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European Network of
Transmission System Operators
for Electricity

QUALITY OF CGMES DATASETS AND CALCULATIONS

FOR SYSTEM OPERATIONS

VERSION 3.3

APPROVED BY CGM OPDE TT

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BUILDING PROCESS SUBTEAM (BP ST)

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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.

- MUST: This word, or the terms “REQUIRED” or “SHALL”, means that the definition is an absolute requirement of the specification.
- MUST NOT: This phrase, or the phrase “SHALL 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 shall 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. One vendor may choose to include the item because a particular marketplace requires it or because the vendor feels that it enhances the product while another vendor may omit the same item. An implementation which does not include a particular option MUST be prepared to interoperate with another implementation which does include the option, though perhaps with reduced functionality. In the same vein an implementation which does include a particular option MUST be prepared to interoperate with another implementation which does not include the option (except, of course, for the feature the option provides.).

Change History

2019-12-20 LOO First draft of QoCDCv3.2

2020-05-13 LOO Since v3.1 the following rules has been added, renamed or deleted

- Level 1
  - SynchronousArea renamed to CGMRegion
  - SourcingTSO renamed to SourcingActor
- Level 3
  - SMRatedSunrealistic
  - TargetDeadbandOutOfRange
  - WindingConnectionAngle
  - VoltageLimitDirection
  - VoltageLimitsConsistency
  - FlowLimitsDirectionConsistency
  - AsymmetricalEquivalent
  - PositiveTransformerB
  - GeneratingUnitSM
  - SMPLimits
  - SubLoadAreaMissing
  - EnergyAreaMissing
  - CurveXYValue renamed to CurveXValue
  - SMQLimits4 has been removed as covered by SMPLimits
  - RCCXValues1 has been removed as covered by RCCXValues2
  - DCNodeContainment removed as covered by cardinality
- Level4
  - IncompleteObject renamed to IncorrectAttributeOrRoleCard
  - CgmSvSshVersionMismatch
- Level 5
  - SvPowerFlowBranchInstances2
  - SynchronousCondenserMode
  - TCCRemoteReactiveFlow
  - EquivalentInjectionContainment moved from level 3 to level5
  - DCLineContainment moved from level 3 to level5
- Level 6
  - FakeVoltage
- Level 7
  - InconsistentTnBaseVoltage
  - ACScheduleMatch1

ACScheduleMatch2

Level 8

TIConvergenceStatMissing

TIConvergenceStatDiverged

2020-03-27 Rule SynchronousArea renamed to CGMRegion and field <synchronousArea> renamed to <cgmRegion>

2020-03-31 sanity check, adding missing cim: prefixes and format check.

2020-04-06 Rule RCCYValues simplified with text from CGMES3.0. Rule LRCExponentModel changed to allow exponents in the range 0 =< exp =<2. Rule RatedS exception for aggregated flag=false removed.

2020-04-06 LRCExponentModel exponent values restricted.

2020-04-06 Rule RatedS changed to ignore aggregate flag.

2020-04-06 Rule CGMRegion severity not correct, changed WARNING->ERROR

2020-04-21 Rule severity revised to match CGM_BP requirements.

- SourcingActor WARNING->ERROR
- SVCSlope WARNING->ERROR
- PhaseCodeGround WARNING->ERROR
- SVCVoltage WARNING->ERROR

2020-04-21 Consistency checks made, e.g. match between severity and shall/should, presence of “cim:” prefixes, spelling, reference to limits etc.

2020-05-11 Changes according to comments from Jun Zhu.

2020-05-12 Updates based on CGM ICT comments. New section “Supporting documents” added.

2020-05-13 Prepared for publish.

2020-05-19 EquivalentInjection moved from rule BranchBaseVoltage to CEBaseVoltage. SeriesCompensator is tested by rules BranchBaseVoltage and CEBaseVoltage, it is removed from rule BranchBaseVoltage. Equivalent shunt added to rule CEBaseVoltage.

2020-06-10 Rule MASPersistency moved back to level 2 from level 5.

2020-06-10 Spelling errors corrected and incorrect sign statement in rule GeneratingUnitNominalP corrected.

2021-06-14 A new version v3.2.1 (release candidate) of QoCDC is opened. This is a track change version. Summary of changes in version 3.2.1:

- Various editorial changes are applied
- For reference data the reference to QoCDC Reference Data document is used in the whole document
- The following rules are modified to decrease the level of ambiguity: FileNameMD, FileNameConsistency, EffectiveDateTime, NameLength, EFCContainment, OperationalLimitSetAtTerminal, PATL2, PowerTransformerEndR, PowerTransformerEndX, RatedS, WindingConnectionAngle, VoltageLimitDirection, GeographicalRegionBD, SVCVoltage, BranchBaseVoltage, CEBaseVoltage, ParticipatingGeneratingUnit, RequiredSvSCSections, RequiredSvTapStep, MAS, MASPersistency, PhaseCodeGround, ValidResourceValue, URNUniqueness, AttributeAndRoleValues, DCEquipmentContainerMapping, SvInjectionLimit,

TIConvergenceStatMissing, TargetDB, TargetDeadbandOutOfRange, EquivalentBranchX, TerminalCount1, TerminalCount2, TerminalSeqNumOrder, MeasTerminal, AcceptableDuration, CNRequiredInEQOperations, ControlModeCompatibility, ModelDescription, SwitchOpenVsConnected, SvPowerFlowBranchInstances, InconsistentCurrentLimits, CGMCongestion, InconsistentTnBaseVoltage, ACTielineBV, ControlOfAnotherIsland, VoltageTargetsAtTN, EquivalentInjectionControlEnabled, TapChangerTargetRange, TCCRemoteReactiveFlow, ShuntQ, DERActivePowerInfeedDiffE, NetInterchange1, NetInterchange2, VoltageTargetAndDeadbandAtTN, ControlAreaInstance. UnpairedTieFlow, GenActivePowerInfeedLim, SynchronousCondenser, DCLineContainment, CGMTieFlowImbalance, GeneratingUnitMaxPGen, LRCExponentModel, LCRCoefficientModel, SMPLimits, EIActivePowerInfeedLim, ENIActivePowerInfeedLim, EIReactivePowerInfeedLim, ENIReactivePowerInfeedLim, ModelCreated, ScenarioTime, PowerTransformerEndRatedU, TapPosition, RCCXValues3.

- The following ruled are modified/deleted to fit to the present way of exchanging: ModelingAuthority is deleted, MCFirst and MCSecond are replaced by rule MCFirstSecond, ReactiveControlAtBus is deleted, EIReactivePowerInfeedDiffW was replaced, CGMVoltageProfile is deleted, GeneratingUnitLimits is deleted.
- The rules that require references to ISO country codes use codes for countries defined in QoCDC Reference data document.
- Table 2 is modified.
- Section 2.11 is modified and most of the content is moved to section 12. Further changes are expected in section 12, but this is informational section and not critical.
- Section 2.12 is introduced.
- Section 3.2 is introduced and parts revised.
- Section 5.4.1. was added to provide additional information regarding generation limits. Various rules are built on that information.

Summary of changes in version 3.3 compared to v3.2.1:

- New rule constant “SIZE_OF_ISLAND_WITHOUT_CONTROL” added and used by rule ControlOfIslandIsMissing
- Section 2.12 was updated adding item 6) related to the current limits rounding for the purpose of QAS reporting
- Section 2.13 was added to document modifications of CGMES 2.4 introduced by QoCDC.
- Section 3.2.1 was added to explain the file naming convention for datasets for intraday process.
- The following new rules were added: IncorrectDataTypeFormat, Exception, TooManyTapChangers, NoFlowControlAtNonRetainedSW, SMOperatingModeConsistency, ControlOfIslandIsMissing, KirchhoffsFirstLaw, PairedEICompatibility
- The following rules were replaced by IncorrectDataTypeFormat rule : ValidResourceValue, ValidAboutValue, ValidIDValue, DecimalComma, NotaNumber
- The following rules were modified, the type of the change is indicated for each rule: CEBaseVoltage (functional), ControlModeCompatibility (clarification), RCCYValues (clarification), TargetDeadbandOutOfRange (functional), DanglingReference (functional), SvPowerFlowBranchInstances2 (clarification), DisconnectedTerminal (clarification), SwitchTerminals (clarification), SwitchVL (clarification), SwitchTN1

(clarification), ControlOfAnotherIsland (functional), GenReactivePowerInfeedLim (functional), GenRCCPowerInfeed (clarification), NetInterchange1 (functional), NetInterchange2 (functional), RequiredSvTapStep (functional), InconsistentCurrentLimits (functional), UnpairedTieFlow (functional), SlackNode (functional), NoLTCTapChangerControl (clarification), ShuntCompensatorSensitivity (clarification), IGMConvergence (clarification), CGMConvergence (clarification), EffectiveDateTime (clarification), ScenarioTime (clarification).

- Editorial changes were applied in the document
- Annex B was updated to be aligned with the implementation.

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1 SUMMARY

The document “Quality of CGMES Datasets and Calculations” aims to increase the quality and consistency of power network model data that is exchanged to support the following processes:

- Coordinated security assessment;
- Coordinated Capacity Calculations;
- Unavailability Planning Coordination;
- Short-term & Medium-Term Adequacy
- After-the-fact analysis of events;
- Ad-hoc system studies;
- System development planning;
- Dynamic Stability Assessment;
- TYNDP and other strategic system studies;
- Inter TSO compensation;

Quality is a concept that can be expressed as the “fitness for purpose” for a target process. This entails that the exchanged data can be processed, is consistent and is interpreted the same way by all users (in other words: is interoperable) and will lead to plausible calculation results. It also means that the data can be processed smoothly in an automated (machine to machine) environment without the explicit need for human intervention. This document contains 8 levels of validation further described below.

2 INTRODUCTION

2.1 OVERVIEW

The purpose of this document is to consolidate and structure the necessary quality criteria and quality indicators that are applicable to the CGMES instances files used by TSOs and RSCs in order to produce plausible Individual Grid Models (IGMs) and Common Grid Models (CGMs) that are fit for purpose for subsequent business processes, such as:

- Coordinated security analysis
- Coordinated Capacity Calculation
- Unavailability Planning Coordination
- Short-term & Medium-Term Adequacy
- After-the-fact analysis of events
- Ad-hoc system studies
- System development planning
- Dynamic Stability Assessment
- TYNDP and other strategic system studies
- Inter TSO compensation

The first four bullets are defined as RSC services, the following bullets are processes covered by regional processes and TYNDP.

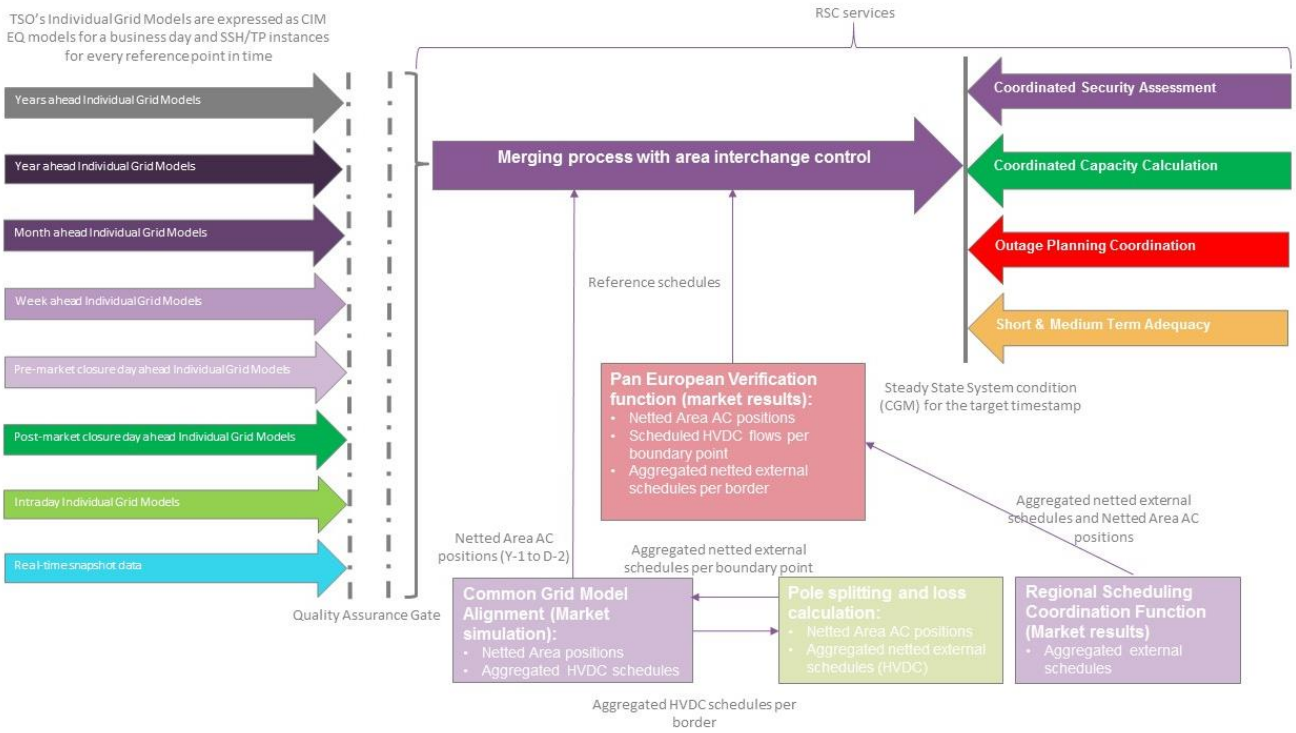

Figure 1 Context of operational data exchanges leading to Common Grid Models

Netted Area AC positions and scheduled flows on HVDC interconnectors (necessary input data for the merging process) is exchanged in the Reporting Information Market Document, based on ESMP (European Style Market Profile), IEC 62325 series[1]. The validation of the scheduling data that is provided in these documents is not in scope of this document. The schedules themselves are used for coordination validation.

The first edition of this document was issued on the 2nd of May 2016. The second edition of this document was approved by ENTSO-E System Operations Committee on the 12th of October 2016 to act as input for the design of the three Quality Gates:

- Local Quality Gate, covering first three validation levels;
- Global Quality Gate, covering levels 4-7;
- EMF Quality Gate, covering level 8.

This edition incorporates experience gained while running interoperability tests, revealing the need for additional validation rules and improving some existing rules.

As the QoCDC document evolved new rules has been defined and old revised. The rules are aligned with CGMES 2.4.15 specification and the consolidated CGMES specification that is evolving in parallel with the QoCDC.

Although this document is designed for system operation it includes useful rules applicable for TYNDP and other processes. Hence the rules defined here are may also be used in other processes not directly covered in this document.

This document collects experiences from implementing CIM and CGMES and can be seen also as an input to the CGMES roadmap and potentially integrated in future releases of CIM and CGMES documents.

Hopefully the document can also influence developing extensions of CIM as well as profiling methods supporting more efficient integration of market and network data.

2.2 PRECONDITIONS FOR AUTOMATED MERGING

For an interrupt-free, automated exchange process (i.e. without human interference), several criteria need to be met. The criteria are specified at several levels where level 1 is the most basic and done first followed by the higher levels in order.

Level 1 covers meta data in file names and packaging of CIMXML files.

Level 2 covers the structure and syntax of the individual CIMXML files as well as the meta data header.

Level 3 covers constraints that can be evaluated within the scope of the CIMXML files.

Level 4 covers issues that can be detected during model assembly.

Level 5 covers cross profile consistency of data

[1] IEC 62325 documents are based on transactions between parties and areas, identified by EIC mRIDs. For the CGM processes, we identify ControlArea by UUID/Legacy ID and use an attribute to specify EIC code for this area. External mapping can be applied to link instance data exchanged via the two standards.

Level 6 collects diagnostic information that may help solve convergence issues by identifying modelling issues that seem troublesome.

Level 7 focuses on coordination of IGMs in terms of neighbouring TSOs and reference values.

Level 8 focuses on convergence behaviour of IGMs and CGMs and on the plausibility of the CGM.

The steps in the automated process and where the validation levels appear in this process is shown in Figure 2~~Figure 2~~.

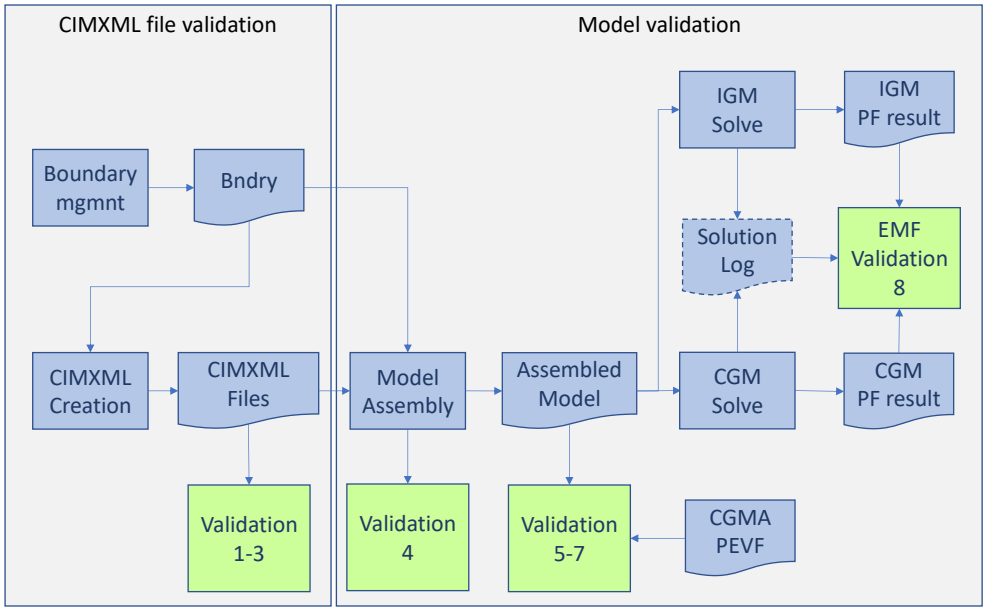

Figure 2 The Automated process annotated with validation levels

The symbols in Figure 2~~Figure 2~~ has the following meanings:

- Blue box – data processing.
- Blue document – CIMXML file or another file.
- Green box – validation.

The green boxes in Figure 2~~Figure 2~~ show where the validation according to the levels 1 to 8 appears in the automated workflow.

The workflow steps are:

- Boundary management (Boundary mgmnt) where the boundary is created (Bndry), this is a manual process at this point, should be automated eventually. The process description is out of scope of this document.
- IGM or CGM creation where CIMXML files are created. This is a TSO or RSC internal process. This process description is out of scope of this document.
- Once CIMXML files have been created, they are automatically uploaded to OPDM (not shown in Figure 2~~Figure 2~~) where they are validated with levels 1 to 3 rules.
- CIMXML files are assembled per EffectiveDateTime into models. The assembly process is validated with level 4 rules.

- The assembled model is validated with level 5, 6 and 7 rules.
- The assembled model, IGM or CGM, is solved in power flow for each EffectiveDateTime and the solution is validated with level 8 rules.

The rules at levels 1 to 6 should block publication to OPDM if the severity is ERROR. The rules at levels 7 and 8 should not block publication regardless of severity. It is advisable to have this as a configuration option in the implementation of the rules.

2.3 GUIDING PRINCIPLES

The following principles for validation and rejection of data apply:

- **Fit for purpose**: the validation rules only focus on issues that may impact the business process/usability of the models. Rejection (error level) only applies if the data cannot be processed further in the business process or harms the subsequent processes.
- **Selectivity**: rejection of bad data shall be done on the smallest unit of data.
- **Traceability**: if a process fails, it shall be possible to trace back the root cause (adequate messages and diagnostics).
- **Harmonization**: power flow settings and automatic corrections are predefined.
- **Maintainability**: validation rules are specified in XML syntax of the rules is specified in XSD. Instructions for implementation of the validation rules are provided in the XML.

2.4 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 61968-100:2013, Application integration at electric utilities – System interfaces for distribution management – Part 100: Implementation profiles
- IEC 61970-301:2016 RLV (Red Line Version), Energy management system application program interface (EMS-API) - Part 301: Common information model (CIM) base
- IEC 61970-452:2017 (Edition 3.0), Energy management system application program interface (EMS-API) - Part 452: CIM static transmission network model profiles
- IEC 61970-453:2014 (Edition 2.0) and AMD1:2018 CSV, Energy management system application program interface (EMS-API) - Part 453: Diagram layout profile
- IEC 61970-501:2006 (Edition 1.0), Energy management system application program interface (EMS-API) - Part 501: Common Information Model Resource Description Framework (CIM RDF) schema
- IEC 61970-552: 2013 (Edition 1.0), Energy management system application program interface (EMS-API) - Part 552: CIMXML Model exchange format. The older ID formats according to section 6.4 is allowed.

- IEC TS 61970-600-1:2017, Energy management system application program interface (EMS-API) - Part 600-1: Common Grid Model Exchange Specification (CGMES) - Structure and rule [2]
- IEC TS 61970-600-2:2017, Energy management system application program interface (EMS-API) - Part 600-2: Common Grid Model Exchange Specification (CGMES) - Exchange profiles specification
- IEC 62325-451-1, Framework for energy market communications – Part 451-1: Acknowledgement business process and contextual model for CIM European market
- IEC 62325-451-5, Framework for energy market communications – Part 451-5: Status request business process and contextual model for CIM European market
- ISO 8601:2005, Data elements and interchange formats – Information interchange – Representation of dates and times
- Extensible Mark-up Language (XML) 1.0 (Fifth Edition), *W3C Recommendation 26 November 2008 (*https://www.w3.org/TR/2008/REC-xml-20081126/ *)*
- Key words for use in RFCs to Indicate Requirement Levels, *Network Working Group Best Current Practice, Harvard University March 1997* (https://www.ietf.org/rfc/rfc2119.txt)
- QoCDC Reference Data document

2.5 DOCUMENT HIERARCHY

The following document hierarchy is applicable:

1. IEC 61970 CIM UML16v28 and IEC 61968 CIM UML 12v08 are used as the standard for the network model exchanges
2. CGMES 2.4.15 profile available as a UML information model with file name ENTSOE-CGMES_v2.4.15_Aug2014_XMI.zip, Refer also to https://www.entsoe.eu/digital/common-information-model/
3. IEC TS 61970-600-1:2017 and IEC TS 61970-600-2 Ed1 (CGMES 2.4) is a subset of the IEC canonical information model and adds some ENTSO-E extensions to the standard and specifies the profiles in CIM RDF XML in which the Individual grid models (IGMs) and Common Grid Models (CGMs) are exchanged
4. EMF Requirements specification (current approved version 2.0) specifies the merging process from individual Grid Models (IGMs) to Common Grid Models (CGMs). Refer also to: https://extra.entsoe.eu/SOC/IT/WP%204/EMF%20requirements%20specification%20v2_final.pdf
5. This document consolidates the identified necessary validation rules to ensure integration of all components featuring IGMs and CGMs that are fit for purpose. This document is used together with QoCDC Reference Data document.

[2] The QoCDC document provides additional normative rules not covered by the IEC TS 61970-600 specifications. In a few cases they supersede IEC TS 61970-600.

2.6 INFORMATION MODELS

The validation rules in this document relate to information models that describe the network data being exchanged, i.e. CGMES 2.4. The CIM/XML format (IEC 61970-552) used in this exchange has a header with meta data about the exchanged network data. As CIM/XML header does not cover all meta data needed, hence the file names have been used to carry additional meta data. To do this the file name string has been divided in pieces where each piece describes a specific meta data. Additionally, human readable file names were considered an important requirement, at least in the initial phases where the automated processes are not fully commissioned.

2.7 NUMBER PRECISION

Limited and possibly different precision in implementations of import/export tools as well as power flow solvers may result in small deviations of numeric values between IGMs. Hence it is advised to use a small tolerance in comparisons. The numeric tolerance was decided based on experience from empirical analysis of IGMs triggering the rules and is defined as a factor of 0.0005, used in comparison of values as follows:

- Value1
- Value2
- Abs(Value1 - Value2) < Abs(Value1)*0.0005 or
  Abs(Value1 - Value2) < Abs(Value2)*0.0005

The future amendments of this document may lead to change of the numerical tolerance, so it is advised to have this factor as configurable in the implementation of the rules.

See also FBOD5 from IEC TS 61970-600-1:2017.

2.8 GROSS VS NET PRODUCTION VALUES

The business process capacity allocation and congestion forecast use net production values, not gross values. Hence all production values shall be considered being net values. This also means that any instances of the GrossToNetActivePowerCurves class in an IGM shall not be present.

2.9 INTEGRATION OF VALIDATORS

Validation can be done by off-line validators that run as an executable program or script on a single file or a set of files in a folder and produce output in human readable form, and/or by client-server processes, such as designated quality portals that use “request” and “reply” messages in accordance with IEC 61968-100. The rule templates describing errors or warnings in this document are examples how tools may report errors and warnings. The XML templates are expected to be filled with the missing data when errors or warnings are reported.

2.10 TERMS AND DEFINITIONS

Table 1 specifies the terms and definitions that are used in this document. A more detailed description of some terms can be found in IEC TS 61970-600-1:2017.

473 **Table 1 Terms used and their definitions**

Term	Definition
Assembly	The process of combining information from a single Modeling Authority Set (serialized in separate instance files) into a coherent data set in which all RDF references have been resolved.
Base Voltage	Defines a system base voltage which is referenced when converting to per unit values inside power flow tools.
Boundary Information	Is a set of data related to the boundary points and related AC or DC interconnections. The boundary information includes at least identifiers and names of boundary points, substations, tie-lines.
Boundary Set	As defined in the CGMES, it is a dataset that contains all boundary points and ENTSO-E reference data necessary for a given grid model exchange. A boundary set can have different coverage depending on the requirements of the common grid model exchange. A complete boundary set is necessary to assemble a pan-European power system model.
Boundary Point (BP)	Boundary Point defines the point of common coupling between two Modeling Authority Sets (MAS). A Boundary point could be a ConnectivityNode or a TopologicalNode placed on a tie-line or in a substation. A Boundary point must be contained in a Boundary Set and must not be contained in the MAS of a TSO. A Boundary point is referenced by Terminals in the MAS of a TSO. ConnectivityNode and TopologicalNode are terms specified in IEC CIM standards.
CGM	Common Grid Model, i.e. the steady state pan-European system state for a given point in time.
CGMES	Common Grid Model Exchange Specification
DACF	Day Ahead Congestion Forecast
Dangling reference	A dangling reference is just like a broken link on the web. In a model assembly it's a reference to an identified object that should have a description in the assembly and, simply, doesn't.
EIC	The EIC (Energy Identification Coding scheme) is standardized by ENTSO-E for a unique identification of the market participants and other entities active within the Energy Internal European Market (IEM). Over and above Market Participants (Parties - object type "X"), the EIC also covers other entities by allocating a unique code to the following object types: Areas – object type "Y", Areas for inter System Operator data interchange Measuring Points – object type "Z", Energy Metering points Resource objects – object type "W", such as Production plants, consumption units, etc. Tie-lines – object type "T", International tie lines between areas Location – object type "V", Physical or logical place where a market participant or IT system is located Substations – object type "A"

Term	Definition
	The EIC is based on fixed length alphanumeric codes which can be broken down as follows: A 2-character number identifying the Issuing Office assigned by ENTSO-E. One Character identifying the object type that the code represents. 12 digits, uppercase characters or minus signs allocated by the issuing office 1 check character to ensure the code validity. Valid characters of an EIC code are A-Z, 0-9 and “-“.
EQ	Equipment profile in CGMES, describing the physical property of equipment and its connectivity.
EQBD	Equipment Boundary profile in CGMES.
IGM	Individual Grid Model, i.e. all instance data that is necessary to specify a scenario as input and output for a power flow tool (e.g. EQ, SSH, TP and SV).
Merging	The process of combining information from multiple Modeling Authorities and external constraints into a coherent network model with operating assumptions for a given point in time.
Modeling Authority	The organization responsible for modelling its responsibility area.
Modeling Authority Set	A URN/URI referring to the organisation or role sourcing the model in the CIMXML document. Models from the same organisation or role but for different profiles shall have the same urn/uri. Different representation of the same responsibility area, e.g. system development planning model, shall have a different URN/URI if the models are different.
mRID	Master Resource Identifier. The IdentifiedObject class contained in the Core package of the Common Information Model (CIM) is inherited by all PowerSystemResource and many other classes. This class has attributes and associations to be used for naming all CIM objects. The mRID attribute of the IdentifiedObject class provides a straight forward and rigorous means of identity for CIM objects. The IdentifiedObject.mRID is a globally unique machine-readable identifier for an object instance.
OPDE	Operational Planning Data Environment
OPDM	Operational Planning Data Management (Smart file storage and management for Operational Planning Data including validation of file names, RDF/XML structure and syntax).
RDF	Resource Description Framework, as specified in https://www.w3.org/RDF/
rdf:ID/rdf:about	In RDF the rdf:ID identification has the specific meaning that the identifier is unique within a document while the rdf:about identification means the identifier is unique within a name space. If the UUID name space urn:uuid is used for the rdf:about identification the identifiers are globally unique. Hence CIMXML promote using rdf:about identification in the UUID name space for all identifiers.

Term	Definition
	The URN form is used as CIMXML element identification as follows: The prefix “urn:uuid:” is replaced by an underscore “_”. The underscore avoids a numeric starting character for the non-base part of the identifier. Starting the non-base part of the identifier with a numeric character is invalid RDF. The underscore is added in all cases to simplify parsers, even if the UUID starts with a non-numeric character. The prefix is defined as an xml:base=“urn:uuid:” Some examples: rdf:ID=”_26cc8d71-3b7e-4cf8-8c93-8d9d557a4846” the rdf:ID” form. rdf:about=”#_26cc8d71-3b7e-4cf8-8c93-8d9d557a4846” the “hash” form. rdf:about=”urn:uuid:26cc8d71-3b7e-4cf8-8c93-8d9d557a4846” the “urn:uuid:” form.
rdf:resource	Pointer to denote an association or used to reference an enumerated value. The value of rdf:resource is a “resource-uri”, which can specify an XML resource, using the “hash” form or the “urn:uuid:” form or an external resource or enumeration using a namespace prefix (http://....)
SSH	Steady State Hypothesis profile in CGMES, describing the switch and tap positions, control targets, as well as energy generation, consumption and border exchanges at one operating point (in time).
SV	State Variables profile in CGMES, describing the state variables of a power flow solution in terms of complex voltages and power flows.
TP	Topology profile in CGMES, describing the relationship between topological nodes and terminals.
TPBD	Topology Boundary profile in CGMES.
TYNDP	Ten Year Network Development Plan.
URI	Uniform Resource Identifier, i.e. a string of characters used to identify or name a resource.
URL	Uniform Resource Locator, a specific type of URI, which is a reference to a web resource that specifies its location on a computer network and a mechanism for retrieving it.
URN	Uniform Resource Name, a specific type of URI, used to identify a resource by name in a particular namespace. A URN may be used to talk about a resource without implying its location or how to access it.
UUID	Universally Unique Identifier[3], specified as follows: 8 character hex number a dash “-“ 4 character hex number a dash “-“ 4 character hex number

[3] The algorithm is aligned with, and technically compatible with, IEC 9834-8:2004 Information Technology, "Procedures for the operation of OSI Registration Authorities: Generation and registration of Universally Unique Identifiers (UUIDs) and their use as ASN.1 Object Identifier components" ITU-T Rec. X.667, 2004.

Term	Definition
	a dash “-“ 4 character hex number a dash “-“ 12 character hex number where letters are lower case

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2.11 RULES' CONSTANTS

Table 2~~Table 2~~ provides information on the constants used in the rules defined in this document.

Table 2 List of constants used in the rules

Constants used in the rules	Value	Unit with multiplier
NUMERIC_TOLERANCE	0.0005	Multiplication factor
SSH_SV_MAX_P_DIFF	10	MW
SSH_SV_MAX_Q_DIFF	50	Mvar
SSH_SV_TOT_P_DIFF	200	MW
SSH_SV_MAX_TAP_STEP_DIFF	2	Integer number
SSH_SV_MAX_Q_SHUNT_DIFF	1	Mvar
SV_INJECTION_LIMIT	0.1	MVA/MW/Mvar
EQ_BRANCH_X_LIMIT	0.01	Ohm
EQ_RATEDS_REASONABILITY_FACTOR	10	Integer number
EQ_DB_REASONABILITY_FACTOR	2	Integer number
IO_NAME_LENGTH	32	Integer number
IO_DESCRIPTION_LENGTH	256	Integer number
EIC_LENGTH	16	Integer number
SHORT_NAME_LENGTH	12	Integer number
BOUNDARY_BV_MAX_DIFF	0.1	Multiplication factor
PATL_LIMIT_VALUE_DIFF	0.1	Multiplication factor
INTERCH_IMBALANCE_WARNING	50	MW
INTERCH_IMBALANCE_ERROR	200	MW
INTERCH_IMBALANCE_EMF	2	MW
SIZE_OF_ISLAND_WITHOUT_CONTROL	10	Number of TopologicalNode-s in a TopologicalIsland

2.12 VALIDATION HANDLING AND REPORTING OF VALIDATION RESULTS

The following general rules are defined:

1) Validation engines shall always use the latest version of the QoCDC Reference Data document.
2) Many rules are checking basic and fundamental requirements. Non conformity with those rules would change the overall validation result and how it is presented to the users. In order to prevent that different implementations are providing completely different validations results and also to be able to facilitate the comparison of these results, it is recommended that users are given a possibility to select the outcome of the validation if the following rules are triggered. Either the validation is aborted, or the validation process continues, if possible, knowing there will be many errors/warnings reported due to side effect.
    - FileNameMD,
    - FileNameConsistency,
    - IDuniqueness,
    - DanglingReferences,
    - XMLStructure.
3) Validation engines shall report validation results in a user-friendly manner following the descriptions and messages defined for each rule. Some of the descriptions and messages of the rules contain references to constants defined in this document. It is required that when the errors/warnings are reported to users the references to these constants are replated with their numerical value and unit. For instance, if the message contains "… is not >= EQ_BRANCH_X_LIMIT for a two-winding transformer … " the validation engine shall report to the user "… is not >= 0.01 Ohm for a two-winding transformer … "
4) In cases where messages provided by a validation engine shall be further processed in a reporting system, the reporting system shall either use reported numbers with the same number of decimals or apply arithmetical rounding, if necessary.
5) When comparing values with PEVF and CGMA it should be taken into account that:
    - There is no sign convention in PEVF and CGMES as all values are positive and there are different properties for "in domain" and "out domain", which provide flow direction.
    - Net Position means the netted sum of electricity exports and imports for each market time unit for a scheduling zone.
    - If "in domain" is the TSO and "out domain" is the synchronous area, it means an import to the TSO area
    - If "in domain" is the synchronous area and "out domain" is the TSO, it means an export from the TSO area
    - For QAR report and QAS portal, the import is represented by a negative value and the export by a positive value.
6) When reporting violations related to current limits in QAS, values are rounded using standard rounding to integer.
7) Validation engines shall consider that:
    - In many cases an IGM has multiple cim:TopologicalIsland-s. In the cases where an IGM contains multiple cim:TopologicalIsland-s, the island that contains the highest number of associated cim:TopologicalNode-s shall be referred to as main island.

While the validation rules related to load-flow plausibility and convergency status are executed for all islands in an IGM, the status of the main island, “converged” or “diverged”, shall define the overall status of an IGM.

- The CGM is Pan-European, therefore containing multiple synchronous areas and potentially, in case of partial merge, not all IGMs of the synchronous area. Therefore, one more level of grouping is necessary for a CGM. The main island in CGM shall be defined as the cim:TopologicalIsland containing the highest number of IGMs. The number of IGMs in a cim:TopologicalIsland is calculated using the associated cim:TopologicalNode-s affiliated to each IGM part of a cim:TopologicalIsland. The status of the main island, “converged” or “diverged”, shall define the overall status of a CGM.

8) In case a rule is using an optional attribute (having numerical values), which is not provided in the instance data (IGM, CGM) and depending on the rule logic, the rule is not checked.

2.13 MODIFICATIONS IN CGMES 2.4 INTRODUCED BY QOCDC

This section summarizes main changes applied to CGMES v2.4.15 in order to fix issues and align with the QoCDC constraints.

- The multiplicity of the association end Terminal.RegulatingControl is changed from 0..1 to 0..*
- In Topology profile, the inheritance from IdentifiedObject was removed for cim:ACDCTerminal and cim:DCNode
- In StateVariables profile IdentifiedObject.description is added as optional to the profile and used in TopologicalIsland to convey information on the convergence of the topological island, as a temporary solution, not mandatory to be implemented as severity of the rule TIConvergenceStatMissing in Level 8 is a WARNING.

3 LEVEL 1 VALIDATION: META DATA IN FILE NAMES

3.1 INTRODUCTION

According to IEC 61970-600-1:2017 (Common Grid Model Exchange Specification 2.4), rule FILX2, “There is 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.”

It was agreed in the 38th SOC meeting on 5 November 2015 that business processes related to the operational planning shall use a file naming convention. This section defines such name convention which is applied for Individual Grid Models and Common Grid Models exchanged in CGMES. The file names are primarily used for human consumption but are also used for validating file header content and for the storing of meta data in the OPDM. This meta data is used in OPDM for filtering and manually collecting data via the OPDM user interface

As the file names contain information about file type, effective dates and version which is also specified in the file headers, this data needs to be consistent. This is validated in level 2. Meta data is specified both in the file header and the file name. Meta data in the file header FullModel element as described below:

- Modeling Authority (i.e. the name of the TSO or RSC) is included in the Model.modelingAuthoritySet attribute.
- If a Modeling Authority has more than one network region a region specifier is included in the Model.modelingAuthoritySet attribute (further described below).
- The Model.description attribute contains several meta data items, refer to level 2 rule ModelDescription.
- HVDC boundary TopologicalNodes has “HVDC” as the first characters in the IdentifiedObject.description.

Several meta data are embedded as enumerations in the rules. This reference data is defined in the document QoCDC Reference Data. Therefore, when reference data is modified the QoCDC Reference Data document will be updated accordingly.

3.2 FILE NAME AND FILE HEADER

The CIMXML file name convention specifies the meta data parts of the file name, separated by an underscore (‘_’) and applies to both the xml name and the zip name.

Rule FILX1 in IEC TS 61970-600-1:2017 specifies that “a given exchange consists of multiple files. The CGMES defines that all files in a given logical exchange must be zipped together. The tools use zip files directly when importing and exporting, but some business process may require the files to be exchanged in individual zip files”. This is the case for the Common Grid Model building process.

The following mask is to be used to have a valid file name:

<effectiveDateTime>_<businessProcess>_<sourcingActor>_<modelPart>_<fileVersion>

The following additional rules applies for IGM and CGM file names with this mask:

- The parts in the file name are not allowed to contain an underscores “_” or dashes “-”. The dashes are reserved for sub parts within the sourcingActor.
- All four underscores shall be present.
- If a file name part is not used it shall be left empty resulting in two consecutive underscores “__”.
- For <modelPart> SSH, TP and SV all five parts in the mask shall be present.
- For <modelPart> EQ and EQDIFF the <businessProcess> may be absent meaning that the CIMXMLfile can be used with any business process. The mask to use is then
    - <effectiveDateTime>__<sourcingActor>_<modelPart>_<fileVersion>

The <sourcingActor> field has three different layouts:

1. <sourcingTSO> which is always used by a TSO

2. <sourcingRSC>-<cgmRegion> which is used by RSC for a synchronous area file, e.g. a SV file
3. <sourcingRSC>-<cgmRegion>-<sourcingTSO> which is used by RSC for an updated TSO area file, e.g. a SSH file. The sourcingTSO relates to the IGM that has been used to create the CGM.

The mapping of <sourcingTSO>, <sourcingRSC> and <cgmRegion> to the reference data is provided in the QoCDC Reference Data document in the tab “QoCDC Mapping”.

Examples:

- 20180118T0930Z_1D_APG_SSH_001.xml
- 20180117T2230Z_1D_APG_EQ_001.xml
- 20180117T2230Z__APG_EQ_001.xml
- 20180118T1130Z_1D_TSCNET-EU_SV_001.xml
- 20180118T1130Z_1D_TSCNET-EU-APG_SSH_001.xml

The following mask is allowed for boundary files:

<effectiveDateTime>__<sourcingActor>_<modelPart>_<fileVersion>

The following additional rules apply for the boundary set file names mask:

- sourcingActor shall be ENTSOE.
- None of the parts in the file name are allowed to contain an underscore “_” or dash “-”.
- All four file name parts shall be present.
- The number of underscores in a file name is always four.

Examples:

- 20180226T0000Z__ENTSOE_EQBD_101.xml

The effectiveDateTime is the same as the md:Model.scenarioTime in the md:FullModel header.

Each SSH, TP and SV CIMXML file are valid for specific effectiveDateTime. The effectiveDateTime is defined based on the CGMM-v3[4], for example in case of day-ahead process in Article 4(2) as “…each TSO shall build a day-ahead IGM for each market time unit of the day of delivery. The mid-point of each market time unit shall be used as the reference timestamp.” So, for day-ahead IGM, the SSH, TP and SV CIMXML file is valid for a market time unit of one hour, and the reference timestamp is mid-point of an hour (HH:30, HH indicating an hour in UTC notation) represented by effectiveDateTime as YYYYMMDDT**HH30**Z.

EQ, EQDIFF, EQBD and TPBD CIMXML files do not require every hour creation and are valid starting from provided effectiveDateTime until the new EQ or EQDIFF with one of the succeeding effectiveDateTime is provided.

[4] https://docstore.entsoe.eu/Documents/Network%20codes%20documents/Implementation/cacm/cgmm/CGMM-v3.pdf

EQ and EQDIFF CIMXML files are to maintain the same reference timestamp being mid-point of market time unit meaning mid-point of an hour, effectiveDateTime being YYYYMMDDT**HH30**Z.

EQBD and TPBD CIMXML files are created with YYYYMMDDT**0000**Z effectiveDateTime, for both of the CIMXML files as well as the zipped package of those two.

The fileVersion is exactly three characters long positive integer number between 000 and 999, i.e. the first positive integer is 001 and the last 999.

The allowed values for “ModelingAuthority” and “ModelingAuthority URI” are defined in the QoCDC Reference Data document. The tab “QoCDC Mapping” provides the mapping between the reference data and QoCDC notations.

TSO network regions are combined into larger networks called synchronous areas described in the QoCDC Reference Data document. CGMRegions consists of GeographicalRegions or SubGeographicalRegions. For instance, Energinet has one GeographicalRegion and two SubGeographicalRegions (DKW and DKE) in different CGMRegions. Hence DKW and DKE SubGeographicalRegions are included in the QoCDC Reference Data document. If a TSO has HVDC links, they are treated as their own SubGeographicalRegions that are also included in the QoCDC Reference Data document.

The file name templates have proved to create non-unique file names and have been frequently revised due to this. The templates also require reserved characters, underscore (_) and dash (-) to guide parsing the meta data from the file name string. Hence these characters are not allowed in the meta data fields. As the file name templates are not future proof it is advised not to use them in other business processes than covered by this document.

3.2.1 DATASETS FOR INTRADAY PROCESS

At least 24 daily data sets shall be provided corresponding to the time frames from 0:30 to 23:30 CE(S)T. Each TSO shall provide its complete IGM data set according to last agreed exchange programs on the OPDE at least one hour:

- (Minimum Requirement) before each reference time (0:00h, 8:00h and 16:00h CE(S)T), and with at least the next 8 coming hours.

  Intraday files created for reference time:

  - 0:00h CE(S)T should be built with the market data available at the PEVF of 22:30h CE(S)T of the day before the energy delivery day
  - 8:00h CE(S)T should be built with the market data available at the PEVF of 06:30h CE(S)T of the energy delivery day.
  - 16:00h CE(S)T should be built with the market data available at the PEVF of 14:30h CE(S)T of the energy delivery day.

- (Final target) before each business time with a rolling forecast from DACF to IDCF with an hourly update (without merging DACF and IDCF processes) and with all the remaining hours of the business day. The provision of IGMs can start with 29 hours ahead (30 in case of autumn daylight saving) for all 24 data sets, up to 01 hour ahead for one data set.

Intraday files created for IGM delivery window from (hh-1):00h ending at hh:00h CE(S)T should be built with the market data available at the Pan-European Verification Platform (PEVF) of hh-0:30 CE(S)T.

To manage the intraday process, all LFC Blocks of the synchronous areas provide the intraday exchange programs after every intraday market gate, for a given market time unit (MTU). Allowed MTUs are 1/4h, 1/2h, 1h. Starting from 18:30h CE(S)T of the day before the intraday process up to 23:30h CE(S)T of the day of the intraday process, publication of preliminary reference program by PEVF is provided to the OPDE, on the hourly basis at the moment.

For intraday, the value for <businessProcess> is a two-character string indicating the *hour-ahead* defined as *the difference between the scenario time and the gate closure time*. Allowed values are 29 hours ahead (30 in case of autumn daylight saving) to 01 hour ahead.

Example of filenames in the case of data provision for the minimum requirement scope and three referenced time is provided in Table 3~~Table 3~~.

Table 3 Example of intraday filename convention for minimum requirement IGMs provision

Reference time CET	IGM delivery window	File name Scenario time in UTC Example naming provided during CET (UTC+1)	PEVF: date, version, delivery
0:00h	22:00-23:00h CET on 31.12.2021. Day before the ID process	20211231T2330Z_01_APG_SV_001.xml	20220101 v005 delivered at 22:30h CET on 31.12.2021. for intraday (A18) process
		20220101T0030Z_02_APG_SV_001.xml	
		20220101T0130Z_03_APG_SV_001.xml	
		20220101T0230Z_04_APG_SV_001.xml	
		20220101T0330Z_05_APG_SV_001.xml	
		20220101T0430Z_06_APG_SV_001.xml	
		20220101T0530Z_07_APG_SV_001.xml	
		20220101T0630Z_08_APG_SV_001.xml	
8:00h	06:00-7:00h CET on 01.01.2022. Day of the ID process	20220101T0730Z_01_APG_SV_001.xml	20220101 v014 delivered at 06:30h CET on 01.01.2022. for intraday (A18) process
		20220101T0830Z_02_APG_SV_001.xml	
		20220101T0930Z_03_APG_SV_001.xml	
		20220101T1030Z_04_APG_SV_001.xml	
		20220101T1130Z_05_APG_SV_001.xml	
		20220101T1230Z_06_APG_SV_001.xml	
		20220101T1330Z_07_APG_SV_001.xml	
		20220101T1430Z_08_APG_SV_001.xml	
16:00h	14:00-15:00h CET on 01.01.2022. Day of the ID process	20220101T1530Z_01_APG_SV_001.xml	20220101 v021 delivered at 14:30h CET on 01.01.2022. for intraday (A18) process
		20220101T1630Z_02_APG_SV_001.xml	
		20220101T1730Z_03_APG_SV_001.xml	
		20220101T1830Z_04_APG_SV_001.xml	
		20220101T1930Z_05_APG_SV_001.xml	
		20220101T2030Z_06_APG_SV_001.xml	
		20220101T2130Z_07_APG_SV_001.xml	
		20220101T2230Z_08_APG_SV_001.xml	

Example of filenames in the case of data provision in full scope, after day-ahead market closure and intraday market opening, 29 hours ahead, full data sets until end of intraday process, is provided in Table 4~~Table 4~~.

Table 4 Example of intraday filename convention for full scope IGMs provision rolling process, example naming provided during CET (UTC+1)

29 hours-ahead, 24 datasets delivery	...	24 hours-ahead, 24 datasets delivery	...	12 hours-ahead, 12 datasets delivery	...	01 hour-ahead, 2 datasets delivery
IGM delivery window: 17:00-18:00 CET PEVF: day-ahead (A01), v001, delivered at 16:30 CET on 31.12.2021.		IGM delivery window: 22:00-23:00 CET PEVF: intraday (A18), v005, Delivered at 22:30 CET on 31.12.2021.		IGM delivery window: 10:00-11:00 CET PEVF: intraday (A18), v017, Delivered at 10:30 CET on 01.01.2022.		IGM delivery window: 21:00-22:00 CET on 01.01.2022. PEVF: intraday (A18), v028, Delivered at 21:30 CET on 01.01.2022.
20211231T2330Z_06_APG_SV_000.xml		20211231T2330Z_01_APG_SV_000.xml				
20220101T0030Z_07_APG_SV_000.xml		20220101T0030Z_02_APG_SV_000.xml				
20220101T0130Z_08_APG_SV_000.xml		20220101T0130Z_03_APG_SV_000.xml				
20220101T0230Z_09_APG_SV_000.xml		20220101T0230Z_04_APG_SV_000.xml				
20220101T0330Z_10_APG_SV_000.xml		20220101T0330Z_05_APG_SV_000.xml				
20220101T0430Z_11_APG_SV_000.xml		20220101T0430Z_06_APG_SV_000.xml				
20220101T0530Z_12_APG_SV_000.xml		20220101T0530Z_07_APG_SV_000.xml				
20220101T0630Z_13_APG_SV_000.xml		20220101T0630Z_08_APG_SV_000.xml				
20220101T0730Z_14_APG_SV_000.xml		20220101T0730Z_09_APG_SV_000.xml				
20220101T0830Z_15_APG_SV_000.xml		20220101T0830Z_10_APG_SV_000.xml				
20220101T0930Z_16_APG_SV_000.xml		20220101T0930Z_11_APG_SV_000.xml				
20220101T1030Z_17_APG_SV_000.xml		20220101T1030Z_12_APG_SV_000.xml				
20220101T1130Z_18_APG_SV_000.xml		20220101T1130Z_13_APG_SV_000.xml		20220101T1130Z_01_APG_SV_000.xml		
20220101T1230Z_19_APG_SV_000.xml		20220101T1230Z_14_APG_SV_000.xml		20220101T1230Z_02_APG_SV_000.xml		
20220101T1330Z_20_APG_SV_000.xml		20220101T1330Z_15_APG_SV_000.xml		20220101T1330Z_03_APG_SV_000.xml		
20220101T1430Z_21_APG_SV_000.xml		20220101T1430Z_16_APG_SV_000.xml		20220101T1430Z_04_APG_SV_000.xml		
20220101T1530Z_22_APG_SV_000.xml		20220101T1530Z_17_APG_SV_000.xml		20220101T1530Z_05_APG_SV_000.xml		
20220101T1630Z_23_APG_SV_000.xml		20220101T1630Z_18_APG_SV_000.xml		20220101T1630Z_06_APG_SV_000.xml		
20220101T1730Z_24_APG_SV_000.xml		20220101T1730Z_19_APG_SV_000.xml		20220101T1730Z_07_APG_SV_000.xml		
20220101T1830Z_25_APG_SV_000.xml		20220101T1830Z_20_APG_SV_000.xml		20220101T1830Z_08_APG_SV_000.xml		
20220101T1930Z_26_APG_SV_000.xml		20220101T1930Z_21_APG_SV_000.xml		20220101T1930Z_09_APG_SV_000.xml		
20220101T2030Z_27_APG_SV_000.xml		20220101T2030Z_22_APG_SV_000.xml		20220101T2030Z_10_APG_SV_000.xml		
20220101T2130Z_28_APG_SV_000.xml		20220101T2130Z_23_APG_SV_000.xml		20220101T2130Z_11_APG_SV_000.xml		
20220101T2230Z_29_APG_SV_000.xml		20220101T2230Z_24_APG_SV_000.xml		20220101T2230Z_12_APG_SV_000.xml		20220101T2230Z_01_APG_SV_000.xml

The consequence of the IGMs delivery according to Minimum Requirement is the re-validation of the already delivered IGMs on QAS with the rolling delivery of PEVF files for the hours between the three referenced times. This does not impact the usability of the IGM in the CGM creation process as IGMs with matching PEVF files are being used for CGM build.

3.2.2 MD:MODEL.DESCRIPTION

The attribute md:Model.description is declared as a string which means it shall be serialised as valid string.

The content of md:Model.description and its sub-elements is defined as follows:

- there is no specific namespace for the elements of the structure;
- MDE field is required;
- BP field is required. It is indicating the business process from level 1 rule BusinessProcess;

- TOOL field is required. It is indicating tool name and version number;
- RSC field is optional for IGM and required for SV and SSH that are created and serialised by a RSC;
- TXT field is optional free text.

Based on this requirement the following XML structure is obtained:

<MDE>

<BP>1D</BP>

<TOOL>PowerFactory 2021</TOOL>

<RSC>N/A</RSC>

<TXT>QoCDC v3.2 test configuration</TXT>

</MDE>

As the XML structure shall be serialized as string representing an escaped character xml structure, the content of md:Model.description for the above structure shall be:

<md:Model.description><MDE><BP>1D</BP><TOOL>PowerFactory 2021</TOOL><RSC>N/A</RSC><TXT>QoCDC v3.2 test configuration</TXT></MDE> </md:Model.description>

3.3 VALIDATION RULES

```
Rule: FileNameMD  Level: 1  Severity: ERROR

      Details:
      Two different file name templates are used:
      1) effectiveDateTime_businessProcess_sourcingActor_modelPart_fileVersion
      2) effectiveDateTime__sourcingActor_modelPart_fileVersion
      The templates have fields separated by four underscores (_).

      Depending on the modelPart field (allowed values are listed in rule ModelPartType)
      the usage of above templates is as follows:
      - EQ shall use both template 1 and 2;
      - SSH, TP and SV shall only use template 1;
      - EQBD and TPBD shall only use template 2.

      The field sourcingActor has sub-fields separated by dashes (-). The following three
      sub-templates are allowed for sourcingActor field:
      - sourcingTSO, which is always used by a TSO;
      - sourcingRSC-cgmRegion, which is used by RSC for a synchronous area file, e.g. a
      SV file;
      - sourcingRSC-cgmRegion-sourcingTSO, which is used by RSC for an updated TSO area
      file, e.g. a SSH file.

      Note that model parts such as DL, DY, GL are not included as they are not in the
      implementation scope of QoCDC.
```

```
746         Justification:
747
748         Message:
749         Number of meta data fields in file name does not match the rules.
750
751         Usage: #IGMRuleSet #CGMRuleSet
752
753   Rule: FileNameConsistency  Level: 1  Severity: ERROR
754
755         Details:
756         Each cimxml file (including EQBD and TPBD) is contained by a single zip container.
757         The file name of the cimxml file within the container must be the same as the name
758         of the container. However, EQBD and TPBD might be zipped together in case they need
759         to be uploaded in OPDE, which is an implementation detail.
760
761         Justification:
762
763         Message:
764         XML instance file name is different from zip container file name.
765
766         Usage: #IGMRuleSet #CGMRuleSet
767
768   Rule: EffectiveDateTime  Level: 1  Severity: ERROR
769
770         Details:
771         The 'effectiveDateTime' in the file name must be a valid datetime
772         in minute resolution in accordance with ISO 8601-2005, basic format
773         with time designator [T] between date and time and ending with
774         UTC designator [Z]. For example, 20180118T1130Z.
775         Use of other
776         date/time specifiers by characters [:.-+YMDHSWP] is not allowed.
777
778         Justification:
779         The relevant time resolution for the business process is minute level and
780         the time in the file name shall match with this attribute.
781
782         Message:
783         EffectiveDateTime in file name is invalid.
784
785         Usage: #IGMRuleSet #CGMRuleSet
786
787   Rule: SourcingActor  Level: 1  Severity: ERROR
788
789         Details:
790         The sourcingActor, that appears in the cimxml file name, is composed as described
791         in rule FileNameMD. The choice on sourcingActor is made by the responsible TSO and
792         it is recorded in the QoCDC Reference Data document. Once decided the
793         sourcingActor should comply with the defined names in the QoCDC Reference Data
794         document.
795
796         Justification:
797         The sourcingActor shall comply with the choices made by a TSO.
798
799         Message:
800         Undefined TSO or network region names specified.
801
```

```
802         Usage: #IGMRuleSet #CGMRuleSet
803
804   Rule: CGMRegion  Level: 1  Severity: ERROR
805
806         Details:
807         TSO networks are organized in synchronous areas including
808         multiple TSO network regions. Each synchronous area is
809         assigned unique identifiers in file names.
810         The allowed synchronous areas are listed in the
811         QoCDC Reference Data document.
812
813         Justification:
814         Needed to uniquely identify synchronous areas for SV of CGM.
815
816         Message:
817         Unidentified synchronous area specified in SV instance filename of CGM.
818
819         Usage: #CGMRuleSet
820
821   Rule: BusinessProcess  Level: 1  Severity: ERROR
822
823         Details:
824         The 'businessProcess' in the file name is restricted according
825         to a list in the QoCDC Reference Data document.
826         See also level 2 rule ModelDescription where the BusinessProcess
827         is required in the Model.description attribute.
828
829         Justification:
830
831         Message:
832         Unknown business process.
833
834         Usage: #IGMRuleSet #CGMRuleSet
835
836
837   Rule: ModelPartType  Level: 1  Severity: ERROR
838
839         Details:
840         The 'modelPart' in the file name is restricted.
841         Note that the profile declarations in the file header are
842         leading and shall be used as meta data to request data.
843
844         The allowed model part types are as follows: DL, DY, EQ, EQBD, EQDIFF, GL, SSH,
845         SV, TP, TPBD.
846
847         Justification:
848
849         Message:
850         Unknown modelPart type in the filename.
851
852         Usage: #IGMRuleSet #CGMRuleSet
853
854
855   Rule: FileVersionType  Level: 1  Severity: ERROR
856
857         Details:
```

```
The 'fileVersion' in the file name must be positive integer value always
represented by three numeric characters ranging from 000 to 999, i.e. the first
positive integer is 001 and the last 999.
Leading zeros are allowed.

Justification:
See this specification section 3.1 and IEC TS 61970-600-1 C.3.1.

Message:
File version must be a number with three numeric character positions.

Usage: #IGMRuleSet #CGMRuleSet
```

4 LEVEL 2 VALIDATION: STRUCTURE SYNTAX AND METADATA

4.1 INTRODUCTION

CGMES data is exchanged as CIM RDF[5] XML[6] files. The Resource Description Framework uses an XML based syntax, allowing relationships to be defined between XML nodes. The first level of syntax validation is to check if the document is well formed in accordance with the XML rules[7].

RDF syntax provides many ways to represent the same set of data. For example, an association between two resources can be written with a resource attribute or by nesting one element within another. This could make it difficult to use some XML tools, such as XSLT processors, with the CIMXML document.

Therefore, only a subset of the RDF Syntax is to be applied in creating CIMXML documents. This syntax simplifies the work of implementers to construct model serialization and deserialization software, as well as to improve the effectiveness of general XML tools when used with CIMXML documents. The reduced syntax is a proper subset of the standard RDF syntax; thus, it can be read by available RDF de-serialization software.

The simplified syntax is for exchanging power system models between utilities. The aim of the IEC 61970-552:2013 (Edition 1.0) specification is to make it easier for implementers to construct de-serialization software for RDF data, to simplify their choices when serializing RDF data, and to improve the effectiveness of general XML tools such as XSLT processors when used with the serialized RDF data.

The reduced syntax does not sacrifice any of the power of the RDF data model. That is, any RDF data can be exchanged using this syntax. Moreover, features of RDF such as the ability to extend a model defined in one document with statements in second document are preserved.

---

[5] Resource Description Framework, i.e. a language recommended by the W3C for expressing meta data that machines can process easily

[6] eXtensible Markup Language, i.e. a subset of the Standard Generalized Markup Language (SGML), ISO 8879, for putting structured data in a text file

[7] The full set is specified in the W3C Recommendation, “Extensible Markup Language: Prolog and Document Type Declaration” Version 1.0, 26 November 2008, available at http://www.w3.org/TR/REC-xml/#sec-prolog-dtd

Errors in XML documents will stop XML applications. The W3C XML specification states that a program should stop processing an XML document if it finds an error. The reason is that XML software should be small, fast, and compatible. HTML browsers are allowed to display HTML documents with errors (like missing end tags). With XML, errors are not allowed.

The CGMES files shall have an XML prolog that declares the version of the XML and in which the encoding is set to UTF-8 (acc. to CENC10 in IEC TS 61970-600-1:2017). Missing encoding is considered an erroneous file.

It shall be possible to trace back the error detected by the validating processor, specifying the file name, error detected and line number in the file.

4.2 RDF SCHEMA

CGMES data is exchanged as CIMXML files, as specified in IEC 61970-552:2013 (Edition 1.0). The older ID formats according to section 6.4 is allowed.

RDFS files, generated from the UML, describe the CGMES profile classes, attributes and roles with cardinalities using an extended RDFS notation described in IEC 61970-501 Ed1.

The RDFS files can be downloaded from the ENTSO-E website. The Resource Description Framework supports extensibility, meaning that classes attributes or roles not used in the CGMES profiles still can be exchanged in CIMXML files. Hence it is allowed for a creator of a CIMXML file to include any information not in the CGMES profiles. However, a receiver of such a CIMXML file will only read the information described by the CGMES profiles defined for the exchange. Hence a creator of a CIMXML with additional information cannot expect a receiver to process the data not described in the CGMES profiles.

The following table specifies which RDFS file is to be used for validation.

Table 5 RDF schema descriptions

ModelProfile value	RDF schema description
http://entsoe.eu/CIM/EquipmentBoundary/3/1	EquipmentBoundaryProfile

	RDFSAugmented-v2_4_15-16Feb2016.rdf
http://entsoe.eu/CIM/TopologyBoundary/3/1	TopologyBoundaryProfileRDFSAugmented-v2_4_15-16Feb2016.rdf
http://entsoe.eu/CIM/EquipmentCore/3/1	EquipmentProfileCoreRDFSAugmented-v2_4_15-4Jul2016.rdf
http://entsoe.eu/CIM/EquipmentCore/3/1 **http://entsoe.eu/CIM/EquipmentOperation/3/1**	EquipmentProfileCoreOperationRDFSAugme

	nted-v2_4_15-4Jul2016.rdf
http://entsoe.eu/CIM/EquipmentCore/3/1 **http://entsoe.eu/CIM/EquipmentShortCircuit/3/1**	EquipmentProfileCoreShortCircuitRDFSAugmented-v2_4_15-4Jul2016.rdf
http://entsoe.eu/CIM/EquipmentCore/3/1 **http://entsoe.eu/CIM/EquipmentOperation/3/1** **http://entsoe.eu/CIM/EquipmentShortCircuit/3/1**	EquipmentProfileCoreShortCircuitOperationRDFSAugmented-v2_4_15-4Jul2016.rdf
http://entsoe.eu/CIM/SteadyStateHypothesis/1/1	SteadyStateHypothesisProf

	ileRDFSAugmented-v2_4_15-16Feb2016.rdf
http://entsoe.eu/CIM/Topology/4/1	TopologyProfileRDFSAugmented-v2_4_15-16Feb2016.rdf
http://entsoe.eu/CIM/StateVariables/4/1	StateVariablesProfileRDFSAugmented-v2_4_15-16Feb2016.rdf
http://entsoe.eu/CIM/DiagramLayout/3/1	DiagramLayoutProfileRDFSAugmented-v2_4_15-

	16Feb2016.rdf
http://entsoe.eu/CIM/GeographicalLocation/2/1	GeographicalLocationProfileRDFSAugmented-v2_4_15-16Feb2016.rdf
http://entsoe.eu/CIM/Dynamics/3/1	DynamicsProfileRDFSAugmented-v2_4_15-16Feb2016.rdf

Any tool implementing the CGMES profile shall check CIMXML data and verifying that

- Class, attribute and role names appearing in a file is defined by the profile.
- Cardinality constraints are respected.

The rules “NotMandatoryClass” or “NotMandatoryProperty” are used to warn about classes, attributes and roles not described by CGMES profiles.

With the class cardinality it is possible to describe if instances of a particular class are required but this feature has not been used. Instead, rules have been created specifying the number of required instances, e.g. the rule “ControlAreaInstance” that requires exactly one instance of the ControlArea class in an IGM. In UML it is possible to specify this as the cardinality on a class, but this capability hasn’t been used for CGMES.

For the attributes and roles, the cardinality value specifies how many times an attribute value or role reference shall appear in a CIMXML file. The rule "IncorrectAttributeOrRoleCard" reports violated cardinality.

4.3 METADATA

The Model header from IEC 61970-552 is validated and cross checked with the meta data in the file name if present in both places.

4.4 VALIDATION RULES

```
Rule: Prolog  Level: 2  Severity: ERROR

      Details:
      The CIMXML file must have a prolog containing attributes
      version and encoding.

      Justification:
      See this specification, section 4.1.

      Message:
      Prolog is missing.

      Usage: #IGMRuleSet #CGMRuleSet

Rule: Encoding  Level: 2  Severity: ERROR

      Details:
      If the encoding is different from UTF-8, it shall be considered an error
      Note: the encoding is case insensitive

      Justification:
      See IEC TS 61970-600-1:2017 GENC10.

      Message:
      Missing encoding or encoding other than UTF-8.

      Usage: #IGMRuleSet #CGMRuleSet

Rule: XMLStructure  Level: 2  Severity: ERROR

      Details:
      If the XML parsing fails, the process is aborted.

      Justification:
      https://www.w3.org/TR/REC-xml/#dt-fatal

      Message:
      XML parsing error.

      Usage: #IGMRuleSet #CGMRuleSet

Rule: FileHeader  Level: 2  Severity: ERROR
```

Details:
Each type of instance file shall have exactly one file header of type FullModel or DifferenceModel.

Justification:
Requirement HGEN2 of IEC TS 61970-600-1:2017, IEC 61970-552, section 5.2.

Message:
Missing file header.

Usage: #IGMRuleSet #CGMRuleSet

Rule: URNUniqueness Level: 2 Severity: ERROR

Details:
A new model ID shall be generated for new instance files, only when the content of the instance data changes. A new version means a new URN. This is a process related rule and cannot be validated in standalone model of validation of an IGM.

Justification:
Requirement HREF1, HREF5 of IEC TS 61970-600-1:2017.

Message:
URN of the instance file already exists.

Usage: #IGMRuleSet #CGMRuleSet

Rule: MAS Level: 2 Severity: ERROR

Details:
1) md:Model.modelingAuthoritySet is required in the header of all instance files.
2) md:Model.modelingAuthoritySet shall have one of the values specified in the QoCDC Reference Data document.
3) md:Model.modelingAuthoritySet of a CGM SV instance file shall be the MAS that creates the state variables. The value of md:Model.modelingAuthoritySet is not validated against QoCDC Reference Data document, but it is recommended to be constructed as follows: MA/Region/Process, where
   - MA is the URI of the MergingAgent
   - Region is the name of the CGMRegion
   - Process is the name of the ProcessType.

Note: This rule intentionally overrides MAPR10 and MARP11 of IEC TS 61970-600-1:2017.

Justification:
Requirement HGEN1 IEC TS 61970-600-1:2017.
The attribute is mandatory for the CGM process.

Message:
Missing or invalid md:Model.modelingAuthoritySet specification.

Usage: #IGMRuleSet #CGMRuleSet

```
Rule: MASPersistency  Level: 2  Severity: ERROR

      Details:
      The rule applies for IGM only. The 'md:Model.modelingAuthoritySet' attribute must
      be persistent for all CIMXML files of an IGM.
      Note that to test this across CIMXML files this must be done for a model where
      all files have been included.

      Justification:
      See this document section 3.1 and IEC TS 61970-600-1 table in C.3.1.

      Message:
      md:Model.modelingAuthoritySet is not persistent across IGM files.

      Usage: #IGMRuleSet


Rule: ModelCreated  Level: 2  Severity: ERROR

      Details:
      The date and time when the model was created.
      It is the time of the serialization.
      The format is an extended format according to the ISO 8601-2005.
      The ENTSO-E exchanges should refer to UTC.
      The 'md:Model.created' attribute must be valid datetime in accordance
      with ISO 8601, extended format with time designator [T] between date
      and time ending with UTC designator [Z]. The characters [:-] shall be used. For
      example, 2018-01-18T11:30:12Z or 2018-01-18T11:30:12.015Z.

      The restriction describes the minimum required specification that a
      receiver shall be prepared to consume. A more precisely specified
      time defined by characters [+YMDHSWP] will be ignored.

      Justification:
      Annex C of IEC TS 61970-600-1:2017.

      Message:
      Invalid Model.created attribute.

      Usage: #IGMRuleSet #CGMRuleSet

Rule: ScenarioTime  Level: 2  Severity: ERROR

      Details:
      The 'md:Model.scenarioTime' attribute must be valid datetime in
      accordance with ISO 8601, extended format with time designator [T]
      between date and time ending with UTC designator [Z].
      The characters [:-] shall be used. For example, 2018-01-18T11:30:00Z,
      2018-01-18T11:30:12.000Z or 2018-01-18T11:30Z.

      The restriction describes the minimum required specification that a
      receiver shall be prepared to consume. A more precisely specified
      time defined by characters [+.YMDHSWP] will be ignored.

      Justification:
      Annex C of IEC TS 61970-600-1:2017.
```

```
1085
1086          Message:
1087          Invalid Model.scenarioTime attribute.
1088
1089          Usage: #IGMRuleSet #CGMRuleSet
1090
1091    Rule: ScenarioTimeConsistency  Level: 2  Severity: ERROR
1092
1093          Details:
1094          The 'md:Model.scenarioTime' attribute shall refer to the same datetime
1095          as the 'effectiveDateTime' in the file name, considering minute
1096          resolution.
1097
1098          Justification:
1099          Necessary to produce consistent meta data for the exchange process.
1100
1101          Message:
1102          The scenarioTime specification in the file header does not match the
1103          effectiveDateTime specified in the file name.
1104
1105          Usage: #IGMRuleSet #CGMRuleSet
1106
1107    Rule: VersionConsistency  Level: 2  Severity: ERROR
1108
1109          Details:
1110          The 'md:Model.version' attribute shall be the same number
1111          as the 'fileVersion' string from the file name converted to an integer.
1112
1113          Justification:
1114          Necessary to produce consistent meta data for the exchange process.
1115
1116          Message:
1117          The model version does not match the file version.
1118
1119          Usage: #IGMRuleSet #CGMRuleSet
1120
1121    Rule: ProfileSpecification  Level: 2  Severity: ERROR
1122
1123          Details:
1124          The 'md:Model.profile' description in the file header is restricted.
1125          Note: The profile declarations in the file header are leading and
1126          shall be used as meta data to request data.
1127          The enumeration values are centrally maintained in
1128          QoCDC Reference Data document.
1129
1130          Justification:
1131          Necessary to determine which RDFS rules to use.
1132          Requirement FBOD2, HGEN1 of IEC TS 61970-600-1:2017
1133          Annex C of IEC/TS 61970-600-1:2017.
1134
1135          Message:
1136          Invalid profile specification.
1137
1138          Usage: #IGMRuleSet #CGMRuleSet
1139
1140
```

Rule: ModelDescription Level: 2 Severity: WARNING

Details:
The md:Model.description attribute is required and shall contain the xml structure that is described in section 3.2.2. The xml structure shall be serialised in the attribute as escaped XML, i.e. still as a string.

Justification:
See this specification section 3.2.2.

Message:
md:Model.description is not provided or does not contain required fields.

Usage: #IGMRuleSet #CGMRuleSet

Rule: NotMandatoryClass Level: 2 Severity: WARNING

Details:
An instance of a class not described in a CGMES profile is ignored and reported.
If an importing tool requires a class not described in a CGMES profile issues may occur for a CGM where other IGMs do not contain instances of the class.

Justification:
Requirement PROF11 of IEC/TS 61970-600-1:2017.

Message:
Class instance in cimxml document is ignored.

Usage: #IGMRuleSet #CGMRuleSet

Rule: NotMandatoryProperty Level: 2 Severity: WARNING

Details:
A role or attribute not described in a CGMES profile is ignored and reported.
If an importing tool require a role or attribute not described in a CGMES profile issues may occur for a CGM where other IGMs do not contain instances of the role or attribute.

Justification:
Requirement PROF11 of IEC/TS 61970-600-1:2017.

Message:
Role or attribute in cimxml document is ignored.

Usage: #IGMRuleSet #CGMRuleSet

Rule: AttributeAndRoleValues Level: 2 Severity: ERROR

Details:
Attribute and role values appearing in a CIMXML document shall have a value.
The rule checks empty attributes that are not of type String.

Notes:
- Example of empty attribute: [cim:class.attribute/] or

```
          [cim:class.attribute][/cim:class.attribute]
        - Example of empty rdf:resource [cim:class.attribute rdf:resouce=""/], note this
        is not a valid reference and it is part of rule XMLStructure.
        Note: the xml angle brackets has been replaced by square parenthesis in
        above examples.


        Justification:
        Only meaningful data shall be exchanged in CIMXML documents.
        See also IEC TS 61970-600-1 NAMC14.

        Message:
        Empty attribute or rdf:resource is present.

        Usage: #IGMRuleSet #CGMRuleSet


Rule: IncorrectDataTypeFormat  Level: 2  Severity: ERROR

        Details:
        Data format shall conform to the datatype defined in the profile.

        Note: This rule reports data format issues for all datatypes.
        A description of the data type specific error is included in the message.
        The format of the message is  "[Message] The [expected datatype]: [datatype detail
        text] is not correct.",
        where
        [expected datatype] is the datatype reference defined by the profile
        [datatype detail text] is either printing the value that does not conform or
        indicating the details of the issue. For example, "The Decimal: decimal comma is
        not correct.".

        Justification:
        See IEC 61970-552.

        Message:
        Datatype does not conform. The [expected datatype]: [datatype detail text] is not
        correct.

        Usage: #IGMRuleSet #CGMRuleSet

Rule: Exception  Level: 2  Severity: ERROR

        Details:
        An exception shall be reported in case of a non-recoverable software error occurs.
        A software error is an error related to the functioning of the software itself and
        not due to the content of the IGMs or CGMs. For instance, programming error or OCL
        rules that do not check for null references and use them in OCL language constructs
        will result in an exception.

        Justification:
        Software errors that are discovered shall be corrected.

        Message:
        A software error has occurred, please report to the developer.
```

```
        Usage: #IGMRuleSet #CGMRuleSet
```

5 LEVEL 3 VALIDATION: CONSTRAINTS AND MAPPING

5.1 CONSTRAINTS FOR NAMING ATTRIBUTES

IEC TS 61970-600-1:2017, Annex B, specifies the maximum length of naming attributes for IdentifiedObject classes in all profile instance files and for ConnectivityNodes and TopologicalNodes in Boundary instance files.

5.2 CONTAINMENT RULES

Equipment containers represent ways of organizing and naming equipment typically found within a substation. As may be seen, there is some flexibility provided in which containers are used in a specific application of the CIM in order to accommodate different international practices as well as differences typically found between transmission and distribution substations. Bay, VoltageLevel, Substation, Line, DCLine and DCConverterUnit are all types of EquipmentContainer. In general, a Bay is contained within a specific VoltageLevel, which in turn is contained within a Substation. Substations and Lines may be contained within a SubGeographicalRegion and as a consequence within a GeographicalRegion.

One containment hierarchy is used with the IdentifiedObject class to create hierarchical naming intended for human consumption. This hierarchy is specifically used to name equipment according to its function in the power system. This is called the functional naming hierarchy. Containment is defined in Equipment instance files and in Equipment Boundary instance files.

5.3 CONSTRAINTS DEFINED BY CGMES

The IEC TS 61970-600-2 specifies additional constraints to the attribute values, conditional associations and enumerations.

5.4 CONSTRAINTS DEFINED BY BEST PRACTICES

This paragraph specifies a number of equipment modelling business rules that have their origin from best practices and common sense in Power Flow calculations. Rationales and justifications are provided in the rules.

5.4.1 LIMIT VALUES

Limit values for a synchronous machine are defined by reactive capability curves that define the limits at a specific operating voltage. Note that CIM/CGMES only allows for one reactive capability curve to cover all operating voltages. Figure 3 shows an example of a reactive capability curve for a synchronous machine with the same capability in motor operating mode as in generator operating

mode. The active power limits in generator operating mode are positive and in motor operating mode - negative.

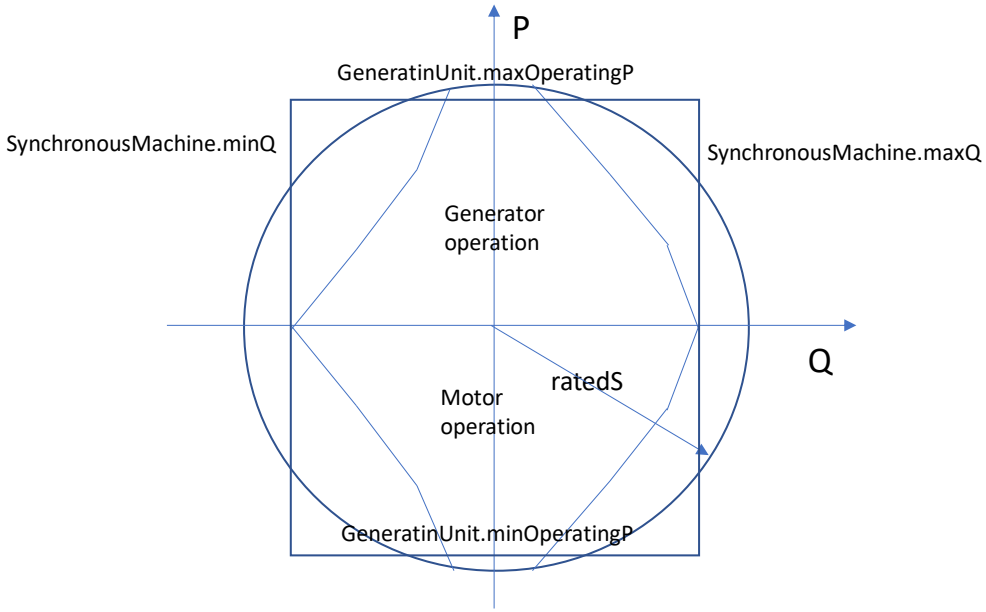

Figure 3 Example Reactive Capability Curve

A reactive capability curve has both active and reactive power limits.

In case the limits are not specified with a reactive capability curve constant limit values are available as follows:

- maxOperatingP and minOperatingP at the cim:GeneratingUnit class;
- maxQ and minQ at the cim:SynchronousMachine. Note that maxQ and minQ are optional attributes which are required if there is no ReactivecapabilityCurve associatied with the machine.

In Figure 3 those four constant limits are shown as a box.

A synchronous machine can be used as condenser, generator, motor (typically a pump in power systems) or a mix of them. The attribute cim:SynchronousMachine.type defines the supported mix of usages and the attribute cim:SynchronousMachine.operatingMode defines the operating mode used at the operating state represented by SSH. This results in a complex relation between

- cim:SynchronousMachine.type,
- cim:SynchronousMachine.operatingMode, and
- the four limit values.

The following three cases represent combinations for generator and motor. Note that condenser type is not included as it has no GeneratingUnit associated and it cannot be used for the purpose of generating active power.

1. An as built generator shall have positive active power limits and can only operate as a generator, see Figure 4.

2. An as built motor shall have negative active power limits and can only operate as a motor, see Figure 5.
3. An as built generator and motor can operate either in generator operating mode or in motor operating mode, see Figure 3, and shall have
    - a positive maxOperatingP, and
    - a negative minOperatingP.

Note that in case 3 the unit can only operate either in generator operating mode or in motor operating mode in a given steady state situation (described in SSH). This means that the practical minimum limit in generator operating mode shall be zero and the practical maximum limit in motor operating mode shall be zero as shown in Figure 6.

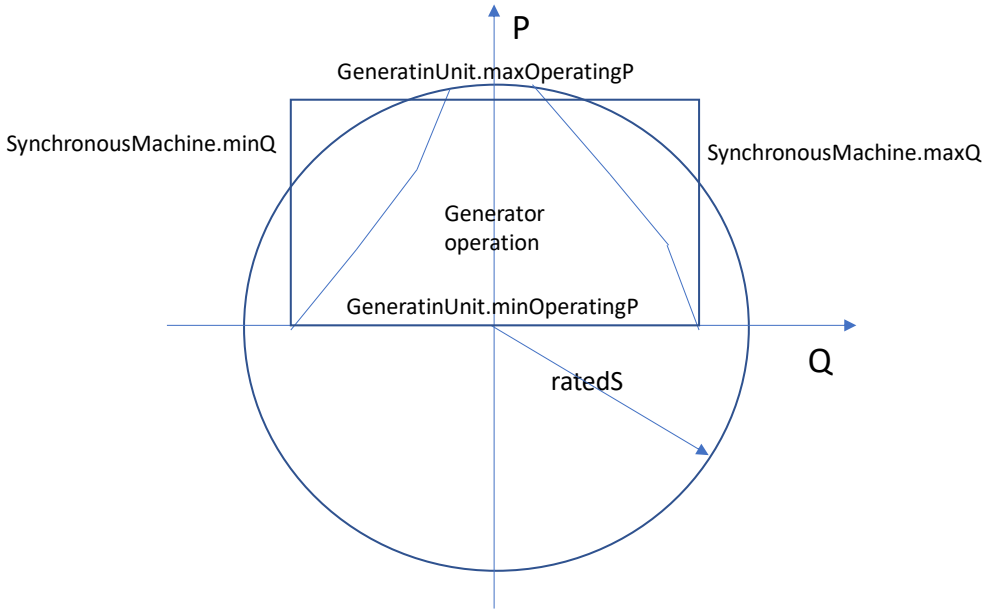

Figure 4 Generator only

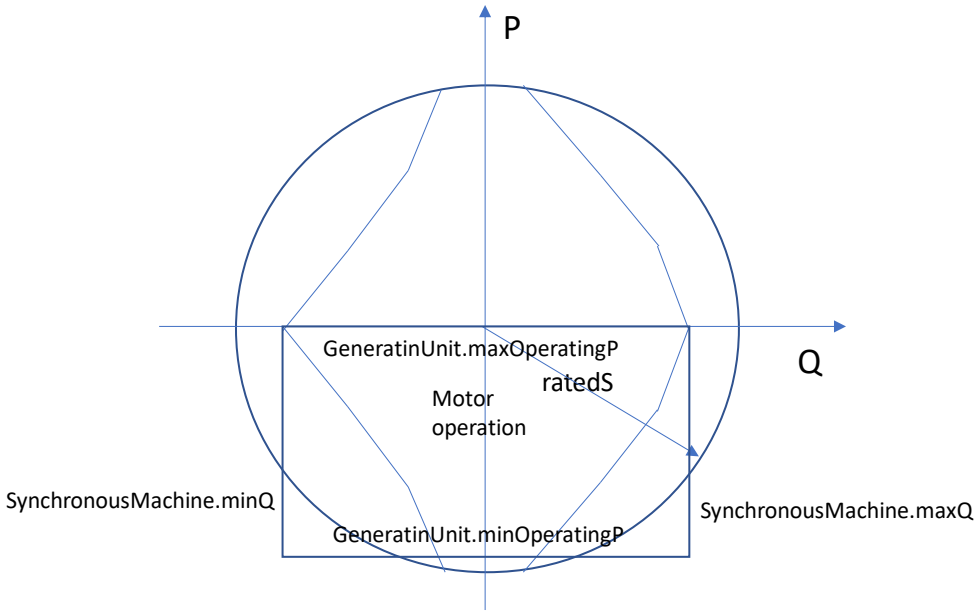

Figure 5 Motor operation only

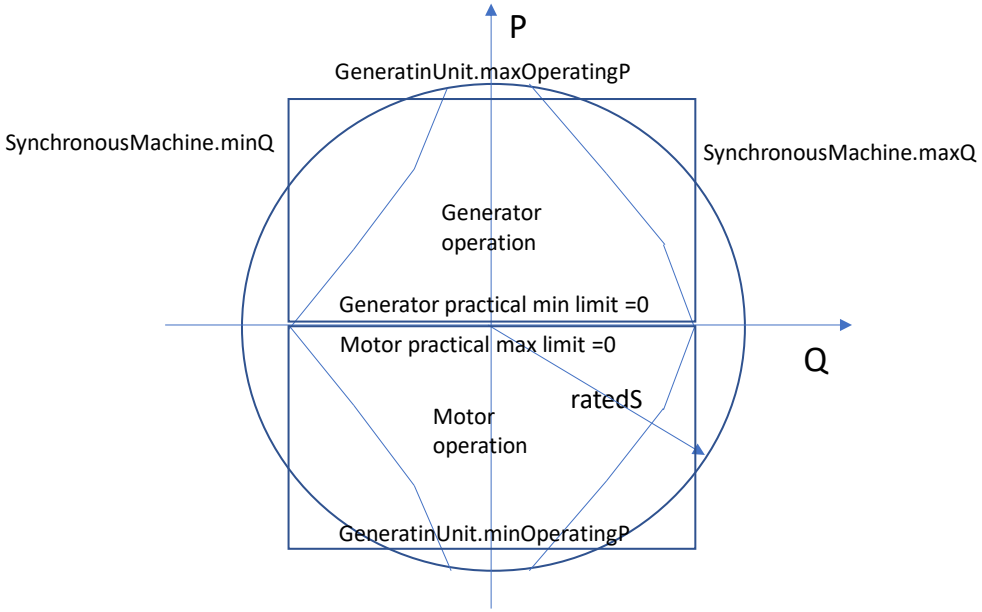

Figure 6 Generator or motor operation

5.5 MAPPING REQUIREMENTS DEFINED BY CGM CONTEXT

The quality checks in this section refer to information that is required to be able to use scheduled and aligned netted area AC positions and target flows on HVDC links as set points in the CGM process.

5.6 VALIDATION RULES

Rule: NameLength Level: 3 Severity: ERROR

Details:
In cases where cim:IdentifiedObject.name is a required attribute, it shall not be empty string and shall not exceed IO_NAME_LENGTH characters for all instances except for instances of subclasses of cim:ACDCTerminal where cim:IdentifiedObject.name may be omitted.

Note: This rule further restricts IEC TS 61970-600-1:2017, IEC TS 61970-600-2:2017 where empty strings are allowed in cim:IdentifiedObject.name.

Justification:
See IEC TS 61970-600-1:2017 B.1.

Message:
cim:IdentifiedObject.name is either missing, empty string or exceeds IO_NAME_LENGTH characters.

Usage: #IGMRuleSet #CGMRuleSet

Rule: DescriptionLength Level: 3 Severity: ERROR

Details:
In every model instance, the length of all instances of cim:IdentifiedObject.description shall not exceed IO_DESCRIPTION_LENGTH characters.

Justification:
See IEC TS 61970-600-1:2017 B.2.

Message:
Length of description instance exceeds IO_DESCRIPTION_LENGTH characters.

Usage: #IGMRuleSet #CGMRuleSet

Rule: EICLength Level: 3 Severity: ERROR

Details:
In every model instance, the length of all instances of entsoe:IdentifiedObject.energyIdentCodeEic must be exactly EIC_LENGTH characters.

Justification:
See IEC TS 61970-600-1:2017 B.3.

Message:
Length of energyIdentCodeEic instance must be exactly EIC_LENGTH characters.

Usage: #IGMRuleSet #CGMRuleSet

Rule: ShortNameLength Level: 3 Severity: ERROR

Details:

```
1384          In every model instance, the length of all instances of
1385          entsoe:IdentifiedObject.shortName shall not exceed
1386          SHORT_NAME_LENGTH characters.
1387
1388          Justification:
1389          See IEC TS 61970-600-1:2017 B.4.
1390
1391          Message:
1392          Length of shortName instance exceeds SHORT_NAME_LENGTH characters.
1393
1394          Usage: #IGMRuleSet #CGMRuleSet
1395
1396    Rule: CNFromEndIsoCode  Level: 3  Severity: ERROR
1397
1398          Details:
1399          In an EQBD document attribute value entsoe:ConnectivityNode.fromEndIsoCode
1400          must be from the country code list – field 'TsoCodeList' in the QoCDC Reference
1401          Data document which is a subset of https://www.iso.org/iso-3166-country-codes.html.
1402
1403          Justification:
1404          See IEC TS 61970-600-1:2017 B.5.
1405
1406          Message:
1407          Country code used that is not in the reference data.
1408
1409          Usage: #IGMRuleSet
1410
1411
1412    Rule: TNFromEndIsoCode  Level: 3  Severity: ERROR
1413
1414          Details:
1415          In a TPBD document attribute value entsoe:TopologicalNode.fromEndIsoCode
1416          must be from the country code list – field 'TsoCodeList' in the QoCDC Reference
1417          Data document which is a subset of https://www.iso.org/iso-3166-country-codes.html.
1418
1419          Justification:
1420          See IEC TS 61970-600-1:2017 B.5.
1421
1422          Message:
1423          Country code used that is not in the reference data.
1424
1425          Usage: #IGMRuleSet
1426
1427
1428    Rule: CNToEndIsoCode  Level: 3  Severity: ERROR
1429
1430          Details:
1431          In an EQBD document attribute value entsoe:ConnectivityNode.toEndIsoCode
1432          must be from the country code list – field 'TsoCodeList' in the QoCDC Reference
1433          Data document which is a subset of https://www.iso.org/iso-3166-country-codes.html.
1434
1435          Justification:
1436          See IEC TS 61970-600-1:2017 B.6.
1437
1438          Message:
1439          Country code used that is not in the reference data.
```

Usage: #IGMRuleSet

Rule: TNToEndIsoCode Level: 3 Severity: ERROR

Details:
In a TPBD document attribute value entsoe:TopologicalNode.toEndIsoCode must be from the country code list – field 'TsoCodeList' in the QoCDC Reference Data document which is a subset of https://www.iso.org/iso-3166-country-codes.html.

Justification:
See IEC TS 61970-600-1:2017 B.6.

Message:
Country code used that is not in the reference data.

Usage: #IGMRuleSet

Rule: CNFromEndNameLength Level: 3 Severity: ERROR

Details:
In every EQBD model instance, the length of all instances of entsoe:ConnectivityNode.fromEndName shall not exceed IO_NAME_LENGTH characters.

Justification:
See IEC TS 61970-600-1:2017 B.7.

Message:
Length of name attribute exceeds IO_NAME_LENGTH characters.

Usage: #IGMRuleSet

Rule: TNFromEndNameLength Level: 3 Severity: ERROR

Details:
In every TPBD model instance, the length of all instances of entsoe:TopologicalNode.fromEndName shall not exceed IO_NAME_LENGTH characters.

Justification:
See IEC TS 61970-600-1:2017 B.7.

Message:
Length of name attribute exceeds IO_NAME_LENGTH characters.

Usage: #IGMRuleSet

Rule: CNToEndNameLength Level: 3 Severity: ERROR

Details:
In every EQBD model instance, the length of all instances of entsoe:ConnectivityNode.toEndName shall not exceed IO_NAME_LENGTH characters.

```
1496          Justification:
1497          See IEC TS 61970-600-1:2017 B.8.
1498
1499          Message:
1500          Length of name attribute exceeds IO_NAME_LENGTH characters.
1501
1502          Usage: #IGMRuleSet
1503
1504    Rule: TNToEndNameLength  Level: 3  Severity: ERROR
1505
1506          Details:
1507          In every TPBD model instance, the length of all instances of
1508          entsoe:TopologicalNode.toEndName shall not exceed IO_NAME_LENGTH
1509          characters.
1510
1511          Justification:
1512          See IEC TS 61970-600-1:2017 B.8.
1513
1514          Message:
1515          Length of name attribute exceeds IO_NAME_LENGTH characters.
1516
1517          Usage: #IGMRuleSet
1518
1519    Rule: CNFromEndNameTsoLength  Level: 3  Severity: ERROR
1520
1521          Details:
1522          In every EQBD model instance, the length of all instances of
1523          entsoe:ConnectivityNode.fromEndNameTso shall not exceed IO_NAME_LENGTH
1524          characters.
1525
1526          Justification:
1527          See IEC TS 61970-600-1:2017 B.9.
1528
1529          Message:
1530          Length of name attribute exceeds IO_NAME_LENGTH characters.
1531
1532          Usage: #IGMRuleSet
1533
1534    Rule: TNFromEndNameTsoLength  Level: 3  Severity: ERROR
1535
1536          Details:
1537          In every TPBD model instance, the length of all instances of
1538          entsoe:TopologicalNode.fromEndNameTso shall not exceed IO_NAME_LENGTH
1539          characters.
1540
1541          Justification:
1542          See IEC TS 61970-600-1:2017 B.9.
1543
1544          Message:
1545          Length of name attribute exceeds IO_NAME_LENGTH characters.
1546
1547          Usage: #IGMRuleSet
1548
1549    Rule: CNToEndNameTsoLength  Level: 3  Severity: ERROR
1550
1551          Details:
```

```
1552          In every EQBD model instance, the length of all instances of
1553          entsoe:ConnectivityNode.toEndNameTso shall not exceed IO_NAME_LENGTH
1554          characters.
1555
1556          Justification:
1557          See IEC TS 61970-600-1:2017 B.10.
1558
1559          Message:
1560          Length of name attribute exceeds IO_NAME_LENGTH characters.
1561
1562          Usage: #IGMRuleSet
1563
1564
1565    Rule: TNToEndNameTsoLength  Level: 3  Severity: ERROR
1566
1567          Details:
1568          In every TPBD model instance, the length of all instances of
1569          entsoe:TopologicalNode.toEndNameTso shall not exceed IO_NAME_LENGTH
1570          characters.
1571
1572          Justification:
1573          See IEC TS 61970-600-1:2017 B.10.
1574
1575          Message:
1576          Length of name attribute exceeds IO_NAME_LENGTH characters.
1577
1578          Usage: #IGMRuleSet
1579
1580    Rule: ShuntCompensatorSensitivity  Level: 3  Severity: ERROR
1581
1582          Details:
1583          The following attribute value, if provided, shall be greater than zero
1584          - cim:ShuntCompensator.voltageSensitivity
1585
1586          Justification:
1587          Decision from 2018-11-09 CGM_BP/EMF meeting.
1588          It was concluded that a negative value is not physically possible.
1589
1590          Message:
1591          VoltageSensitivity attribute value shall be greater than zero.
1592
1593          Usage: #IGMRuleSet
1594
1595    Rule: NumberOfSubstations  Level: 3  Severity: WARNING
1596
1597          Details:
1598          The following number of cim:Substations in an IGM are considered suspicious
1599          - a single cim:Substation which is the min limit.
1600          - one cim:Substation per cim:VoltageLevel which is the max limit.
1601          The upper limit for the number of cim:Substations equals the number of
1602          cim:VoltageLevels.
1603
1604          Justification:
1605          The number of cim:Substations should reflect the design of the power system.
1606
1607          Message:
```

```
1608        The number of cim:Substations does not reflect the design of the power system.
1609
1610        Usage: #IGMRuleSet
1611
1612    Rule: GenerationContainment  Level: 3  Severity: ERROR
1613
1614        Details:
1615        For every instance of cim:HydroPump and cim:GeneratingUnit (and subclasses
1616        thereof), the cim:Equipment.EquipmentContainer referred to,
1617        must be of type cim:Substation. Missing containment is not allowed.
1618
1619        Justification:
1620        See Figure 15 (Core notes) of IEC TS 61970-600-2 section 6.7.11.
1621
1622        Message:
1623        cim:HydroPump and cim:GeneratingUnit must be contained in a cim:Substation.
1624
1625        Usage: #IGMRuleSet
1626
1627    Rule: PTContainment  Level: 3  Severity: ERROR
1628
1629        Details:
1630        For every instance of cim:PowerTransformer, the
1631        cim:Equipment.EquipmentContainer referred to, must be of type
1632        cim:Substation or of type cim:DCConverterUnit. Missing containment is not allowed.
1633
1634        Justification:
1635        See Figure 15 (Core notes) and Figure 5 (diagram DCContainment)
1636        of IEC TS 61970-600-2 sections 6.7.11 and 6.3.9.
1637
1638        Message:
1639        A cim:PowerTransformer must be contained in a cim:Substation
1640        or a cim:DCConverterUnit.
1641
1642        Usage: #IGMRuleSet
1643
1644    Rule: SwitchContainment  Level: 3  Severity: ERROR
1645
1646        Details:
1647        For every instance of Switch (and subclasses thereof), the
1648        cim:Equipment.EquipmentContainer referred to, must be of type
1649        VoltageLevel, of type Bay or of type DCConverterUnit.
1650        Missing containment is not allowed.
1651
1652        Justification:
1653        See Figure 15 (Core notes) and Figure 5 (diagram DCContainment)
1654        of IEC TS 61970-600-2 sections 6.7.11 and 6.3.9.
1655
1656        Message:
1657        Switches must be contained in a VoltageLevel, a Bay or a DCConverterUnit.
1658
1659        Usage: #IGMRuleSet
1660
1661    Rule: SCContainment  Level: 3  Severity: ERROR
1662
1663        Details:
```

```
1664          For every instance of cim:SeriesCompensator, the
1665          cim:Equipment.EquipmentContainer referred to, if provided, must be of
1666          type cim:Line, of type cim:VoltageLevel or of type cim:DCConverterUnit.
1667
1668          Justification:
1669          See Figure 15 (diagram Core notes) in section 6.7.1 of IEC TS 61970-600-2,
1670          Figure 5 (diagram DCContainment) in section 6.3.1 of IEC TS 61970-600-2
1671          and section 6.9.16 of IEC TS 61970-600-2.
1672
1673          Message:
1674          A cim:SeriesCompensator can only be contained in a cim:Line, a cim:VoltageLevel
1675          or a cim:DCConverterUnit.
1676
1677          Usage: #IGMRuleSet
1678
1679    Rule: InjectionContainment  Level: 3  Severity: ERROR
1680
1681          Details:
1682          For every instance of cim:EnergyConsumer subclasses, cim:RotatingMachine
1683          subclasses, cim:ShuntCompensator subclasses, cim:EnergySource,
1684          cim:EquivalentShunt, cim:ExternalNetworkInjection and cim:StaticVarCompensator,
1685          the cim:Equipment.EquipmentContainer referred to, must be of type
1686          cim:VoltageLevel. Missing containment is not allowed.
1687
1688          Justification:
1689          See 6.10.10, 6.7.6 of IEC TS 61970-600-2.
1690
1691          Message:
1692          Injections must be contained in a cim:VoltageLevel.
1693
1694          Usage: #IGMRuleSet
1695
1696    Rule: BusbarSectionContainment  Level: 3  Severity: ERROR
1697
1698          Details:
1699          For every instance of cim:BusbarSection, the cim:Equipment.EquipmentContainer
1700          referred to, must be of type cim:VoltageLevel. Missing containment is not allowed.
1701
1702          Justification:
1703          See Figure 15 (diagram Core notes) of IEC TS 61970-600-2 section 6.10.5.
1704
1705          Message:
1706          A cim:BusbarSection must be contained in a cim:VoltageLevel.
1707
1708          Usage: #IGMRuleSet
1709
1710    Rule: EFCContainment  Level: 3  Severity: ERROR
1711
1712          Details:
1713          For every instance of cim:EarthFaultCompensator, its subclasses and cim:Ground,
1714          the cim:Equipment.EquipmentContainer referred to, must be of type
1715          cim:VoltageLevel. Missing containment is not allowed.
1716
1717          Justification:
1718          See Figure 15 (diagram Core notes) of IEC TS 61970-600-2 section 6.7.6.
1719
```

```
1720          Message:
1721          A subclass of cim:EarthFaultCompensator or cim:Ground must be contained in a
1722          cim:VoltageLevel.
1723
1724          Usage: #IGMRuleSet
1725
1726    Rule: JunctionContainment  Level: 3  Severity: ERROR
1727
1728          Details:
1729          For every instance of cim:Junction (Equipment Boundary file), the
1730          cim:Equipment.EquipmentContainer referred to, must be of type cim:Line.
1731          Missing containment is not allowed.
1732
1733          Justification:
1734          See section 4.4.5 of IEC TS 61970-600-2.
1735
1736          Message:
1737          A cim:Junction must be contained in a cim:Line.
1738
1739          Usage: #IGMRuleSet
1740
1741    Rule: ACDCConvContainment  Level: 3  Severity: ERROR
1742
1743          Details:
1744          For every instance of cim:CsConverter and cim:VsConverter, the
1745          cim:Equipment.EquipmentContainer referred to, must be of type
1746          cim:DCConverterUnit. Missing containment is not allowed.
1747
1748          Justification:
1749          See section 6.3.2 of IEC TS 61970-600-2.
1750
1751          Message:
1752          A cim:ACDCConverter must be contained in a cim:DCConverterUnit.
1753
1754          Usage: #IGMRuleSet
1755
1756    Rule: DCEQContainment  Level: 3  Severity: ERROR
1757
1758          Details:
1759          For every instance of cim:DCSeriesDevice, cim:DCShunt, cim:DCBusbar, cim:DCGround,
1760          cim:DCChopper, cim:DCSwitch, cim:DCBreaker and cim:DCDisconnector, the
1761          cim:Equipment.EquipmentContainer referred to, must be of type
1762          cim:DCConverterUnit. Missing containment is not allowed.
1763
1764          Justification:
1765          See section 6.3.2 of IEC TS 61970-600-2.
1766
1767          Message:
1768          All DC equipment, except cim:DCLineSegment must be contained in a
1769          cim:DCConverterUnit.
1770
1771          Usage: #IGMRuleSet
1772
1773    Rule: CNContainment  Level: 3  Severity: ERROR
1774
1775          Details:
```

```
1776          For cim:ConnectivityNodes according to EQ, the
1777          cim:ConnectivityNode.ConnectivityNodeContainer referred to, must be
1778          of type cim:VoltageLevel, cim:Bay or cim:Line.
1779          For cim:ConnectivityNodes according to EQBD, the
1780          cim:ConnectivityNode.ConnectivityNodeContainer referred to,
1781          must be of type cim:Line. Missing containment is not allowed.
1782
1783          Justification:
1784          See Figure 1 (diagram EquipmentBoundaryProfile), figure 15 (diagram
1785          Core Notes), section 6.7.7 of IEC TS 61970-600-2.
1786
1787          Message:
1788          cim:ConnectivityNode must be contained in a cim:VoltageLevel, cim:Bay
1789          or cim:Line for EQ models and in a cim:Line for Boundary points.
1790
1791          Usage: #IGMRuleSet
1792
1793    Rule: CNTerminals  Level: 3  Severity: WARNING
1794
1795          Details:
1796          cim:ConnectivityNodes that:
1797          - are isolated and do not have any Terminals connecting to equipment.
1798          - have one Terminal that connect to a dead equipment end.
1799
1800          Justification:
1801          Isolated or dead end cim:ConnectivityNodes may indicate a connectivity issue.
1802
1803          Message:
1804          Isolated or dead end ConnectivityNodes may indicate a connectivity issue.
1805
1806          Usage: #IGMRuleSet
1807
1808    Rule: GeneratingUnitNominalP  Level: 3  Severity: WARNING
1809
1810          Details:
1811          According to CGMES the value of cim:GeneratingUnit.nominalP should be positive
1812          and less or equal to cim:RotatingMachine.ratedS.
1813
1814          Justification:
1815          See section 6.6.5 of IEC TS 61970-600-2.
1816
1817          Message:
1818          cim:GeneratingUnit.nominalP outside allowed range.
1819
1820          Usage: #IGMRuleSet
1821
1822    Rule: CEBaseVoltage  Level: 3  Severity: ERROR
1823
1824          Details:
1825          All cim:ConductingEquipment except cim:ACLineSegment, cim:SeriesCompensator,
1826          cim:EquivalentBranch, cim:PowerTransformer and cim:ACDCConverter, must either have
1827          an association with cim:BaseVoltage
1828          or be located within a cim:VoltageLevel or cim:Bay. The exception is because rule
1829          BranchBaseVoltage validates similar conditions.
1830          If both cim:ConductingEquipment.BaseVoltage and containment in a cim:VoltageLevel
1831          or cim:Bay are provided, the association ends cim:ConductingEquipment.BaseVoltage
```

```
1832          and cim:VoltageLevel.BaseVoltage shall refer to the same cim:BaseVoltage.
1833
1834          Justification:
1835          See section 6.7.6 and 6.10.2 of IEC TS 61970-600-2.
1836
1837          Message:
1838          cim:ConductingEquipment that does not have cim:BaseVoltage or refers to different
1839    cim:BaseVoltage via different associations.
1840
1841          Usage: #IGMRuleSet
1842
1843    Rule: NominalVoltage  Level: 3  Severity: ERROR
1844
1845          Details:
1846          For every instance of cim:BaseVoltage, the cim:BaseVoltage.nominalVoltage
1847          value must be greater than zero.
1848
1849          Justification:
1850          See section 6.7.3 of IEC TS 61970-600-2.
1851
1852          Message:
1853          Nominal voltage must be greater than zero.
1854
1855          Usage: #IGMRuleSet
1856
1857    Rule: InstancesOfGeneralClass  Level: 3  Severity: ERROR
1858
1859          Details:
1860          The most specific and detailed class shall in general be instantiated.
1861          Hence more general classes shall not be instantiated. The following classes
1862          are specifically noted as not allowed to instantiate
1863          - cim:EnergyConsumer
1864
1865          Justification:
1866          The level of detail described by the more specific class are needed in studies.
1867          The approved methodologies:
1868          CGMM-v1-plus Article 9, Load, 4(c) (as well CGMM-v2-plus.and CGMM-v3 referencing
1869          to CGMM-v1-plus) and GLDPM-v1: Article 2, Definitions and interpretation,
1870          point 3 and 7, Article 11, 4(9) (as well GLDPM-v2 referencing to GLDPM-v1) foresee
1871          the provision of conforming and non-conforming load flag as well as approved EMF
1872          Requirements, which implies the use specific classes of EnergyConsumer.
1873          IEC 61970-600-1:2017 Common Grid Model Exchange Specification, 5.1
1874          General constraints, GENC11: Instance data to be exchanged must make use of the
1875          most detailed class possible within a profile, i.e.
1876          using sub-typed classes rather than general classes, e.g. NuclearGeneratingUnit
1877          instead GeneratingUnit.
1878          Note that this rule is not applied for GeneratingUnit.
1879
1880          Message:
1881          Instances of type cim:EnergyConsumer are not allowed, the usage of
1882          its subclasses is mandatory.
1883
1884          Usage: #IGMRuleSet
1885
1886    Rule: TerminalCount1  Level: 3  Severity: ERROR
1887
```

```
1888          Details:
1889          Every instance of cim:RegulatingCondEq and its subclasses, cim:EnergyConsumer
1890          and its subclasses, cim:EquivalentInjection, cim:EquivalentShunt, subclasses of
1891          cim:Connector, cim:EnergySource, cim:Ground,
1892          cim:DCBusbar, cim:DCShunt, cim:DCGround
1893          shall only be referenced via a single cim:Terminal instance.
1894
1895          Justification:
1896          cim:ConductingEqupment with a single electrical connection point shall only have
1897          one cim:Terminal.
1898
1899          Message:
1900          Single terminal devices must not be referenced by multiple terminals.
1901
1902          Usage: #IGMRuleSet
1903
1904   Rule: TerminalCount2  Level: 3  Severity: ERROR
1905
1906          Details:
1907          Every instance of cim:Conductor and its subclasses, cim:Switch and its subclasses,
1908          cim:SeriesCompensator, cim:EquivalentBranch, cim:DCLineSegment,
1909          cim:DCSeriesDevice, cim:DCChopper and subclasses of cim:DCSwitch,
1910          shall only be referenced via exactly two cim:Terminal instances.
1911
1912          Justification:
1913          cim:ConductingEqupment with two electrical connection point shall have
1914          two cim:Terminals.
1915
1916          Message:
1917          Two terminal devices must be referenced by exactly two terminals.
1918
1919          Usage: #IGMRuleSet
1920
1921   Rule: TerminalSeqNum  Level: 3  Severity: ERROR
1922
1923          Details:
1924          Every instance of cim:Terminal must have a cim:Terminal.sequenceNumber
1925          if it belongs to an cim:EquivalentBranch or an cim:ACLineSegment
1926          with cim:MutualCoupling.
1927
1928          Justification:
1929          See section 6.7.21 and 6.10.31 of IEC TS 61970-600-2.
1930
1931          Message:
1932          cim:Terminals must have a sequence number if they belong to an cim:EquivalentBranch
1933          or a cim:ACLineSegment with cim:MutualCoupling.
1934
1935          Usage: #IGMRuleSet
1936
1937   Rule: TerminalSeqNumOrder  Level: 3  Severity: ERROR
1938
1939          Details:
1940          In cases where cim:Terminal.sequenceNumber is provided for an instance of
1941          cim:ConductingEquipment or cim:DCConductingEquipment,  at least one
1942          sequenceNumber shall equal to 1. The cim:Terminal.sequenceNumber of other terminals
1943          of same cim:ConductingEquipment or cim:DCConductingEquipment shall follow
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1944          increasing order.
1945
1946          Justification:
1947          See section 6.7.2 of IEC TS 61970-600-2.
1948
1949          Message:
1950          Invalid sequenceNumber for cim:Terminal.
1951
1952          Usage: #IGMRuleSet
1953
1954    Rule: PTTerminalConsistency  Level: 3  Severity: ERROR
1955
1956          Details:
1957          For every instance of cim:PowerTransformerEnd, the cim:Terminal referenced by
1958          the cim:TransformerEnd.Terminal association must be associated with the
1959          cim:PowerTransformer instance, referenced via the
1960          cim:PowerTransformerEnd.PowerTransformer association.
1961
1962          Justification:
1963          See section 6.9.31 of IEC TS 61970-600-2.
1964
1965          Message:
1966          Terminals for PowerTransformers must be defined unambiguously.
1967
1968          Usage: #IGMRuleSet
1969
1970    Rule: MCFirstSecond  Level: 3  Severity: ERROR
1971
1972          Details:
1973          The following shall conform for every instance of cim:MutualCoupling:
1974          1) Association end cim:MutualCoupling.First_Terminal shall refer to a cim:Terminal
1975          of an cim:ACLineSegment.
1976          2) Association end cim:MutualCoupling.Second_Terminal shall refer to a cim:Terminal
1977          of an cim:ACLineSegment.
1978          3) Association ends cim:MutualCoupling.First_Terminal and
1979          cim:MutualCoupling.Second_Terminal shall refer to cim:Terminal-s of different
1980          cim:ACLineSegment-s.
1981
1982
1983          Justification:
1984          See section 6.9.19 of IEC TS 61970-600-2.
1985
1986          Message:
1987          One of the following occurs: 1) cim:MutualCoupling.First_Terminal does not refer
1988          to a cim:Terminal of a cim:ACLineSegment, 2) cim:MutualCoupling.Second_Terminal
1989          does not refer to a cim:Terminal of a cim:ACLineSegment,
1990          3) cim:MutualCoupling.First_Terminal and cim:MutualCoupling.Second_Terminal do not
1991          refer to cim:Terminal-s of different cim:ACLineSegment-s.
1992
1993          Usage: #IGMRuleSet
1994
1995
1996    Rule: LRCExponentModel  Level: 3  Severity: ERROR
1997
1998          Details:
1999          For every instance of cim:LoadResponseCharacteristic where
```

```
2000        cim:LoadResponseCharacteristic.exponentModel is true,
2001        cim:LoadResponseCharacteristic.pVoltageExponent and
2002        cim:LoadResponseCharacteristic.qVoltageExponent must be provided and
2003        be greater or equal than zero and less or equal to two.
2004
2005        Note: The attributes pFrequencyExponent and qFrequencyExponent are not used. The
2006        attributes that are required for coefficient load model covered by rule
2007        LCRCoefficientModel are ignored and not validated when
2008        cim:LoadResponseCharacteristic.exponentModel equals true.
2009
2010        Justification:
2011        See section 6.10.9 of IEC TS 61970-600-2.
2012
2013        Message:
2014        Exponent of per unit voltage effecting real and reactive power must be
2015        specified if cim:LoadResponseCharacteristic.exponentModel is true.
2016
2017        Usage: #IGMRuleSet
2018
2019
2020    Rule: LCRCoefficientModel  Level: 3  Severity: ERROR
2021
2022        Details:
2023        For every instance of cim:LoadResponseCharacteristic where
2024        cim:LoadResponseCharacteristic.exponentModel is false,
2025        cim:LoadResponseCharacteristic.pConstantImpedance and
2026        cim:LoadResponseCharacteristic.pConstantCurrent and
2027        cim:LoadResponseCharacteristic.pConstantPower and
2028        cim:LoadResponseCharacteristic.qConstantImpedance and
2029        cim:LoadResponseCharacteristic.qConstantCurrent and
2030        cim:LoadResponseCharacteristic.qConstantPower must be provided.
2031
2032        Note: The attributes that are required for exponential load model covered by rule
2033        LRCExponentModel are ignored and not validated when
2034        cim:LoadResponseCharacteristic.exponentModel equals false.
2035
2036        Justification:
2037        See section 6.10.9 of IEC TS 61970-600-2.
2038
2039        Message:
2040        Coefficients for ZIP load model must be specified if
2041        cim:LoadResponseCharacteristic.exponentModel is false.
2042
2043        Usage: #IGMRuleSet
2044
2045    Rule: LCRCoefficientParameters  Level: 3  Severity: ERROR
2046
2047        Details:
2048        For every instance of cim:LoadResponseCharacteristic with
2049        cim:LoadResponseCharacteristic.exponentModel is false, the sum of
2050        cim:LoadResponseCharacteristic.pConstantImpedance and
2051        cim:LoadResponseCharacteristic.pConstantCurrent and
2052        cim:LoadResponseCharacteristic.pConstantPower values must be 1 and
2053        the sum of cim:LoadResponseCharacteristic.qConstantImpedance and
2054        cim:LoadResponseCharacteristic.qConstantCurrent and
2055        cim:LoadResponseCharacteristic.qConstantPower values must be 1.
```

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2056
2057          Justification:
2058          See section 6.10.9 of IEC TS 61970-600-2.
2059
2060          Message:
2061          Invalid coefficient parameters for cim:LoadResponseCharacteristic.
2062
2063          Usage: #IGMRuleSet
2064
2065    Rule: MeasTerminal  Level: 3  Severity: ERROR
2066
2067          Details:
2068          The association end cim:Measurement.Terminal shall reference a cim:Terminal of the
2069          cim:Equipment referenced by cim:Measurement.PowerSystemResource except in cases
2070          where cim:Measurement.measurementType is either cim:TapPosition or
2071          cim:SwitchPosition in which the association is not exchanged.
2072
2073          Justification:
2074          See section 6.5.18 of IEC TS 61970-600-2.
2075
2076          Message:
2077          cim:Measurement.Terminal does not refer to a cim:Terminal of a cim:Equipment
2078          referenced by cim:Measurement.PowerSystemResource.
2079
2080          Usage: #IGMRuleSet
2081
2082
2083    Rule: MeasType  Level: 3  Severity: ERROR
2084
2085          Details:
2086          For every instance of cim:Measurement, the value of
2087          cim:Measurement.measurementType is limited to 'ThreePhasePower',
2088          'ThreePhaseActivePower', 'ThreePhaseReactivePower', 'LineCurrent',
2089          'PhaseVoltage', 'LineToLineVoltage', 'Angle', 'TapPosition',
2090          'SwitchPosition'.
2091
2092          Justification:
2093          See section 6.5.18 of IEC TS 61970-600-2.
2094
2095          Message:
2096          Invalid measurement type.
2097
2098          Usage: #IGMRuleSet
2099
2100    Rule: MeasUnit  Level: 3  Severity: ERROR
2101
2102          Details:
2103          For every instance of cim:Measurement, the value of
2104          cim:Measurement.unitSymbol is restricted to 'cim:UnitSymbol.V',
2105          'cim:UnitSymbol.A', 'cim:UnitSymbol.W', 'cim:UnitSymbol.VA',
2106          'cim:UnitSymbol.VAr', 'cim:UnitSymbol.deg', 'cim:UnitSymbol.Hz',
2107          'cim:UnitSymbol.none'.
2108
2109          Justification:
2110          See section 6.5.18 of IEC TS 61970-600-2.
2111
```

```
2112          Message:
2113          Invalid measurement unit symbol.
2114
2115          Usage: #IGMRuleSet
2116
2117
2118    Rule: CATieFlow  Level: 3  Severity: ERROR
2119
2120          Details:
2121          For every instance of cim:ControlArea for which the value of
2122          cim:ControlArea.type is cim:ControlAreaTypeKind.Interchange,
2123          cim:TieFlow instances must be provided.
2124
2125          Justification:
2126          This is necessary to compute interchange.
2127
2128          Message:
2129          cim:TieFlows must be defined for cim:ControlArea, no cim:TieFlows found.
2130
2131          Usage: #IGMRuleSet
2132
2133    Rule: TargetDB  Level: 3  Severity: ERROR
2134
2135          Details:
2136          For every instance of cim:RegulatingControl (SSH) for which the value of
2137          cim:RegulatingControl.discrete is true and cim:RegulatingControl.enabled
2138          is true, cim:RegulatingControl.targetDeadband must be provided and must be
2139          greater than 0.
2140
2141          Justification:
2142          If cim:RegulatingControl.discrete is set to true and no deadband
2143          is provided the power flow algorithm may not reach a solution but may continue
2144          to try find one which results in hunting.
2145
2146
2147          Message:
2148          Target deadband is either not provided if the regulating control is discrete and
2149          active or it is not greater than zero.
2150
2151          Usage: #IGMRuleSet
2152
2153
2154    Rule: OperationalLimitValue  Level: 3  Severity: ERROR
2155
2156          Details:
2157          For every instance of cim:VoltageLimit, the value of cim:VoltageLimit.value
2158          must be > 0. For every instance of cim:CurrentLimit, the value
2159          of cim:CurrentLimit.value must be > 0. For every instance of
2160          cim:ActivePowerLimit, the value of cim:ActivePowerLimit.value must be > 0.
2161          For every instance of cim:ApparentPowerLimit, the value of
2162          cim:ApparentPowerLimit.value must be > 0.
2163
2164          Justification:
2165          See section 6.8.5 of IEC TS 61970-600-2.
2166
2167          Message:
```

```
2168          OperationalLimit values must be positive.
2169
2170          Usage: #IGMRuleSet
2171
2172    Rule: AcceptableDuration  Level: 3  Severity: ERROR
2173
2174          Details:
2175          The usage of the attribute cim:OperationalLimitType.acceptableDuration
2176          depends on the value of the entsoe:OperationalLimitType.limitType attribute as
2177          follows:
2178          - patl: acceptableDuration is not used;
2179          - patlt: usage of acceptableDuration is restricted, i.e. it is not used as another
2180          way to express the severity of the limit;
2181          - tatl: acceptableDuration is used to define several TATL limit types
2182          - tc: acceptableDuration is not used as an immediate tripping is expected
2183          - tct: acceptableDuration is used as the limit is less than the tc limit and
2184             describe how long the violation may sustain before tripping.
2185          If acceptableDuration is not used the attribute can be completely omitted
2186          or if included the acceptableDuration value shall be ignored.
2187
2188          Justification:
2189          See section 6.8.9.1 and 6.8.7 of IEC TS 61970-600-2.
2190
2191          Message:
2192          cim:OperationalLimitType.acceptableDuration is not provided for TATL and TCT limit
2193          types.
2194
2195          Usage: #IGMRuleSet
2196
2197    Rule: OperationalLimitSetAtTerminal  Level: 3  Severity: WARNING
2198
2199          Details:
2200          The association end cim:OperationalLimitSet.Terminal is required.
2201          Note the association end cim:OperationalLimitSet.Equipment is neither checked nor
2202          reported in this rule.
2203
2204          Justification:
2205          The limits in question are related to power flow, hence they are
2206          linked to the cim:Terminal.
2207          Less options also simplifies data exchange.
2208
2209          Message:
2210          The OperationalLimitSet is not linked to a Terminal.
2211
2212          Usage: #IGMRuleSet
2213
2214    Rule: PATL1  Level: 3  Severity: ERROR
2215
2216          Details:
2217          Every instance of cim:ACLineSegment and cim:SeriesCompensator,
2218          that is not aggregated, shall have at least one
2219          cim:OperationalLimitSet linked to one of its cim:Terminals.
2220          A cim:OperationalLimitSet shall have at least one
2221          cim:OperationalLimit of type entsoe:LimitTypeKind.patl.
2222          Equipment is aggregated when cim:Equipment.aggregate is present
2223          and set to 'true'.
```

```
2224
2225        Justification:
2226        See section 6.8.7 of IEC TS 61970-600-2.
2227
2228        Message:
2229        PATL missing for cim:ACLineSegment or cim:SeriesCompensator.
2230
2231        Usage: #IGMRuleSet
2232
2233    Rule: PATL2  Level: 3  Severity: ERROR
2234
2235        Details:
2236        Every instance of cim:PowerTransformer, that is not aggregated
2237        (cim:Equipment.aggregate equals to false or it is missing), shall have at least
2238        one cim:OperationalLimitSet with at least one cim:OperationalLimit of type
2239        entsoe:LimitTypeKind.patl linked to one of cim:Terminal-s of the
2240        cim:PowerTransformer.
2241
2242        Justification:
2243        See section 6.8.7 of IEC TS 61970-600-2.
2244
2245        Message:
2246        A non-aggregated cim:PowerTrainsformer which has not a cim:OperationalLimitSet with
2247        at least one cim:OperationalLimit of type entsoe:LimitTypeKind.patl associated to
2248        any of its cim:Terminal-s.
2249
2250        Usage: #IGMRuleSet
2251
2252
2253    Rule: PATL3  Level: 3  Severity: ERROR
2254
2255        Details:
2256        There shall be only one PATL limitType per cim:OperationalLimitSet and type
2257        - cim:ActivePowerLimit
2258        - cim:CurrentLimit or cim:ApparentPowerLimit
2259        This means that an cim:OperationalLimitSet may have two PATL values, one for
2260        cim:CurrentLimit or cim:ApparentPowerLimit and one for cim:ActivePowerLimit.
2261
2262        Justification:
2263        See section 6.8.9.1 of IEC TS 61970-600-2.
2264
2265        Message:
2266        Redundant PATL not allowed for OperationalLimitSet.
2267
2268        Usage: #IGMRuleSet
2269
2270    Rule: PATL4  Level: 3  Severity: WARNING
2271
2272        Details:
2273        For an instance of cim:ACLineSegment or cim:SeriesCompensator the limit values
2274        of the same cim:OperationalLimitType.limitType shall not differ more than
2275        PATL_LIMIT_VALUE_DIFF between the two sides, e.g. a cim:CurrentLimit
2276        of type PATL.
2277
2278        Justification:
2279        Based on engineering practice.
```

```
2280
2281          Message:
2282          Differing limit values on two sides of the equipment above PATL_LIMIT_VALUE_DIFF.
2283
2284          Usage: #IGMRuleSet
2285
2286    Rule: PATL5  Level: 3  Severity: WARNING
2287
2288          Details:
2289          PATL type on voltage limits shall be ignored.
2290
2291          Justification:
2292          See section 6.8.9.1 of IEC TS 61970-600-2:2017.
2293
2294          Message:
2295          PATL voltage limit is ignored.
2296
2297          Usage: #IGMRuleSet
2298
2299    Rule: CNRequiredInEQOperations  Level: 3  Severity: ERROR
2300
2301          Details:
2302          The association end cim:Terminal.ConnectivityNode is required in cases where
2303          EQ Operation profile is specified in the header.
2304          The different kinds of models are described in IEC TS 61970-600-1:2017 PROF4.
2305
2306          Justification:
2307          See section 6.7.7 and rules PROF4 and PROF5 of IEC TS 61970-600-1:2017.
2308
2309          Message:
2310          The association end cim:Terminal.ConnectivityNode is not provided for a  model that
2311          contains EQ Operation profile.
2312
2313          Usage: #IGMRuleSet
2314
2315
2316    Rule: EnergySourceVoltage  Level: 3  Severity: ERROR
2317
2318          Details:
2319          For cim:EnergySource the attributes voltageMagnitude and voltageAngle
2320          are optional to include in EQ. The attributes are intended for the
2321          case when a strong network is providing power to a weak
2322          distribution network. Hence it is wrong to use these attributes
2323          in transmission studies and they shall not at all be used.
2324
2325          Justification:
2326          The use case for these attributes is not appropriate for transmission.
2327          See IEC TS 61970-600-1:2017 section E.19.
2328
2329          Message:
2330          The use case for cim:EnergySource attributes voltageMagnitude
2331          and voltageAngle is not allowed for transmission.
2332
2333          Usage: #IGMRuleSet
2334
2335    Rule: ControlModeCompatibility  Level: 3  Severity: ERROR
```

```
2336
2337          Details:
2338          The cim:TapChangerControl or cim:RegulatingControl can only control a cim:Terminal
2339          at a cim:ConductingEquipment compatible with its type,
2340          - A phase shift tap changer can only do the cim:RegulatingControl.mode
2341              - active power control
2342          - A ratio tap changer can only do the cim:RegulatingControl.mode-s
2343              - voltage
2344              - reactivePower
2345              - powerFactor
2346          - A cim:SynchronousMachine or cim:ShuntCompensator instance can only
2347            do the cim:RegulatingControl.mode-s
2348              - voltage
2349              - reactivePower
2350              - powerFactor
2351          - A cim:StativeVarCompensator can only do the cim:RegulatingControl.mode-s
2352              - voltage
2353              - reactivePower
2354          - A cim:BusbarSection instance can only be controlled by a cim:RegulatingControl
2355          in mode (cim:RegulatingControl.mode):
2356              - voltage
2357
2358          The following cim:RegulatingControl.modes are not at all allowed
2359              - currentFlow
2360              - admittance
2361              - timeScheduled
2362              - temperature
2363
2364
2365          Justification:
2366          Only meaningful combinations of data are allowed.
2367
2368          Message:
2369          cim:TapChangerControl or cim:RegulatingControl with invalid
2370          cim:RegulatingControl.mode.
2371
2372          Usage: #IGMRuleSet
2373
2374    Rule: ACLineSegmentR  Level: 3  Severity: ERROR
2375
2376          Details:
2377          For every instance of cim:ACLineSegment the value of
2378          cim:ACLineSegment.r must be greater than or equal to zero.
2379
2380          Justification:
2381          Negative resistance means negative losses.
2382          This is not allowed for real equipment.
2383
2384          Message:
2385          Negative resistance not allowed for cim:ACLineSegment.
2386
2387          Usage: #IGMRuleSet
2388
2389
2390    Rule: ACLineSegmentX  Level: 3  Severity: WARNING
2391
```

```
2392          Details:
2393          For every instance of cim:ACLineSegment the value of
2394          cim:ACLineSegment.x should be greater than or equal to EQ_BRANCH_X_LIMIT Ohm.
2395
2396          Justification:
2397          Too small impedances cause numerical instability when
2398          solving the power flow.
2399
2400          Message:
2401          Reactance value should be greater than or equal to EQ_BRANCH_X_LIMIT.
2402
2403          Usage: #IGMRuleSet
2404
2405    Rule: SeriesCompensatorX  Level: 3  Severity: WARNING
2406
2407          Details:
2408          For every instance of cim:SeriesCompensator the value of
2409          abs(cim:SeriesCompensator.x) should be greater than or equal to
2410          EQ_BRANCH_X_LIMIT Ohm.
2411
2412          Justification:
2413          Too small impedances cause numerical instability when
2414          solving the power flow.
2415
2416          Message:
2417          Reactance value should be greater than or equal to EQ_BRANCH_X_LIMIT.
2418
2419          Usage: #IGMRuleSet
2420
2421
2422    Rule: EquivalentBranchX  Level: 3  Severity: WARNING
2423
2424          Details:
2425          For every instance of EquivalentBranch (EB) the total impedance should be greater
2426          than or equal to EQ_BRANCH_X_LIMIT Ohm. The total impedance is computed by
2427          sqrt(EB.x * EB.x + EB.x21 * EB.x21). In cases where EB.x21 is not provided, it is
2428          equal to zero in the equation for calculation of the total impedance.
2429
2430          Justification:
2431          Too small impedances cause numerical instability when
2432          solving the power flow.
2433
2434          Message:
2435          Total impedance should be greater than or equal to EQ_BRANCH_X_LIMIT Ohm.
2436
2437          Usage: #IGMRuleSet
2438
2439    Rule: DCLineSegmentR  Level: 3  Severity: ERROR
2440
2441          Details:
2442          For every instance of cim:DCLineSegment the value of
2443          cim:DCLineSegment.resistance and the value of the associated
2444          cim:PerLengthDCLineParameter.resistance must be greater than zero.
2445
2446          Justification:
2447          Negative resistance means negative losses.
```

This is not allowed for real equipment.

Message:
Negative resistance not allowed for cim:DCLineSegment.

Usage: #IGMRuleSet

Rule: PowerTransformerEndR Level: 3 Severity: WARNING

Details:
cim:PowerTransformerEnd.r shall conform to the following rules:
- Be equal to 0 Ohm for the 2nd winding (the winding with cim:TransformerEnd.endNumber = 2, i.e. lower voltage end) of a two-winding transformer;
- Be greater than or equal to EQ_BRANCH_X_LIMIT Ohm for the 1st winding (the winding with cim:TransformerEnd.endNumber = 1, i.e. highest voltage end) of a two-winding transformer;
- Be greater than or equal to EQ_BRANCH_X_LIMIT Ohm for all windings of a three-winding transformer.

Justification:
Negative resistance means negative losses.
This is not allowed for real equipment.

Message:
PowerTransformerEnd.r is either: 1) different than 0 Ohm for 2nd winding of a two-winding transformer or 2) not greater than or equal to EQ_BRANCH_X_LIMIT Ohm for all windings of a three-winding transformer or 3) not greater than or equal to EQ_BRANCH_X_LIMIT Ohm for 1st winding of a two-winding transformer.

Usage: #IGMRuleSet

Rule: PowerTransformerEndRatedU Level: 3 Severity: WARNING

Details:
The cim:PowerTransformerEnd.ratedU attribute must be greater than zero.

Justification:
The cim:PowerTransformerEnd.ratedU attribute is used in pu calculations.

Message:
cim:PowerTransformerEnd.ratedU should be greater than zero.

Usage: #IGMRuleSet

Rule: PowerTransformerEndX Level: 3 Severity: WARNING

Details:
cim:PowerTransformerEnd.x shall conform to the following rules:
- Be greater than or equal to EQ_BRANCH_X_LIMIT Ohm for the 1st winding (the winding with cim:TransformerEnd.endNumber = 1, i.e. highest voltage end) of a two-winding transformer;
- Be equal to 0 Ohm for the 2nd winding (the winding with cim:TransformerEnd.endNumber = 2, i.e. lower voltage end) of a two-winding transformer;

```
2504          - the abs(cim:PowerTransformerEnd.x) be    greater than or equal to
2505            EQ_BRANCH_X_LIMIT Ohm for all windings of a three-winding transformer.
2506
2507          Justification:
2508          Transformers with zero series reactance do not exist.
2509          At a two winding transformer the series reactance is specified
2510          at the high voltage side and the low voltage side isn't used.
2511
2512          Message:
2513          One of the following occurs: 1) The value of 1st winding
2514          (cim:TransformerEnd.endNumber = 1) is not greater than or equal to
2515          EQ_BRANCH_X_LIMIT Ohm for a two-winding transformer. 2) The value of 2nd winding
2516          (cim:TransformerEnd.endNumber = 2) is not 0 Ohm.  3) The absolute value is not
2517          greater than or equal to EQ_BRANCH_X_LIMIT Ohm for each of the windings of a
2518          three-winding transformer.
2519
2520          Usage: #IGMRuleSet
2521
2522
2523    Rule: LinearShuntCompensatorG  Level: 3  Severity: ERROR
2524
2525          Details:
2526          For every instance of cim:LinearShuntCompensator the value of
2527          cim:LinearShuntCompensator.gPerSection must be greater than or
2528          equal to zero.
2529
2530          Justification:
2531          The charging conductance represents the losses, which should
2532          be non-negative.
2533
2534          Message:
2535          cim:LinearShuntCompensator gPerSection must be non-negative.
2536
2537          Usage: #IGMRuleSet
2538
2539    Rule: ShuntCompensatorSections  Level: 3  Severity: ERROR
2540
2541          Details:
2542          For every instance of cim:ShuntCompensator the value of
2543          cim:ShuntCompensator.normalSections must be greater than or equal to zero
2544          and less or equal to cim:ShuntCompensator.maximumSections.
2545
2546          Justification:
2547          The sections specify the shunt compensator sections in use,
2548          which should be non-negative.
2549
2550          Message:
2551          cim:ShuntCompensator.normalSections outside allowed range.
2552
2553          Usage: #IGMRuleSet
2554
2555    Rule: ConverterLosses  Level: 3  Severity: ERROR
2556
2557          Details:
2558          For every instance of cim:CsConverter and cim:VsConverter, the value
2559          of cim:ACDCConverter.idleLoss, cim:ACDCConverter.switchingLoss and
```

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2560          cim:ACDCConverter.resistiveLoss, if provided, must be greater than
2561          or equal to zero.
2562
2563          Justification:
2564          Losses cannot be negative.
2565
2566          Message:
2567          Negative losses are not allowed for Converter, losses must
2568          be greater than or equal to zero.
2569
2570          Usage: #IGMRuleSet
2571
2572    Rule: SVCRatings  Level: 3  Severity: WARNING
2573
2574          Details:
2575          For every instance of cim:StaticVarCompensator, the value of
2576          cim:StaticVarCompensator.capacitiveRating must be positive. The
2577          value of cim:StaticVarCompensator.inductiveRating must be negative.
2578          Zero values are not allowed.
2579
2580          Justification:
2581          See IEC TS 61970-600-2:2017, section 6.9.44.
2582
2583          Message:
2584          Capacitive rating should be greater than zero, inductive rating should
2585          be lower than zero for SVC.
2586
2587          Usage: #IGMRuleSet
2588
2589    Rule: SVCSlope  Level: 3  Severity: ERROR
2590
2591          Details:
2592          The cim:StaticVarCompensator.slope must be positive or zero.
2593
2594          Justification:
2595          The reactive power output of the SVC is proportional to the
2596          difference between the voltage at the regulated bus and the voltage
2597          setpoint. When the regulated bus voltage is equal to the voltage
2598          setpoint, the reactive power output is zero.
2599          cim:RequlatingControl is used as it has capabilities missing from SVC,
2600          e.g. the controlled point.
2601
2602          Message:
2603          cim:StaticVarCompensator.slope must be positive or zero.
2604
2605          Usage: #IGMRuleSet
2606
2607    Rule: GeneratingUnitMaxPGen  Level: 3  Severity: ERROR
2608
2609          Details:
2610          For every instance of cim:GeneratingUnit, cim:HydroGeneratingUnit,
2611          cim:NuclearGeneratingUnit, cim:SolarGeneratingUnit, cim:ThermalGeneratingUnit and
2612          cim:WindGeneratingUnit, with cim:SynchronousMachine.type equal to generator
2613          (cim:SynchronousMachineKind.generator), the value
2614          of cim:GeneratingUnit.maxOperatingP must be greater than zero.
2615          Note that the limits follow generation sign convention.
```

```
2616
2617          Justification:
2618          The name plate ratings are used as a reference.
2619
2620          Message:
2621          Invalid operating limit, cim:GeneratingUnit.maxOperatingP must
2622          be greater than zero.
2623
2624          Usage: #IGMRuleSet
2625
2626    Rule: SynchronousCondenser  Level: 3  Severity: ERROR
2627
2628          Details:
2629          A synchronous condenser (cim:SynchronousMachine.type equal to
2630          SynchronousMachineKind.condenser) has no capability for active power output.
2631          Therefore, such cim:SynchronousMachine shall not be associated with a
2632          cim:GeneratingUnit.
2633
2634
2635          Justification:
2636          The name plate ratings are used as a reference.
2637          See IEC TS 61970-600-2:2017, section 6.9.47.
2638
2639          Message:
2640          A synchronous condenser is associated with cim:GeneratingUnit.
2641
2642          Usage: #IGMRuleSet
2643
2644    Rule: SMQLimits1  Level: 3  Severity: WARNING
2645
2646          Details:
2647          For a cim:SynchronousMachine, the value of
2648          cim:SynchronousMachine.maxQ should be greater than or equal to the value
2649          of cim:SynchronousMachine.minQ, if provided.
2650          Note that the limits follow generation sign convention.
2651
2652
2653          Justification:
2654          The name plate ratings are used as a reference.
2655
2656          Message:
2657          Invalid operating limits for Synchronous Machine.
2658
2659          Usage: #IGMRuleSet
2660
2661    Rule: SMQLimits2  Level: 3  Severity: ERROR
2662
2663          Details:
2664          For a cim:SynchronousMachine, either
2665          cim:SynchronousMachine.minQ and cim:SynchronousMachine.maxQ must be
2666          provided, or an association to a cim:ReactiveCapabilityCurve must exist. If
2667          cim:ReactiveCapabilityCurve exists cim:SynchronousMachine.minQ
2668          and cim:SynchronousMachine.maxQ shall be ignored.
2669
2670          Justification:
2671          See IEC TS 61970-600-2:2017, section 6.9.47.
```

```
2672
2673          Message:
2674          Missing operating limits for Synchronous Machine.
2675
2676          Usage: #IGMRuleSet
2677
2678    Rule: RatedS  Level: 3  Severity: ERROR
2679
2680          Details:
2681          cim:RotatingMachine.ratedS is required and shall be greater than zero.
2682          cim:PowerTransfomerEnd.ratedS is required and shall be greater than zero.
2683          Justification:
2684          RatedS is required for data validation.
2685          See IEC TS 61970-600-2:2017, section 6.9.41.
2686
2687          Message:
2688          cim:RotatingMachine.ratedS or cim:PowerTransfomerEnd.ratedS is either not provided
2689          or it is zero.
2690
2691          Usage: #IGMRuleSet
2692
2693    Rule: SMQLimits3  Level: 3  Severity: WARNING
2694
2695          Details:
2696          For every instance of cim:SynchronousMachine with exactly one cim:GeneratingUnit
2697          the following rules applies
2698          - abs(maxP) Less or Equal ratedS
2699          - abs(minP) Less or Equal ratedS
2700          - abs(maxQ) Less or Equal ratedS
2701          - abs(minQ) Less or Equal ratedS
2702          where
2703          - maxP is cim:GeneratingUnit.maxOperatingP
2704          - maxQ is cim:SynchronousMachine.maxQ
2705          - minP is cim:GeneratingUnit.minOperatingP
2706          - minQ is cim:SynchronousMachine.minQ
2707          - ratedS is cim:RotatingMachine.ratedS
2708
2709          Justification:
2710          The limit values should be inside the rated capability.
2711
2712          Message:
2713          Inconsistent cim:SynchronousMachine and cim:GeneratingUnit limits.
2714
2715          Usage: #IGMRuleSet
2716
2717
2718    Rule: SMPLimits Level: 3  Severity: WARNING
2719
2720          Details:
2721          For a cim:SynchronousMachine associated with a cim:GeneratingUnit or its
2722          subclasses, the active power limits should relate to cim:SynchronousMachine.type
2723          as follows:
2724          - generator or generatorOrCondenser,
2725             - cim:GeneratingUnit.minOperatingP greater than or equal to 0,
2726             - cim:GeneratingUnit.maxOperatingP greater than 0,
2727             - cim:GeneratingUnit.maxOperatingP greater than or equal to
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2728              cim:GeneratingUnit.minOperatingP.
2729         - motor or motorOrCondenser,
2730            - cim:GeneratingUnit.minOperatingP less than 0,
2731            - cim:GeneratingUnit.maxOperatingP less than or equal to 0,
2732            - cim:GeneratingUnit.maxOperatingP greater than or equal to
2733              cim:GeneratingUnit.minOperatingP.
2734         - generatorOrMotor or generatorOrCondenserOrMotor,
2735            - cim:GeneratingUnit.minOperatingP less than 0 and
2736              cim:GeneratingUnit.maxOperatingP greater than 0.
2737
2738         Note:
2739         1) As there is no cim:GeneratingUnit associated with cim:SynchronousMachine in
2740         cases of condenser only type, the condenser cannot be included in this rule.
2741         2) Depending on sign conventions of applications applied to motor operating mode,
2742         the meaning operating active power limits defined by
2743         cim:GeneratingUnit.maxOperatingP and cim:GeneratingUnit.minOperatingP maybe
2744         affected. For instance, if maxOperatingP=-5 and minOperatingP=-100 the instance
2745         data will pass the validation in case it is a motor. However, for an application
2746         which has positive limits (e.g. Pmax and Pmin) for motor mode, the mapping would
2747         be Pmax = minOperatingP and Pmin = maxOperatingP.
2748
2749         Justification:
2750         The active power limit values depend on the cim:SynchronousMachine.type
2751         and this dependence need to be described.
2752
2753         Message:
2754         The active power limit values do not match the cim:SynchronousMachine.type.
2755
2756         Usage: #IGMRuleSet
2757
2758   Rule: CurveStyle  Level: 3  Severity: ERROR
2759
2760         Details:
2761         The cim:Curve.curveStyle enumerated value cim:CurveStyle.constantYValue
2762         is not allowed.
2763
2764         Justification:
2765         The cim:CurveStyle.constantYValue gives too inaccurate
2766         compared with cim:CurveStyle.straightLineYValues.
2767
2768         Message:
2769         The cim:CurveStyle.constantYValue enumeration is not allowed.
2770
2771         Usage: #IGMRuleSet
2772
2773   Rule: RCCYValues  Level: 3  Severity: ERROR
2774
2775         Details:
2776         For every instance of cim:CurveData, for which the cim:CurveData.Curve
2777         refers to a cim:ReactiveCapabilityCurve, the cim:CurveData.y2value
2778         must be greater or equal than cim:CurveData.y1value.
2779         If cim:CurveData.y2value and cim:CurveData.y1value are equal for all
2780         curve points this is considered an error.
2781
2782         Justification:
2783         The name plate ratings are used as a reference.
```

```
2784
2785        Message:
2786        Invalid reactive capability curve data.
2787
2788        Usage: #IGMRuleSet
2789
2790    Rule: CurveXValues  Level: 3  Severity: WARNING
2791
2792        Details:
2793        For every instance of cim:CurveData, for which the cim:CurveData.Curve
2794        refers to a cim:ReactiveCapabilityCurve, the cim:CurveData.xvalue shall
2795        be different, e.g. in the case of two cim:CurveData called CD1 and CD2 the
2796        following shall give a warning when CD1.xvalue = CD2.xvalue.
2797
2798        Justification:
2799        All x values in a reactive capability curve
2800        shall differ for the curve to be meaningful.
2801
2802        Message:
2803        Some points in the reactive capability curve have the same x value.
2804
2805        Usage: #IGMRuleSet
2806
2807
2808    Rule: RCCXValues2  Level: 3  Severity: ERROR
2809
2810        Details:
2811        For a cim:SynchronousMachine with a cim:ReactiveCapabilityCurve the number of
2812        cim:CurveData instances depends on the attribute cim:SynchronousMachine.type
2813        as follows
2814        - condenser, one cim:CurveData instance with cim:CurveData.xvalue = 0.
2815        - generator or generatorOrCondenser, at least two cim:CurveData instances with
2816          cim:CurveData.xvalue greater or equal 0.
2817        - motor or motorOrCondenser, at least two cim:CurveData instances with
2818          cim:CurveData.xvalue less or equal 0.
2819        - generatorOrMotor or generatorOrCondenserOrMotor, at least three cim:CurveData
2820          instances with at least
2821          one having cim:CurveData.xvalue greater or equal 0 and
2822          and one having cim:CurveData.xvalue less or equal 0.
2823
2824        Justification:
2825        A cim:ReactiveCapabilityCurve for a Pump Storage unit shall have
2826        at least three curve points. A cim:SynchronousMachine operating as
2827        either motor or generator shall have at least two curve points. A
2828        cim:SynchronousMachine operating as condenser shall have at least one curve point.
2829
2830        Message:
2831        Invalid number of curve points in reactive capability curve data.
2832
2833        Usage: #IGMRuleSet
2834
2835    Rule: RCCXValues3  Level: 3  Severity: ERROR
2836
2837        Details:
2838        For each instance of cim:ReactiveCapabilityCurve, all instances of cim:CurveData
2839        shall have cim:CurveData.xvalue that is
```

```
2840        1) greater than or equal to the cim:GeneratingUnit.minOperatingP, and
2841        2) less than or equal to the cim:GeneratingUnit.maxOperatingP .
2842        cim:GeneratingUnit.minOperatingP and cim:GeneratingUnit.maxOperatingP are
2843        attributes of the cim:GeneratingUnit associated with the cim:SynchronousMachine to
2844        which the cim:ReactiveCapabilityCurve applies.
2845
2846        Justification:
2847        A cim:ReactiveCapabilityCurve must stay within the maximum capability of the unit.
2848
2849        Message:
2850        Invalid reactive capability curve data for cim:SynchronousMachine.
2851
2852        Usage: #IGMRuleSet
2853
2854    Rule: RCCXValues4  Level: 3  Severity: WARNING
2855
2856        Details:
2857        For every instance of cim:ReactiveCapabilityCurve, each cim:CurveData instance
2858        must satisfy the following relation
2859        - x*x+y1*y1 LE ratedS*ratedS and x*x+y2*y2 LE ratedS*ratedS
2860        where
2861        - LE = less or equal
2862        - x= cim:CurveData.xvalue
2863        - y1 = cim:CurveData.y1value
2864        - y2 = cim:CurveData.y2value
2865        - ratedS = cim:RotatingMachine.ratedS * (1 + NUMERIC_TOLERANCE)
2866
2867        Justification:
2868        A cim:ReactiveCapabilityCurve must cover the full operating range.
2869
2870        Message:
2871        Invalid reactive capability curve data for cim:SynchronousMachine.
2872
2873        Usage: #IGMRuleSet
2874
2875    Rule: VSCYValues  Level: 3  Severity: ERROR
2876
2877        Details:
2878        For every instance of cim:CurveData, for which the cim:CurveData.Curve
2879        refers to a cim:VsCapabilityCurve, the cim:CurveData.y2value must
2880        be greater than cim:CurveData.y1value.
2881
2882        Justification:
2883        The name plate ratings are used as a reference.
2884
2885        Message:
2886        Invalid cim:VsCapabilityCurve data.
2887
2888        Usage: #IGMRuleSet
2889
2890    Rule: VSCXValues  Level: 3  Severity: ERROR
2891
2892        Details:
2893        For every instance of cim:CurveData, for which the cim:CurveData.Curve
2894        refers to a cim:VSCapabilityCurve, at least two instances of the
2895        cim:CurveData are associated.
```

```
2896
2897          Justification:
2898          A curve consists of at least two curve points.
2899
2900          Message:
2901          Invalid cim:VSCapabilityCurve data.
2902
2903          Usage: #IGMRuleSet
2904
2905    Rule: PhaseCodeGround  Level: 3  Severity: ERROR
2906
2907          Details:
2908          Multiple cim:ConductingEquipment-s are typically connected to the same
2909          cim:TopologicalNode via their cim:Terminal-s.
2910          The phase codes of the cim:Terminal-s of the following grounding equipment shall
2911    be N:
2912          - cim:PetersenCoil
2913          - cim:Ground
2914          - cim:GroundingImpedance
2915          Note that cim:GroundDisconnector will have phase code N at the two sides.
2916
2917          Justification:
2918          Ohms and Kirchoffs laws.
2919
2920          Message:
2921          Grounding equipment shall have phase code N only.
2922
2923          Usage: #IGMRuleSet
2924
2925
2926    Rule: ControlAreaInstance  Level: 3  Severity: ERROR
2927
2928          Details:
2929          Exactly one cim:ControlArea instance per IGM with following attributes
2930          must be defined:
2931          - cim:ControlArea.type is cim:ControlAreaTypeKind.Interchange
2932          - an entsoe:IdentifiedObject.energyIdentCodeEic shall be one of the codes defined
2933          in the QoCDC Reference Data document in column “RegionEic”.
2934
2935          Justification:
2936          The cim:ControlArea of type interchange is the model equivalent of
2937          a SchedulingArea.
2938
2939          Message:
2940          cim:ControlArea instance of type cim:ControlAreaTypeKind.Interchange is missing or
2941          does not have correct entsoe:IdentifiedObject.energyIdentCodeEic.
2942
2943          Usage: #IGMRuleSet
2944
2945    Rule: DCEquipmentContainerMapping  Level: 3  Severity: ERROR
2946
2947          Details:
2948          For each cim:DCConverterUnit and cim:DCLine instance the attribute
2949          entsoe:IdentifiedObject.energyIdentCodeEic is required. The third character of the
2950          EIC code shall be 'T'.
2951
```

```
2952          Justification:
2953          The mapping of reference schedules for HVDC links is done via
2954          the EIC T codes. The EIC T code is also used to identify DC equipment
2955          containers that belong to the same HVDC pole.
2956
2957          Message:
2958          EIC code for cim:DCConverterUnit or cim:DCLine is either not provided or it is not
2959          a 'T' code.
2960
2961          Usage: #IGMRuleSet
2962
2963    Rule: RCandTCCcontrollingObjects  Level: 3  Severity: WARNING
2964
2965          Details:
2966          A cim:RegulatingControl or cim:TapChangerControl shall have at least one
2967          controlling object. The cardinality
2968          - cim:RegulatingControl[0..1]-[0..*]cim:RegulatingCondEq
2969          - cim:TapChangerControl[0..1]-[0..*]cim:TapChanger
2970          are currently allowing no controlling objects.
2971
2972          Justification:
2973          A cim:RegulatingControl or cim:TapChangerControl without controlling objects
2974          cannot perform control.
2975          It is important for IGMs quality and CGM creation process to indicate
2976          these occurrences.
2977
2978          Message:
2979          cim:RegulatingControl or cim:TapChangerControl without controlling objects.
2980
2981          Usage: #IGMRuleSet
2982
2983    Rule: SMRatedSunrealistic  Level: 3  Severity: WARNING
2984
2985          Details:
2986          If a cim:SynchronousMachine has a rated power way beyond the specified
2987          active and reactive limit values or way outside the reactive capability curve
2988          the rated power value is not realistic.
2989          A EQ_RATEDS_REASONABILITY_FACTOR (RSRF) is used to determine if a rated power
2990          is reasonable.
2991          To be realistic and reasonable the cim:RotatingMachine.ratedS shall if an active
2992          or reactive power limit is present be less than
2993          - max(abs(cim:SynchronousMachine.minQ),
2994             abs(cim:SynchronousMachine.maxQ),
2995             abs(cim:GeneratingUnit.minOperatingP,
2996             abs(cim:GeneratingUnit.maxOperatingP))*RSRF
2997          - max(abs(CurveData.xvalue),
2998             abs(CurveData.y1value),
2999             abs(CurveData.y2value))*RSRF
3000          for all x, y1 and y2 values.
3001
3002          Justification:
3003          Rated powers may be given a large and unrealistic value that will impact other
3004          rules which may result in erroneous reporting by them.
3005
3006          Message:
3007          Unrealistic cim:RotatingMachine.ratedS specified.
```

```
3008
3009          Usage: #IGMRuleSet
3010
3011    Rule: TargetDeadbandOutOfRange  Level: 3  Severity: WARNING
3012
3013          Details:
3014          If the cim:RegulatingControl.targetDeadband has a value similar to the
3015          cim:RegulatingControl.targetValue this means that it has no effect and
3016          that the cim:RegulatingControl is in practice disabled. Disabling a
3017          cim:RegulatingControl this way shouldn't be used, instead use the
3018          cim:RegulatingControl.enabled flag.
3019          cim:RegulatingControl.targetDeadband/EQ_DB_REASONABILITY_FACTOR
3020          should be less than the cim:RegulatingControl.targetValue.
3021          With a value of 2 for the EQ_DB_REASONABILITY_FACTOR this means that
3022          if the cim:RegulatingControl.targetDeadband is greater than twice the
3023          cim:RegulatingControl.targetValue this means that the target will always stay
3024          inside the dead band.
3025          The rule is only activated when cim:RegulatingControl.discrete="true",
3026          cim:RegulatingControl.enabled="true" and
3027          cim:RegulatingControl.mode= RegulatingControlModeKind.voltage.
3028
3029          Justification:
3030          Using other ways than cim:RegulatingControl.enabled flag shouldn't be used.
3031
3032          Message:
3033          cim:RegulatingControl has been potentially disabled with a large
3034          cim:RegulatingControl.targetDeadband.
3035
3036          Usage: #IGMRuleSet
3037
3038    Rule: WindingConnectionAngle  Level: 3  Severity: WARNING
3039
3040          Details:
3041          The cim:PhaseTapChangerAsymmetrical.windingConnectionAngle attribute in real
3042          grids can only have the following values:
3043          - +/-150;
3044          - +/-120;
3045          - +/-90;
3046          - +/-60;
3047          - +/-30.
3048          Values can be expressed as integer or float. Non-zero decimals are not allowed in
3049          case the value is expressed as float.
3050          Justification:
3051          Asymmetrical phase tap changers are built for specific connection angles.
3052
3053          Message:
3054          cim:PhaseTapChangerAsymmetrical.windingConnectionAngle value is not
3055          one of the defined values.
3056
3057          Usage: #IGMRuleSet
3058
3059    Rule: VoltageLimitDirection  Level: 3  Severity: WARNING
3060
3061          Details:
3062          A cim:VoltageLimit should be specified with a direction high or low, i.e. the
3063          cim:OperationalLimitType.direction value should be one of
```

```
        - cim:OperationalLimitDirectionKind.high
        - cim:OperationalLimitDirectionKind.low

        Justification:
        If the direction is missing it is not possible to check the voltage value.

        Message:
        cim:OperationalLimitType.direction is either 1) not provided or 2) it is not set
        to cim:OperationalLimitDirectionKind.high or
        cim:OperationalLimitDirectionKind.low.

        Usage: #IGMRuleSet

Rule: VoltageLimitsConsistency  Level: 3  Severity: WARNING

        Details:
        cim:VoltageLimit within a given cim:OperationalLimitSet with direction
        cim:OperationalLimitDirectionKind.high should be
        greater than cim:VoltageLimit with direction
        cim:OperationalLimitDirectionKind.low.

        Justification:
        cim:VoltageLimit not consistent with the specified direction are meaningless.

        Message:
        cim:VoltageLimit values are not consistent with the specified directions.

        Usage: #IGMRuleSet

Rule: FlowLimitsDirectionConsistency  Level: 3  Severity: WARNING

        Details:
        Branch flow limits cim:CurrentLimit, cim:ApparentPowerLimit and
        cim:ActivePowerLimit should have a cim:OperationalLimitType.direction with value
        cim:OperationalLimitDirectionKind.absoluteValue.

        Justification:
        Branch flow can go in both directions on the branch. Hence the direction should be
        specified as an absoluteValue.

        Message:
        Branch flow limits with other direction than absoluteValue.

        Usage: #IGMRuleSet

Rule: AsymmetricalEquivalent  Level: 3  Severity: WARNING

        Details:
        cim:EquivalentBranch with EquivalentBranch.r not equal to EquivalentBranch.r21 or
        EquivalentBranch.x not equal to EquivalentBranch.x21 should not be used.

        Justification:
        Equivalents with different impedance in different directions may result in poor
        convergence, hence reporting the difference support error tracing in data.

        Message:
```

```
3120          cim:EquivalentBranch with asymmetrical impedances.
3121
3122          Usage: #IGMRuleSet
3123
3124
3125    Rule: PositiveTransformerB  Level: 3  Severity: WARNING
3126
3127          Details:
3128          Two-winding transformer with positive shunt (cim:PowerTransformerEnd.b > 0)
3129          that are not equivalenced (cim:Equipment.aggregate = false)
3130          shouldn't have positive PowerTransformerEnd.b.
3131
3132          Justification:
3133          Two winding transformers are reactive and should not have
3134          positive cim:PowerTransformerEnd.b.
3135
3136          Message:
3137          Two winding transformer with positive shunt.
3138
3139          Usage: #IGMRuleSet
3140
3141    Rule: SubLoadAreaMissing  Level: 3  Severity: ERROR
3142
3143          Details:
3144          The reference cim:LoadGroup->cim:SubLoadArea is required. The class cim:LoadGroup
3145          in in EQ core while cim:SubLoadArea is in operation. Hence a BB model using
3146          classes cim:ConformLoad and cim:NonConformLoad will get an error if cim:SubLoadArea
3147          instances are missing. As a CGM may contain both NB and BB models the
3148          cardinality for the BB models need to be 0..1 but for the NB models 1.
3149          This is solved by making the reference cim:LoadGroup->cim:SubLoadArea optional
3150          and have this rule checking that NB models do have the references.
3151
3152          Justification:
3153          This is a bug fix of CGMES2.4.15.
3154
3155          Message:
3156          The reference cim:LoadGroup->cim:SubLoadArea is missing.
3157
3158          Usage: #IGMRuleSet
3159
3160    Rule: EnergyAreaMissing  Level: 3  Severity: ERROR
3161
3162          Details:
3163          The reference cim:ControlArea->cim:EnergyArea is required for NB models
3164          but not for BB models.
3165
3166          Justification:
3167          Required for NB models according to diagram note in CGMES2.4.15.
3168
3169          Message:
3170          The reference cim:ControlArea->cim:EnergyArea is missing.
3171
3172          Usage: #IGMRuleSet
3173
3174    Rule: GeneratingUnitSM  Level: 3  Severity: ERROR
3175
```

```
3176        Details:
3177        A cim:GeneratingUnit or any of its subclasses is not allowed to have more
3178        than one cim:RotatingMachine.
3179
3180        Justification:
3181        Having more than one cim:RotatingMachine with a cim:GeneratingUnit will make
3182        active and reactive limits dynamically dependent of the number of operational
3183        cim:RotatingMachine-s which makes scheduling difficult as this information
3184        is missing.
3185
3186        Message:
3187        A cim:GeneratingUnit is not allowed to have more than one cim:RotatingMachine.
3188
3189        Usage: #IGMRuleSet
3190
3191  Rule: TooManyTapChangers  Level: 3  Severity: ERROR
3192
3193        Details:
3194        Multiple tap changers can be combined within one power transformer. To avoid
3195        interpretation issues and to be close to real power transformer, the following is
3196        introduced.
3197        Only one phase shifting and one ratio changing tap changer can be modelled on a
3198        terminal of a cim:PowerTransformer.
3199        Maximum two cim:TapChanger-s are allowed per cim:PowerTransformerEnd as follows:
3200        - one subtype of cim:PhaseTapChanger
3201        - one cim:RatioTapChanger, being either:
3202            - OLTC cim:RatioTapChanger
3203           or
3204            - manually adjustable cim:RatioTapChanger.
3205
3206        Justification:
3207        A real power transformer does not have more than one on-load tap changer of the
3208        same kind at the cim:PowerTransformerEnd or more than one manually adjustable.
3209
3210        Message:
3211        More than allowed cim:TapChanger-s at cim:PowerTransformerEnd.
3212
3213        Usage: #IGMRuleSet
3214
3215  Rule: NoFlowControlAtNonRetainedSW  Level: 3  Severity: ERROR
3216
3217        Details:
3218        cim:RegulatingControl.Terminal can reference a cim:Terminal of a non-retained
3219        cim:Switch (i.e. where cim:Switch.retained is set to false) only if
3220        cim:RegulatingControl.mode is cim:RegulatingControlModeKind.voltage.
3221
3222        Justification:
3223        Non-retained cim:Switch-es are not included in a power flow solution, hence
3224        it is not possible for the power flow calculation to control their cim:Terminal-s.
3225        cim:Terminal-s of retained cim:Switch-es can be included in flow control.
3226
3227        Message:
3228        A non-retained cim:Switch has flow control, i.e. cim:RegulatingControl.Terminal
3229        refers to a cim:Terminal of that cim:Switch.
3230
3231        Usage: #IGMRuleSet
```

6 LEVEL 4 VALIDATION: MODEL ASSEMBLY

6.1 INTRODUCTION

Model assembly refers to the process of fulfilling the dependencies as specified in the file headers of instance files, starting with the official ENTSO-E EquipmentBoundary and TopologyBoundary instances, followed by the EQ, SSH, TP and SV instances of a Modelling Authority or multiple Modelling Authorities. Note that the meta data <md:Model.DependentOn> statements describe which instance models were used when the IGM was assembled, but the official ENTSO-E boundary files[8] are always to be used for the validation and merging process, instead of any other referenced boundary set.

In model instances, rdf:ID values always refer to unique objects within in that particular model instance file, whereas rdf:about values refer to objects that are unique in the namespace. As descriptive information is provided in multiple, associated files or model parts, it needs to be checked if all the mandatory data is complete for all identified objects.

In model instances, rdf:resource attributes always refer to objects that have been defined via a rdf:ID or rdf:about previously in the same model instance or any other model instance that is part of the assembly. It is intended to define an association to this object, acting as a pointer.

A dangling reference is just like a broken link on the web. In a model assembly it's a reference to an identified object that should have a description in the assembly and, simply, doesn't.

[8] The official boundary set can be recognized via the description field in the header. The most recent version is to be used at all times (highest version number)

6.2 FILE HEADERS – DEPENDENCIES

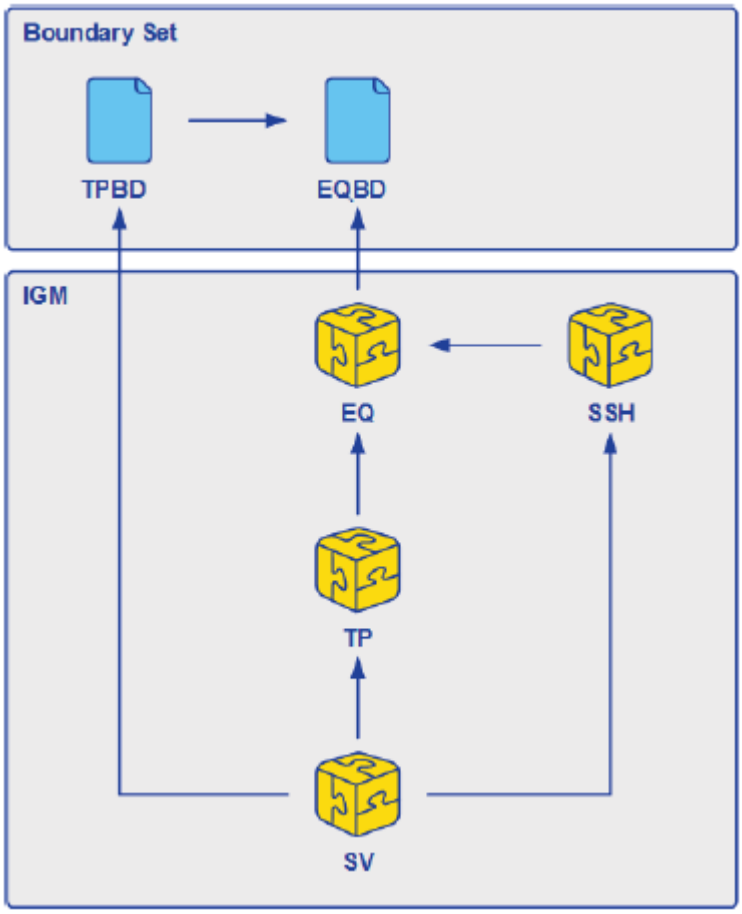

Figure 7 Dependencies of CGMES model instances

Figure 7~~Figure 7~~ is an easier to read version of the figure from PROF10 in IEC TS 61970-600-1 Ed 1.

The references in Figure 7~~Figure 7~~ are required and rules for them has been implemented in section 6.4. IGMs may include references between CIMXML files other than the ones in Figure 7~~Figure 7~~, such references are ignored.

CGMES Individual Grid Models and Common Grid Models are exchanged in separate EQ instance files (model parts) which may be reused for multiple scenario times. Instance files 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 'incomplete' – it may have dangling references and cannot be used except when combined with one or more other instance file as specified in the file header dependencies. When this occurs, validation for completeness can only be performed when all the parts are present. The md:Model.DependentOn role with multiplicity [0..*] in a CIMXML file header is used to list other CIMXML files that this CIMXML file depend on. This is explained in Annex C and rule PROF10 of TS 61970-600-1:2017.

For the Common Grid Model process, the boundary set is considered as reference data.

6.3 FILE HEADERS – GENERAL REQUIREMENTS

Model exchange typically involves the exchange of a collection of CIMXML files (model parts), each of which contains instance data, referred to as a model, and a header. The structure and semantics of each model are described by a profile, which is not included in the exchanged data. The exchange of CIMXMLfiles is governed by a collection of profiles described in IEC TS 61970-600 parts 1 and 2.

A header section describes the content of the model section contained in the CIMXML file e.g. the date the model was created, description etc. The header may also identify other models and their relationship to them. Such information is important when the models are part of a work flow where, for example, the models have relations to each other, e.g. a Supersedes and/or DependentOn referring to other CIMXML files. The Model class that has the above relations that are described in IEC 61970-552 Ed2.

The use of DependentOn and Supersedes for IGMs is shown in Figure 8~~Figure 8~~. The figure is described in more detail further down in the document.

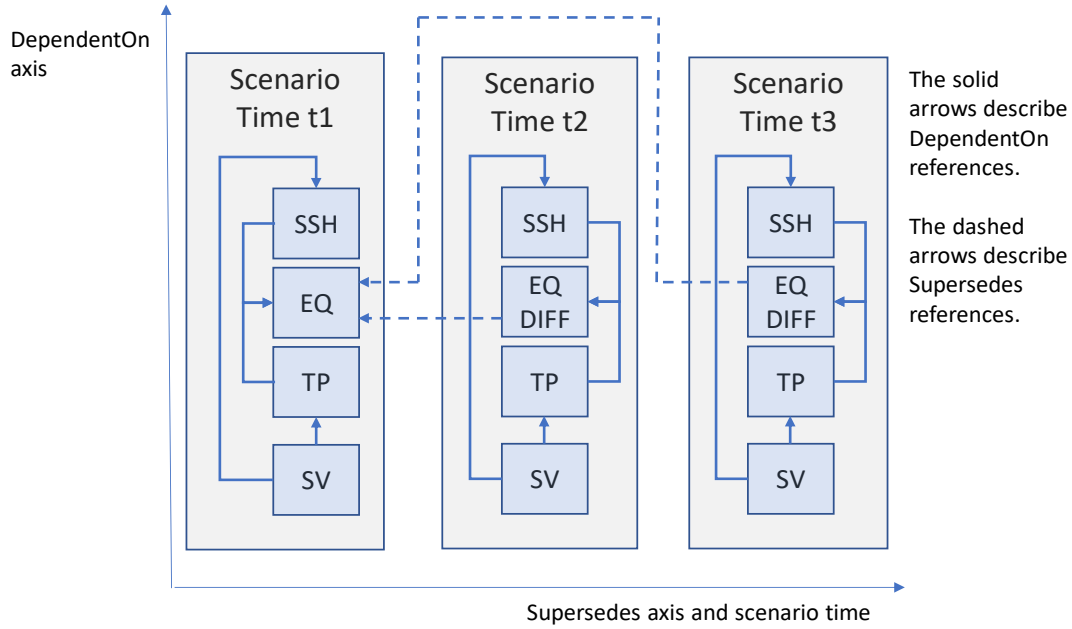

Figure 8 Use of DependentOn and Supersedes in IGMs

Supersedes is restricted to the use cases:

- Update of the same limit values multiple times.
- Complete replacement of SSH files at CGM creation.

The relation between IGM and CGM files is shown by the example in Figure 9~~Figure 9~~.

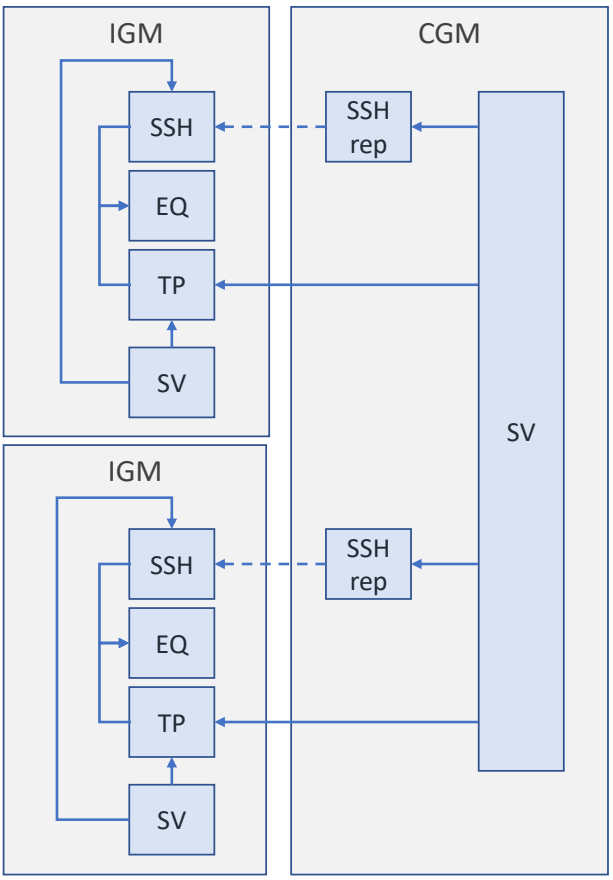

Figure 9 Example of relations between IGM and CGM files

Figure 9~~Figure 9~~ show two IGMs to the left and one CGM that is merging the IGMs to the right.

The header section shall always be the first element in a CIMXML document. The header section elements are:

- FullModel element
- DifferenceModel element

The data in the model section following the header is defined by one or more profiles listed within the header.

Elements or objects in a CIMXML file may have references to elements (objects or resources) in other CIMXML documents. The references are exemplified in Figure 8~~Figure 8~~ and Figure 9~~Figure 9~~ above.

To use a CIMXML difference file it must be applied to the CIMXML file it Supersedes, i.e. the difference description in the DifferenceModel element is applied to the superseded CIMXML file and the operations to apply are

- Addition of new objects
- Deletion of existing objects
- Update of attribute values

These operations result in a new CIMXML file that contains the combination of superseding and the superseded files as shown in Figure 10~~Figure 10~~.

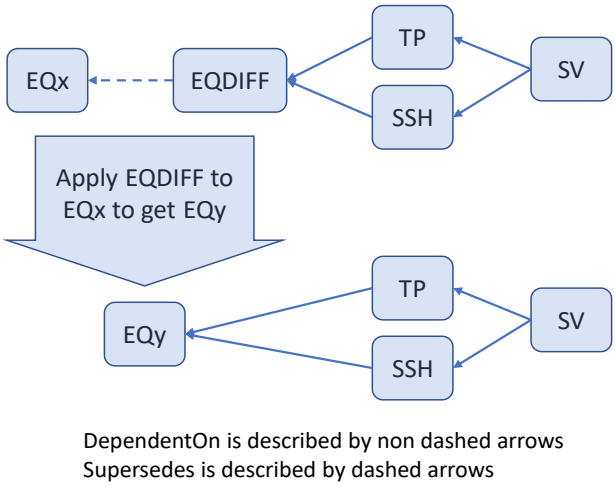

Figure 10 Application of DIFF files

In Figure 10~~Figure 10~~ the FullModel EQ file EQx is Superseded by the difference file EQDIFF. Applying the differences in EQDIFF result in a new EQ file EQy. EQy has the same meta data as EQDIFF which means the mRID, scenario time, description, profiles, MAS etc. are the same. Hence the DependentOn references from TP and SSH to the original EQDIFF are not affected and also work with the new EQy.

Figure 11~~Figure 11~~ shows that the application of the Supersedes to the EQx file happens in the middleware (MW; OPDE in this case) which means that Receivers (see Figure 11~~Figure 11~~, the Receiver is the client using CIMXML files, e.g. an RSC) don't need to bother with EQDIFF files nor the Supersedes reference.

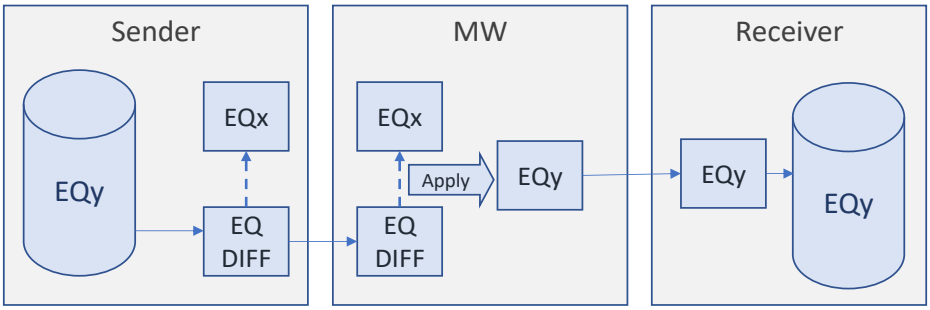

Figure 11 Applying the EQDIFF at the middleware

In Figure 11~~Figure 11~~ the EQDIFF file is transferred to the middleware (OPDE) where it is applied to the Superseded EQx file to create the EQy file. This is required also for the validation of the EQDIFF as the validation can only be made on the EQy file, not on the EQDIFF alone.

6.4 VALIDATION RULES

```
Rule: TPBD->EQBD  Level: 4  Severity: ERROR

      Details:
      Every TPBD file shall have an 'md:Model.DependentOn'
      reference to the EQBD file.

      Justification:
      IEC TS 61970-600-1:2017, requirement HREF2: "Dependent IDs refer to
      IDs of the dependent files at the time of the export".
      IEC TS 61970-600-1:2017, requirement PROF10.

      Message:
      Invalid md:Model.DependentOn statement(s) in TPBD.

      Usage: #IGMRuleSet #CGMRuleSet

Rule: EQ->EQBD  Level: 4  Severity: ERROR

      Details:
      Every EQ file shall have an 'md:Model.DependentOn'
      reference to the EQBD file that was used for the
      serialization.

      Justification:
      IEC TS 61970-600-1:2017, requirement HREF2: "Dependent IDs refer to
      IDs of the dependent files at the time of the export".
      IEC TS 61970-600-1:2017, requirement PROF10.

      Message:
      Invalid md:Model.DependentOn statement(s) in EQ.

      Usage: #IGMRuleSet #CGMRuleSet

Rule: TP->EQ,TP->EQDIFF  Level: 4  Severity: ERROR

      Details:
      Every TP file shall have an
      'md:Model.DependentOn' reference to a EQ or EQDIFF file.
      Note: This is a minimum requirement so more references may be present.

      Justification:
      IEC TS 61970-600-1:2017, requirement HREF2: "Dependent IDs refer to
      IDs of the dependent files at the time of the export".
      IEC TS 61970-600-1:2017, requirement PROF10.

      Message:
      Invalid md:Model.DependentOn statement(s) in TP.

      Usage: #IGMRuleSet #CGMRuleSet

Rule: SSH->EQ,SSH->EQDIFF  Level: 4  Severity: ERROR

      Details:
```

```
3378          Every SSH file shall have an
3379          'md:Model.DependentOn' reference to a EQ or EQDIFF file.
3380          Note: This is a minimum requirement so more references may be present.
3381
3382          Justification:
3383          IEC TS 61970-600-1:2017, requirement HREF2: "Dependent IDs refer to
3384          IDs of the dependent files at the time of the export".
3385          IEC TS 61970-600-1:2017, requirement PROF10.
3386
3387          Message:
3388          Invalid md:Model.DependentOn statement(s) in SSH.
3389
3390          Usage: #IGMRuleSet #CGMRuleSet
3391
3392    Rule: DY->EQ,DY->EQDIFF  Level: 4  Severity: ERROR
3393
3394          Details:
3395          Every DY file shall have an
3396          'md:Model.DependentOn' reference to a EQ or EQDIFF file.
3397          Note: This is a minimum requirement so more references may be present.
3398
3399          Justification:
3400          IEC TS 61970-600-1:2017, requirement HREF2: "Dependent IDs refer to
3401          IDs of the dependent files at the time of the export".
3402          IEC TS 61970-600-1:2017, requirement PROF10.
3403
3404          Message:
3405          Invalid md:Model.DependentOn statement(s) in DY.
3406
3407          Usage: #IGMRuleSet #CGMRuleSet
3408
3409    Rule: SV->SSH,SV->TP,SV->TPBD  Level: 4  Severity: ERROR
3410
3411          Details:
3412          Every SV file shall have 'md:Model.DependentOn' references to the files
3413          - SSH input files to the power flow calculation.
3414          - TP files with the power flow busses used in the power flow calculation.
3415          - TPBD files with the power flow busses in the boundary
3416          Note: This is a minimum requirement so more references may be present.
3417
3418          Justification:
3419          IEC TS 61970-600-1:2017, requirement HREF2: "Dependent IDs refer to
3420          IDs of the dependent files at the time of the export".
3421          IEC TS 61970-600-1:2017, requirement PROF10.
3422
3423          Message:
3424          Invalid md:Model.DependentOn statement(s), SV must have reference to TP, SSH
3425          and TPBD (used as input data for the power flow calculations).
3426
3427          Usage: #IGMRuleSet #CGMRuleSet
3428
3429    Rule: GL->EQ,GL->EQBD  Level: 4  Severity: ERROR
3430
3431          Details:
3432          Every GL model file has 'md:Model.DependentOn'
3433          references to the EQ model file and EQBD model file that
```

```
3434          were used for the serialization. The reference to the EQ model file is required
3435          and EQBD model file is optional.
3436          Note: This is a minimum requirement so more references may be present.
3437
3438          Justification:
3439          IEC TS 61970-600-1:2017, requirement HREF2: "Dependent IDs refer to
3440          IDs of the dependent files at the time of the export".
3441          IEC TS 61970-600-1:2017, requirement PROF10.
3442
3443          Message:
3444          Invalid md:Model.DependentOn statement(s), GL must have reference to EQ.
3445
3446          Usage: #IGMRuleSet #CGMRuleSet
3447
3448    Rule: DL->EQ,DL->EQDIFF,DL->TP,DL->DY  Level: 4  Severity: ERROR
3449
3450          Details:
3451          Every DL file shall have 'md:Model.DependentOn'
3452          references to the EQ or EQDIFF file, the TP file and to
3453          the DY file that were used for the serialization. The
3454          reference to the EQ model file is required and the references to
3455          TP and DY model files are optional.
3456          Note: This is a minimum requirement so more references may be present.
3457
3458          Justification:
3459          IEC TS 61970-600-1:2017, requirement HREF2: "Dependent IDs refer to
3460          IDs of the dependent files at the time of the export".
3461          IEC TS 61970-600-1:2017, requirement PROF10.
3462
3463          Message:
3464          Invalid md:Model.DependentOn statement(s), DL must have reference to EQ.
3465
3466          Usage: #IGMRuleSet #CGMRuleSet
3467
3468    Rule: EQDIFF->EQ  Level: 4  Severity: ERROR
3469
3470          Details:
3471          Every EQDIFF file shall only have a md:Model.Supersedes
3472          references to the EQ file it updates as it is not correct to use
3473          md:Model.DependentOn for a CIMXML file that replaces or supersedes another.
3474          The elements of the following types are allowed in the EQDIFF document
3475          - cim:VoltageLimit
3476          - cim:CurrentLimit
3477          - cim:ActivePowerLimit
3478          - cim:ApparentPowerLimit
3479          This rule restricts use of difference models and is CGM_BP specific.
3480
3481          Justification:
3482          IEC TS 61970-600-1:2017 annex C.2.
3483          EMF meeting decision in Rome 2018-10-05.
3484
3485          Message:
3486          Invalid md:Model.Supersedes statement(s), reference to EQ only allowed.
3487
3488          Usage: #IGMRuleSet #CGMRuleSet
3489
```

```
Rule: EQDIFFOperationalLimit  Level: 4  Severity: ERROR

      Details:
      An EQDIFF file is only allowed to contain subclasses of OperationalLimit.
      This is a temporary solution for exchange of limit values in EQ
      that in the future will be in SHH.
      This rule restricts use of difference models and is CGM_BP specific.

      Justification:
      IEC TS 61970-600-1:2017 annex C.2.
      EMF meeting decision in Rome 2018-10-05.

      Message:
      Not allowed CIM class in EQDIFF file.

      Usage: #IGMRuleSet

Rule: DanglingReference  Level: 4  Severity: ERROR

      Details:

      For all references (part of the CGMES profiles and additional, if existing), the
      mRID specified in every rdf:resource in the assembly of
      cimxml instance files shall be defined in an existing rdf:ID and rdf:about
      part of the data exchange.

      Justification:
      See IEC TS 61970-600-1:2017 Requirement 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 must have fulfilled references (no dangling references are allowed).”

      Message:
      Dangling reference found.

      Usage: #IGMRuleSet #CGMRuleSet

Rule: IncorrectAttributeOrRoleCard  Level: 4  Severity: ERROR

      Details:
      All mandatory attributes and associations must be provided for the
      assembled model  according to cardinalities given by profiles specified
      in md:Model.profile for each of the assembled CIMXML files.

      Justification:
      See IEC TS 61970-600-1:2017 Requirements PROF5 and PROF7.

      Message:
      Cardinality violated for attribute or role,
      too many or too few values or references provided.

      Usage: #IGMRuleSet #CGMRuleSet

Rule: CgmSvSshVersionMismatch  Level: 4  Severity: ERROR
```

Details:
A CGM will have updated SSH files (referencing to original data by Supersede statement) for each IGM and a single SV file
with the complete solution for the included IGMs. The updated SSH CIMXML files and the resulting CIMXML SV file should have:
- the same md:Model.scenarioTime.
- a new md:Model.version number that is the same for the SV and SSH CIMXML files.
Note: Section 6.6 of the ENTSO-E CGM Building process Implementation guide AC part, version 1.3, 13 May 2020 provides details on IGM substitution and rules related to md:Model.scenarioTime.

Justification:
Versioning of CGM is important for sustainable CGM building process.

Message:
Different fileVersion or effectiveDateTime in SSH and SV from CGM.

Usage: #CGMRuleSet

7 LEVEL 5 VALIDATION: CONSISTENCY OF ASSEMBLED MODEL

7.1 INTRODUCTION

In this level, consistency between equipment characteristics in EQ and scenario data from the other instance data files is validated.

7.2 VALIDATION RULES

Rule: GeographicalRegionBD Level: 5 Severity: WARNING

Details:
cim:GeographicalRegion-s should be agreed on by modelling authorities and be described in the equipment boundary.

Justification:
cim:GeographicalRegion is used to organise equipment geographically and regions that corresponds to a network model managed by a TSO which is also the ModelingAuthority for the network.

Message:
cim:GeographicalRegion from the boundary is not used.

Usage: #IGMRuleSet

Rule: GeographicalRegion Level: 5 Severity: ERROR

Details:
An IGM shall have a single cim:GeographicalRegion. cim:SubGeographicalRegion-s in an IGM shall refer to a single cim:GeographicalRegion.

```
3593
3594          Justification:
3595          cim:GeographicalRegion is used to organise equipment geographically and regions
3596          that corresponds to a network model managed by a TSO which is also the
3597          ModelingAuthority for the network.
3598          Each IGM shall be described by one cim:GeographicalRegion.
3599          See also IEC TS 61970-600-1 E.13.
3600
3601          Message:
3602          More than one GeographicalRegion in IGM or cim:SubGeographicalRegion-s refer to
3603          multiple cim:GeographicalRegion-s.
3604
3605          Usage: #IGMRuleSet
3606
3607
3608    Rule: LineContainment  Level: 5  Severity: ERROR
3609
3610          Details:
3611          For every instance of cim:ACLineSegment, the cim:Equipment.EquipmentContainer
3612          referred to, if provided, must be of type cim:Line.
3613
3614          Justification:
3615          See Figure 15 (diagram Core notes) and
3616          section 6.9.16 of IEC TS 61970-600-2.
3617
3618          Message:
3619          cim:ACLineSegments can only be contained in a cim:Line.
3620
3621          Usage: #IGMRuleSet
3622
3623    Rule: EquivalentInjectionContainment  Level: 5  Severity: ERROR
3624
3625          Details:
3626          Every cim:EquivalentInjection shall be contained by a
3627          - cim:VoltageLevel if not in a boundary point.
3628          - If in a boundary point, preferably it is contained in a cim:Line or
3629             not contained at all with provided association to cim:BaseVoltage.
3630
3631          Justification:
3632          All equipment shall be contained, also cim:EquivalentInjection, but as it is
3633          allowed not to have cim:EquivalentInjection contained this is
3634          allowed for backwards compatibility.
3635          See also IEC TS 61970-600-2 6.7.6.
3636
3637          Message:
3638          cim:EquivalentInjection containment error.
3639
3640          Usage: #IGMRuleSet
3641
3642
3643    Rule: DCLineContainment  Level: 5  Severity: ERROR
3644
3645          Details:
3646          For every instance of cim:DCLineSegment, the cim:Equipment.EquipmentContainer
3647          referred to, must be of type cim:DCLine. In the case of modelling back to back
3648          configuration the association shall point to EquipmentContainer of type
```

```
3649          cim:Substation. Missing containment is not allowed.
3650
3651          Justification:
3652          See section 6.3.15 of IEC TS 61970-600-2
3653
3654          Message:
3655          cim:DCLineSegment must be contained in a cim:DCLine or a cim:Substation.
3656
3657          Usage: #IGMRuleSet
3658
3659
3660    Rule: BaseVoltageNotInBoundary  Level: 5  Severity: WARNING
3661
3662          Details:
3663          All cim:BaseVoltages should be agreed on by modeling authorities and
3664          be in the boundary.
3665          If a matching base voltage is already in the boundary it
3666          should be used.
3667          If a matching base voltage is not in the boundary, consider
3668          to add it in the boundary so that it can be reused by others.
3669
3670
3671          Justification:
3672          An agreement on the base voltages is required to get interoperability.
3673          Rule added at CGM_BP meeting in Zagreb 2019-05-23.
3674
3675          Message:
3676          cim:BaseVoltage not in boundary.
3677
3678          Usage: #IGMRuleSet
3679
3680
3681    Rule: SVCVoltage  Level: 5  Severity: ERROR
3682
3683          Details:
3684          The association end cim:RegulatingCondEq.RegulatingControl is required.
3685          cim:RequlatingControl.targetValue shall be greater than zero if
3686          cim:RequlatingControl.mode is RegulatingControlModeKind.voltage.
3687          The attributes cim:StaticVarCompensator.sVCControlMode and
3688          cim:StaticVarCompensator.voltageSetPoint are ignored at both model validation and
3689          control logic of the SVC.
3690
3691          Justification:
3692          The reactive power output of the SVC is proportional to the
3693          difference between the voltage at the regulated bus and the voltage
3694          setpoint. When the regulated bus voltage is equal to the voltage
3695          setpoint, the reactive power output is zero.
3696          RequlatingControl is used as it has capabilities missing from SVC,
3697          e.g. the controlled point.
3698          See IEC TS 61970-600-2:2017, section 6.9.44.
3699
3700          Message:
3701          cim:RegulatingCondEq.RegulatingControl is not provided or
3702          cim:RequlatingControl.targetValue is not greater than zero.
3703
3704
```

```
3705          Usage: #IGMRuleSet
3706
3707    Rule: TapChangerNeutralU  Level: 5  Severity: ERROR
3708
3709          Details:
3710          The cim:TapChanger.neutralU shall be the same as cim:PowerTransformerEnd.ratedU.
3711
3712          Justification:
3713          See section E.2.2. of IEC TS 61970-600-1:2017.
3714
3715          Message:
3716          The neutralU differs from ratedU.
3717
3718          Usage: #IGMRuleSet
3719
3720    Rule: ControlLinkedToTopology  Level: 5  Severity: WARNING
3721
3722          Details:
3723          The controlled cim:Terminal at a cim:RegulatingControl (RC) or
3724          cim:TapChangerControl (TCC) must be linkedto a cim:TopologicalNode (TN).
3725          In case cim:Switch cim:Terminals are not included in TP and if the
3726          controlled point is a cim:Switch cim:Terminal the controlled point is lost.
3727          The cardinality for cim:Terminal.TopologicalNode is 1 so it is required,
3728          hence all cim:Terminals must be present in TP regardless of the type of
3729          conducting equipment, it is linked to.
3730          This rule shouldn't be needed if all cim:Terminals where present in TP.
3731
3732          Justification:
3733          If a RC or TCC is not linked to a TN the changes in the control variables will not
3734          affect the target value in the power flow calculation.
3735          See section E.12 of IEC TS 61970-600-1:2017.
3736
3737          Message:
3738          Terminal controlled by cim:RegulatingControl or cim:TapChangerControl is not
3739          linked to a cim:TopologicalNode.
3740
3741          Usage: #IGMRuleSet
3742
3743    Rule: BranchBaseVoltage  Level: 5  Severity: ERROR
3744
3745          Details:
3746          Every instance of cim:ACLineSegment, cim: SeriesCompensator or cim:EquivalentBranch
3747          must have an association cim:ConductingEquipment.BaseVoltage.
3748
3749          Note: PowerTransformerEnd already has required association with
3750          cim:TransformerEnd.BaseVoltage.
3751
3752          Justification:
3753          See section 6.7.6, 6.10.42, 6.12.2 and 6.10.2 of IEC TS 61970-600-2.
3754
3755          Message:
3756          Either cim:ACLineSegment, cim:EquivalentBranch, or cim:SeriesCompensator has no
3757          BaseVoltage.
3758
3759          Usage: #IGMRuleSet
3760
```

```
Rule: EquivalentInjectionControlEnabled  Level: 5  Severity: WARNING

      Details:
      Boundary cim:EquivalentInjections should have control disabled,
      cim:EquivalentInjection.regulationCapability should be false, and
      cim:EquivalentInjection.regulationStatus shall also be set to false.
      An cim:EquivalentInjection may have control enabled only if it represents an
      HVDC converter.
      cim:EquivalentInjections that are result of network reduction may have control
      enabled, if so realistic reactive power limits shall be provided.
      Note: An HVDC Boundary Point has a cim:IdentifiedObject.description
      attribute equal to 'HVDC'.

      Justification:
      Excessive reactive resources do not properly reflect power system behaviour.

      Message:
      Boundary cim:EquivalentInjections representing AC networks should
      not control voltage.

      Usage: #IGMRuleSet

Rule: NoLTCTapChangerControl  Level: 5  Severity: WARNING

      Details:
      If cim:TapChanger.ltcFlag is false, no TapChangerControl object should be
      referenced by cim:TapChanger.TapChangerControl.

      Justification:
      See section E.9.3. of IEC TS 61970-600-1:2017.

      Message:
      A TapChangerControl found for a TapChanger that cannot be changed under load.

      Usage: #IGMRuleSet

Rule: SvTapStepInstances  Level: 5  Severity: ERROR

      Details:
      A cim:SvTapStep instance is expected for all cim:TapChanger instances
      defined in EQ.

      Justification:
      See section E.9.3. of IEC TS 61970-600-1:2017.

      Message:
      Missing SvTapStep for TapChanger.

      Usage: #IGMRuleSet #CGMRuleSet

Rule: SvPowerFlowInstances  Level: 5  Severity: ERROR

      Details:
      cim:SvPowerFlow class is required to be instantiated for the following classes:
      - subclasses of the cim:RotatingMachine
      - subclasses of the cim:EnergyConsumer
```

- cim:EquivalentInjection
- cim:ExternalNetworkInjection
- cim:ShuntCompensator
- cim:StaticVarCompensator
- cim:EnergySource.

Justification:
See section 9.5.4 of IEC TS 61970-600-2.

Message:
Missing SvPowerFlow for Equipment.

Usage: #IGMRuleSet #CGMRuleSet

Rule: SvPowerFlowBranchInstances Level: 5 Severity: ERROR

Details:
The following shall conform:
1) For cim:TieFlow, which association end cim:TieFlow.ControlArea refers to a cim:ControlArea with cim:ControlArea.type equal to cim:ControlAreaTypeKind.Interchange, the association end cim:TieFlow.Terminal shall refer to a cim:Terminal of either cim:ACLineSegment, cim:PowerTransformer or cim:Switch and its subclasses. The cim:Terminal referenced by the association end cim:TieFlow.Terminal shall be associated with a boundary cim:TopologicalNode that conforms to item 2).
2) A boundary cim:TopologicalNode that is connected to an IGM shall have
- One cim:EquivalentInjection
- One of the following equipment: cim:ACLineSegment, cim:PowerTransformer or a retained cim:Switch (cim:Switch.retained=true) and its subclasses.

Justification:
See BPPL1 of IEC TS 61970-600-1:2017.
Normally, cim:EquivalentBranch-es result from a power system reduction process that depends on its state, e.g. connectivity. Therefore, cim:EquivalentBranch-es are not persistent over time as new ones may be created while previous ones deleted. Branches connected at the network boundary need to be well defined and unambiguously identifiable, as they are representing non-equivalent objects connected to a boundary point agreed between the two parties on a given border. The cim:EquivalentBranch is not meeting such criteria by nature hence, it shall not connect to a boundary point.

Message:
One of the following occurs: 1) A cim:TieFlow with a cim:TieFlow.Terminal referring to either a cim:Terminal that is not connected to a boundary cim:TopologicalNode or it is not a cim:Terminal of one of the following: cim:ACLineSegment, cim:PowerTransformer or a retained cim:Switch and its subclasses; 2) A boundary cim:TopologicalNode connected to the IGM that does not have one cim:EquivalentInjection and one of the following: cim:ACLineSegment, cim:PowerTransformer, or a retained cim:Switch and its subclasses.

Usage: #IGMRuleSet #CGMRuleSet

Rule: SvPowerFlowBranchInstances2 Level: 5 Severity: ERROR

Details:

```
3873          Branches shall have cim:SvPowerFlow instantiated at its cim:Terminals for
3874          the following branch classes:
3875          - cim:SeriesCompensator
3876          - cim:ACLineSegment
3877          - cim:PowerTransformer
3878          - cim:EquivalentBranch
3879          - cim:Switch where cim:Switch.retained is true.
3880
3881          Justification:
3882          The power flow result for branches cannot be reviewed without cim:SvPowerFlow.
3883          This is needed when solutions for the same IGM or CGM computed by different
3884          tools are compared.
3885          Note that computing the flows by scripts based on solved voltages may not
3886          give the same result as the original power flow.
3887
3888          Message:
3889          Missing cim:SvPowerFlow for a branch.
3890
3891          Usage: #IGMRuleSet #CGMRuleSet
3892
3893    Rule: DisconnectedTerminal  Level: 5  Severity: ERROR
3894
3895          Details:
3896          If the associated cim:ACDCTerminal.connected status is false, the flow
3897          specified in the cim:SvPowerFlow.p and cim:SvPowerFlow.q shall be zero.
3898
3899          Justification:
3900          See section 9.5.4. of IEC TS 61970-600-2.
3901
3902          Message:
3903          Zero flow expected for disconnected terminal.
3904
3905          Usage: #IGMRuleSet #CGMRuleSet
3906
3907    Rule: TopologicalIslandInstance  Level: 5  Severity: ERROR
3908
3909          Details:
3910          In case a solved model is exchanged for a single MAS the state variables
3911          profile must include at least one instance of cim:TopologicalIsland.
3912
3913          Justification:
3914          See section E.6 of IEC TS 61970-600-1:2017.
3915
3916          Message:
3917          Missing cim:TopologicalIsland.
3918
3919          Usage: #IGMRuleSet #CGMRuleSet
3920
3921    Rule: SmallTopologicalIsland  Level: 5  Severity: WARNING
3922
3923          Details:
3924          A small cim:TopologicalIsland with TNs having zero voltage is in most cases
3925          meaningless and should not be exchanged.
3926          A cim:TopologicalIsland with three or fewer cim:TopologicalNodes is small.
3927
3928          Justification:
```

```
3929          A small cim:TopologicalIsland is typically not energized and does not contribute
3930          to the interconnected network solution. The number of three cim:TopologicalNodes
3931          as a small island is selected to catch disconnected three winding transformers.
3932
3933          Message:
3934          Small cim:TopologicalIsland found.
3935
3936          Usage: #IGMRuleSet #CGMRuleSet
3937
3938    Rule: SlackNode  Level: 5  Severity: WARNING
3939
3940          Details:
3941          For every cim:TopologicalIsland the
3942          cim:TopologicalIsland.AngleRefTopologicalNode should refer to the
3943          cim:TopologicalNode with a cim:SynchronousMachine having the highest
3944          cim:SynchronousMachine.referencePriority. The priority values are
3945          - 0 not included in slack node determination.
3946          - 1 is the highest.
3947          - 2 and on are decreasing priorities. If no cim:SynchronousMachine with
3948             cim:SynchronousMachine.referencePriority specified is available the
3949             cim:TopologicalIsland.AngleRefTopologicalNode can be set to any
3950             cim:TopologicalNode.
3951
3952          Justification:
3953          See section E.4 of IEC TS 61970-600-1:2017
3954          If different power flow solutions have the same angle reference
3955          for the same network solutions are easier to compare.
3956          If not, the linear offset is to be expected.
3957
3958          Message:
3959          A cim:SynchronousMachine with valid ReferencePriority exists
3960          but is not used for defining the angle reference node in topological island.
3961
3962          Usage: #IGMRuleSet
3963
3964    Rule: SwitchTerminals  Level: 5  Severity: ERROR
3965
3966          Details:
3967          For every instance of cim:Switch, cim:Breaker, cim:Disconnector,
3968          cim:GroundDisconnector and cim:LoadBreakSwitch,
3969          it is not allowed to have its cim:Terminals connected to the
3970          same cim:ConnectivityNode.
3971
3972          Justification:
3973          See section E.17 of IEC TS 61970-600-1:2017.
3974
3975          Message:
3976          A switch cannot have its terminals connect the same cim:ConnectivityNode.
3977
3978          Usage: #IGMRuleSet
3979
3980    Rule: SwitchVL  Level: 5  Severity: ERROR
3981
3982          Details:
3983          For every instance of cim:Switch, cim:Breaker, cim:Disconnector,
3984          cim:GroundDisconnector and cim:LoadBreakSwitch,
```

```
3985          it is not allowed to connect cim:ConnectivityNode or cim:TopologicalNode
3986          in different cim:VoltageLevels.
3987
3988          Justification:
3989          See section E.17 of IEC TS 61970-600-1:2017.
3990
3991          Message:
3992          A cim:Switch cannot connect to cim:ConnectivityNodes or cim:TopologicalNodes
3993          in different cim:VoltageLevels.
3994
3995          Usage: #IGMRuleSet
3996
3997    Rule: SwitchTN1  Level: 5  Severity: ERROR
3998
3999          Details:
4000          For every instance of cim:Switch, cim:Breaker, cim:Disconnector,
4001          cim:GroundDisconnector and cim:LoadBreakSwitch,
4002          with cim:Switch.retained is true,
4003          its cim:Terminals shall be associated with different cim:TopologicalNodes.
4004
4005          Justification:
4006          See section E.17 of IEC TS 61970-600-1:2017.
4007
4008          Message:
4009          Retained cim:Switch cim:Terminals cannot be associated with the same
4010          cim:TopologicalNode.
4011
4012          Usage: #IGMRuleSet
4013
4014    Rule: SwitchOpenVsConnected  Level: 5  Severity: ERROR
4015
4016          Details:
4017          The attribute cim:ACDCTerminal.connected shall always be set to true for terminals
4018          of cim:Switch or its subclasses.
4019
4020          Justification:
4021          A cim:Terminal has switching capability due to the attribute
4022          cim:ACDCTerminal.connected flag, a cim:Equipment can be disconnected with this
4023          flag. For cim:Switch-es this means it is possible to break the conducting path at
4024          three places:
4025          - cim:ACDCTerminal.connected side 1 (cim:ACDCTerminal.sequenceNumber=1)
4026          - cim:Switch.open
4027          - cim:ACDCTerminal.connected side 2 (cim:ACDCTerminal.sequenceNumber=2)
4028          Evaluating switch status then means inspecting the three flags for every switch.
4029
4030          Message:
4031          cim:ACDCTerminal.connected is not set to true for a cim:Switch or its subclasses.
4032
4033          Usage: #IGMRuleSet
4034
4035    Rule: ParticipatingGeneratingUnit  Level: 5  Severity: WARNING
4036
4037          Details:
4038          This rule applies when generation slack is used.
4039          cim:GeneratingUnit-s that pick-up mismatch shall have a cim:GeneratingUnit.normalPF
4040          greater than 0. At least one such unit is required in every electrical island.
```

```
4041
4042          Justification:
4043          GeneratingUnits cannot pick-up mismatch if this data is unspecified.
4044
4045          Message:
4046          No GeneratingUnit with .normalPF greater than 0 in an island.
4047
4048          Usage: #IGMRuleSet
4049
4050    Rule: ControlOfAnotherIsland  Level: 5  Severity: WARNING
4051
4052          Details:
4053          A cim:RegulatingControl or cim:TapChangerControl should not control a
4054          cim:TopologicalNode in another cim:TopologicalIsland than its
4055          controlling equipment is located.
4056          The rule is applied for cim:RegulatingControl.enabled equal true. In addition, the
4057          rule applies to objects only within the IGM as references to objects in another
4058          MAS will be reported as dangling references.
4059
4060          Justification:
4061          There is no feedback loop to the control in this case.
4062
4063          Message:
4064          A controlled cim:TopologicalNode is in another cim:TopologicalIsland
4065          than the controlling equipment.
4066
4067          Usage: #IGMRuleSet
4068
4069    Rule: TapChangerTargetRange  Level: 5  Severity: WARNING
4070
4071          Details:
4072          A tap changer cannot reach a cim:RegulatingControl.targetValue outside its
4073          capability.
4074          The tap changer upper capability limit (TCUC) in per unit is
4075          - TCUC = 1+cim:RatioTapChanger.stepVoltageIncrement/100*
4076             (cim:TapChanger.highStep-cim:TapChanger.neutralStep)
4077          The tap changer lower capability limit (TCLC) in per unit is
4078          - TCLC = 1-cim:RatioTapChanger.stepVoltageIncrement/100*
4079             (cim:TapChanger.neutralStep-cim:TapChanger.lowStep)
4080          The TCUC and TCLC are in per unit (PU)
4081          The target value in PU is TargetValuePU =
4082          cim:RegulatingControl.targetValue/cim:BaseVoltage.nominalVoltage
4083          where the cim:BaseVoltage is from the controlled Terminal.
4084          The rule is
4085          - min(TCLC,TCUC) GreaterOrEqual TargetValuePU LessOrEqual max(TCLC,TCUC)
4086          Note1: The cim:TapChanger.controlEnabled and
4087          cim:RequlatingControl.enabled flags are to be considered.
4088          Note2: cim:TapChangerControlMode shall be set to voltage control.
4089
4090          Justification:
4091          The transformer cannot meet the requested target value.
4092
4093          Message:
4094          The cim:RegulatingControl.targetValue outside the cim:TapChanger
4095          capability.
4096
```

```
4097          Usage: #IGMRuleSet #CGMRuleSet
4098
4099    Rule: IDuniqueness  Level: 5  Severity: ERROR
4100
4101          Details:
4102          All mRIDs (rdf:ID or rdf:about) in a model shall
4103          be unique.
4104
4105          Justification:
4106          All mRIDs (rdf:ID or rdf:about) shall be globally unique
4107          as stated in IEC 61970-552.
4108          See IEC TS 61970-600-1:2017 GENC1.
4109
4110          Message:
4111          mRID (rdf:ID or rdf:about) not unique within model.
4112
4113          Usage: #IGMRuleSet #CGMRuleSet
4114
4115    Rule: TCCRemoteReactiveFlow  Level: 5  Severity: WARNING
4116
4117          Details:
4118          A cim:TapChangerControl (TCC) controlling reactive power flow should control the
4119          flow at one of the cim:Terminal-s belonging
4120          to cim:PowerTransformerEnd-s in the cim:PowerTransformer where the
4121          cim:TapChanger is located.
4122          Control a remote cim:Terminal (even if it is within the MAS) not belonging to the
4123          cim:PowerTransformer
4124          with the cim:TapChanger is not allowed.
4125          Note: A result of this is that multiple cim:TapChanger-s cannot be
4126          controlled by the same TCC.
4127
4128          Justification:
4129          A power transformer cannot efficiently control reactive power flow
4130          other than on its own terminals.
4131
4132          Message:
4133          A cim:TapChangerControl for reactive power flow is controlling a
4134          cim:Terminal that is not connected to one of the cim:PowerTransformerEnd-s.
4135
4136          Usage: #IGMRuleSet
4137
4138    Rule: SynchronousCondenserMode  Level: 5  Severity: WARNING
4139
4140          Details:
4141          For a synchronous condenser (cim:SynchronousMachine.type = condenser)
4142          there is no capability for real power output.
4143          In this case, the cim:SynchronousMachine.operationMode should be condenser.
4144
4145          Justification:
4146          The name plate ratings are used as a reference.
4147          See IEC TS 61970-600-2:2017, section 6.9.47.
4148
4149          Message:
4150          A synchronous condenser should have cim:SynchronousMachine.operatingMode
4151          set to condenser.
4152
```

```
4153          Usage: #IGMRuleSet #CGMRuleSet
4154
4155    Rule: SMOperatingModeConsistency  Level: 5  Severity: ERROR
4156
4157          Details:
4158          The SynchronousMachine.operatingMode shall be consistent with the
4159          SynchronousMachine.type.
4160          – SynchronousMachine.operatingMode = “motor” shall be provided for
4161          SynchronousMachine.type in ["motor", "generatorOrMotor", "motorOrCondenser",
4162          "generatorOrCondenserOrMotor"],
4163          – SynchronousMachine.operatingMode = “condenser" shall be provided for
4164          SynchronousMachine.type in ["condenser", "generatorOrCondenser",
4165          "motorOrCondenser", "generatorOrCondenserOrMotor"], and
4166          – SynchronousMachine.operatingMode = “generator” shall be provided for
4167          SynchronousMachine.type in ["generator", "generatorOrMotor",
4168          "generatorOrCondenser", "generatorOrCondenserOrMotor"].
4169
4170          Justification:
4171          A cim:SynchronousMachine can only operate with the modes it is built for.
4172
4173          Message:
4174          The cim:SynchronousMachine.operatingMode is inconsistent with
4175          cim:SynchronousMachine.type.
4176
4177          Usage: #IGMRuleSet
4178
4179    Rule: ControlOfIslandIsMissing  Level: 5  Severity: ERROR
4180
4181          Details:
4182          A cim:TopologicalIsland which contains less than SIZE_OF_ISLAND_WITHOUT_CONTROL
4183          cim:TopologicalNode-s is considered as a small island. It shall have at least one
4184          equipment controlling the voltage, e.g
4185          - cim:EquivalentInjection with cim:EquivalentInjection.regulationStatus=true,
4186            nonzero cim:EquivalentInjection.regulationTarget and valid reactive power limits
4187          - cim:SynchronousMachine with
4188              - control enabled for both cim:SynchronousMachine and cim:RegulatingControl
4189              - cim:SynchronousMachine.operatingMode = generator or condenser
4190          - cim:StaticVarCompensator with control enabled for both SVC and
4191            cim:RegulatingControl
4192
4193          Justification:
4194          A small island that does not have equipment controlling the voltage will not
4195          converge in power flow. Hence at least one controlling equipment must be present.
4196          If the island has the voltage controlled by resources in another IGM the
4197          EquivalentInjection at the boundary shall have its control enabled.
4198
4199          Message:
4200          The island does not have any equipment controlling the voltage.
4201
4202          Usage: #IGMRuleSet #CGMRuleSet
4203
```

8 LEVEL 6 VALIDATION: IGM AND CGM PLAUSIBILITY

8.1 INTRODUCTION

In this category, the focus is on identifying modelling assumptions in scenarios that impact convergence behaviour. From experience, the following root causes have been identified:

- Multiple electrical islands in an individual grid model;
- Insufficient voltage control capabilities;
- (Large) negative loads;
- Large reactive power values on PQ nodes;
- Unrealistic voltage target values (outside voltage limits of TSOs);
- Impact of cables not modelled (affects the power factor when performing load scaling);
- Low impedance equipment (short cables or low impedance transformers).

8.2 INDICATORS (AFTER LOAD FLOW CALCULATION)

- Large slack node deviation value (active power).
- Solved state variables far from initial (complex) voltage values.
- Oscillation in voltage deviations during iterations.
- A lot of iterations needed before convergence tolerance is met.
- Multiple synchronous machines are bound (switched to PQ nodes).
- Mathematical solution cannot be found (diverging voltage deviations between iterations).

8.3 INTERPOLATION IN REACTIVE CAPABILITY CURVE

A reactive capability curve typically has at least two curve points. If an interpolation function is not available three possible approximations are possible

1. Min of pairwise negative Q values and max of pairwise positive Q values, see Figure 12~~Figure 12~~
2. Mean value of pairwise Q values, see Figure 13~~Figure 13~~.
3. Max of pairwise negative Q values and min of pairwise positive Q values, see Figure 14~~Figure 14~~.

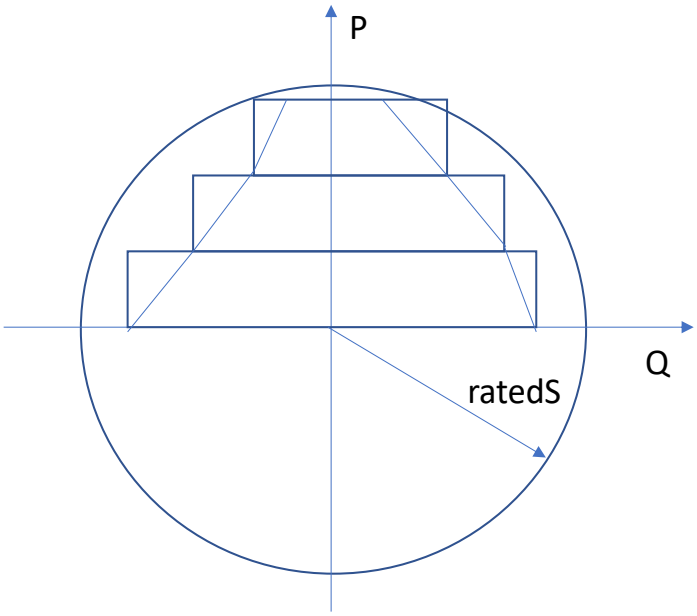

Figure 12 Pairwise max Value

The corners in the boxes in Figure 12~~Figure 12~~ represents the max positive or min negative reactive limit value of the two capability curve points covered by a box. This is option allows the largest deviation from the limit values. The reactive power at limit will always be greater than the capability curve limit.

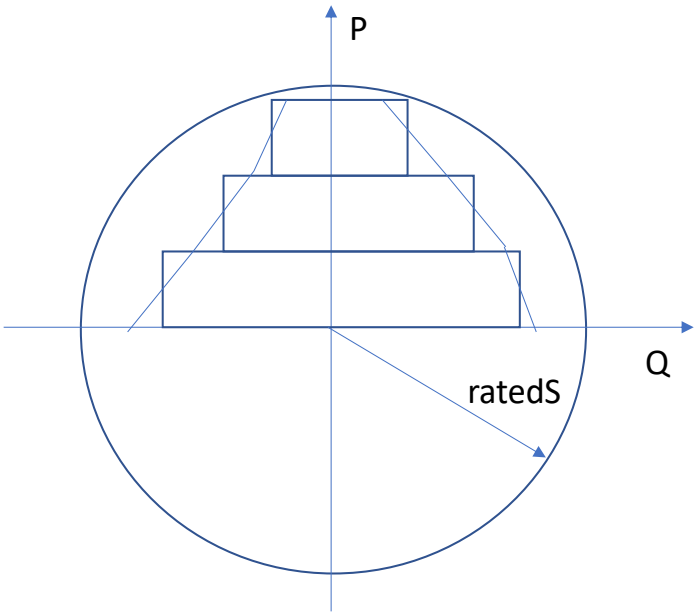

Figure 13 Pairwise Mean Value

For this option a reactive power at the limit may stay within the capability curve limit.

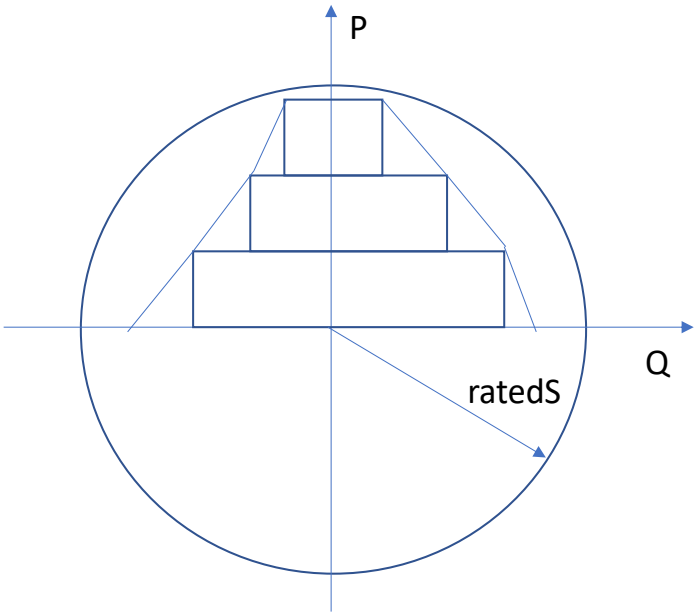

Figure 14 Pairwise Min Value

For this is option a reactive power at the limit will always be inside the reactive capability curve.

8.4 VALIDATION RULES

```
Rule: SCSections  Level: 6  Severity: ERROR

      Details:
      For every instance of cim:ShuntCompensator, cim:LinearShuntCompensator and
      cim:NonLinearShuntCompensator, the value of cim:ShuntCompensator.sections
      should be lower than or equal to the value of
      cim:ShuntCompensator.maximumSections.

      Justification:

      Message:
      Number of sections out of range.

      Usage: #IGMRuleSet #CGMRuleSet

Rule: GenActivePowerInfeedLim  Level: 6  Severity: WARNING

      Details:
      The negated value of cim:RotatingMachine.p shall be within the following range
      depending on the value of cim:SynchronousMachine.operatingMode:
      1) In case of cim:SynchronousMachineOperatingMode.generator
      - [cim:GeneratingUnit.minOperatingP,cim:GeneratingUnit.maxOperatingP] if
        cim:GeneratingUnit.minOperatingP is greater than or equal to zero.
      - [0,cim:GeneratingUnit.maxOperatingP] if cim:GeneratingUnit.minOperatingP is less
        than zero.
      2) In case of cim:SynchronousMachineOperatingMode.motor
```

```
        - [cim:GeneratingUnit.minOperatingP,cim:GeneratingUnit.maxOperatingP] if
          cim:GeneratingUnit.minOperatingP is less than zero and
          cim:GeneratingUnit.maxOperatingP is less than or equal to zero.
        - [cim:GeneratingUnit.minOperatingP,0] if cim:GeneratingUnit.maxOperatingP is
          greater than zero.
        3) In case of cim:SynchronousMachineOperatingMode.condenser
        cim:RotatingMachine.p shall equal to zero as there is no active power output.

        Note 1: Negation is necessary due to the load sign convention.
        Note 2: A cim:SynchronousMachine with cim:RotatingMachine.p = 0 is considered out
        of service if cim:SynchronousMachine.operatingMode is either
        cim:SynchronousMachineOperatingMode.motor or
        cim:SynchronousMachineOperatingMode.generator.
        Note 3: In cases where the operating mode is
        cim:SynchronousMachineOperatingMode.condenser the synchronous machine might in
        reality output small amounts of active power. This rule will generate warning that
        can be assessed. It could then be advised that as such amounts do not have
        substantial effect on the IGM, condensers shall be modelled with zero active power.

        Justification:
        Load sign convention is used for the power infeed, whereas nameplate ratings are
        used for the operating limits.

        Message:
        Active power output of the cim:SynchronousMachine is out of range.

        Usage: #IGMRuleSet #CGMRuleSet

Rule: GenActivePowerInfeedDiffW  Level: 6  Severity: WARNING

        Details:
        For every instance of cim:SynchronousMachine, the value of
        cim:RotatingMachine.p should not deviate more than SSH_SV_MAX_P_DIFF MW
        from the value of cim:SvPowerFlow.p for the associated terminal.
        Note that disconnected synchronous machines should have zero values in SSH.

        Justification:
        The SSH data should be based on a solved power flow (CGMM) and as a consequence,
        the values in SSH (input) and SV (calculation results) should not be far away.

        Message:
        Assumed generation infeed of cim:SynchronousMachine deviates from calculated
        generation infeed more than SSH_SV_MAX_P_DIFF.

        Usage: #IGMRuleSet #CGMRuleSet

Rule: GenActivePowerInfeedDiffE  Level: 6  Severity: ERROR

        Details:
        The aggregated sum of the values of cim:RotatingMachine.p shall not
        deviate more than SSH_SV_TOT_P_DIFF MW from the aggregated sum of the values of
        cim:SvPowerFlow.p for the terminals connected to synchronous machines.
        Note that disconnected synchronous machines should have zero values in SSH.

        Justification:
        The SSH data should be based on a solved power flow (CGMM) and as a consequence,
```

```
4327        the values in SSH (input) and SV (calculation results) should not be far away.
4328
4329        Message:
4330        Assumed aggregated active power generation infeed deviates from calculated
4331        generation infeed more than SSH_SV_TOT_P_DIFF MW.
4332
4333        Usage: #IGMRuleSet #CGMRuleSet
4334
4335  Rule: GenReactivePowerInfeedDiffW  Level: 6  Severity: WARNING
4336
4337        Details:
4338        For every instance of cim:SynchronousMachine, the value of
4339        cim:RotatingMachine.q should not deviate more than SSH_SV_MAX_Q_DIFF MVAr
4340        from the value of cim:SvPowerFlow.q for the associated terminal.
4341        Note that disconnected synchronous machines should have zero values in SSH.
4342
4343        Justification:
4344        Considering the Power Flow settings, the reactive power shift
4345        should be minimal.
4346
4347        Message:
4348        Potential reactive power problem located for cim:SynchronousMachine, assumed
4349        reactive power generation of cim:SynchronousMachine deviates from calculated
4350        more than SSH_SV_MAX_Q_DIFF MVAr.
4351
4352        Usage: #IGMRuleSet #CGMRuleSet
4353
4354  Rule: GenReactivePowerInfeedLim  Level: 6  Severity: WARNING
4355
4356        Details:
4357        The reactive power provided to the network by a cim:SynchronousMachine shall
4358        stay within limits regardless if it is controlling or not
4359        - negated cim:RotatingMachine.q greater or equal than cim:SynchronousMachine.minQ
4360          if provided
4361        - negated cim:RotatingMachine.q less or equal than cim:SynchronousMachine.maxQ
4362          if provided
4363        Note1: cim:RotatingMachine.q shall be negated due to the load sign convention.
4364        The rule is applied for all cim:SynchronousMachine-s with and without associated
4365        cim:ReactiveCapabilityCurve.
4366
4367
4368        Justification:
4369        The reactive power infeed at PQ nodes should be within limits.
4370
4371        Message:
4372        Generation reactive power infeed out of range.
4373
4374        Usage: #IGMRuleSet #CGMRuleSet
4375
4376  Rule: GenRCCPowerInfeed  Level: 6  Severity: WARNING
4377
4378        Details:
4379        The power provided to the network by a cim:SynchronousMachine should stay
4380        within limits regardless if it is controlling or not. This rule applies
4381        when a reactive capability curve is present. Active power is restricted as
4382        - RCCCD = RCC.mRID=CD[CD.Curve]
```

```
4383          - -RM.p LE max(RCCCD/CD.xvalue) and
4384          - -RM.p GE min(RCCCD/CD.xvalue)
4385          where
4386          - The notation above is an XPath expression
4387          - RCC = cim:ReactiveCapabilityCurve
4388          - RCCCD = The cim:CurveData points that belongs to the RCC
4389          - CD = cim:CurveData
4390          - RM = cim:RotatingMachine, note this is load sign convention
4391          - LE = Less or Equal
4392          - GE = Greater or Equal
4393          Reactive power is restricted as
4394          - CD1 = min(RCCCD[CD.xvalue LE -RM.p])
4395          - CD2 = min(RCCCD[CD.xvalue GE -RM.p])
4396          - RM.q LE interpolate(CD2/CD.y2value, CD2/CD.xvalue, CD1/CD.y2value,
4397                CD1/CD.xvalue, -RM.p)
4398          - RM.q GE interpolate(CD2/CD.y1value, CD2/CD.xvalue, CD1/CD.y1value,
4399                CD1/CD.xvalue, -RM.p)
4400          where
4401          - CD1 = nearest lower active power limit point
4402          - CD2 = nearest higher active power limit point
4403          - interpolate(w1, z1, w2, z2, w) is a function with parameters
4404             - w1 and z1 = the first coordinate point
4405             - w2 and z2 = the second coordinate point
4406             - w = the value along the w axis to interpolate the value along
4407                the z axis
4408             In case interpolation is not used, the mean value between w1
4409             and w2 should be used as limit.
4410
4411          Justification:
4412          The active and reactive power infeed at PQ nodes should be within limits.
4413
4414          Message:
4415          Generation active and/or reactive power infeed out of range.
4416
4417          Usage: #IGMRuleSet #CGMRuleSet
4418
4419    Rule: ValidDER  Level: 6  Severity: WARNING
4420
4421          Details:
4422          For every instance of a DistributedEnergyResource (DER), e.g.
4423          cim:EnergySource, the value of cim:EnergySource.activePower
4424          should be lower than or equal to zero.
4425
4426          Justification:
4427          Due to the load sign convention, decentralized infeed must be
4428          negative or zero.
4429          See IEC TS 61970-600-2:2017 section 7.8.6.
4430
4431          Message:
4432          DER infeed acts as a load.
4433
4434          Usage: #IGMRuleSet #CGMRuleSet
4435
4436    Rule: DERActivePowerInfeedDiffW  Level: 6  Severity: WARNING
4437
4438          Details:
```

```
4439          For every instance of cim:EnergySource, the value of
4440          cim:EnergySource.activePower should not deviate more than SSH_SV_MAX_P_DIFF MW
4441          from the value of cim:SvPowerFlow.p for the associated terminal.
4442          Note that disconnected DER should have zero values in SSH.
4443
4444          Justification:
4445          The SSH data should be based on a solved power flow (CGMM) and as a consequence,
4446          the values in SSH (input) and SV (calculation results) should not be far away.
4447
4448          Message:
4449          Assumed generation infeed of cim:EnergySource deviates from calculated generation
4450          infeed more than SSH_SV_MAX_P_DIFF MW.
4451
4452          Usage: #IGMRuleSet #CGMRuleSet
4453
4454    Rule: DERActivePowerInfeedDiffE  Level: 6  Severity: ERROR
4455
4456          Details:
4457          The aggregated sum of the values of cim:EnergySource.activePower shall not
4458          deviate more than SSH_SV_TOT_P_DIFF MW from the aggregated sum of the values of
4459          cim:SvPowerFlow.p for the terminals connected to cim:EnergySource.
4460          Note that disconnected DER should have zero values in SSH.
4461
4462          Justification:
4463          The SSH data should
4464          be based on a solved power flow (CGMM) and as a consequence, the values in
4465          SSH (input) and SV (calculation results) should not be far away.
4466
4467          Message:
4468          Assumed aggregated active power generation infeed deviates from calculated
4469          generation infeed more than SSH_SV_TOT_P_DIFF MW.
4470
4471          Usage: #IGMRuleSet #CGMRuleSet
4472
4473    Rule: DERReactivePowerInfeedDiffW  Level: 6  Severity: WARNING
4474
4475          Details:
4476          For every instance of cim:EnergySource, the value of
4477          cim:EnergySource.reactivePower should not deviate more than SSH_SV_MAX_Q_DIFF MVAr
4478          from the value of cim:SvPowerFlow.q for the associated terminal.
4479          Note that disconnected DER should have zero values in SSH.
4480
4481          Justification:
4482          The SSH data should be based on a solved power flow (CGMM) and as a consequence,
4483          the values in SSH (input) and SV (calculation results) should not be far away.
4484
4485          Message:
4486          Assumed generation infeed of cim:EnergySource deviates from calculated generation
4487          infeed more than SSH_SV_MAX_Q_DIFF MVAr.
4488
4489          Usage: #IGMRuleSet #CGMRuleSet
4490
4491    Rule: ValidLoad  Level: 6  Severity: WARNING
4492
4493          Details:
4494          For every instance of cim:StationSupply, cim:ConformLoad and
```

```
4495        cim:NonConformLoad, the value of cim:EnergyConsumer.p should be greater
4496        than or equal to zero.
4497
4498        Justification:
4499        Due to the load sign convention, all loads should be
4500        positive or zero. Decentralized generation should be modelled explicitly.
4501        See IEC TS 61970-600-2:2017 section 7.8.5.
4502
4503        Message:
4504        Load infeed acts as a generator.
4505
4506        Usage: #IGMRuleSet #CGMRuleSet
4507
4508   Rule: LoadActivePowerInfeedDiffW  Level: 6  Severity: WARNING
4509
4510        Details:
4511        For every instance of cim:StationSupply, cim:ConformLoad and
4512        cim:NonConformLoad, the value of cim:EnergyConsumer.p should not deviate
4513        more than SSH_SV_MAX_P_DIFF MW from the value of cim:SvPowerFlow.p for the
4514        associated terminal. Note that disconnected loads should have zero values in SSH.
4515
4516        Justification:
4517        The SSH data should be based on a solved power flow (CGMM) and as a consequence,
4518        the values in SSH (input) and SV (calculation results) should not be far away.
4519
4520        Message:
4521        Assumed consumption deviates from calculated consumption more than
4522        SSH_SV_MAX_P_DIFF MW.
4523
4524        Usage: #IGMRuleSet #CGMRuleSet
4525
4526   Rule: LoadActivePowerInfeedDiffE  Level: 6  Severity: ERROR
4527
4528        Details:
4529        The aggregated sum of the values of cim:EnergyConsumer.p shall not
4530        deviate more than SSH_SV_TOT_P_DIFF MW from the aggregated sum of the values of
4531        cim:SvPowerFlow.p for the associated terminals. Note that disconnected
4532        loads should have zero values in SSH.
4533
4534        Justification:
4535        The SSH data should be based on a solved power flow (CGMM) and as a consequence,
4536        the values in SSH (input) and SV (calculation results) should not be far away.
4537
4538        Message:
4539        Assumed aggregated consumption deviates from calculated consumption
4540        more than SSH_SV_TOT_P_DIFF MW.
4541
4542        Usage: #IGMRuleSet #CGMRuleSet
4543
4544   Rule: LoadReactivePowerInfeedDiffW  Level: 6  Severity: WARNING
4545
4546        Details:
4547        For every instance of cim:StationSupply, cim:ConformLoad and
4548        cim:NonConformLoad, the value of cim:EnergyConsumer.q should not deviate
4549        more than SSH_SV_MAX_Q_DIFF MVAr from the value of cim:SvPowerFlow.q for the
4550        associated terminal. Note that disconnected loads should have zero values in SSH.
```

```
4551
4552          Justification:
4553          Considering the Power Flow settings, the reactive power shift
4554          should be minimal.
4555
4556          Message:
4557          Potential reactive power problem located for load instance, assumed reactive power
4558          deviates from calculated more than SSH_SV_MAX_Q_DIFF MVAr.
4559
4560          Usage: #IGMRuleSet #CGMRuleSet
4561
4562    Rule: ENIActivePowerInfeedLim  Level: 6  Severity: WARNING  Template: RuleModel
4563          Details:
4564          The negated value of cim:ExternalNetworkInjection.p should be within the range
4565          [cim:ExternalNetworkInjection.minP, cim:ExternalNetworkInjection.maxP]. The
4566          validation takes into account that both cim:ExternalNetworkInjection.minP and
4567          cim:ExternalNetworkInjection.maxP will be negative if the equivalent injection is
4568          representing load operating range as cim:ExternalNetworkInjection.minP and
4569          cim:ExternalNetworkInjection.maxP are following generator sign convention (i.e.
4570          positive sign when generating power).
4571          Note1: Negation is necessary due to the load sign convention.
4572          Note2: An instance with cim:ExternalNetworkInjection.p = 0
4573          is considered out of service.
4574
4575          Justification:
4576          Load sign convention is used for the power infeed. The operating point should be
4577          within defined limits.
4578
4579          Message:
4580          ExternalNetworkInjection active power infeed is out of range.
4581
4582          Usage: #IGMRuleSet #CGMRuleSet
4583
4584    Rule: ENIReactivePowerInfeedLim  Level: 6  Severity: WARNING
4585
4586          Details:
4587          The negated value of cim:ExternalNetworkInjection.q should be within the range
4588          [cim:ExternalNetworkInjection.minQ, cim:ExternalNetworkInjection.maxQ]. The
4589          validation takes into account that both cim:ExternalNetworkInjection.minQ and
4590          cim:ExternalNetworkInjection.maxQ will be negative if the equivalent injection is
4591          representing load operating range as cim:ExternalNetworkInjection.minQ and
4592          cim:ExternalNetworkInjection.maxQ are following generator sign convention (i.e.
4593          positive sign when generating power).
4594          Note1: Negation is necessary due to the load sign convention.
4595
4596          Justification:
4597          Load sign convention is used for the power infeed. The operating point should be
4598          within defined limits.
4599
4600          Message:
4601          ExternalNetworkInjection reactive power infeed is out of range.
4602
4603          Usage: #IGMRuleSet #CGMRuleSet
4604
4605    Rule: ENIActivePowerInfeedDiffW  Level: 6  Severity: WARNING
4606
```

```
4607          Details:
4608          For every instance of cim:ExternalNetworkInjection, the value of
4609          cim:ExternalNetworkInjection.p should not deviate more than SSH_SV_MAX_P_DIFF MW
4610          from the value of cim:SvPowerFlow.p for the associated terminal
4611
4612          Justification:
4613          The SSH data should be based on a solved power flow (CGMM)
4614          and as a consequence, the values in SSH (input) and SV (calculation results)
4615          should not be far away.
4616          Note: cim:ExternalNetworkInjection should not be used frequently considering its
4617          purpose.
4618
4619          Message:
4620          Assumed external injection deviates from calculated
4621          more than SSH_SV_MAX_P_DIFF MW.
4622
4623          Usage: #IGMRuleSet #CGMRuleSet
4624
4625    Rule: ENIActivePowerInfeedDiffE  Level: 6  Severity: ERROR
4626
4627          Details:
4628          The aggregated sum of the values of cim:ExternalNetworkInjection.p shall
4629          not deviate more than SSH_SV_TOT_P_DIFF MW from the aggregated sum of the
4630          values of cim:SvPowerFlow.p for the associated terminals
4631
4632          Justification:
4633          The SSH data should be based on a solved power flow (CGMM) and as a consequence,
4634          the values in SSH (input) and SV (calculation results) should not be far away.
4635          Note: cim:ExternalNetworkInjection should not be used frequently considering its
4636          purpose.
4637
4638          Message:
4639          Assumed aggregated sum of external injections deviates from calculated
4640          more than SSH_SV_TOT_P_DIFF MW
4641
4642          Usage: #IGMRuleSet #CGMRuleSet
4643
4644    Rule: ENIReactivePowerInfeedDiffW  Level: 6  Severity: WARNING
4645
4646          Details:
4647          For every cim:ExternalNetworkInjection the value of
4648          cim:ExternalNetworkInjection.q should not deviate
4649          more than SSH_SV_MAX_Q_DIFF MVAr from the value of cim:SvPowerFlow.q for the
4650          associated terminal.
4651          Note that disconnected loads should have zero values in SSH.
4652
4653          Justification:
4654          Considering the Power Flow settings, the reactive power shift
4655          should be minimal.
4656
4657          Message:
4658          Potential reactive power problem located for cim:ExternalNetworkInjection,
4659          assumed reactive power deviates from calculated more than
4660          SSH_SV_MAX_Q_DIFF MVAr
4661
4662          Usage: #IGMRuleSet #CGMRuleSet
```

Rule: EIActivePowerInfeedLim Level: 6 Severity: WARNING

Details:
The negated value of non-boundary cim:EquivalentInjection.p should be within the range [cim:EquivalentInjection.minP, cim:EquivalentInjection.maxP]. The validation takes into account that both cim:EquivalentInjection.maxP and cim:EquivalentInjection.minP will be negative if the equivalent injection is representing load operating range as cim:EquivalentInjection.minP and cim:EquivalentInjection.maxP are following generator sign convention (i.e. positive sign when generating power).
Note1: Negation is necessary due to the load sign convention.
Note2: An instance with cim:EquivalentInjection.p = 0 is considered out of service.

Justification:
Load sign convention is used for the power infeed. The operating point should be within defined limits.

Message:
EquivalentInjection active power infeed is out of range.

Usage: #IGMRuleSet #CGMRuleSet

Rule: EIReactivePowerInfeedLim Level: 6 Severity: WARNING

Details:
The negated value of non-boundary cim:EquivalentInjection.q should be with the range [cim:EquivalentInjection.minQ, cim:EquivalentInjection.maxQ]. The validation takes into account that both cim:EquivalentInjection.maxQ and cim:EquivalentInjection.minQ will be negative if the equivalent injection is representing load operating range as cim:EquivalentInjection.minQ and cim:EquivalentInjection.maxQ are following generator sign convention (i.e. positive sign when generating power).
Note1: Negation is necessary due to the load sign convention.

Justification:
Load sign convention is used for the power infeed. The operating point should be within defined limits.

Message:
EquivalentInjection reactive power infeed is out of range.

Usage: #IGMRuleSet #CGMRuleSet

Rule: EIActivePowerInfeedDiffW Level: 6 Severity: WARNING

Details:
For every non-boundary cim:EquivalentInjection, the value of cim:EquivalentInjection.p should not deviate more than SSH_SV_MAX_P_DIFF MW from the value of cim:SvPowerFlow.p for the associated terminal

Justification:
The SSH data should be based on a solved power flow (CGMM) and as a consequence, the values in SSH (input) and SV (calculation results) should not be far away.
Note: cim:EquivalentInjection should not be used frequently considering its purpose.

```
4719
4720          Message:
4721          Assumed non-boundary cim:EquivalentInjection injection deviates from calculated
4722          more than SSH_SV_MAX_P_DIFF MW.
4723
4724          Usage: #IGMRuleSet #CGMRuleSet
4725
4726    Rule: EIActivePowerInfeedDiffE  Level: 6  Severity: ERROR
4727
4728          Details:
4729          The aggregated sum of the values of non-boundary cim:EquivalentInjection.p
4730          shall not deviate more than SSH_SV_TOT_P_DIFF MW from the aggregated sum of
4731          the values of cim:SvPowerFlow.p for the associated terminals
4732
4733          Justification:
4734          The SSH data should be based on a solved power flow (CGMM) and as a consequence,
4735          the values in SSH (input) and SV (calculation results) should not be far away.
4736          Note: cim:EquivalentInjection should not be used frequently considering its
4737          purpose.
4738
4739          Message:
4740          Assumed non-boundary cim:EquivalentInjection aggregated injection deviates from
4741          calculated more than SSH_SV_TOT_P_DIFF MW.
4742
4743          Usage: #IGMRuleSet #CGMRuleSet
4744
4745    Rule: EIReactivePowerInfeedDiffW  Level: 6  Severity: WARNING
4746
4747          Details:
4748          For every instance of cim:EquivalentInjection, the value of
4749          cim:EquivalentInjection.q should not deviate more than SSH_SV_MAX_Q_DIFF Mvar
4750          from the value of cim:SvPowerFlow.q for the associated terminal.
4751
4752
4753          Justification:
4754          The SSH data should be based on a solved power flow (CGMM) and as a consequence,
4755          the values in SSH (input) and SV (calculation results) should not be far away.
4756
4757          Message:
4758          Assumed generation infeed of cim:EquivalentInjection deviates from calculated
4759          generation
4760          infeed more than SSH_SV_MAX_Q_DIFF Mvar.
4761
4762          Usage: #IGMRuleSet #CGMRuleSet
4763
4764
4765    Rule: NetInterchange1  Level: 6  Severity: WARNING
4766
4767          Details:
4768          For a cim:ControlArea of type interchange the aggregated sum of the values
4769          of cim:SvPowerFlow.p for cim:Terminals referenced by cim:TieFlow.Terminal shall
4770          not deviate from the value of cim:ControlArea.netInterchange with more than
4771          cim:ControlArea.pTolerance, if provided. In cases where cim:ControlArea.pTolerance
4772          is not provided the value of INTERCH_IMBALANCE_WARNING MW is used in the comparison.
4773
4774          There are some implications from other rules to be considered:
```

4775 1) According to level 5 rule SvPowerFlowBranchInstances the cim:Terminal referenced
4776 by a cim:TieFlow.Terminal is located at a boundary
4777 cim:TopologicalNode, hence the attribute cim:TieFlow.positiveFlowIn
4778 is always true.
4779 2) According to level 5 rule SvPowerFlowBranchInstances2 the cim:Terminal
4780 of cim:ACLineSegment, cim:PowerTransformer or retained cim:Switch, etc. should have
4781 a cim:SvPowerFlow.
4782 3) According to level 5 rule SvPowerFlowInstances every cim:EquivalentInjection
4783 has a cim:SvPowerFlow.
4784
4785 As a consequence cim:SvPowerFlow related to boundary cim:EquivalentInjection-s
4786 must be used in the summation but with negated value. cim:SvPowerFlow participates
4787 in the sum if the cim:Terminal is a terminal of cim:EquivalentInjection, which is
4788 connected to a boundary cim:TopologicalNode, referenced by a cim:Terminal, which
4789 is also associated to a cim:TieFlow through cim:TieFlow.Terminal.
4790
4791 Note1: cim:ControlArea.netInterchange include AC and DC exchanges.
4792 Note2: An HVDC Boundary cim:TopologicalNode has a cim:IdentifiedObject.description
4793 attribute with leading characters 'HVDC'.
4794
4795 Justification:
4796 Area interchange control uses ControlArea.netInterchange as
4797 set point, the TieFlow terminals as State Variables and the ConformLoad
4798 within the ControlArea as Control Variables.
4799
4800 Message:
4801 Netted Area position not respected more than INTERCH_IMBALANCE_WARNING MW or
4802 cim:ControlArea.pTolerance, if provided.
4803
4804 Usage: #IGMRuleSet #CGMRuleSet
4805
4806 Rule: NetInterchange2 Level: 6 Severity: ERROR
4807
4808 Details:
4809 For a cim:ControlArea of type interchange the aggregated sum of the values
4810 of cim:SvPowerFlow.p for cim:Terminals referenced by cim:TieFlow.Terminal
4811 shall not deviate from the value of cim:ControlArea.netInterchange with more
4812 than INTERCH_IMBALANCE_ERROR MW.
4813 There are some implications from other rules to be considered:
4814 1) According to level 5 rule SvPowerFlowBranchInstances the cim:Terminal
4815 referenced by a cim:TieFlow.Terminal is located at a boundary
4816 cim:TopologicalNode, hence the attribute cim:TieFlow.positiveFlowIn
4817 is always true.
4818 2) According to level 5 rule SvPowerFlowBranchInstances2 the cim:Terminal
4819 of cim:ACLineSegment, cim:PowerTransformer or retained cim:Switch, etc. should have
4820 a cim:SvPowerFlow.
4821 3) According to level 5 rule SvPowerFlowInstances every cim:EquivalentInjection
4822 has a cim:SvPowerFlow.
4823
4824 As a consequence cim:SvPowerFlow related to boundary cim:EquivalentInjection-
4825 scim:Terminal must be used in the summation but with negated value.
4826 cim:SvPowerFlow participates in the sum if the cim:Terminal is a terminal of
4827 cim:EquivalentInjection, which is connected to a boundary cim:TopologicalNode,
4828 referenced by a cim:Terminal, which is also associated to a cim:TieFlow through
4829 cim:TieFlow.Terminal.
4830 Note1: cim:ControlArea.netInterchange include AC and DC exchanges.

Note2: An HVDC Boundary TopologicalNode has a cim:IdentifiedObject.description attribute with leading characters 'HVDC'.

Justification:
Area interchange control uses ControlArea.netInterchange as set point, the TieFlow terminals as State Variables and the ConformLoad within the ControlArea as Control Variables.

Message:
Netted Area position severely not respected for more than INTERCH_IMBALANCE_ERROR MW.

Usage: #IGMRuleSet #CGMRuleSet

Rule: TapPosition Level: 6 Severity: WARNING

Details:
For every instance of cim:RatioTapChanger, cim:PhaseTapChangerLinear, cim:PhaseTapChangerSymmetrical and cim:PhaseTapChangerAsymmetrical, which has cim:RegulatingControl.enabled equal to true, the value of cim:TapChanger.step should not deviate more than SSH_SV_MAX_TAP_STEP_DIFF from the value of cim:SvTapStep.position.

Justification:
Considering the Power Flow settings, the tap position shift should be minimal. The SSH data should be based on a solved power flow (CGMM) and as a consequence, the values in SSH (input) and SV (calculation results) should not be far away.

Message:
Initial tap position deviates more than SSH_SV_MAX_TAP_STEP_DIFF from calculated.

Usage: #IGMRuleSet #CGMRuleSet

Rule: ShuntQ Level: 6 Severity: WARNING

Details:
The rule is checking if cim:SvPowerFlow.q of a cim:LinearShuntCompensator is consistent with cim:SvShuntCompensatorSections.sections. Therefore, for every instance of cim:LinearShuntCompensator, which has cim:RegulatingControl.enabled equals true, the value of cim:SvPowerFlow.q should not deviate more than SSH_SV_MAX_Q_SHUNT_DIFF MVAr from the negated product of the value of cim:SvShuntCompensatorSections.sections, the value of cim:LinearShuntCompensator.bPerSection and the squared value of cim:SvVoltage.v at the cim:TopologicalNode where the cim:LinearShuntCompensator is connected to.

Justification:

Message:
Calculated reactive power output of cim:LinearShuntCompensator differs from cim:SvPowerFlow.q of a cim:LinearShuntCompensator with more than SSH_SV_MAX_Q_SHUNT_DIFF Mvar.

Usage: #IGMRuleSet #CGMRuleSet

Rule: SvInjectionLimit Level: 6 Severity: WARNING

Details:
The absolute value of cim:SvInjection.pInjection shall be less than the SV_INJECTION_LIMIT MW.
The absolute value of cim:SvInjection.qInjection shall be less than the SV_INJECTION_LIMIT Mvar.
cim:SvInjection is instantiated only if P and Q tolerances defined in the power flow calculation settings are not met.

Justification:
The cim:SvInjection values gives the accuracy of the power flow solution.
Large values of cim:SvInjection.pInjection and cim:SvInjection.qInjection indicates a poorly converged power flow solution.
Lots of cim:SvInjection instances below limit will clutter the SV file.

Message:
cim:SvInjection which has either pInjection or qInjection greater than SV_INJECTION_LIMIT.

Usage: #IGMRuleSet #CGMRuleSet

Rule: VoltageProfile Level: 6 Severity: WARNING

Details:
Where a cim:VoltageLimit exists for an energized cim:TopologicalNode, the value of cim:SvVoltage.v
should be lower than or equal to the value of cim:VoltageLimit.value associated with cim:OperationalLimitType.limitType=highVoltage and higher than or equal to the value of cim:VoltageLimit.value associated with cim:OperationalLimitType.limitType=lowVoltage.
In case of multiple limits, the most restrictive shall be used.

Justification:
Considering the Power Flow settings, all voltages should be within defined operational limits.
See IEC TS 61970-600-2:2017 section 6.8.7.

Message:
Calculated voltage out of range.

Usage: #IGMRuleSet #CGMRuleSet

Rule: VoltageTargetsAtTN Level: 6 Severity: WARNING

Details:
For all cim:RegulatingControl instances, with cim:RegulatingControl.discrete=false (including its subclass cim:TapchangerControl)
regulating the same cim:TopologicalNode their cim:RegulatingControl.targetValues should be equal. This rule is for continuous controls, for which RegulatingControl.mode equals RegulatingControlModeKind.voltage and RegulatingControl.enabled equals true.

Justification:
The power flow solver need a single voltage target per cim:TopologicalNode

4943 and the cim:RegulatingControl.targetValues differ the power flow will
4944 have to pick a value. If different Power Flow applications use different
4945 strategies to pick a value the voltage
4946 solution will differ between them which is the reason to warn.
4947
4948 Message:
4949 Conflicting target values of cim:RegulatingControl regulating voltage at the same
4950 cim:TopologicalNode.
4951
4952 Usage: #IGMRuleSet #CGMRuleSet
4953
4954 Rule: VoltageTargetAndDeadbandAtTN Level: 6 Severity: WARNING
4955
4956 Details:
4957 For all cim:RegulatingControl (including its subclass cim:TapChangerControl)
4958 instances at a cim:TopologicalNode with one or more cim:RegulatingControls that
4959 have:
4960 - cim:RegulatingControl.discrete set to true
4961 - cim:RegulatingControl.enabled set to true, and
4962 - cim:RegulatingControl.mode set to cim:RegulatingControlModeKind.voltage,
4963 shall have cim:RegulatingControl.targetValue within the intersection of regulating
4964 ranges formed by all discrete cim:RegulatingControl regulating a
4965 cim:TopologicalNode.
4966 The range for a discrete control (cim:RegulatingControl.discrete set to true) is
4967 {cim:RegulatingControl.targetValue - cim:RegulatingControl.targetDeadband/2,
4968 cim:RegulatingControl.targetValue + cim:RegulatingControl.targetDeadband/2}
4969
4970 Note: the rule is validating both if the ranges of discrete regulating control form
4971 intersection and if the target values of all regulating controls are within the
4972 intersection regulating range.
4973
4974 Justification:
4975 The power flow solver need a single deadband per cim:TopologicalNode
4976 and if the deadbands differ the power flow will have to pick a value. If different
4977 Power Flow applications use different strategies to pick a value the voltage
4978 solution will differ between them which is the reason to warn.
4979
4980 Message:
4981 Either 1) Regulating ranges of discrete regulating controls do not create
4982 intersection or 2) the target values of regulating controls are not within the
4983 intersection range.
4984
4985 Usage: #IGMRuleSet #CGMRuleSet
4986
4987 Rule: EnergizedBoundaryTN Level: 6 Severity: ERROR
4988
4989 Details:
4990 A boundary cim:TopologicalNode with a non-zero cim:EquivalentInjection.p or
4991 cim:EquivalentInjection.q is supposed to be energized and shall have a
4992 solved voltage, i.e. cim:SvVoltage.v shall not be zero.
4993
4994 Justification:
4995 All boundary cim:TopologicalNodes in a power flow model shall have a
4996 solved voltage.
4997
4998 Message:

```
4999          Boundary cim:TopologicalNode with injecting cim:EquivalentInjection without
5000          solved cim:SvVoltage.v.
5001
5002          Usage: #IGMRuleSet #CGMRuleSet
5003
5004    Rule: FakeVoltage  Level: 6  Severity: WARNING
5005
5006          Details:
5007          A cim:TopologicalNode with a solved voltage equal to the
5008          cim:BaseVoltage.nominalVoltage is suspected to copy that value rather than
5009          solving to power flow.
5010
5011          Justification:
5012          This is to prevent from faking the voltage.
5013
5014          Message:
5015          Voltage at cim:TopologicalNode may be fake.
5016
5017          Usage: #IGMRuleSet #CGMRuleSet
5018
5019    Rule: InvalidVoltage  Level: 6  Severity: ERROR
5020
5021          Details:
5022          A cim:SvVoltage lower than 0.4 per unit and greater than 0 is not allowed.
5023
5024          Justification:
5025          A cim:SvVoltage lower than 0.4 per unit and greater than 0 is not reasonable.
5026
5027          Message:
5028          A cim:SvVoltage lower than 0.4 per unit and greater than 0 is not allowed.
5029
5030          Usage: #IGMRuleSet #CGMRuleSet
5031
5032    Rule: DiscreteControl  Level: 6  Severity: ERROR
5033
5034          Details:
5035          For every instance of cim:RegulatingControl (SSH) for which the value of
5036          cim:RegulatingControl.discrete is true and cim:RegulatingControl.enabled
5037          is true the control variables must move in discrete steps. Hence no decimals
5038          are allowed for the following attributes values:
5039          - cim:ShuntCompensator.sections
5040          - related cim:SvShuntCompensatorSections.sections
5041          - cim:TapChanger.step
5042          - related cim:SvTapStep.position.
5043
5044          Justification:
5045          If cim:RegulatingControl.discrete is set to true it is not possible
5046          to move the control variables continuously.
5047
5048          Message:
5049          cim:ShuntCompensator.sections or cim:TapChanger.step or
5050          SvShuntCompensatorSection.sections or SvTapStep.position
5051          shall be an integer value in discrete control.
5052
5053          Usage: #IGMRuleSet #CGMRuleSet
5054
```

```
Rule: ContinuousControl  Level: 6  Severity: WARNING

      Details:
      For every instance of cim:RegulatingControl (SSH) for which the value of
      cim:RegulatingControl.discrete is false and cim:RegulatingControl.enabled
      is true means continuous control. For devices natively being discrete this
      means an imprecise modelling of the behaviour for
      - cim:ShuntCompensator
      - cim:TapChanger.

      Justification:
      If cim:RegulatingControl.discrete is false continuous control is used
      which is an imprecise model.
      For as built equipment the most precise model should be used.

      Message:
      cim:ShuntCompensator or cim:TapChanger should not be used with continuous control.

      Usage: #IGMRuleSet #CGMRuleSet

Rule: RequiredSvVoltage  Level: 6  Severity: ERROR

      Details:
      Instances of cim:SvVoltage is required for all cim:TopologicalNodes.
      If power flow didn't create a solution for a cim:TopologicalNode
      cim:SvVoltage angle and voltage shall be set to zero.

      Justification:
      Instances of cim:SvVoltage is required to know where power flow managed
      to solve.

      Message:
      cim:SvVoltage is missing for cim:TopologicalNode.

      Usage: #IGMRuleSet #CGMRuleSet

Rule: RequiredSvSCSections  Level: 6  Severity: ERROR

      Details:
      The following shall be satisfied for cim:ShuntCompensator:
      1) Each instance of cim:ShuntCompensator shall have cim:SvShuntCompensatorSections
      instantiated.
      2) For a cim:ShuntCompensator that is not used in control by power flow (no
      cim:RegulatingControl associated or if cim:RegulatingControl.enabled equals false)
      the value of SvShuntCompensatorSections.sections shall be the same as
      cim:ShuntCompensator.sections.

      Justification:
      Instances of cim:SvShuntCompensatorSections is required to tell the number
      of sections that was used in the solution.

      Message:
      cim:SvShuntCompensatorSections is missing for shunt compensator or the
      cim:SvShuntCompensatorSections.sections is not the same as
      cim:ShuntCompensator.sections.
```

Usage: #IGMRuleSet #CGMRuleSet

Rule: RequiredSvTapStep Level: 6 Severity: ERROR

Details:

For a cim:TapChanger that is not used in control (no cim:TapChangerControl associated or if cim:RegulatingControl.enabled equals false) by power flow the value of SvTapStep.position shall be the same as cim:TapChanger.step.

Justification:
Instances of cim:SvTapStep is required to tell the step number that was used in the solution.

Message:
cim:SvTapStep.position is not the same as cim:TapChanger.step.

Usage: #IGMRuleSet #CGMRuleSet

Rule: KirchhoffsFirstLaw Level: 6 Severity: ERROR

Details:
The sum of cim:SvPowerFlow.p and sum of cim:SvPowerFlow.q for all cim:SvPowerFlow-s connected to a cim:TopologicalNode shall be within the solution tolerance provided by SV_INJECTION_LIMIT MW/Mvar. If solution tolerance is exceeded a cim:SvInjection shall be provided (the association end the cim:TopologicalNode.SvInjection is required).

Note: cim:SvPowerFlow-s of non-retained cim:Switch (cim:Switch.retained is false) shall be excluded.

Justification:
The sum of power flow into a node is zero according to Kirchhoffs first law. The power flow in non-retained cim:Switch-es may not have been correctly computed and be inconsistent with the other power flows on the cim:TopologicalNode. Hence non-retained cim:Switch-es shall be excluded from the summation to achieve a more robust result.

Message:
The sum of the cim:SvPowerFlow-s reported on a cim:TopologicalNode is not within the solution tolerance and there is no SvInjection provided.

Usage: #IGMRuleSet #CGMRuleSet

9 LEVEL 7 VALIDATION: COORDINATION

9.1 INTRODUCTION

In this category, we validate IGMs against other IGMs and against reference data. This can only be done when neighbouring TSO issued their IGMs for the same scenarioTime and if reference data from PEVF or CGMA is available for the same scenarioTime. The referenced MAS always applies to IGM the referenced Power System Resources belong to.

9.2 VALIDATION RULES

```
Rule: InconsistentCurrentLimits  Level: 7  Severity: WARNING

      Details:
      The value of cim:CurrentLimit.value is expected to be the same for a
      tie line on both sides of the boundary point.
      The rule applies only for cim:CurrentLimit which has association end
      cim:OperatingLimit.OperatingLimitType referencing a cim:OperatingLimitType with
      entsoe: OperatingLimitType.limitType equal to entsoe:LimitTypeKind.patl.
      The lowest limit shall be used in studies.
      To allow for a small deviation the limit values standard rounding to integer is
      applied before comparing and provided for the reporting.

      Justification:
      Tie line data is supposed to be coordinated by TSOs.

      Message:
      Current limits of type PATL are inconsistent at a tie line.

      Usage: #CGMRuleSet


Rule: UnpairedTieFlow  Level: 7  Severity: WARNING

      Details:
      The rule is checking updated SSH values only.
      An AC boundary cim:TopologicalNode which has two branches and two
      cim:EquivalentInjections linking two IGMs is a paired boundary cim:TopologicalNode.
      In this case the cim:EquivalentInjection-s shall have the sum of p and the sum of
      q values  equal to zero (no transfer of power).

      Note: An HVDC Boundary Point has a cim:IdentifiedObject.description
      attribute with leading characters equal to 'HVDC'.

      Justification:
      cim:TieFlow is typically calculated at the AC Tie Line terminal,
      connected to the boundary point for AC Tie Lines (regardless of its
      position on the Tie line) and at the Point of Common Coupling for HVDC
      links.

      Message:
      A paired AC boundary point has cim:EquivalentInjection-s that are not aligned.

      Usage: #CGMRuleSet

Rule: ACTielineBV  Level: 7  Severity: ERROR

      Details:
      For a cim:ControlArea of type interchange all cim:TieFlow branches, which:
      - are not connected to an HVDC boundary point, and
      - have a direct association to cim:BaseVoltage
      shall have a cim:BaseVoltage.nominalVoltage that deviates no more than
      BOUNDARY_BV_MAX_DIFF from the cim:BaseVoltage.nominalVoltage of the
      boundary point obtained from the association end cim:TopologicalNode.BaseVoltage.
```

```
5214          Note: An HVDC Boundary Point has a cim:IdentifiedObject.description
5215          attribute equal to 'HVDC'.
5216
5217          Justification:
5218          See section 6.10.2 of IEC TS 61970-600-2:2017.
5219
5220          Message:
5221          AC Tie line nominalVoltage deviates from the boundary point base voltage
5222          more than BOUNDARY_BV_MAX_DIFF.
5223
5224          Usage: #IGMRuleSet #CGMRuleSet
5225
5226    Rule: ACScheduleMatch1  Level: 7  Severity: WARNING
5227
5228          Details:
5229          The sum of cim:SvPowerFlow.p should match
5230          the value of the external AC schedule with the same cim:ControlArea EIC 'Y'
5231          code within INTERCH_IMBALANCE_WARNING MW threshold. The following conditions apply
5232          when creating the sum:
5233          - cim:SvPowerFlow related to boundary cim:EquivalentInjection-s   must be used in
5234            the summation but with negated value.
5235          - cim:SvPowerFlow participates in the sum if the cim:Terminal is a terminal of
5236            cim:EquivalentInjection which is connected to a boundary cim:TopologicalNode
5237            (HVDC Boundary TopologicalNode-s are excluded), referenced by a cim:Terminal,
5238            which is also associated to a cim:TieFlow through cim:TieFlow.Terminal.
5239
5240          Note: An HVDC Boundary cim:TopologicalNode has a cim:IdentifiedObject.description
5241          attribute with leading characters 'HVDC'.
5242
5243          Justification:
5244          In the Reporting Information Market Document, issued by PEVF or CGMA,
5245          the EIC 'Y' code is found in the domain.mRID, in the IGM it is the value
5246          of attribute entsoe:IdentifiedObject.EnergyIdentCodeEic for the ControlArea
5247          instance.
5248
5249          Message:
5250          AC tie flows doesn't match the scheduled interchange value
5251          more than INTERCH_IMBALANCE_WARNING MW.
5252
5253          Usage: #IGMRuleSet #CGMRuleSet
5254
5255    Rule: ACScheduleMatch2  Level: 7  Severity: ERROR
5256
5257          Details:
5258          The sum of cim:SvPowerFlow.p tie flows should match
5259          the value of the external AC schedule with the same cim:ControlArea
5260          EIC 'Y' code within INTERCH_IMBALANCE_ERROR MW threshold.
5261          The following conditions apply when creating the sum:
5262          - cim:SvPowerFlow related to boundary cim:EquivalentInjection-s   must be used in
5263            the summation but with negated value.
5264          - cim:SvPowerFlow participates in the sum if the cim:Terminal is a terminal of
5265            cim:EquivalentInjection which is connected to a boundary cim:TopologicalNode
5266            (HVDC Boundary TopologicalNode-s are excluded), referenced by a cim:Terminal
5267            which is also associated to a cim:TieFlow through cim:TieFlow.Terminal.
5268
5269          Note: An HVDC Boundary TopologicalNode has a cim:IdentifiedObject.description
```

```
5270          attribute with leading characters 'HVDC'.
5271
5272          Justification:
5273          In the Reporting Information Market Document, issued by PEVF or CGMA,
5274          the EIC 'Y' code is found in the domain.mRID, in the IGM it is the value
5275          of attribute entsoe:IdentifiedObject.EnergyIdentCodeEic for the ControlArea
5276          instance.
5277
5278          Message:
5279          AC tie flows doesn't match the scheduled interchange values
5280          more than INTERCH_IMBALANCE_ERROR MW.
5281
5282          Usage: #IGMRuleSet #CGMRuleSet
5283
5284
5285    Rule: HVDCScheduleMatch1  Level: 7  Severity: WARNING
5286
5287          Details:
5288          The cim:SvPowerFlow.p value should match the value
5289          of the external schedule for the same cim:ControlArea
5290          EIC 'Y' code and with the same connectingLine_RegisteredResource EIC 'T'
5291          code within INTERCH_IMBALANCE_WARNING MW threshold. The following conditions apply:
5292          - cim:SvPowerFlow related to boundary cim:EquivalentInjection-s   must be used but
5293            with negated value.
5294          - cim:SvPowerFlow participates in the comparison if the cim:Terminal is a terminal
5295            of cim:EquivalentInjection which is connected to a boundary cim:TopologicalNode
5296            (HVDC Boundary TopologicalNode), referenced by a cim:Terminal, which is also
5297            associated to a cim:TieFlow through cim:TieFlow.Terminal.
5298
5299          Note: An HVDC Boundary cim:TopologicalNode has a cim:IdentifiedObject.description
5300          attribute with leading characters 'HVDC'.
5301
5302          Justification:
5303          In the Reporting Information Market Document, issued by PEVF or CGMA,
5304          the EIC 'Y' code is found in the domain.mRID, in the IGM it is the value
5305          of attribute entsoe:IdentifiedObject.EnergyIdentCodeEic for the cim:ControlArea
5306          instance. The EIC 'T' code is found in the TimeSeries in the
5307          connectingLine_RegisteredResource.mRID, in the IGM it is the value of
5308          attribute entsoe:IdentifiedObject.EnergyIdentCodeEic for the Boundary
5309          point instance, the terminal is connected to.
5310
5311          Message:
5312          HVDC flow doesn't match the scheduled interchange value
5313          more than INTERCH_IMBALANCE_WARNING MW.
5314
5315          Usage: #IGMRuleSet #CGMRuleSet
5316
5317    Rule: HVDCScheduleMatch2  Level: 7  Severity: ERROR
5318
5319          Details:
5320          The cim:SvPowerFlow.p value shall match the value
5321          of the external schedule for the same cim:ControlArea
5322          EIC 'Y' code and with the same connectingLine_RegisteredResource EIC 'T'
5323          code within INTERCH_IMBALANCE_ERROR MW threshold. The following conditions apply:
5324          - cim:SvPowerFlow related to boundary cim:EquivalentInjection-s   must be used but
5325            with negated value.
```

- cim:SvPowerFlow participates in the comparison if the cim:Terminal is a terminal of cim:EquivalentInjection which is connected to a boundary cim:TopologicalNode (HVDC Boundary TopologicalNode), referenced by a cim:Terminal, which is also associated to a cim:TieFlow through cim:TieFlow.Terminal.

Note: An HVDC Boundary cim:TopologicalNode has a cim:IdentifiedObject.description attribute with leading characters 'HVDC'.

Justification:
In the Reporting Information Market Document, issued by PEVF or CGMA, the EIC 'Y' code is found in the domain.mRID, in the IGM it is the value of attribute entsoe:IdentifiedObject.EnergyIdentCodeEic for the cim:ControlArea instance. The EIC 'T' code is found in the TimeSeries in the connectingLine_RegisteredResource.mRID, in the IGM it is the value of attribute entsoe:IdentifiedObject.EnergyIdentCodeEic for the Boundary point instance, the terminal is connected to.

Message:
HVDC flow doesn't match the scheduled interchange value more than INTERCH_IMBALANCE_ERROR MW

Usage: #IGMRuleSet #CGMRuleSet

Rule: NetInterchangeMatch1 Level: 7 Severity: WARNING

Details:
For every cim:ControlArea of type interchange, the value of cim:ControlArea.netInterchange should not deviate more than INTERCH_IMBALANCE_WARNING MW from the sum of the netted area AC and DC positions in the aggregated netted external schedules (PEVF or CGMA) for the same scenarioTime and with the same EIC 'Y' code. If no netted area AC or DC positions or netted external schedule can be found for the control area this rule skipped.

Justification:
In the Reporting Information Market Document, issued by PEVF or CGMA, the EIC 'Y' code is found in the domain.mRID, in the IGM it is the value of attribute entsoe:IdentifiedObject.EnergyIdentCodeEic for the cim:ControlArea instance.

Message:
cim:ControlArea netInterchange deviates more than INTERCH_IMBALANCE_WARNING MW from netted area position.

Usage: #IGMRuleSet #CGMRuleSet

Rule: NetInterchangeMatch2 Level: 7 Severity: ERROR

Details:
For every cim:ControlArea of type interchange, the value of cim:ControlArea.netInterchange should not deviate more than INTERCH_IMBALANCE_ERROR MW from the sum of the netted area AC and DC positions in the aggregated netted external schedules (PEVF or CGMA) for the same scenarioTime and with the same EIC 'Y' code. If no netted area AC or DC positions or netted external schedule can be found for the control area this rule skipped.

```
5382
5383          Justification:
5384          In the Reporting Information Market Document, issued by PEVF or CGMA,
5385          the EIC 'Y' code is found in the domain.mRID, in the IGM it is the value
5386          of attribute entsoe:IdentifiedObject.EnergyIdentCodeEic for the
5387          cim:ControlArea instance.
5388
5389          Message:
5390          cim:ControlArea netInterchange deviates more than INTERCH_IMBALANCE_ERROR MW from
5391          netted area position.
5392
5393          Usage: #IGMRuleSet #CGMRuleSet
5394
5395    Rule: InconsistentTnBaseVoltage  Level: 7  Severity: WARNING
5396
5397          Details:
5398          All equipment with a direct association to cim:BaseVoltage connected to a
5399          cim:TopologicalNode shall have a cim:BaseVoltage.nominalVoltage that deviates no
5400          more than BOUNDARY_BV_MAX_DIFF   from the cim:BaseVoltage.nominalVoltage of the
5401          cim:BaseVoltage referenced by the association end cim:TopologicalNode.BaseVoltage.
5402
5403
5404          Justification:
5405          If the cim:BaseVoltage.nominalVoltage differs this may indicate a topology error.
5406
5407          Message:
5408          cim:BaseVoltages.nominalVoltage at a cim:TopologicalNode differs
5409          more than BOUNDARY_BV_MAX_DIFF from the cim:BaseVoltage.nominalVoltage of the
5410          connected equipment.
5411
5412          Usage: #IGMRuleSet
5413
5414    Rule: PairedEICompatibility  Level: 7  Severity: ERROR
5415
5416          Details:
5417          The rule is checking SSH information for a CGM.
5418          The two cim:EquivalentInjection-s at a boundary cim:TopologicalNode shall have:
5419          - control disabled (cim:EquivalentInjection.regulationStatus = false)
5420          - the sum of their active power injections shall equal zero
5421            (cim:EquivalentInjection.p)
5422          - the sum of their reactive power injections shall equal zero
5423            (cim:EquivalentInjection.q)
5424
5425          Justification:
5426          A cim:EquivalentInjection represents the power flow towards a boundary
5427          cim:TopologicalNode.
5428          If the neighbouring IGM has voltage control capability this could be modelled by
5429          enabling the cim:EquivalentInjection control
5430           (cim:EquivalentInjection.regulationStatus set to true).
5431          When a CGM is built and both networks are connected at a boundary
5432          - the cim:EquivalentInjection control shall be disabled to avoid duplicate
5433            controls.
5434          - the sum of their active and reactive powers must equal zero not to disturb the
5435            solution.
5436
5437          Message:
```

```
5438        Paired cim:EquivalentInjection-s at a boundary shall have control disabled
5439        (cim:EquivalentInjection.regulationStatus = false),
5440        the sum of the active power (cim:EquivalentInjection.p) shall equal zero and
5441        the sum of the reactive power (cim:EquivalentInjection.q) shall equal zero.
5442
5443        Usage: #CGMRuleSet
5444
```

5445 10 LEVEL 8 VALIDATION: CONVERGENCE BEHAVIOUR AND CGM 5446 PLAUSIBILITY

5447 10.1 CONVERGENCE BEHAVIOUR OF IGM

5448 In this section the focus is on the convergence behaviour of the Individual Grid Model, before the
5449 actual merge is initiated.

5450 The Individual Grid Models are expected to be based on a solved model in the local tool, which is
5451 expressed in the operating assumptions and topology derived from this solved case.

5452 The only IGM specific rule is IGMConvergence first in section 10.3.

5453 10.2 PLAUSIBILITY OF CGM

5454 In this section the focus is on calculation results that impact credibility of the CGM solution, because
5455 the modelling assumptions for the IGMs with respect to the boundary flows do not reflect reality.

5456 10.3 VALIDATION RULES

```
5457  Rule: IGMConvergence  Level: 8  Severity: ERROR
5458
5459        Details:
5460        This rule applies to IGMs only.
5461        It shall be possible to solve the power flow with the following power
5462        flow settings:
5463        - Full Newton Raphson power flow algorithm.
5464        - Switched shunt adjustment must be set to enabled for shunts used for
5465          voltage regulation.
5466        - Transformer tap adjustment is set to enabled.
5467        - Q limits shall be respected for EquivalentInjection,
5468          ExternalNetworkInjection, SynchronousMachines, SVCs and
5469          SynchronousCondensers (also for slack node/swing bus).
5470        - Distributed generation slack is set to enabled
5471          (proportional to GeneratingUnit.normalPF).
5472        - Maximum mismatch is set to SV_INJECTION_LIMIT MW and SV_INJECTION_LIMIT MVAr per
5473          node.
5474        - Controlled node voltage error convergence tolerance = 0.0001 pu
5475          (The largest difference between actual and scheduled voltage magnitude in
5476          per unit at each node where voltage is subject to control to a set point,
5477          and for which at least one of the devices participating in the control of
5478          bus voltage to its set point is not at a reactive power limit, must be less
```

```
5479          than the controlled bus voltage error convergence tolerance).
5480
5481        Justification:
5482
5483        Message:
5484        Power flow could not be calculated for IGM with required settings.
5485        Check diagnostic messages.
5486
5487        Usage: #IGMRuleSet
5488
5489    Rule: CGMConvergence  Level: 8  Severity: WARNING
5490
5491        Details:
5492        This rule applies to CGMs only.
5493        It shall be possible to solve the power flow with the following power
5494        flow settings:
5495        - Full Newton Raphson power flow algorithm.
5496        - Switched shunt adjustment must be set to enabled for shunts used for
5497          voltage regulation.
5498        - Transformer tap adjustment is set to enabled.
5499        - Q limits shall be respected for EquivalentInjection,
5500          ExternalNetworkInjection, SynchronousMachines, SVCs and
5501          SynchronousCondensers (also for slack node/swing bus).
5502        - Area interchange control is set to enabled.
5503        - Maximum mismatch is set to SV_INJECTION_LIMIT MW and SV_INJECTION_LIMIT MVAr per
5504          node.
5505        - Controlled node voltage error convergence tolerance = 0.0001 pu
5506          (The largest difference between actual and scheduled voltage magnitude in
5507          per unit at each node where voltage is subject to control to a set point,
5508          and for which at least one of the devices participating in the control of
5509          bus voltage to its set point is not at a reactive power limit, must be less
5510          than the controlled bus voltage error convergence tolerance).
5511
5512        Justification:
5513
5514        Message:
5515        Power flow could not be calculated for CGM with required settings.
5516        Check diagnostic messages.
5517
5518        Usage: #CGMRuleSet
5519
5520    Rule: TIConvergenceStatMissing  Level: 8  Severity: WARNING
5521
5522        Details:
5523        This rule applies to both IGMs and CGMs. cim:IdentifiedObject.description is added
5524        to State Variables profile as required attribute. The
5525        cim:IdentifiedObject.description of cim:TopologicalIsland shall have one the
5526        following string values: “converged” and “diverged” which represents the
5527        convergence status of the cim:TopologicalIsland.
5528
5529        Justification:
5530        It should be possible to conclude if a cim:TopologicalIslands has diverged or
5531        converged.
5532
5533        Message:
5534        Convergence status (cim:IdentifiedObject.description) is not provided for
```

```
5535          cim:TopologicalIsland.
5536
5537          Usage: #IGMRuleSet #CGMRuleSet
5538
5539    Rule: TIConvergenceStatDiverged  Level: 8  Severity: WARNING
5540
5541          Details:
5542          This rule applies to both IGMs and CGMs. Convergence status for
5543          cim:TopologicalIsland is diverged. The
5544          cim:IdentifiedObject.description of the cim:TopologicalIsland shall then
5545          contain the text "diverged".
5546
5547          Justification:
5548          It should be possible to conclude if a cim:TopologicalIslands has diverged or
5549          converged.
5550
5551          Message:
5552          Convergence status is diverged for cim:TopologicalIsland
5553
5554          Usage: #IGMRuleSet #CGMRuleSet
5555
5556    Rule: CGMConvergenceRelaxed  Level: 8  Severity: ERROR
5557
5558          Details:
5559          This rule applies to CGMs only.
5560          It shall be possible to solve the power flow with the following power
5561          flow settings:
5562          - Full Newton Raphson power flow algorithm.
5563          - Q limits shall be ignored (also for slack node/swing bus) meaning
5564            unlimited reactive resources.
5565          - Area interchange control is set to enabled.
5566          - Maximum mismatch is set to 0.5 MW and 0.5 MVAr per node.
5567          - Controlled node voltage error convergence mismatch = 0.0001 pu
5568            (The largest difference between actual and scheduled voltage magnitude in
5569            per unit at each node where voltage is subject to control to a setpoint,
5570            and for which at least one of the devices participating in the control of
5571            bus voltage to its setpoint is not at a reactive power limit, must be less
5572            than the controlled bus voltage error convergence mismatch).
5573
5574          Justification:
5575
5576          Message:
5577          Power flow could not be calculated for CGM with relaxed Q limits.
5578          Check diagnostic messages.
5579
5580          Usage: #CGMRuleSet
5581
5582    Rule: Congestion  Level: 8  Severity: WARNING
5583
5584          Details:
5585          This rule applies to both IGMs and CGMs.
5586          There should be no base case violations considering PATL limits.
5587          The rule is applied only for PATL limits in cases where there is a cim:SvPowerFlow
5588          at the terminal where the cim:OperationalLimitSet is.
5589
5590          Justification:
```

```
5591
5592          Message:
5593          Base case violation.
5594
5595          Usage: #IGMRuleSet #CGMRuleSet
5596
5597    Rule: CGMTieFlowImbalance  Level: 8  Severity: WARNING
5598
5599          Details:
5600          This rule applies to CGMs only.
5601          The sum of the solved tie flows for each cim:ControlArea of type
5602          interchange shall equal the cim:ControlArea.netInterchange plus/minus
5603          an INTERCH_IMBALANCE_EMF MW. i.e.
5604          o TFS less than or equal to cim:ControlArea.netInterchange +
5605                INTERCH_IMBALANCE_EMF MW
5606          o TFS greater than or equal to cim:ControlArea.netInterchange -
5607                INTERCH_IMBALANCE_EMF MW
5608          Where TFS (TieFlow sum) is computed as
5609          o TFS = sum(cim:SvPowerFlow.p) of cim:EquivalentInjection-s which cim:Terminal
5610          connects to the same boundary point (cim:TopologicalNode) where there is a
5611          cim:Terminal referenced by the association end cim:TieFlow.Terminal.
5612
5613          Note: This rule is built on the fact that the CGM SV instance file and the updated
5614          SSH instance files of IGMs are consistent hence contain updated values of
5615          cim:SvPowerFlow. i.e. cim:EquivalentInjection has the same output as the flow of
5616          the interconnection in the CGM SV instance file.
5617
5618          Justification:
5619
5620          Message:
5621          The sum of solved tie flows for a cim:ControlArea deviates from the cim:ControlArea
5622          interchange tolerance INTERCH_IMBALANCE_EMF MW.
5623
5624          Usage: #CGMRuleSet
5625
5626
```

5627 11 ANNEX A: SUPPORTING DOCUMENTS, FOR INFORMATION 5628 ONLY

5629 11.1 INTRODUCTION

5630 This section contains references to documents that support the rules.

5631 11.2 QOCDC REFERENCE DATA DOCUMENT

5632 The QoCDC Reference Data document provides all reference data e.g. enumerations and shared
5633 resources needed when validating the rules defined in this QoCDC document.

11.3 RULE DESCRIPTIONS

In section 12 a format for documenting rules is described. The rules are documented in XML files based on this format and one XML document per level exists. The XML documents are machine processable enabling translation to other formats to avoiding copy and pasting from the QoCDC word document. The xml documents are provided for information only.

The XML documents can be found in the archive “QoDCRules 3 edition.zip” that is available for download from ENTSO-E file repository together with this QoCDC document.

12 ANNEX B: DESCRIPTION OF RULES, FOR INFORMATION ONLY

This section provides information on how the rules are described. A UML model that describes the rules has been created, see Figure 15.

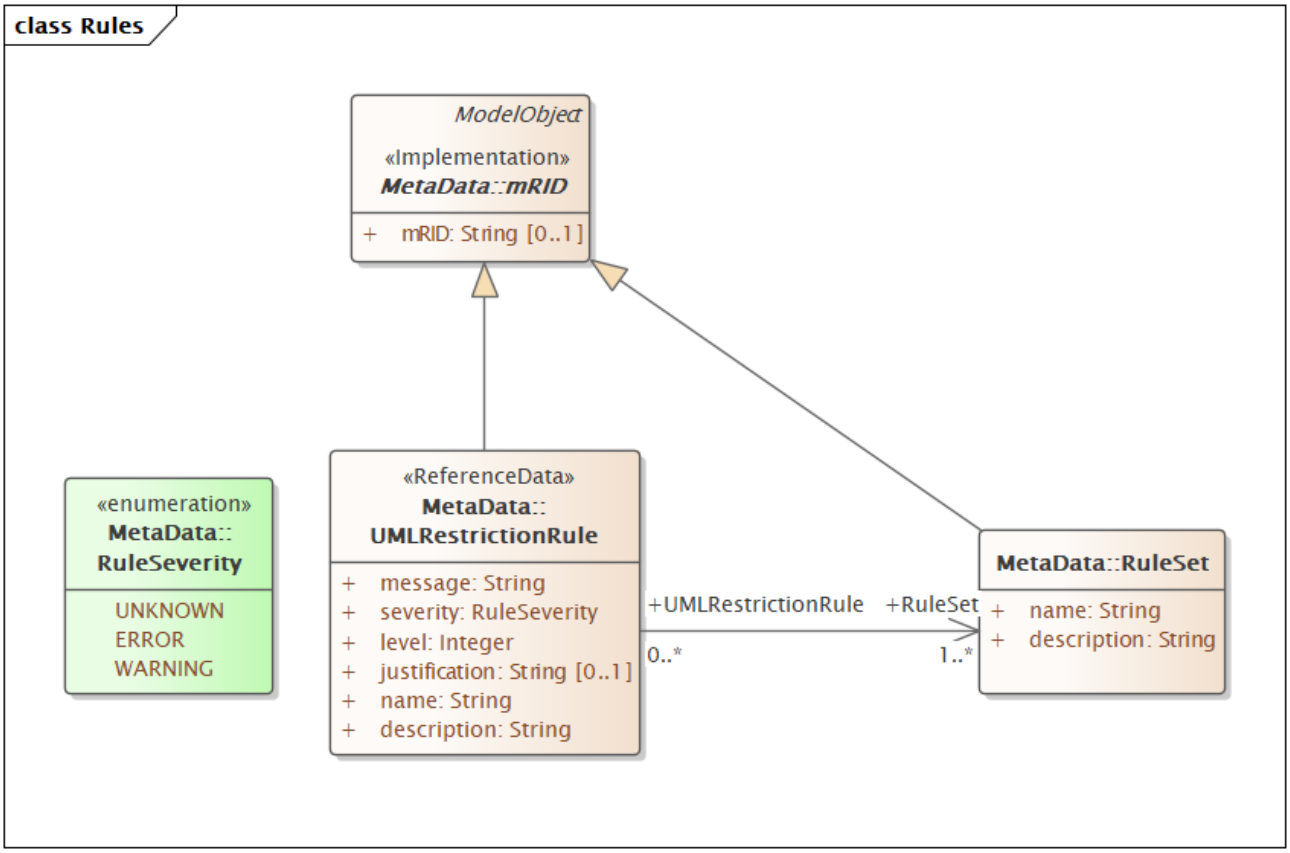

FIGURE 15 RULE DESCRIPTION INFORMATION MODEL

The UML model is converted to the ecore format so it can be loaded in Eclipse Modelling Framework (EMF).

All rules are described in the xml file UMLDescriptionRules.xml that is compliant with the UML model in . The file UMLDescriptionRules.xml is also loaded together with the IGM or CMG data in EMF which means it is validated together with the IGM/CGM.

All rule texts in previous sections are generated from UMLDescriptionRules.xml and the texts are also included in the messages sent to the Quality Portal.