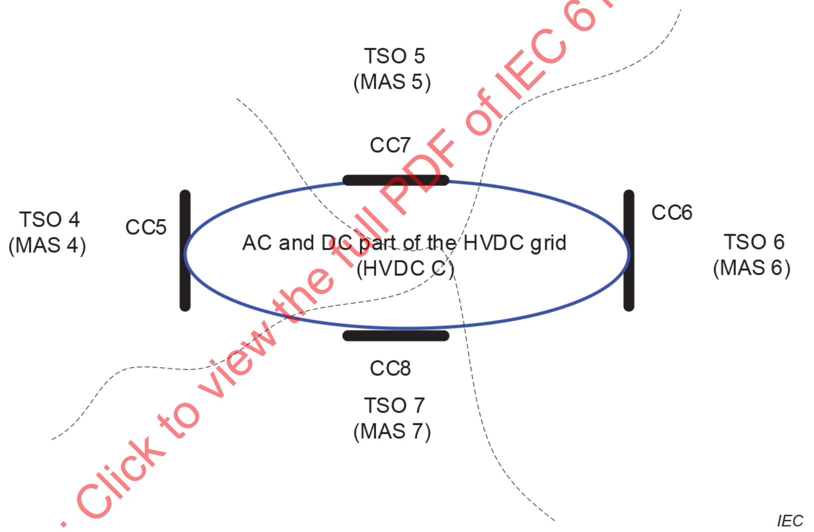
Figure 4 – HVDC as interconnection or internal line


Figure 5 – HVDC grid</td></tr>
<tr><td>BPPL5.</td><td>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).</td></tr>
<tr><td>BPPL6.</td><td>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).</td></tr>
<tr><td>BPPL7.</td><td>The simplified exchange of an HVDC link could be applied to internal HVDC links (systems) as well as to HVDC interconnections.</td></tr>
<tr><td>BPPL8.</td><td>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 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).</td></tr>
<tr><td>BPPL9.</td><td>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.</td></tr>
<tr><td>BPPL10.</td><td>Left blank intentionally.</td></tr>
</table>

ID	Specification
BPPL11.	In particular cases a Boundary point can be placed on a DCLineSegment and could possibly represent a different authority. However, the CGMES does not allow a separation of the HVDC model at a Boundary point on a DCLineSegment.
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.
BPPL13.	BoundaryPoint attributes that relate to "To" and "From" sides are not indicating the direction of the power flow, but they are identifying which MAS and elements in that MAS shall connect to the respective sides of the BoundaryPoint. Therefore, for a BoundaryPoint connecting two AC MAS-es the "From" and "To" sides do not have functional meaning. For a BoundaryPoint connecting AC and DC MAS-es where there at least two BoundaryPoint-s per HVDC link, the "From" and "To" sides have functional meaning indicating which AC MAS shall be connected to which side of the DC MAS.

5.8 Model merging process

ID	Specification
MAPR1.	A complete merged model (solved or unsolved power system model) contains information from more than one model authority set. Part of the reason for the division into files per MAS is to create better flexibility when it comes to how complete merged models for different purposes are formed from base parts. Model management systems can be designed based on this capability.
MAPR2.	Among instance files which are to be combined to form a merged model, there is no overlap – each object, association or attribute appears in one and only one of the instance files being combined.
MAPR3.	(Informative) The model merging procedure in the CGMES is based on the Model Authority Sets concept. The procedure includes the following steps: – Model management system (calculation tool/software) imports all MAS (full set of files for MAS for each Model Authority and Boundary MAS). Depending on the implementation of the import process, the Boundary MAS must be imported first in case other MAS are subsequently imported. The following files/MAS should be available for import. • At least two models from Model Authorities are available and represented in two different MAS. These models have necessary references to the Boundary set. • System operator (TSO or DSO) models which include classes (EquivalentInjection for SSH profile; SvPowerFlow and SvVoltage for SV) represent the flow between the MAS and the voltage of the Boundary points. • Boundary MAS: Equipment boundary instance files that cover, but are not limited to, the area represented in the merged model. – EquivalentInjection.p and EquivalentInjection.q are set to zero, if a tie-line or a ConnectivityNode is connected by two MAS, i.e. radial connections are not modified. It is not necessary that these parameters be set to zero at the time of the import. Additional functions should be made available for users to cover all necessary use cases when dealing with Model Authority MAS and Boundary MAS. – A power flow may be performed to obtain a solution for the merged model.
MAPR4.	An update of the merged power system model is performed via an update of the concerned MAS (i.e. replacing of MAS files). A power flow solution is necessary to update the common state variables file valid for the updated merged model.
MAPR5.	(Informative) State variable instance file (distribution) for the common grid model includes SvPowerFlow for injections of Boundary points. In order to solve a merged model these injections are set to zero in case a Boundary point successfully connects the two MAS. Due to MAPR4 in case a business process requires an update of SSH to represent the values in SV (including SvPowerFlow) the merged solved model can have different than zero values for the EquivalentInjection-s connected to the boundary point matching the calculated power flow. Some injections (SvPowerFlow) may differ from zero to represent the exchange with other areas not included in the merged model.
MAPR6.	The exported merged model shall have only one instance of SvVoltage per Boundary point.

ID	Specification
MAPR7.	The CGMES does not fix the content of a merged model. Different business processes shall define the type (EQ, SSH, TP, SV, etc.) of data needed in the merged model depending on the objectives.
MAPR8.	The CGMES supports export of unsolved merged model. The model can be a node-breaker or bus-branch model representation type and shall always include SSH instance files (distribution) if the purpose of the exchange is to perform (without data additions) a power flow calculation in a different application.

ID	Specification
MAPR9.	(Informative) The exported merged model contains multiple MAS. These exported multiple MAS include all changes which are introduced on the merged model (changes made in the software which is used to merge the model) per MAS. The chart in Figure 6 illustrates the merge process:

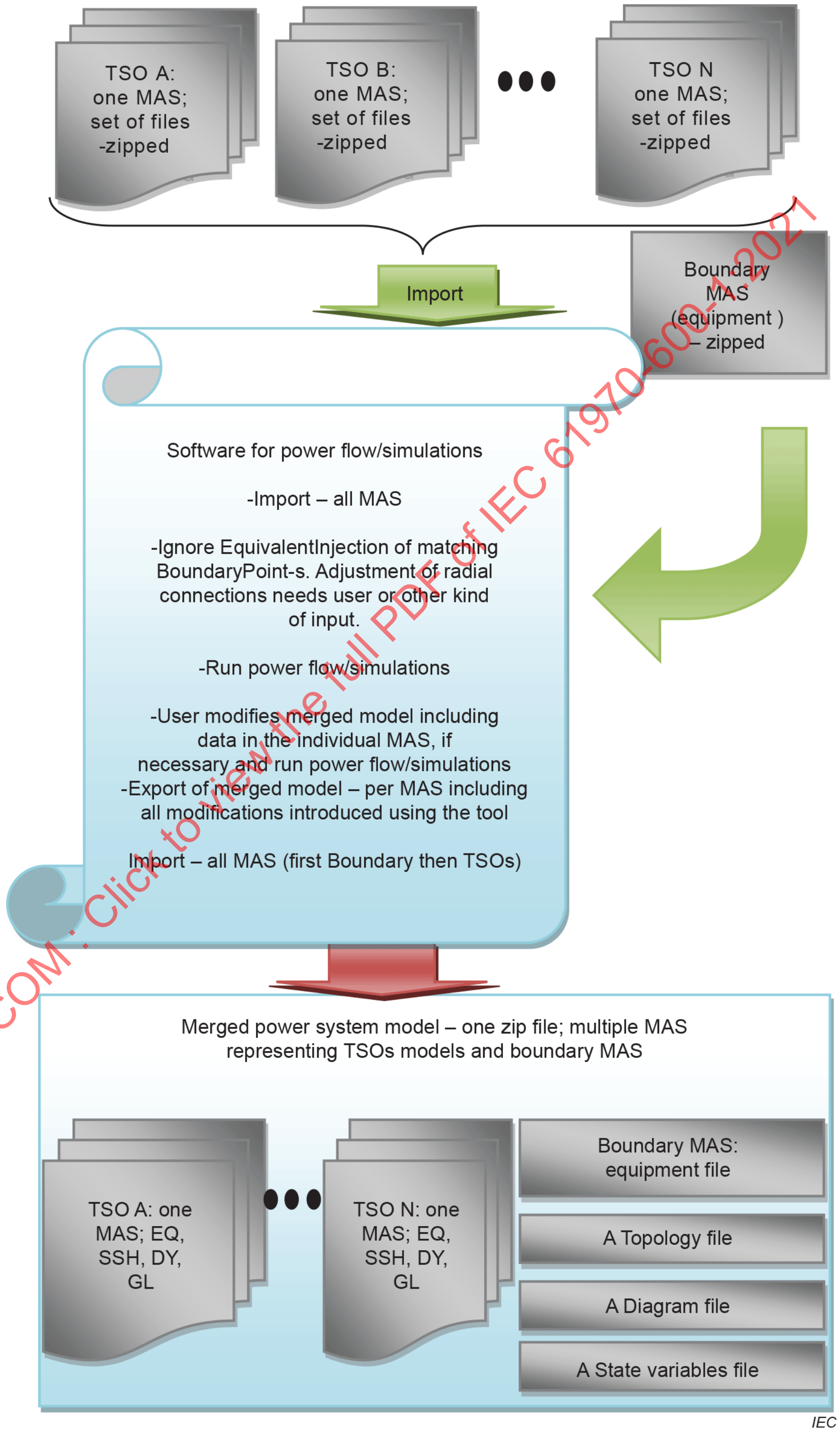


Figure 6 – Merge process

ID	Specification
MAPR10.	The model authority set defined in file header of a state variable instance file of a merged model is the model authority set which creates the state variables.

ID	Specification
MAPR11.	The model authority set defined in file header of a diagram layout instance file of a merged model is the model authority set which creates the diagram layout.
MAPR12.	The model authority set defined in file header of a topology instance file of a merged model is the model authority set which creates the topology as an output of topology processing.

5.9 CIM XML document/distribution validity

In order to be considered a valid model, a given combined set of CIM XML document/distribution shall adhere to the following criteria:

ID	Specification
MVAL1.	The file shall be well-formed as defined by the Extensible Markup Language (XML) 1.0 (Second Edition) (http://www.w3.org/TR/REC-xml).
MVAL2.	The file shall adhere to the rules set forth in the Simplified RDF Syntax for Power System Model Exchange as defined in IEC 61970-552:2016.
MVAL3.	Left blank intentionally.
MVAL4.	**Serialisation clarifications (normative):** This document does not modify serialisation related rules defined in IEC 61970-552:2016 and IEC TS 61970-600-1:2017. **Serialisation recommendations (informative):** Next editions of this document will ensure that there is closer alignment with IEC 61970-552 and RDF specifications. Therefore, implementations should expect changes in the following direction: – Header information is added to denote CIMXML version. – xml:base="urn:uuid:" is not declared. Therefore, all prefix shall be explicit. – It is not recommended to use other namespaces (RFC8141) however if this is the case then the prefix "urn:[URN namespace]" shall be declared explicitly. – rdf:ID shall not be used. – If all mRID are encoded using UUID standard (GENC4) then there are two methods: • 1.xml:base="urn:uuid:" is declared in the header which means that all rdf:about will be assumed rdf:about="urn:uuid:26cc8d71-3b7e-4cf8-8c93-8d9d557a4846" even if the instance data is like this rdf:about="#26cc8d71-3b7e-4cf8-8c93-8d9d557a4846" • 2.xml:base="urn:uuid:" is not declared in the header which means that all rdf:about shall be like this rdf:about="urn:uuid:26cc8d71-3b7e-4cf8-8c93-8d9d557a4846" – Mixture of encoding of mRID is allowed (GENC6), hence the presence of xml:base="urn:uuid:" does not make a difference if all mRID have the same encoding. Therefore, all prefix shall be explicit.

ID	Specification
MVAL5.	In general the concrete classes in a profile are the leaf (or the most specialised class). A profile like SSH that is depending on the EQ shall in general have the same abstract classes as EQ. However, to meet various modelling requirement, limiting the need to change profile definition and simplifying the profile definition, classes can be defined as concrete and serialised in the profile instance file. This includes cases were EQ has defined more specialised classes as concrete. In this case the associated profile, e.g. SSH, can add attribute and/or association to the object by serialising it in an abstract class to the object, e.g. the Equipment class to ACLineSegment. The two examples below illustrate this requirement: 1. SSH profile includes a concrete class Equipment with a required attribute inService, however the SSH profile does not include concrete class ACLineSegment. In this case the rdf.about of the Equipment instance in SSH is the rdf:ID of the ACLineSegment in Core EQ instance file. ACLineSegment is not instantiated in SSH instance file. As the Equipment.inService is a required attribute in SSH, Equipment shall be instantiated with rdf:about in SSH instance file for all classes that inherit from Equipment. - Core EQ instance file includes: *<cim:ACLineSegment rdf:ID="**_f732688e-bace-4ece-bc2b-5d9792608092**">* … *</cim:ACLineSegment>* - SSH instance file includes: *<cim:Equipment rdf:**about**="**_f732688e-bace-4ece-bc2b-5d9792608092**">* *<cim: Equipment.inService>true</cim: Equipment.inService>* *</cim: Equipment >* 2. SSH profile includes a concrete class Equipment with a required attribute inService, the SSH profile also includes a concrete class BatteryUnit which inherits the attribute inService from Equipment. In this case Equipment is not instantiated as BatteryUnit is a concrete class in SSH. The rdf:about is used due to the fact that BatteryUnit is also instantiated in Core EQ instance file. - Core EQ instance file includes: *<cim:BatteryUnit rdf:ID="**_f732688e-bace-4ece-bc2b-5d9792608092**">* … *</cim: BatteryUnit >* - SSH instance file includes: *<cim: BatteryUnit rdf:**about**="**_f732688e-bace-4ece-bc2b-5d9792608092**">* … *<cim: Equipment.inService>true</cim: Equipment.inService>* … *</cim: BatteryUnit >*

5.10 Naming Convention

The CGMES, which uses multiple profiles, serves various business processes. These business processes have different needs in terms of naming information. There is no single set of rules which could be applied to deal with the specificities of different business processes axes such as:

- Bilateral, regional, pan-European data exchanges;
- Operational (day ahead and related processes), long term planning data exchanges;
- Node-breaker, bus-branch based data exchanges;
- Voluntary, project oriented, obligatory by an exchange process, obligatory by law data exchanges.

A restriction related to naming could serve one business process well but may represent a significant constraint for another business process. In addition, actors involved in the exchange are not necessarily the same.

Naming is a complex issue as different applications or processes can have naming conventions that are inconsistent or conflicting with naming conventions used by other applications or processes.

CGMES applies the following naming principles:

- Names are for humans. They shall not be used for any purposes of object identification.
- Naming rules shall be driven by the use cases (mainly information presentation), not restricted by limitations of vendors systems and UML/profiling tools.
- Names are important in many cases. But restrictive requirements on naming may result in the interoperability issues. For example, the dynamically-created names may not be storable in the underlying data source, resulting in information loss.
- Physical modelling entities, such as Substation, Equipment, etc., require a name to be specified, while naming is optional for the components that make up a physical modelling entity, such as Terminal, RatioTapChanger, etc.
- Conceptual modelling entities may or may not require a name to be specified depending on whether these modelling entities shall be presented to end-users. DiagramObjects, for example, are meaningless for human audiences. TopologicalIsland, on the other hand, may require a name to be provided, since they could be shown in the power flow reports.
- Names of conceptual modelling entities shall be optional whenever possible. For example, if the conceptual modelling can be characterized by one or a combination of its attributes, then naming shall be optional. As an example, name for BaseVoltage may not be required, since it is characterized by attribute BaseVoltage.nominalVoltage, which could optionally serve as name. By the same token, if a conceptual modelling entity is uniquely associated with a physical modelling entity, then its name can be derived from the associated physical modelling entity if needed.

Therefore, the objective of the CGMES naming convention is to define a common framework related to naming rules which could be further restricted by different business processes.

The following rules related to the naming convention are defined:

ID	Specification
NAMC1.	(Informative) Business processes can further define constraints related to the naming convention. Relevant information should be made available to all parties participating in the data exchange and vendors should be informed. This will allow: – System operators (TSOs and DSOs) experts to be aware and respect requirements related to naming in the models. – Vendors developing tools for power system analyses to ensure that: • System operators (TSOs and DSOs) experts are able to supply the names as required by the business process; • An agreement for naming translation between requirements in the business process and the proprietary formats or SO databases is in place; • Export and import functionalities are compliant with the data exchange rules. – Vendors developing validation tools to adjust validation rules valid for the business process.
NAMC2.	The restrictions related to the naming convention are considered obligatory for any tool importing or exporting naming data if the tool claims compliance with the CGMES.

ID	Specification
NAMC3.	Further restrictions can be applied by different business processes. Business process restrictions on naming shall define required and optional attributes related to naming. These restrictions or rules should not contradict this naming convention and are considered mandatory for all parties participating in a given business process. – Tools used to validate instance data shall be able to validate against different sets of naming conventions which are applied to exchanges based on the CGMES. – Tools used for various power system analyses shall provide users with the opportunity to cope with different naming rules.
NAMC4.	Due to the current inheritance structure of the CIM used for the profile, the naming convention primarily addresses the attributes of the class IdentifiedObject.
NAMC5.	The name related attributes have an informational character intended for human reading for explanations outside the classes. Software solutions must not count on this information to complete physical links of the power system model. All necessary links between different parts of the CIM XML are expressed by the reference schema which uses rdf:ID.
NAMC6.	Names shall conform to UTF-8.
NAMC7.	In cases where tools using instance data (compliant with the CGMES exchanges) need uniqueness rules, this shall be handled in the importing function based on requirements defined by the users.
NAMC8.	It is obligatory that information exchanged in name related attributes is not modified by the tools within an exchange, i.e. – step 1: Tool A imports data from Tool B and modifies initial information to fit user requirement of tool limitation; – step 2: Tool A is obliged to export the imported data in the same form and content as the data exported from Tool B. One of the main reasons behind this rule is the fact that exchanges in the ENTSO-E are meant to be bi-directional, i.e. there is a sending party and a receiving party which exchange models within studies and do not necessarily consume only the data.
NAMC9.	The tools shall provide users with the ability to add and maintain naming related information for classes which represent physical equipment as well as classes which represent elements important for business processes (e.g. TopologicalNode). This information is then mapped onto relevant attributes and can be exported for the purpose of the exchange.
NAMC10.	There is no need for a specific naming convention when it comes to the names of the instance files due to file header information which is defined by IEC CIM standards and the CGMES.

ID	Specification
NAMC11.	(Informative). This rule is included only as an overview. The detail requirement is included in the profile specification. Table 1 and Table 2 summarise the use of name related attributes in the different profiles. They provide the length of the strings that are needed for the exchange for all classes that inherit from IdentifiedObject. The constraints do not apply to internal implementation of tools.

Table 1 – IdentifiedObject attributes

IdentifiedObject	String length, characters	Equipment Core profile	Operation profile	Short circuit profile	Topology profile	Steady State Hypothesis profile	State variables profile	Diagram layout profile	Geographical location profile
.name	128 max	✓r	✓r	×	✓o	×	✓r	✓r	✓o
.description	256 max	✓o	✓o	×	✓o	×	×	✓o	×
.energyIdentCodeEic (deprecated)	16 exactly	✓o	×	×	✓o	×	×	×	×
.shortName (deprecated)	12 max	✓o	×	×	✓o	×	×	×	×

Table 2 – IdentifiedObject attributes in EQBD profile

IdentifiedObject	String length, characters	Equipment boundary profile (deprecated)
.name	128 max	✓r
.description	256 max	✓o
.energyIdentCodeEic (deprecated)	16 exactly	✓o
.shortName (deprecated)	12 max	✓o

Legend: ✓r – the attribute is present in the profile and required (required means that it is mandatory that this attribute be present in the instance data); ✓o – the attribute is present in the profile and optional; × – the attribute is not present in the profile.

ID	Specification
NAMC12.	Left blank intentionally.
NAMC13.	Left blank intentionally.
NAMC14.	Name related attributes of the IdentifiedObject that are required and have no minimum length defined or zero can be exchanged as empty string i.e. <IdentifiedObject.name></IdentifiedObject.name>

6 CGMES governance

6.1 General

The overall governing process of the CGMES is a complex process and includes the following sub-processes:

- Standardisation process – a process to develop the CGMES, and which relies on the latest IEC CIM related standards.

- Interoperability process – the process to conduct IOPs targeting verification of the CGMES and IEC CIM standards. Feedback to standardisation bodies and organisations involved in the development of different profiles which form part of the CGMES.
- Business process – all business processes which use the CGMES. They define requirements and request additional improvements due to business needs.
- CGMES conformity process – this process ensures that tools used by parties involved in an exchange utilising the CGMES are implementing the CGMES correctly.
- Implementation process – the implementation process is triggered by a business process/need. It aims to apply a certain version of the CGMES to a business process.

6.2 Versions of the CGMES and the profiles

Each version of the CGMES and the profiles part of the CGMES has its unique version identifier. The following rules related to versioning are defined:

ID	Specification
VERS1.	The format of a version of the CGMES is xx.yy.zzz where xx, yy and zzz are non-negative integers, and shall not contain leading zeroes, and: – xx – names the major version of the CGMES – yy – names the minor version of the CGMES – zzz –names the revision version of the CGMES
VERS2.	Each profile part of the CGMES is assigned with a version defined by the profile URI which shall be declared in the file header of the instance files. The profile URI is specified in the UML of the CGMES.
VERS3.	A profile URI changes every time a minor or a major version of a profile is released.
VERS4.	The namespace URI of the European extensions changes every time a minor or a major version of the extension package is released.
VERS5.	The namespace UML changes every time the CGMES changes the base version of the CIM, e.g. the base UML changes from CIM 16 to CIM 17.
VERS6.	Each of the CGMES profiles is related to a profile defined by the IEC. The ENTSO-E UML lists the base URI of the IEC profiles for information only and to link a specific profile of the CGMES to the closest IEC CIM profile. This information is provided in the base URI attribute of the version class to each profile of the CGMES.
VERS7.	A minor version is a compatible change to a profile. The minor version shall be incremented if new, backwards compatible functionality is introduced to the CGMES. It shall be incremented if any functionality is marked as deprecated. It may be incremented if substantial new functionality or improvements are introduced to the CGMES by adding additional profiles and/or European extension. It may include revision level changes. Revision version shall be reset to 0 when minor version is incremented.
VERS8.	The number of a major version shall be incremented if any backwards incompatible changes are introduced to the CGMES, e.g. something is deleted. It may include minor version and revision level changes if the amount of changes is significant. The major version will also be incremented if one or more profile is no longer backwards compatible. Minor and revision version numbers shall be reset to 0 when major version is incremented.
VERS9.	Updates belonging to a minor version update should not break the interoperability for a major profile exchange. This means that a tool which supports a profile version, e.g. 2.4 (2 major version, and 4 minor version) shall be able to import a file which is generated based on profile version 2.5 where all the additional classes, attributes and associations are ignored.
VERS10.	The revision version shall be incremented if only backwards compatible error fixes are introduced. A fix is defined as an internal change that fixes incorrect behaviour. Updating documentation or a class, an attribute or a profile to reflect the intended behaviour are considered error fixes.
VERS11.	A pre-release version may be denoted by appending a hyphen and a series of dot separated identifiers immediately following the revision version. Identifiers shall comprise only ASCII alphanumeric and hyphen [0-9a-Za-z-]. Identifiers shall not be empty. Numeric identifiers shall not include leading zeroes. A pre-release version indicates that the version is unstable and might not satisfy the intended compatibility requirements as denoted by its associated normal version. Example: 2.5.0-alpha.
VERS12.	Once a versioned package has been released, the contents of that version shall not be modified. Any modifications must be released as a new version.

ID	Specification
VERS13.	The key words "must", "must not", "required", "shall", "shall not", "should", "should not", "recommended", "may", and "optional" in this section of the CGMES are to be interpreted as described in RFC 2119.

6.3 Conformity assessment

Conformity assessment of tools is necessary to confirm that tools comply with a given profile part of the CGMES and may be used for model exchange in a given business process. Conformity assessment is business driven and ensures reliability of the model exchanges by confirming interoperability between applications. The conformity assessment processes that shall be followed is defined in the ENTSO-E CGMES Conformity Assessment Framework.

Each new version of a tool shall be tested for conformity with a particular version of the CGMES used in business processes prior to its usage in the business processes. Parties involved in the exchange are responsible for ensuring that tools which they use in the same business processes conform to the CGMES.

Test configurations (models) representing the main functionalities of the profiles of the CGMES shall be publicly available to all interested parties no later than 3 months after the approval of a major or minor release of the CGMES or its profiles. Depending on the complexity of the changes in the profiles the decision body approving the implementation of the CGMES shall either confirm this deadline or specify another deadline.

Conformity assessment shall preferably rely on a machine-readable way of defining the validation rules and describing the constraints valid for a certain profile. Object Constraint Language (OCL) or W3C Shapes Constraints Language (SHACL) can be used for this purpose.

6.4 Implementation process

The implementation of a version of the CGMES for use in a business process is launched as soon as the conformity assessment process has been finalised. The following rules are defined for the implementation process:

- The implementation process is triggered by the body responsible for the model exchange. The body defines the deadline when the implementation process shall end, and the business process switches to the new version of the CGMES.
- The implementation process includes a period during which TSOs, DSOs, and Vendors shall upgrade their tools and a period during which a trial tests running the business process with the new version of the CGMES. This is especially valid for operational exchanges where the exchange shall be reliable and completed more frequently than a planning model exchange process.
- The CGMES contains various profiles. The implementation of each of them can have a different schedule depending on the business needs.
- Due to the different requirements of the business processes, different versions of the CGMES profiles can be simultaneously operational. Vendors, TSOs, RSCs and DSOs shall adapt the implementation process and the support to the model exchange processes and be able to cope with a variety of the CGMES versions used in the exchanges.
- Business processes shall be adapted in order to allow smooth interfaces between main types of exchange such as planning to planning, operation to operation, operation to planning, interface with distribution, etc. Business processes shall aim to use a limited number of different versions of the CGMES in order to decrease maintenance effort by TSOs, RSCs, DSOs, and Vendors, and facilitate interoperability of data exchanges between business processes.

Annex A
(xxxx)

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