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European Network of
Transmission System Operators
for Electricity

QUALITY OF CGMES DATASETS AND CALCULATIONS

FOR SYSTEM OPERATIONS

VERSION 3.3.1

APPROVED BY CGM OPDE TT

26 MAY 2023

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.

Summary of changes in version 3.3.1 compared to v3.3:

- The references to RDFS were replaced by a link to the website. RDFS for CGMES v2.4.15 will not be updated even if outdated.
- Section 2.12 is updated with additional rules related to comparisons with reference data and float numbers.
- The following constraints are modified: CNTerminals, DiscreteControl, UnpairedTieFlow, PairedEICCompatility, CGMRegion, FileNameMD, SourcingActor, InconsistentCurrentLimits, InvalidVoltage, ControlOfIslandIsMissing.
- Messages of the rules were updated to reflect on what is violated.

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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.

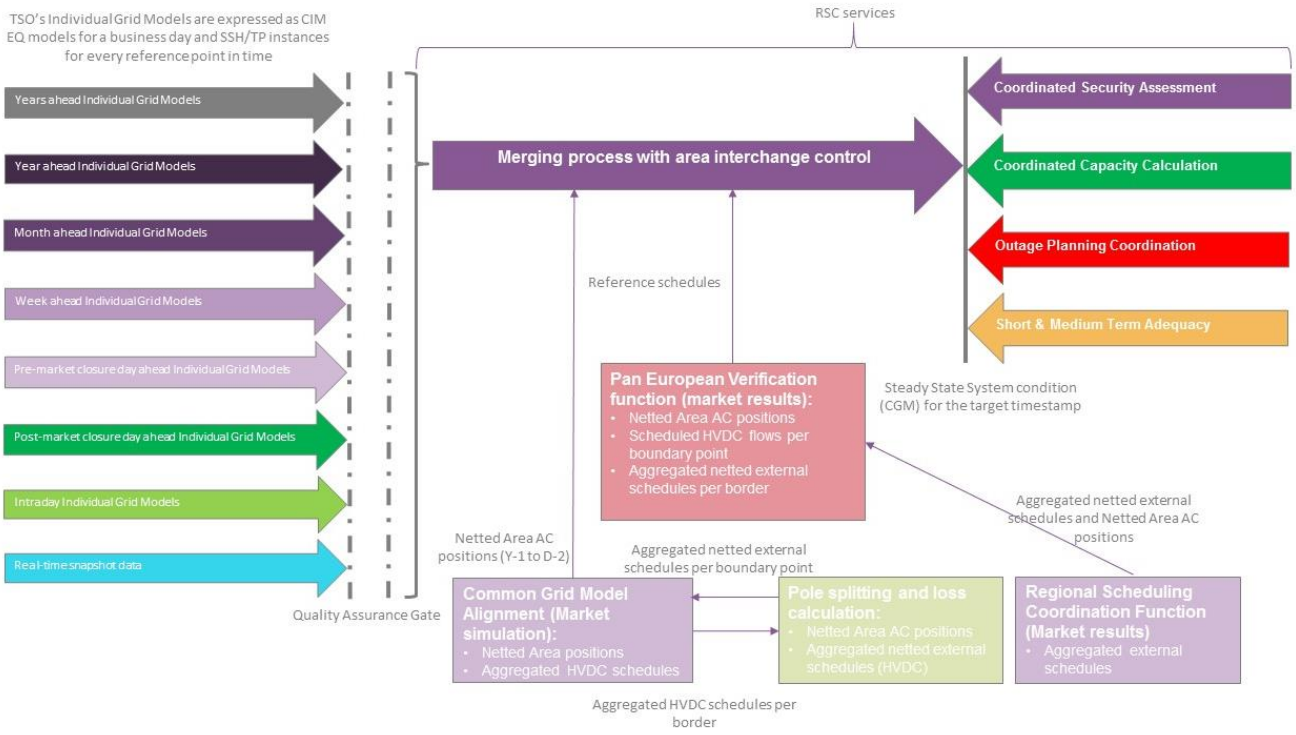

Figure 1 Context of operational data exchanges leading to Common Grid Models

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.

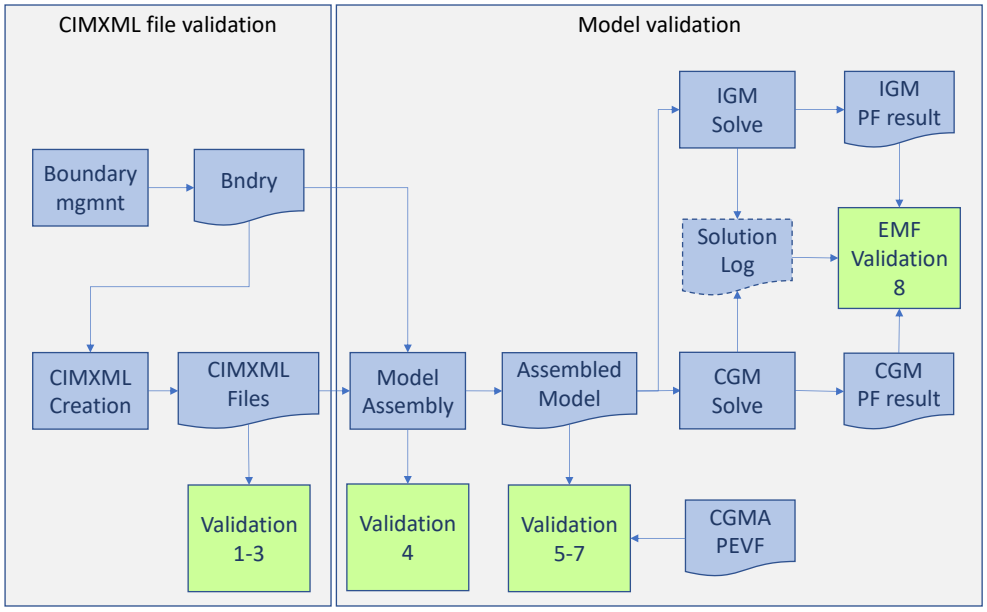

Figure 2 The Automated process annotated with validation levels

The symbols in 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 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) 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, the document is located here: https://www.entsoe.eu/data/cim/cim-for-grid-models-exchange/.

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 profiles available as a UML information model. 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)[3] is a subset of the IEC canonical information model and adds some ENTSO-E extensions to the technical specification 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.

[3] Note these specifications are withdrawn by IEC and then cannot be purchased in the IEC webstore.

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.

482 **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[4], specified as follows: 8 character hex number a dash “-“ 4 character hex number a dash “-“ 4 character hex number

[4] 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 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

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.
9) In case a rule requires comparison of data with Reference data of type string, the comparison of the string shall not be case sensitive.
10) An attribute defined as xsd:float can be constrained to integer in given cases. This means that the value can include leading zero, but no decimal value or can fully conform to xsd:integer. Example of valid values are: "1", "001", "1.0", "1.000000" (as positive or negative value). Example of invalid value are: "1.", "1.1", "1.000000001".
11) Validation engines shall inform which of the rules/constraints are implemented. Different validation engines can cover parts of the rules due to integration or other limitations. For instance ENTSO-E Rule Set Library/SUV information is provided in the users guide.

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[5], 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,

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

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.

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 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	20220101T1530Z_01_APG_SV_001.xml	20220101 v021 delivered at 14:30h CET
		20220101T1630Z_02_APG_SV_001.xml	

	on 01.01.2022. Day of the ID process	20220101T1730Z_03_APG_SV_001.xml	on 01.01.2022. for intraday (A18) process
		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 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.
```

```
753         The field sourcingActor has sub-fields separated by dashes (-). The following three
754         sub-templates are allowed for sourcingActor field:
755         - sourcingTSO, which is always used by a TSO;
756         - sourcingRSC-cgmRegion, which is used by RSC for a synchronous area file, e.g.,
757       a
758         SV file;
759         - sourcingRSC-cgmRegion-sourcingTSO, which is used by RSC for an updated TSO area
760         file, e.g., a SSH file.
761
762         Note that model parts such as DL, DY, GL are not included as they are not in the
763         implementation scope of QoCDC.
764         This rule only checks the structure of the filename, i.e., the "_" and the "-" and
765         does not check the content of the fields against QoCDC Reference Data document.
766
767         Justification:
768
769         Message:
770         The structure of the file name does not match the rules.
771
772         Usage: #IGMRuleSet #CGMRuleSet
773
774   Rule: FileNameConsistency  Level: 1  Severity: ERROR
775
776         Details:
777         Each cimxml file (including EQBD and TPBD) is contained by a single zip container.
778         The file name of the cimxml file within the container must be the same as the name
779         of the container. However, EQBD and TPBD might be zipped together in case they need
780         to be uploaded in OPDE, which is an implementation detail.
781
782         Justification:
783
784         Message:
785         XML instance file name is different from zip container file name.
786
787         Usage: #IGMRuleSet #CGMRuleSet
788
789   Rule: EffectiveDateTime  Level: 1  Severity: ERROR
790
791         Details:
792         The 'effectiveDateTime' in the file name must be a valid datetime
793         in minute resolution in accordance with ISO 8601-2005, basic format
794         with time designator [T] between date and time and ending with
795         UTC designator [Z]. For example, 20180118T1130Z.
796         Use of other
797         date/time specifiers by characters [:.-+YMDHSWP] is not allowed.
798
799         Justification:
800         The relevant time resolution for the business process is minute level and
801         the time in the file name shall match with this attribute.
802
803         Message:
804         EffectiveDateTime in file name is invalid.
805
806         Usage: #IGMRuleSet #CGMRuleSet
807
808   Rule: SourcingActor  Level: 1  Severity: ERROR
```

Details:
The sourcingActor, that appears in the cimxml file name, is composed as described in rule FileNameMD. The choice on sourcingActor is made by the responsible TSO and it is recorded in the QoCDC Reference Data document. Once decided the sourcingActor should comply with the defined names in the QoCDC Reference Data document.
This rule checks if the values of the following fields “sourcingRSC” and “sourcingTSO” from the sourcingActor part of the file name is one of the allowed values in the QoCDC Reference Data document. The rule does not check the field “cgmRegion”.

Justification:
The sourcingActor shall comply with the choices made by a TSO.

Message:
sourcingRSC or/and sourcingTSO parts of the file name has/have value(s) that are not included in the QoCDC Reference Data document.

Usage: #IGMRuleSet #CGMRuleSet

Rule: CGMRegion Level: 1 Severity: ERROR

Details:
The sourcingActor, that appears in the cimxml file name, is composed as described in rule FileNameMD. This rule checks if the value of the field “cgmRegion” from the sourcingActor part of the file name is one of the allowed values in the QoCDC Reference Data document. The rule does not check the fields “sourcingRSC” and “sourcingTSO”.
Justification:
Needed to uniquely identify synchronous areas for SV of CGM.

Message:
cgmRegion part of the file name has value that is not included in the QoCDC Reference Data document.

Usage: #CGMRuleSet

Rule: BusinessProcess Level: 1 Severity: ERROR

Details:
The 'businessProcess' in the file name is restricted according to a list in the QoCDC Reference Data document.
See also level 2 rule ModelDescription where the BusinessProcess is required in the Model.description attribute.

Justification:

Message:
Unknown business process.

Usage: #IGMRuleSet #CGMRuleSet

Rule: ModelPartType Level: 1 Severity: ERROR

Details:

```
865         The 'modelPart' in the file name is restricted.
866         Note that the profile declarations in the file header are
867         leading and shall be used as meta data to request data.
868
869         The allowed model part types are as follows: DL, DY, EQ, EQBD, EQDIFF, GL, SSH,
870         SV, TP, TPBD.
871
872         Justification:
873
874         Message:
875         Unknown modelPart type in the filename.
876
877         Usage: #IGMRuleSet #CGMRuleSet
878
879
880   Rule: FileVersionType  Level: 1  Severity: ERROR
881
882         Details:
883         The 'fileVersion' in the file name must be positive integer value always
884         represented by three numeric characters ranging from 000 to 999, i.e. the first
885         positive integer is 001 and the last 999.
886         Leading zeros are allowed.
887
888         Justification:
889         See this specification section 3.1 and IEC TS 61970-600-1 C.3.1.
890
891         Message:
892         File version is not a number with three numeric character positions.
893
894         Usage: #IGMRuleSet #CGMRuleSet
```

895 4 LEVEL 2 VALIDATION: STRUCTURE SYNTAX AND METADATA

896 4.1 INTRODUCTION

897 CGMES data is exchanged as CIM RDF[6] XML[7] files. The Resource Description Framework uses an
898 XML based syntax, allowing relationships to be defined between XML nodes. The first level of syntax
899 validation is to check if the document is well formed in accordance with the XML rules[8].

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

---

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

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

[8] 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

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.

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 https://www.entsoe.eu/data/cim/cim-for-grid-models-exchange/. 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.

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]
```

```
1097          between date and time ending with UTC designator [Z].
1098          The characters [:-] shall be used. For example, 2018-01-18T11:30:00Z,
1099          2018-01-18T11:30:12.000Z or 2018-01-18T11:30Z.
1100
1101          The restriction describes the minimum required specification that a
1102          receiver shall be prepared to consume. A more precisely specified
1103          time defined by characters [+.YMDHSWP] will be ignored.
1104
1105          Justification:
1106          Annex C of IEC TS 61970-600-1:2017.
1107
1108          Message:
1109          Invalid Model.scenarioTime attribute.
1110
1111          Usage: #IGMRuleSet #CGMRuleSet
1112
1113    Rule: ScenarioTimeConsistency  Level: 2  Severity: ERROR
1114
1115          Details:
1116          The 'md:Model.scenarioTime' attribute shall refer to the same datetime
1117          as the 'effectiveDateTime' in the file name, considering minute
1118          resolution.
1119
1120          Justification:
1121          Necessary to produce consistent meta data for the exchange process.
1122
1123          Message:
1124          The scenarioTime specification in the file header does not match the
1125          effectiveDateTime specified in the file name.
1126
1127          Usage: #IGMRuleSet #CGMRuleSet
1128
1129    Rule: VersionConsistency  Level: 2  Severity: ERROR
1130
1131          Details:
1132          The 'md:Model.version' attribute shall be the same number
1133          as the 'fileVersion' string from the file name converted to an integer.
1134
1135          Justification:
1136          Necessary to produce consistent meta data for the exchange process.
1137
1138          Message:
1139          The model version does not match the file version.
1140
1141          Usage: #IGMRuleSet #CGMRuleSet
1142
1143    Rule: ProfileSpecification  Level: 2  Severity: ERROR
1144
1145          Details:
1146          The 'md:Model.profile' description in the file header is restricted.
1147          Note: The profile declarations in the file header are leading and
1148          shall be used as meta data to request data.
1149          The enumeration values are centrally maintained in
1150          QoCDC Reference Data document.
1151
1152          Justification:
```

```
1153          Necessary to determine which RDFS rules to use.
1154          Requirement FBOD2, HGEN1 of IEC TS 61970-600-1:2017
1155          Annex C of IEC/TS 61970-600-1:2017.
1156
1157          Message:
1158          Invalid profile specification.
1159
1160          Usage: #IGMRuleSet #CGMRuleSet
1161
1162
1163    Rule: ModelDescription  Level: 2  Severity: WARNING
1164
1165          Details:
1166          The md:Model.description attribute is required and shall contain the xml structure
1167          that is described in section 3.2.2. The xml structure shall be serialised in the
1168          attribute as escaped XML, i.e. still as a string.
1169
1170          Justification:
1171          See this specification section 3.2.2.
1172
1173          Message:
1174          md:Model.description is not provided or does not contain required fields.
1175
1176          Usage: #IGMRuleSet #CGMRuleSet
1177
1178    Rule: NotMandatoryClass  Level: 2  Severity: WARNING
1179
1180          Details:
1181          An instance of a class not described in a CGMES
1182          profile is ignored and reported.
1183          If an importing tool requires a class not described in a CGMES
1184          profile issues may occur for a CGM where other IGMs do not contain
1185          instances of the class.
1186
1187          Justification:
1188          Requirement PROF11 of IEC/TS 61970-600-1:2017.
1189
1190          Message:
1191          Class instance in cimxml document is ignored.
1192
1193          Usage: #IGMRuleSet #CGMRuleSet
1194
1195    Rule: NotMandatoryProperty  Level: 2  Severity: WARNING
1196
1197          Details:
1198          A role or attribute not described in a CGMES profile is ignored and reported.
1199          If an importing tool require a role or attribute not described in a CGMES
1200          profile issues may occur for a CGM where other IGMs do not contain
1201          instances of the role or attribute.
1202
1203          Justification:
1204          Requirement PROF11 of IEC/TS 61970-600-1:2017.
1205
1206          Message:
1207          Role or attribute in cimxml document is ignored.
1208
```

```
1209          Usage: #IGMRuleSet #CGMRuleSet
1210
1211    Rule: AttributeAndRoleValues  Level: 2  Severity: ERROR
1212
1213          Details:
1214          Attribute and role values appearing in a CIMXML document shall have a value.
1215          The rule checks empty attributes that are not of type String.
1216
1217          Notes:
1218          - Example of empty attribute: [cim:class.attribute/] or
1219            [cim:class.attribute][/cim:class.attribute]
1220          - Example of empty rdf:resource [cim:class.attribute rdf:resouce=""/], note this
1221          is not a valid reference and it is part of rule XMLStructure.
1222          Note: the xml angle brackets has been replaced by square parenthesis in
1223          above examples.
1224
1225
1226          Justification:
1227          Only meaningful data shall be exchanged in CIMXML documents.
1228          See also IEC TS 61970-600-1 NAMC14.
1229
1230          Message:
1231          Empty attribute or rdf:resource is present.
1232
1233          Usage: #IGMRuleSet #CGMRuleSet
1234
1235
1236    Rule: IncorrectDataTypeFormat  Level: 2  Severity: ERROR
1237
1238          Details:
1239          Data format shall conform to the datatype defined in the profile.
1240
1241          Note: This rule reports data format issues for all datatypes.
1242          A description of the data type specific error is included in the message.
1243          The format of the message is  "[Message] The [expected datatype]: [datatype detail
1244          text] is not correct.",
1245          where
1246          [expected datatype] is the datatype reference defined by the profile
1247          [datatype detail text] is either printing the value that does not conform or
1248          indicating the details of the issue. For example, "The Decimal: decimal comma is
1249          not correct.".
1250
1251          Justification:
1252          See IEC 61970-552.
1253
1254          Message:
1255          Datatype does not conform. The [expected datatype]: [datatype detail text] is not
1256          correct.
1257
1258          Usage: #IGMRuleSet #CGMRuleSet
1259
1260    Rule: Exception  Level: 2  Severity: ERROR
1261
1262          Details:
1263          An exception shall be reported in case of a non-recoverable software error occurs.
1264          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.

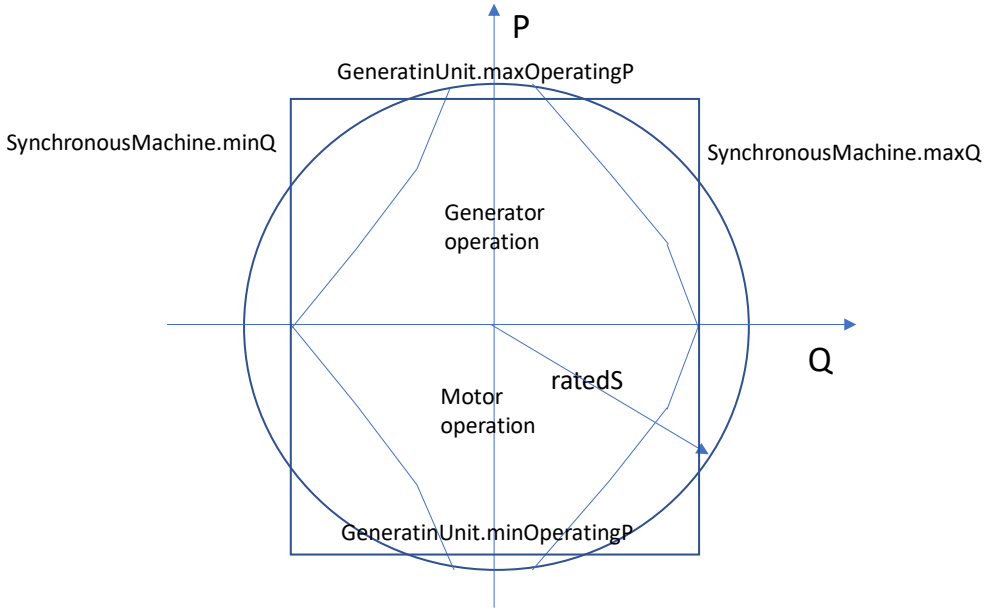

Figure 3 Example Reactive Capability Curve

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.

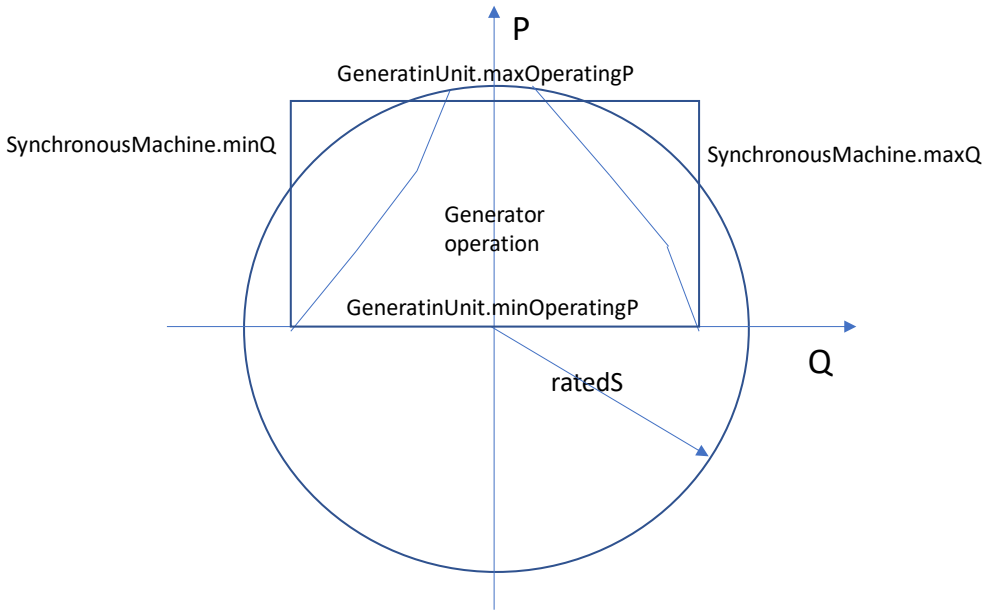

Figure 4 Generator only

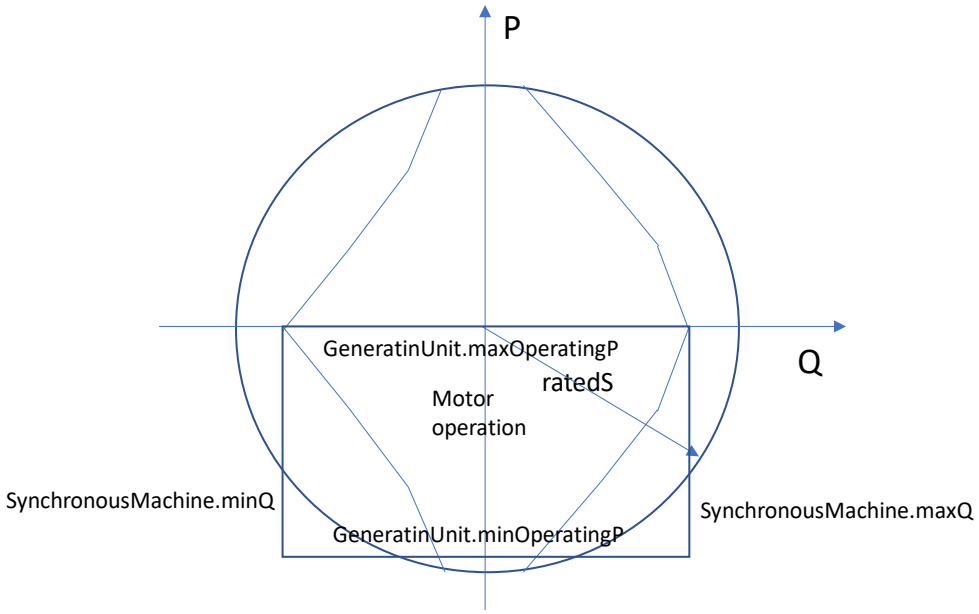

Figure 5 Motor operation only

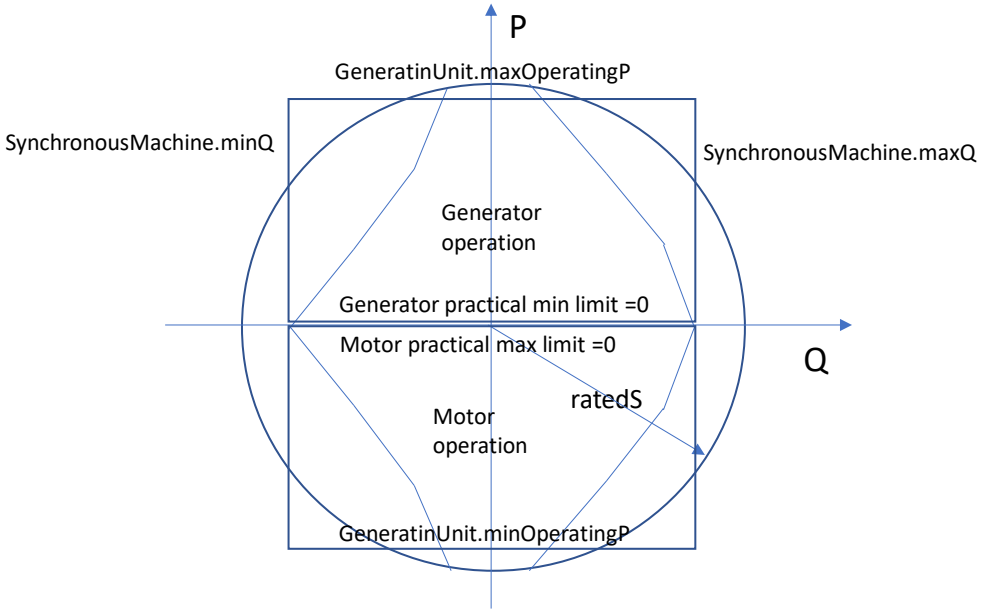

Figure 6 Generator or motor operation

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:

```
1406          In every model instance, the length of all instances of
1407          entsoe:IdentifiedObject.shortName shall not exceed
1408          SHORT_NAME_LENGTH characters.
1409
1410          Justification:
1411          See IEC TS 61970-600-1:2017 B.4.
1412
1413          Message:
1414          Length of shortName instance exceeds SHORT_NAME_LENGTH characters.
1415
1416          Usage: #IGMRuleSet #CGMRuleSet
1417
1418    Rule: CNFromEndIsoCode  Level: 3  Severity: ERROR
1419
1420          Details:
1421          In an EQBD document attribute value entsoe:ConnectivityNode.fromEndIsoCode
1422          must be from the country code list – field 'TsoCodeList' in the QoCDC Reference
1423          Data document which is a subset of https://www.iso.org/iso-3166-country-codes.html.
1424
1425          Justification:
1426          See IEC TS 61970-600-1:2017 B.5.
1427
1428          Message:
1429          Country code used that is not in the reference data.
1430
1431          Usage: #IGMRuleSet
1432
1433
1434    Rule: TNFromEndIsoCode  Level: 3  Severity: ERROR
1435
1436          Details:
1437          In a TPBD document attribute value entsoe:TopologicalNode.fromEndIsoCode
1438          must be from the country code list – field 'TsoCodeList' in the QoCDC Reference
1439          Data document which is a subset of https://www.iso.org/iso-3166-country-codes.html.
1440
1441          Justification:
1442          See IEC TS 61970-600-1:2017 B.5.
1443
1444          Message:
1445          Country code used that is not in the reference data.
1446
1447          Usage: #IGMRuleSet
1448
1449
1450    Rule: CNToEndIsoCode  Level: 3  Severity: ERROR
1451
1452          Details:
1453          In an EQBD document attribute value entsoe:ConnectivityNode.toEndIsoCode
1454          must be from the country code list – field 'TsoCodeList' in the QoCDC Reference
1455          Data document which is a subset of https://www.iso.org/iso-3166-country-codes.html.
1456
1457          Justification:
1458          See IEC TS 61970-600-1:2017 B.6.
1459
1460          Message:
1461          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.

```
1518          Justification:
1519          See IEC TS 61970-600-1:2017 B.8.
1520
1521          Message:
1522          Length of name attribute exceeds IO_NAME_LENGTH characters.
1523
1524          Usage: #IGMRuleSet
1525
1526    Rule: TNToEndNameLength  Level: 3  Severity: ERROR
1527
1528          Details:
1529          In every TPBD model instance, the length of all instances of
1530          entsoe:TopologicalNode.toEndName shall not exceed IO_NAME_LENGTH
1531          characters.
1532
1533          Justification:
1534          See IEC TS 61970-600-1:2017 B.8.
1535
1536          Message:
1537          Length of name attribute exceeds IO_NAME_LENGTH characters.
1538
1539          Usage: #IGMRuleSet
1540
1541    Rule: CNFromEndNameTsoLength  Level: 3  Severity: ERROR
1542
1543          Details:
1544          In every EQBD model instance, the length of all instances of
1545          entsoe:ConnectivityNode.fromEndNameTso shall not exceed IO_NAME_LENGTH
1546          characters.
1547
1548          Justification:
1549          See IEC TS 61970-600-1:2017 B.9.
1550
1551          Message:
1552          Length of name attribute exceeds IO_NAME_LENGTH characters.
1553
1554          Usage: #IGMRuleSet
1555
1556    Rule: TNFromEndNameTsoLength  Level: 3  Severity: ERROR
1557
1558          Details:
1559          In every TPBD model instance, the length of all instances of
1560          entsoe:TopologicalNode.fromEndNameTso shall not exceed IO_NAME_LENGTH
1561          characters.
1562
1563          Justification:
1564          See IEC TS 61970-600-1:2017 B.9.
1565
1566          Message:
1567          Length of name attribute exceeds IO_NAME_LENGTH characters.
1568
1569          Usage: #IGMRuleSet
1570
1571    Rule: CNToEndNameTsoLength  Level: 3  Severity: ERROR
1572
1573          Details:
```

```
1574          In every EQBD model instance, the length of all instances of
1575          entsoe:ConnectivityNode.toEndNameTso shall not exceed IO_NAME_LENGTH
1576          characters.
1577
1578          Justification:
1579          See IEC TS 61970-600-1:2017 B.10.
1580
1581          Message:
1582          Length of name attribute exceeds IO_NAME_LENGTH characters.
1583
1584          Usage: #IGMRuleSet
1585
1586
1587    Rule: TNToEndNameTsoLength  Level: 3  Severity: ERROR
1588
1589          Details:
1590          In every TPBD model instance, the length of all instances of
1591          entsoe:TopologicalNode.toEndNameTso shall not exceed IO_NAME_LENGTH
1592          characters.
1593
1594          Justification:
1595          See IEC TS 61970-600-1:2017 B.10.
1596
1597          Message:
1598          Length of name attribute exceeds IO_NAME_LENGTH characters.
1599
1600          Usage: #IGMRuleSet
1601
1602    Rule: ShuntCompensatorSensitivity  Level: 3  Severity: ERROR
1603
1604          Details:
1605          The following attribute value, if provided, shall be greater than zero
1606          - cim:ShuntCompensator.voltageSensitivity
1607
1608          Justification:
1609          Decision from 2018-11-09 CGM_BP/EMF meeting.
1610          It was concluded that a negative value is not physically possible.
1611
1612          Message:
1613          VoltageSensitivity attribute value is not greater than zero.
1614
1615          Usage: #IGMRuleSet
1616
1617    Rule: NumberOfSubstations  Level: 3  Severity: WARNING
1618
1619          Details:
1620          The following number of cim:Substations in an IGM are considered suspicious
1621          - a single cim:Substation which is the min limit.
1622          - one cim:Substation per cim:VoltageLevel which is the max limit.
1623          The upper limit for the number of cim:Substations equals the number of
1624          cim:VoltageLevels.
1625
1626          Justification:
1627          The number of cim:Substations should reflect the design of the power system.
1628
1629          Message:
```

```
1630        The number of cim:Substations is outside defined limitations.
1631
1632        Usage: #IGMRuleSet
1633
1634    Rule: GenerationContainment  Level: 3  Severity: ERROR
1635
1636        Details:
1637        For every instance of cim:HydroPump and cim:GeneratingUnit (and subclasses
1638        thereof), the cim:Equipment.EquipmentContainer referred to,
1639        must be of type cim:Substation. Missing containment is not allowed.
1640
1641        Justification:
1642        See Figure 15 (Core notes) of IEC TS 61970-600-2 section 6.7.11.
1643
1644        Message:
1645        A cim:HydroPump and a cim:GeneratingUnit is not contained in a cim:Substation.
1646
1647        Usage: #IGMRuleSet
1648
1649    Rule: PTContainment  Level: 3  Severity: ERROR
1650
1651        Details:
1652        For every instance of cim:PowerTransformer, the
1653        cim:Equipment.EquipmentContainer referred to, must be of type
1654        cim:Substation or of type cim:DCConverterUnit. Missing containment is not allowed.
1655
1656        Justification:
1657        See Figure 15 (Core notes) and Figure 5 (diagram DCContainment)
1658        of IEC TS 61970-600-2 sections 6.7.11 and 6.3.9.
1659
1660        Message:
1661        A cim:PowerTransformer is not contained in either a cim:Substation
1662        or a cim:DCConverterUnit.
1663
1664        Usage: #IGMRuleSet
1665
1666    Rule: SwitchContainment  Level: 3  Severity: ERROR
1667
1668        Details:
1669        For every instance of Switch (and subclasses thereof), the
1670        cim:Equipment.EquipmentContainer referred to, must be of type
1671        VoltageLevel, of type Bay or of type DCConverterUnit.
1672        Missing containment is not allowed.
1673
1674        Justification:
1675        See Figure 15 (Core notes) and Figure 5 (diagram DCContainment)
1676        of IEC TS 61970-600-2 sections 6.7.11 and 6.3.9.
1677
1678        Message:
1679        A cim:Switch is not contained in either a VoltageLevel, a Bay or a DCConverterUnit.
1680
1681        Usage: #IGMRuleSet
1682
1683    Rule: SCContainment  Level: 3  Severity: ERROR
1684
1685        Details:
```

```
1686        For every instance of cim:SeriesCompensator, the
1687        cim:Equipment.EquipmentContainer referred to, if provided, must be of
1688        type cim:Line, of type cim:VoltageLevel or of type cim:DCConverterUnit.
1689
1690        Justification:
1691        See Figure 15 (diagram Core notes) in section 6.7.1 of IEC TS 61970-600-2,
1692        Figure 5 (diagram DCContainment) in section 6.3.1 of IEC TS 61970-600-2
1693        and section 6.9.16 of IEC TS 61970-600-2.
1694
1695        Message:
1696        A cim:SeriesCompensator is not contained in either a cim:Line, a cim:VoltageLevel
1697        or a cim:DCConverterUnit.
1698
1699        Usage: #IGMRuleSet
1700
1701   Rule: InjectionContainment  Level: 3  Severity: ERROR
1702
1703        Details:
1704        For every instance of cim:EnergyConsumer subclasses, cim:RotatingMachine
1705        subclasses, cim:ShuntCompensator subclasses, cim:EnergySource,
1706        cim:EquivalentShunt, cim:ExternalNetworkInjection and cim:StaticVarCompensator,
1707        the cim:Equipment.EquipmentContainer referred to, must be of type
1708        cim:VoltageLevel. Missing containment is not allowed.
1709
1710        Justification:
1711        See 6.10.10, 6.7.6 of IEC TS 61970-600-2.
1712
1713        Message:
1714        A single terminal equipment that produces/consumes power is not contained in a
1715   cim:VoltageLevel.
1716
1717        Usage: #IGMRuleSet
1718
1719   Rule: BusbarSectionContainment  Level: 3  Severity: ERROR
1720
1721        Details:
1722        For every instance of cim:BusbarSection, the cim:Equipment.EquipmentContainer
1723        referred to, must be of type cim:VoltageLevel. Missing containment is not allowed.
1724
1725        Justification:
1726        See Figure 15 (diagram Core notes) of IEC TS 61970-600-2 section 6.10.5.
1727
1728        Message:
1729        A cim:BusbarSection is not contained in a cim:VoltageLevel.
1730
1731        Usage: #IGMRuleSet
1732
1733   Rule: EFCContainment  Level: 3  Severity: ERROR
1734
1735        Details:
1736        For every instance of cim:EarthFaultCompensator, its subclasses and cim:Ground,
1737        the cim:Equipment.EquipmentContainer referred to, must be of type
1738        cim:VoltageLevel. Missing containment is not allowed.
1739
1740        Justification:
1741        See Figure 15 (diagram Core notes) of IEC TS 61970-600-2 section 6.7.6.
```

```
1742
1743          Message:
1744          A subclass of cim:EarthFaultCompensator or cim:Ground is not contained in a
1745          cim:VoltageLevel.
1746
1747          Usage: #IGMRuleSet
1748
1749    Rule: JunctionContainment  Level: 3  Severity: ERROR
1750
1751          Details:
1752          For every instance of cim:Junction (Equipment Boundary file), the
1753          cim:Equipment.EquipmentContainer referred to, must be of type cim:Line.
1754          Missing containment is not allowed.
1755
1756          Justification:
1757          See section 4.4.5 of IEC TS 61970-600-2.
1758
1759          Message:
1760          A cim:Junction is not contained in a cim:Line.
1761
1762          Usage: #IGMRuleSet
1763
1764    Rule: ACDCConvContainment  Level: 3  Severity: ERROR
1765
1766          Details:
1767          For every instance of cim:CsConverter and cim:VsConverter, the
1768          cim:Equipment.EquipmentContainer referred to, must be of type
1769          cim:DCConverterUnit. Missing containment is not allowed.
1770
1771          Justification:
1772          See section 6.3.2 of IEC TS 61970-600-2.
1773
1774          Message:
1775          A cim:ACDCConverter is not contained in a cim:DCConverterUnit.
1776
1777          Usage: #IGMRuleSet
1778
1779    Rule: DCEQContainment  Level: 3  Severity: ERROR
1780
1781          Details:
1782          For every instance of cim:DCSeriesDevice, cim:DCShunt, cim:DCBusbar, cim:DCGround,
1783          cim:DCChopper, cim:DCSwitch, cim:DCBreaker and cim:DCDisconnector, the
1784          cim:Equipment.EquipmentContainer referred to, must be of type
1785          cim:DCConverterUnit. Missing containment is not allowed.
1786
1787          Justification:
1788          See section 6.3.2 of IEC TS 61970-600-2.
1789
1790          Message:
1791          A DC equipment is not contained in a cim:DCConverterUnit.
1792
1793          Usage: #IGMRuleSet
1794
1795    Rule: CNContainment  Level: 3  Severity: ERROR
1796
1797          Details:
```

For cim:ConnectivityNodes according to EQ, the
cim:ConnectivityNode.ConnectivityNodeContainer referred to, must be
of type cim:VoltageLevel, cim:Bay or cim:Line.
For cim:ConnectivityNodes according to EQBD, the
cim:ConnectivityNode.ConnectivityNodeContainer referred to,
must be of type cim:Line. Missing containment is not allowed.

Justification:
See Figure 1 (diagram EquipmentBoundaryProfile), figure 15 (diagram
Core Notes), section 6.7.7 of IEC TS 61970-600-2.

Message:
A cim:ConnectivityNode is not contained in either a cim:VoltageLevel, cim:Bay
or cim:Line for EQ models and in a cim:Line for Boundary points.

Usage: #IGMRuleSet

Rule: CNTerminals Level: 3 Severity: WARNING

Details:
Not connected cim:ConnectivityNode-s shall not be present in the models. For a cim:ConnectivityNode to be considered connected it shall have at least one cim:ConductingEquipment, which is a multiterminal equipment (i.e. has more than one cim:Terminal).

Justification:
Isolated or dead end cim:ConnectivityNode-s may indicate a connectivity issue.

Message:
The cim:ConnectivityNode is not connected to equipment that has more than one cim:Terminal.

Usage: #IGMRuleSet

Rule: GeneratingUnitNominalP Level: 3 Severity: WARNING

Details:
According to CGMES the value of cim:GeneratingUnit.nominalP should be positive
and less or equal to cim:RotatingMachine.ratedS.

Justification:
See section 6.6.5 of IEC TS 61970-600-2.

Message:
cim:GeneratingUnit.nominalP is outside allowed range.

Usage: #IGMRuleSet

Rule: CEBaseVoltage Level: 3 Severity: ERROR

Details:
All cim:ConductingEquipment except cim:ACLineSegment, cim:SeriesCompensator,
cim:EquivalentBranch, cim:PowerTransformer and cim:ACDCConverter, must either have
an association with cim:BaseVoltage
or be located within a cim:VoltageLevel or cim:Bay. The exception is because rule

```
1854          BranchBaseVoltage validates similar conditions.
1855          If both cim:ConductingEquipment.BaseVoltage and containment in a cim:VoltageLevel
1856          or cim:Bay are provided, the association ends cim:ConductingEquipment.BaseVoltage
1857          and cim:VoltageLevel.BaseVoltage shall refer to the same cim:BaseVoltage.
1858
1859          Justification:
1860          See section 6.7.6 and 6.10.2 of IEC TS 61970-600-2.
1861
1862          Message:
1863          A cim:ConductingEquipment that does not have cim:BaseVoltage or refers to different
1864    cim:BaseVoltage via different associations.
1865
1866          Usage: #IGMRuleSet
1867
1868    Rule: NominalVoltage  Level: 3  Severity: ERROR
1869
1870          Details:
1871          For every instance of cim:BaseVoltage, the cim:BaseVoltage.nominalVoltage
1872          value must be greater than zero.
1873
1874          Justification:
1875          See section 6.7.3 of IEC TS 61970-600-2.
1876
1877          Message:
1878          Nominal voltage is not greater than zero.
1879
1880          Usage: #IGMRuleSet
1881
1882    Rule: InstancesOfGeneralClass  Level: 3  Severity: ERROR
1883
1884          Details:
1885          The most specific and detailed class shall in general be instantiated.
1886          Hence more general classes shall not be instantiated. The following classes
1887          are specifically noted as not allowed to instantiate
1888          - cim:EnergyConsumer
1889
1890          Justification:
1891          The level of detail described by the more specific class are needed in studies.
1892          The approved methodologies:
1893          CGMM-v1-plus Article 9, Load, 4(c) (as well CGMM-v2-plus.and CGMM-v3 referencing
1894          to CGMM-v1-plus) and GLDPM-v1: Article 2, Definitions and interpretation,
1895          point 3 and 7, Article 11, 4(9) (as well GLDPM-v2 referencing to GLDPM-v1) foresee
1896          the provision of conforming and non-conforming load flag as well as approved EMF
1897          Requirements, which implies the use specific classes of EnergyConsumer.
1898          IEC 61970-600-1:2017 Common Grid Model Exchange Specification, 5.1
1899          General constraints, GENC11: Instance data to be exchanged must make use of the
1900          most detailed class possible within a profile, i.e.
1901          using sub-typed classes rather than general classes, e.g. NuclearGeneratingUnit
1902          instead GeneratingUnit.
1903          Note that this rule is not applied for GeneratingUnit.
1904
1905          Message:
1906          Instances of type cim:EnergyConsumer are present.
1907
1908          Usage: #IGMRuleSet
1909
```

Rule: TerminalCount1 Level: 3 Severity: ERROR

Details:
Every instance of cim:RegulatingCondEq and its subclasses, cim:EnergyConsumer and its subclasses, cim:EquivalentInjection, cim:EquivalentShunt, subclasses of cim:Connector, cim:EnergySource, cim:Ground, cim:DCBusbar, cim:DCShunt, cim:DCGround shall only be referenced via a single cim:Terminal instance.

Justification:
cim:ConductingEqupment with a single electrical connection point shall only have one cim:Terminal.

Message:
A single terminal equipment that is referenced by multiple terminals.

Usage: #IGMRuleSet

Rule: TerminalCount2 Level: 3 Severity: ERROR

Details:
Every instance of cim:Conductor and its subclasses, cim:Switch and its subclasses, cim:SeriesCompensator, cim:EquivalentBranch, cim:DCLineSegment, cim:DCSeriesDevice, cim:DCChopper and subclasses of cim:DCSwitch, shall only be referenced via exactly two cim:Terminal instances.

Justification:
cim:ConductingEqupment with two electrical connection point shall have two cim:Terminals.

Message:
A two terminal equipment that is not referenced by exactly two terminals.

Usage: #IGMRuleSet

Rule: TerminalSeqNum Level: 3 Severity: ERROR

Details:
Every instance of cim:Terminal must have a cim:Terminal.sequenceNumber if it belongs to an cim:EquivalentBranch or an cim:ACLineSegment with cim:MutualCoupling.

Justification:
See section 6.7.21 and 6.10.31 of IEC TS 61970-600-2.

Message:
A cim:Terminal of either an cim:EquivalentBranch or a cim:ACLineSegment with cim:MutualCoupling that does not have a sequence number declared.

Usage: #IGMRuleSet

Rule: TerminalSeqNumOrder Level: 3 Severity: ERROR

Details:
In cases where cim:Terminal.sequenceNumber is provided for an instance of cim:ConductingEquipment or cim:DCConductingEquipment, at least one

```
1966          sequenceNumber shall equal to 1. The cim:Terminal.sequenceNumber of other terminals
1967          of same cim:ConductingEquipment or cim:DCConductingEquipment shall follow
1968          increasing order.
1969
1970          Justification:
1971          See section 6.7.2 of IEC TS 61970-600-2.
1972
1973          Message:
1974          Invalid sequenceNumber for a cim:Terminal.
1975
1976          Usage: #IGMRuleSet
1977
1978    Rule: PTTerminalConsistency  Level: 3  Severity: ERROR
1979
1980          Details:
1981          For every instance of cim:PowerTransformerEnd, the cim:Terminal referenced by
1982          the cim:TransformerEnd.Terminal association must be associated with the
1983          cim:PowerTransformer instance, referenced via the
1984          cim:PowerTransformerEnd.PowerTransformer association.
1985
1986          Justification:
1987          See section 6.9.31 of IEC TS 61970-600-2.
1988
1989          Message:
1990          Assignment of PowerTransformer’s terminals is not consistent.
1991
1992          Usage: #IGMRuleSet
1993
1994    Rule: MCFirstSecond  Level: 3  Severity: ERROR
1995
1996          Details:
1997          The following shall conform for every instance of cim:MutualCoupling:
1998          1) Association end cim:MutualCoupling.First_Terminal shall refer to a cim:Terminal
1999          of an cim:ACLineSegment.
2000          2) Association end cim:MutualCoupling.Second_Terminal shall refer to a cim:Terminal
2001          of an cim:ACLineSegment.
2002          3) Association ends cim:MutualCoupling.First_Terminal and
2003          cim:MutualCoupling.Second_Terminal shall refer to cim:Terminal-s of different
2004          cim:ACLineSegment-s.
2005
2006
2007          Justification:
2008          See section 6.9.19 of IEC TS 61970-600-2.
2009
2010          Message:
2011          One of the following occurs: 1) cim:MutualCoupling.First_Terminal does not refer
2012          to a cim:Terminal of a cim:ACLineSegment, 2) cim:MutualCoupling.Second_Terminal
2013          does not refer to a cim:Terminal of a cim:ACLineSegment,
2014          3) cim:MutualCoupling.First_Terminal and cim:MutualCoupling.Second_Terminal do not
2015          refer to cim:Terminal-s of different cim:ACLineSegment-s.
2016
2017          Usage: #IGMRuleSet
2018
2019
2020    Rule: LRCExponentModel  Level: 3  Severity: ERROR
2021
```

```
        Details:
        For every instance of cim:LoadResponseCharacteristic where
        cim:LoadResponseCharacteristic.exponentModel is true,
        cim:LoadResponseCharacteristic.pVoltageExponent and
        cim:LoadResponseCharacteristic.qVoltageExponent must be provided and
        be greater or equal than zero and less or equal to two.

        Note: The attributes pFrequencyExponent and qFrequencyExponent are not used. The
        attributes that are required for coefficient load model covered by rule
        LCRCoefficientModel are ignored and not validated when
        cim:LoadResponseCharacteristic.exponentModel equals true.

        Justification:
        See section 6.10.9 of IEC TS 61970-600-2.

        Message:
        Exponent of per unit voltage effecting real and reactive power is not
        specified but cim:LoadResponseCharacteristic.exponentModel is true.

        Usage: #IGMRuleSet


Rule: LCRCoefficientModel  Level: 3  Severity: ERROR

        Details:
        For every instance of cim:LoadResponseCharacteristic where
        cim:LoadResponseCharacteristic.exponentModel is false,
        cim:LoadResponseCharacteristic.pConstantImpedance and
        cim:LoadResponseCharacteristic.pConstantCurrent and
        cim:LoadResponseCharacteristic.pConstantPower and
        cim:LoadResponseCharacteristic.qConstantImpedance and
        cim:LoadResponseCharacteristic.qConstantCurrent and
        cim:LoadResponseCharacteristic.qConstantPower must be provided.

        Note: The attributes that are required for exponential load model covered by rule
        LRCExponentModel are ignored and not validated when
        cim:LoadResponseCharacteristic.exponentModel equals false.

        Justification:
        See section 6.10.9 of IEC TS 61970-600-2.

        Message:
        Coefficients for ZIP load model is not specified but
        cim:LoadResponseCharacteristic.exponentModel is false.

        Usage: #IGMRuleSet

Rule: LCRCoefficientParameters  Level: 3  Severity: ERROR

        Details:
        For every instance of cim:LoadResponseCharacteristic with
        cim:LoadResponseCharacteristic.exponentModel is false, the sum of
        cim:LoadResponseCharacteristic.pConstantImpedance and
        cim:LoadResponseCharacteristic.pConstantCurrent and
        cim:LoadResponseCharacteristic.pConstantPower values must be 1 and
        the sum of cim:LoadResponseCharacteristic.qConstantImpedance and
```

```
2078        cim:LoadResponseCharacteristic.qConstantCurrent and
2079        cim:LoadResponseCharacteristic.qConstantPower values must be 1.
2080
2081        Justification:
2082        See section 6.10.9 of IEC TS 61970-600-2.
2083
2084        Message:
2085        The sum of coefficient parameters for a cim:LoadResponseCharacteristic does not
2086    equal 1.
2087
2088        Usage: #IGMRuleSet
2089
2090    Rule: MeasTerminal  Level: 3  Severity: ERROR
2091
2092        Details:
2093        The association end cim:Measurement.Terminal shall reference a cim:Terminal of the
2094        cim:Equipment referenced by cim:Measurement.PowerSystemResource except in cases
2095        where cim:Measurement.measurementType is either cim:TapPosition or
2096        cim:SwitchPosition in which the association is not exchanged.
2097
2098        Justification:
2099        See section 6.5.18 of IEC TS 61970-600-2.
2100
2101        Message:
2102        cim:Measurement.Terminal does not refer to a cim:Terminal of a cim:Equipment
2103        referenced by cim:Measurement.PowerSystemResource.
2104
2105        Usage: #IGMRuleSet
2106
2107
2108    Rule: MeasType  Level: 3  Severity: ERROR
2109
2110        Details:
2111        For every instance of cim:Measurement, the value of
2112        cim:Measurement.measurementType is limited to 'ThreePhasePower',
2113        'ThreePhaseActivePower', 'ThreePhaseReactivePower', 'LineCurrent',
2114        'PhaseVoltage', 'LineToLineVoltage', 'Angle', 'TapPosition',
2115        'SwitchPosition'.
2116
2117        Justification:
2118        See section 6.5.18 of IEC TS 61970-600-2.
2119
2120        Message:
2121        Invalid measurement type.
2122
2123        Usage: #IGMRuleSet
2124
2125    Rule: MeasUnit  Level: 3  Severity: ERROR
2126
2127        Details:
2128        For every instance of cim:Measurement, the value of
2129        cim:Measurement.unitSymbol is restricted to 'cim:UnitSymbol.V',
2130        'cim:UnitSymbol.A', 'cim:UnitSymbol.W', 'cim:UnitSymbol.VA',
2131        'cim:UnitSymbol.VAr', 'cim:UnitSymbol.deg', 'cim:UnitSymbol.Hz',
2132        'cim:UnitSymbol.none'.
2133
```

```
2134          Justification:
2135          See section 6.5.18 of IEC TS 61970-600-2.
2136
2137          Message:
2138          Invalid measurement unit symbol.
2139
2140          Usage: #IGMRuleSet
2141
2142
2143    Rule: CATieFlow  Level: 3  Severity: ERROR
2144
2145          Details:
2146          For every instance of cim:ControlArea for which the value of
2147          cim:ControlArea.type is cim:ControlAreaTypeKind.Interchange,
2148          cim:TieFlow instances must be provided.
2149
2150          Justification:
2151          This is necessary to compute interchange.
2152
2153          Message:
2154          cim:TieFlow-s are not defined for cim:ControlArea, no cim:TieFlow-s found.
2155
2156          Usage: #IGMRuleSet
2157
2158    Rule: TargetDB  Level: 3  Severity: ERROR
2159
2160          Details:
2161          For every instance of cim:RegulatingControl (SSH) for which the value of
2162          cim:RegulatingControl.discrete is true and cim:RegulatingControl.enabled
2163          is true, cim:RegulatingControl.targetDeadband must be provided and must be
2164          greater than 0.
2165
2166          Justification:
2167          If cim:RegulatingControl.discrete is set to true and no deadband
2168          is provided the power flow algorithm may not reach a solution but may continue
2169          to try find one which results in hunting.
2170
2171
2172          Message:
2173          Target deadband is either not provided if the regulating control is discrete and
2174          active or it is not greater than zero.
2175
2176          Usage: #IGMRuleSet
2177
2178
2179    Rule: OperationalLimitValue  Level: 3  Severity: ERROR
2180
2181          Details:
2182          For every instance of cim:VoltageLimit, the value of cim:VoltageLimit.value
2183          must be > 0. For every instance of cim:CurrentLimit, the value
2184          of cim:CurrentLimit.value must be > 0. For every instance of
2185          cim:ActivePowerLimit, the value of cim:ActivePowerLimit.value must be > 0.
2186          For every instance of cim:ApparentPowerLimit, the value of
2187          cim:ApparentPowerLimit.value must be > 0.
2188
2189          Justification:
```

```
2190        See section 6.8.5 of IEC TS 61970-600-2.
2191
2192        Message:
2193        A OperationalLimit value is not positive.
2194
2195        Usage: #IGMRuleSet
2196
2197    Rule: AcceptableDuration  Level: 3  Severity: ERROR
2198
2199        Details:
2200        The usage of the attribute cim:OperationalLimitType.acceptableDuration
2201        depends on the value of the entsoe:OperationalLimitType.limitType attribute as
2202        follows:
2203        - patl: acceptableDuration is not used;
2204        - patlt: usage of acceptableDuration is restricted, i.e. it is not used as another
2205        way to express the severity of the limit;
2206        - tatl: acceptableDuration is used to define several TATL limit types
2207        - tc: acceptableDuration is not used as an immediate tripping is expected
2208        - tct: acceptableDuration is used as the limit is less than the tc limit and
2209           describe how long the violation may sustain before tripping.
2210        If acceptableDuration is not used the attribute can be completely omitted
2211        or if included the acceptableDuration value shall be ignored.
2212
2213        Justification:
2214        See section 6.8.9.1 and 6.8.7 of IEC TS 61970-600-2.
2215
2216        Message:
2217        cim:OperationalLimitType.acceptableDuration is not provided for TATL and TCT limit
2218        types.
2219
2220        Usage: #IGMRuleSet
2221
2222    Rule: OperationalLimitSetAtTerminal  Level: 3  Severity: WARNING
2223
2224        Details:
2225        The association end cim:OperationalLimitSet.Terminal is required.
2226        Note the association end cim:OperationalLimitSet.Equipment is neither checked nor
2227        reported in this rule.
2228
2229        Justification:
2230        The limits in question are related to power flow, hence they are
2231        linked to the cim:Terminal.
2232        Less options also simplifies data exchange.
2233
2234        Message:
2235        The OperationalLimitSet is not linked to a Terminal.
2236
2237        Usage: #IGMRuleSet
2238
2239    Rule: PATL1  Level: 3  Severity: ERROR
2240
2241        Details:
2242        Every instance of cim:ACLineSegment and cim:SeriesCompensator,
2243        that is not aggregated, shall have at least one
2244        cim:OperationalLimitSet linked to one of its cim:Terminals.
2245        A cim:OperationalLimitSet shall have at least one
```

```
2246          cim:OperationalLimit of type entsoe:LimitTypeKind.patl.
2247          Equipment is aggregated when cim:Equipment.aggregate is present
2248          and set to 'true'.
2249
2250          Justification:
2251          See section 6.8.7 of IEC TS 61970-600-2.
2252
2253          Message:
2254          PATL is missing for cim:ACLineSegment or cim:SeriesCompensator.
2255
2256          Usage: #IGMRuleSet
2257
2258   Rule: PATL2  Level: 3  Severity: ERROR
2259
2260          Details:
2261          Every instance of cim:PowerTransformer, that is not aggregated
2262          (cim:Equipment.aggregate equals to false or it is missing), shall have at least
2263          one cim:OperationalLimitSet with at least one cim:OperationalLimit of type
2264          entsoe:LimitTypeKind.patl linked to one of cim:Terminal-s of the
2265          cim:PowerTransformer.
2266
2267          Justification:
2268          See section 6.8.7 of IEC TS 61970-600-2.
2269
2270          Message:
2271          A non-aggregated cim:PowerTrainsformer which has not a cim:OperationalLimitSet with
2272          at least one cim:OperationalLimit of type entsoe:LimitTypeKind.patl associated to
2273          any of its cim:Terminal-s.
2274
2275          Usage: #IGMRuleSet
2276
2277
2278   Rule: PATL3  Level: 3  Severity: ERROR
2279
2280          Details:
2281          There shall be only one PATL limitType per cim:OperationalLimitSet and type
2282          - cim:ActivePowerLimit
2283          - cim:CurrentLimit or cim:ApparentPowerLimit
2284          This means that an cim:OperationalLimitSet may have two PATL values, one for
2285          cim:CurrentLimit or cim:ApparentPowerLimit and one for cim:ActivePowerLimit.
2286
2287          Justification:
2288          See section 6.8.9.1 of IEC TS 61970-600-2.
2289
2290          Message:
2291          Redundant PATL is present for a OperationalLimitSet.
2292
2293          Usage: #IGMRuleSet
2294
2295   Rule: PATL4  Level: 3  Severity: WARNING
2296
2297          Details:
2298          For an instance of cim:ACLineSegment or cim:SeriesCompensator the limit values
2299          of the same cim:OperationalLimitType.limitType shall not differ more than
2300          PATL_LIMIT_VALUE_DIFF between the two sides, e.g. a cim:CurrentLimit
2301          of type PATL.
```

2302
2303 Justification:
2304 Based on engineering practice.
2305
2306 Message:
2307 Differing limit values on two sides of the equipment above PATL_LIMIT_VALUE_DIFF.
2308
2309 Usage: #IGMRuleSet
2310
2311 Rule: PATL5 Level: 3 Severity: WARNING
2312
2313 Details:
2314 PATL type on voltage limits shall be ignored.
2315
2316 Justification:
2317 See section 6.8.9.1 of IEC TS 61970-600-2:2017.
2318
2319 Message:
2320 PATL voltage limit is ignored.
2321
2322 Usage: #IGMRuleSet
2323
2324 Rule: CNRequiredInEQOperations Level: 3 Severity: ERROR
2325
2326 Details:
2327 The association end cim:Terminal.ConnectivityNode is required in cases where
2328 EQ Operation profile is specified in the header.
2329 The different kinds of models are described in IEC TS 61970-600-1:2017 PROF4.
2330
2331 Justification:
2332 See section 6.7.7 and rules PROF4 and PROF5 of IEC TS 61970-600-1:2017.
2333
2334 Message:
2335 The association end cim:Terminal.ConnectivityNode is not provided for a model that
2336 contains EQ Operation profile.
2337
2338 Usage: #IGMRuleSet
2339
2340
2341 Rule: EnergySourceVoltage Level: 3 Severity: ERROR
2342
2343 Details:
2344 For cim:EnergySource the attributes voltageMagnitude and voltageAngle
2345 are optional to include in EQ. The attributes are intended for the
2346 case when a strong network is providing power to a weak
2347 distribution network. Hence it is wrong to use these attributes
2348 in transmission studies and they shall not at all be used.
2349
2350 Justification:
2351 The use case for these attributes is not appropriate for transmission.
2352 See IEC TS 61970-600-1:2017 section E.19.
2353
2354 Message:
2355 cim:EnergySource.voltageMagnitude and/or cim:EnergySource.voltageAngle are
2356 present.
2357

```
2358          Usage: #IGMRuleSet
2359
2360    Rule: ControlModeCompatibility  Level: 3  Severity: ERROR
2361
2362          Details:
2363          The cim:TapChangerControl or cim:RegulatingControl can only control a cim:Terminal
2364          at a cim:ConductingEquipment compatible with its type,
2365          - A phase shift tap changer can only do the cim:RegulatingControl.mode
2366             - active power control
2367          - A ratio tap changer can only do the cim:RegulatingControl.mode-s
2368             - voltage
2369             - reactivePower
2370             - powerFactor
2371          - A cim:SynchronousMachine or cim:ShuntCompensator instance can only
2372            do the cim:RegulatingControl.mode-s
2373             - voltage
2374             - reactivePower
2375             - powerFactor
2376          - A cim:StativeVarCompensator can only do the cim:RegulatingControl.mode-s
2377             - voltage
2378             - reactivePower
2379          - A cim:BusbarSection instance can only be controlled by a cim:RegulatingControl
2380          in mode (cim:RegulatingControl.mode):
2381             - voltage
2382
2383          The following cim:RegulatingControl.modes are not at all allowed
2384             - currentFlow
2385             - admittance
2386             - timeScheduled
2387             - temperature
2388
2389
2390          Justification:
2391          Only meaningful combinations of data are allowed.
2392
2393          Message:
2394          cim:TapChangerControl or cim:RegulatingControl with invalid
2395          cim:RegulatingControl.mode.
2396
2397          Usage: #IGMRuleSet
2398
2399    Rule: ACLineSegmentR  Level: 3  Severity: ERROR
2400
2401          Details:
2402          For every instance of cim:ACLineSegment the value of
2403          cim:ACLineSegment.r must be greater than or equal to zero.
2404
2405          Justification:
2406          Negative resistance means negative losses.
2407          This is not allowed for real equipment.
2408
2409          Message:
2410          A cim:ACLineSegment with negative resistance.
2411
2412          Usage: #IGMRuleSet
2413
```

```
Rule: ACLineSegmentX  Level: 3  Severity: WARNING

      Details:
      For every instance of cim:ACLineSegment the value of
      cim:ACLineSegment.x should be greater than or equal to EQ_BRANCH_X_LIMIT Ohm.

      Justification:
      Too small impedances cause numerical instability when
      solving the power flow.

      Message:
      Reactance value is not greater than or equal to EQ_BRANCH_X_LIMIT.

      Usage: #IGMRuleSet

Rule: SeriesCompensatorX  Level: 3  Severity: WARNING

      Details:
      For every instance of cim:SeriesCompensator the value of
      abs(cim:SeriesCompensator.x) should be greater than or equal to
      EQ_BRANCH_X_LIMIT Ohm.

      Justification:
      Too small impedances cause numerical instability when
      solving the power flow.

      Message:
      Reactance value is not greater than or equal to EQ_BRANCH_X_LIMIT.

      Usage: #IGMRuleSet


Rule: EquivalentBranchX  Level: 3  Severity: WARNING

      Details:
      For every instance of EquivalentBranch (EB) the total impedance should be greater
      than or equal to EQ_BRANCH_X_LIMIT Ohm. The total impedance is computed by
      sqrt(EB.x * EB.x + EB.x21 * EB.x21). In cases where EB.x21 is not provided, it is
      equal to zero in the equation for calculation of the total impedance.

      Justification:
      Too small impedances cause numerical instability when
      solving the power flow.

      Message:
      Total impedance is not greater than or equal to EQ_BRANCH_X_LIMIT Ohm.

      Usage: #IGMRuleSet

Rule: DCLineSegmentR  Level: 3  Severity: ERROR

      Details:
      For every instance of cim:DCLineSegment the value of
      cim:DCLineSegment.resistance and the value of the associated
      cim:PerLengthDCLineParameter.resistance must be greater than zero.
```

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

Message:
A cim:DCLineSegment with negative resistance.

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 is not 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;

```
2526          - Be equal to 0 Ohm for the 2nd winding (the winding with
2527            cim:TransformerEnd.endNumber = 2, i.e. lower voltage end) of a two-winding
2528            transformer;
2529          - the abs(cim:PowerTransformerEnd.x) be greater than or equal to
2530            EQ_BRANCH_X_LIMIT Ohm for all windings of a three-winding transformer.
2531
2532          Justification:
2533          Transformers with zero series reactance do not exist.
2534          At a two winding transformer the series reactance is specified
2535          at the high voltage side and the low voltage side isn't used.
2536
2537          Message:
2538          One of the following occurs: 1) The value of 1st winding
2539          (cim:TransformerEnd.endNumber = 1) is not greater than or equal to
2540          EQ_BRANCH_X_LIMIT Ohm for a two-winding transformer. 2) The value of 2nd winding
2541          (cim:TransformerEnd.endNumber = 2) is not 0 Ohm.  3) The absolute value is not
2542          greater than or equal to EQ_BRANCH_X_LIMIT Ohm for each of the windings of a
2543          three-winding transformer.
2544
2545          Usage: #IGMRuleSet
2546
2547
2548    Rule: LinearShuntCompensatorG  Level: 3  Severity: ERROR
2549
2550          Details:
2551          For every instance of cim:LinearShuntCompensator the value of
2552          cim:LinearShuntCompensator.gPerSection must be greater than or
2553          equal to zero.
2554
2555          Justification:
2556          The charging conductance represents the losses, which should
2557          be non-negative.
2558
2559          Message:
2560          cim:LinearShuntCompensator.gPerSection is not non-negative.
2561
2562          Usage: #IGMRuleSet
2563
2564    Rule: ShuntCompensatorSections  Level: 3  Severity: ERROR
2565
2566          Details:
2567          For every instance of cim:ShuntCompensator the value of
2568          cim:ShuntCompensator.normalSections must be greater than or equal to zero
2569          and less or equal to cim:ShuntCompensator.maximumSections.
2570
2571          Justification:
2572          The sections specify the shunt compensator sections in use,
2573          which should be non-negative.
2574
2575          Message:
2576          cim:ShuntCompensator.normalSections is outside allowed range.
2577
2578          Usage: #IGMRuleSet
2579
2580    Rule: ConverterLosses  Level: 3  Severity: ERROR
2581
```

```
2582          Details:
2583          For every instance of cim:CsConverter and cim:VsConverter, the value
2584          of cim:ACDCConverter.idleLoss, cim:ACDCConverter.switchingLoss and
2585          cim:ACDCConverter.resistiveLoss, if provided, must be greater than
2586          or equal to zero.
2587
2588          Justification:
2589          Losses cannot be negative.
2590
2591          Message:
2592          The losses of a Converter are not greater than or equal to zero.
2593
2594          Usage: #IGMRuleSet
2595
2596    Rule: SVCRatings  Level: 3  Severity: WARNING
2597
2598          Details:
2599          For every instance of cim:StaticVarCompensator, the value of
2600          cim:StaticVarCompensator.capacitiveRating must be positive. The
2601          value of cim:StaticVarCompensator.inductiveRating must be negative.
2602          Zero values are not allowed.
2603
2604          Justification:
2605          See IEC TS 61970-600-2:2017, section 6.9.44.
2606
2607          Message:
2608          Capacitive rating is not greater than zero and/or inductive rating is not lower
2609    than zero for a SVC.
2610
2611          Usage: #IGMRuleSet
2612
2613    Rule: SVCSlope  Level: 3  Severity: ERROR
2614
2615          Details:
2616          The cim:StaticVarCompensator.slope must be positive or zero.
2617
2618          Justification:
2619          The reactive power output of the SVC is proportional to the
2620          difference between the voltage at the regulated bus and the voltage
2621          setpoint. When the regulated bus voltage is equal to the voltage
2622          setpoint, the reactive power output is zero.
2623          cim:RequlatingControl is used as it has capabilities missing from SVC,
2624          e.g. the controlled point.
2625
2626          Message:
2627          cim:StaticVarCompensator.slope is not positive or zero.
2628
2629          Usage: #IGMRuleSet
2630
2631    Rule: GeneratingUnitMaxPGen  Level: 3  Severity: ERROR
2632
2633          Details:
2634          For every instance of cim:GeneratingUnit, cim:HydroGeneratingUnit,
2635          cim:NuclearGeneratingUnit, cim:SolarGeneratingUnit, cim:ThermalGeneratingUnit and
2636          cim:WindGeneratingUnit, with cim:SynchronousMachine.type equal to generator
2637          (cim:SynchronousMachineKind.generator), the value
```

of cim:GeneratingUnit.maxOperatingP must be greater than zero.
Note that the limits follow generation sign convention.

Justification:
The name plate ratings are used as a reference.

Message:
A cim:GeneratingUnit.maxOperatingP is not greater than zero.

Usage: #IGMRuleSet

Rule: SynchronousCondenser Level: 3 Severity: ERROR

Details:
A synchronous condenser (cim:SynchronousMachine.type equal to SynchronousMachineKind.condenser) has no capability for active power output. Therefore, such cim:SynchronousMachine shall not be associated with a cim:GeneratingUnit.

Justification:
The name plate ratings are used as a reference.
See IEC TS 61970-600-2:2017, section 6.9.47.

Message:
A synchronous condenser is associated with cim:GeneratingUnit.

Usage: #IGMRuleSet

Rule: SMQLimits1 Level: 3 Severity: WARNING

Details:
For a cim:SynchronousMachine, the value of cim:SynchronousMachine.maxQ should be greater than or equal to the value of cim:SynchronousMachine.minQ, if provided.
Note that the limits follow generation sign convention.

Justification:
The name plate ratings are used as a reference.

Message:
cim:SynchronousMachine.maxQ is not greater than or equal to cim:SynchronousMachine.minQ.

Usage: #IGMRuleSet

Rule: SMQLimits2 Level: 3 Severity: ERROR

Details:
For a cim:SynchronousMachine, either cim:SynchronousMachine.minQ and cim:SynchronousMachine.maxQ must be provided, or an association to a cim:ReactiveCapabilityCurve must exist. If cim:ReactiveCapabilityCurve exists cim:SynchronousMachine.minQ and cim:SynchronousMachine.maxQ shall be ignored.

```
2694          Justification:
2695          See IEC TS 61970-600-2:2017, section 6.9.47.
2696
2697          Message:
2698          Missing operating limits for a Synchronous Machine.
2699
2700          Usage: #IGMRuleSet
2701
2702    Rule: RatedS  Level: 3  Severity: ERROR
2703
2704          Details:
2705          cim:RotatingMachine.ratedS is required and shall be greater than zero.
2706          cim:PowerTransfomerEnd.ratedS is required and shall be greater than zero.
2707          Justification:
2708          RatedS is required for data validation.
2709          See IEC TS 61970-600-2:2017, section 6.9.41.
2710
2711          Message:
2712          cim:RotatingMachine.ratedS or cim:PowerTransfomerEnd.ratedS is either not provided
2713          or it is zero.
2714
2715          Usage: #IGMRuleSet
2716
2717    Rule: SMQLimits3  Level: 3  Severity: WARNING
2718
2719          Details:
2720          For every instance of cim:SynchronousMachine with exactly one cim:GeneratingUnit
2721          the following rules applies
2722          - abs(maxP) Less or Equal ratedS
2723          - abs(minP) Less or Equal ratedS
2724          - abs(maxQ) Less or Equal ratedS
2725          - abs(minQ) Less or Equal ratedS
2726          where
2727          - maxP is cim:GeneratingUnit.maxOperatingP
2728          - maxQ is cim:SynchronousMachine.maxQ
2729          - minP is cim:GeneratingUnit.minOperatingP
2730          - minQ is cim:SynchronousMachine.minQ
2731          - ratedS is cim:RotatingMachine.ratedS
2732
2733          Justification:
2734          The limit values should be inside the rated capability.
2735
2736          Message:
2737          Inconsistent cim:SynchronousMachine and cim:GeneratingUnit limits.
2738
2739          Usage: #IGMRuleSet
2740
2741
2742    Rule: SMPLimits Level: 3  Severity: WARNING
2743
2744          Details:
2745          For a cim:SynchronousMachine associated with a cim:GeneratingUnit or its
2746          subclasses, the active power limits should relate to cim:SynchronousMachine.type
2747          as follows:
2748          - generator or generatorOrCondenser,
2749             - cim:GeneratingUnit.minOperatingP greater than or equal to 0,
```

```
            - cim:GeneratingUnit.maxOperatingP greater than 0,
            - cim:GeneratingUnit.maxOperatingP greater than or equal to
              cim:GeneratingUnit.minOperatingP.
        - motor or motorOrCondenser,
            - cim:GeneratingUnit.minOperatingP less than 0,
            - cim:GeneratingUnit.maxOperatingP less than or equal to 0,
            - cim:GeneratingUnit.maxOperatingP greater than or equal to
              cim:GeneratingUnit.minOperatingP.
        - generatorOrMotor or generatorOrCondenserOrMotor,
            - cim:GeneratingUnit.minOperatingP less than 0 and
              cim:GeneratingUnit.maxOperatingP greater than 0.

        Note:
        1) As there is no cim:GeneratingUnit associated with cim:SynchronousMachine in
        cases of condenser only type, the condenser cannot be included in this rule.
        2) Depending on sign conventions of applications applied to motor operating mode,
        the meaning operating active power limits defined by
        cim:GeneratingUnit.maxOperatingP and cim:GeneratingUnit.minOperatingP maybe
        affected. For instance, if maxOperatingP=-5 and minOperatingP=-100 the instance
        data will pass the validation in case it is a motor. However, for an application
        which has positive limits (e.g. Pmax and Pmin) for motor mode, the mapping would
        be Pmax = minOperatingP and Pmin = maxOperatingP.

        Justification:
        The active power limit values depend on the cim:SynchronousMachine.type
        and this dependence need to be described.

        Message:
        The active power limit values do not match the cim:SynchronousMachine.type.

        Usage: #IGMRuleSet

Rule: CurveStyle  Level: 3  Severity: ERROR

        Details:
        The cim:Curve.curveStyle enumerated value cim:CurveStyle.constantYValue
        is not allowed.

        Justification:
        The cim:CurveStyle.constantYValue gives too inaccurate
        compared with cim:CurveStyle.straightLineYValues.

        Message:
        A cim:CurveStyle.constantYValue enumeration is declared.

        Usage: #IGMRuleSet

Rule: RCCYValues  Level: 3  Severity: ERROR

        Details:
        For every instance of cim:CurveData, for which the cim:CurveData.Curve
        refers to a cim:ReactiveCapabilityCurve, the cim:CurveData.y2value
        must be greater or equal than cim:CurveData.y1value.
        If cim:CurveData.y2value and cim:CurveData.y1value are equal for all
        curve points this is considered an error.
```

```
2806          Justification:
2807          The name plate ratings are used as a reference.
2808
2809          Message:
2810          Invalid reactive capability curve data.
2811
2812          Usage: #IGMRuleSet
2813
2814    Rule: CurveXValues  Level: 3  Severity: WARNING
2815
2816          Details:
2817          For every instance of cim:CurveData, for which the cim:CurveData.Curve
2818          refers to a cim:ReactiveCapabilityCurve, the cim:CurveData.xvalue shall
2819          be different, e.g. in the case of two cim:CurveData called CD1 and CD2 the
2820          following shall give a warning when CD1.xvalue = CD2.xvalue.
2821
2822          Justification:
2823          All x values in a reactive capability curve
2824          shall differ for the curve to be meaningful.
2825
2826          Message:
2827          Some points in the reactive capability curve have the same x value.
2828
2829          Usage: #IGMRuleSet
2830
2831
2832    Rule: RCCXValues2  Level: 3  Severity: ERROR
2833
2834          Details:
2835          For a cim:SynchronousMachine with a cim:ReactiveCapabilityCurve the number of
2836          cim:CurveData instances depends on the attribute cim:SynchronousMachine.type
2837          as follows
2838          - condenser, one cim:CurveData instance with cim:CurveData.xvalue = 0.
2839          - generator or generatorOrCondenser, at least two cim:CurveData instances with
2840            cim:CurveData.xvalue greater or equal 0.
2841          - motor or motorOrCondenser, at least two cim:CurveData instances with
2842            cim:CurveData.xvalue less or equal 0.
2843          - generatorOrMotor or generatorOrCondenserOrMotor, at least three cim:CurveData
2844            instances with at least
2845            one having cim:CurveData.xvalue greater or equal 0 and
2846            and one having cim:CurveData.xvalue less or equal 0.
2847
2848          Justification:
2849          A cim:ReactiveCapabilityCurve for a Pump Storage unit shall have
2850          at least three curve points. A cim:SynchronousMachine operating as
2851          either motor or generator shall have at least two curve points. A
2852          cim:SynchronousMachine operating as condenser shall have at least one curve point.
2853
2854          Message:
2855          Invalid number of curve points in reactive capability curve data.
2856
2857          Usage: #IGMRuleSet
2858
2859    Rule: RCCXValues3  Level: 3  Severity: ERROR
2860
2861          Details:
```

```
2862        For each instance of cim:ReactiveCapabilityCurve, all instances of cim:CurveData
2863        shall have cim:CurveData.xvalue that is
2864        1) greater than or equal to the cim:GeneratingUnit.minOperatingP, and
2865        2) less than or equal to the cim:GeneratingUnit.maxOperatingP .
2866        cim:GeneratingUnit.minOperatingP and cim:GeneratingUnit.maxOperatingP are
2867        attributes of the cim:GeneratingUnit associated with the cim:SynchronousMachine to
2868        which the cim:ReactiveCapabilityCurve applies.
2869
2870        Justification:
2871        A cim:ReactiveCapabilityCurve must stay within the maximum capability of the unit.
2872
2873        Message:
2874        Invalid reactive capability curve data for a cim:SynchronousMachine.
2875
2876        Usage: #IGMRuleSet
2877
2878    Rule: RCCXValues4  Level: 3  Severity: WARNING
2879
2880        Details:
2881        For every instance of cim:ReactiveCapabilityCurve, each cim:CurveData instance
2882        must satisfy the following relation
2883        - x*x+y1*y1 LE ratedS*ratedS and x*x+y2*y2 LE ratedS*ratedS
2884        where
2885        - LE = less or equal
2886        - x= cim:CurveData.xvalue
2887        - y1 = cim:CurveData.y1value
2888        - y2 = cim:CurveData.y2value
2889        - ratedS = cim:RotatingMachine.ratedS * (1 + NUMERIC_TOLERANCE)
2890
2891        Justification:
2892        A cim:ReactiveCapabilityCurve must cover the full operating range.
2893
2894        Message:
2895        Invalid reactive capability curve data for a cim:SynchronousMachine.
2896
2897        Usage: #IGMRuleSet
2898
2899    Rule: VSCYValues  Level: 3  Severity: ERROR
2900
2901        Details:
2902        For every instance of cim:CurveData, for which the cim:CurveData.Curve
2903        refers to a cim:VsCapabilityCurve, the cim:CurveData.y2value must
2904        be greater than cim:CurveData.y1value.
2905
2906        Justification:
2907        The name plate ratings are used as a reference.
2908
2909        Message:
2910        Invalid cim:VsCapabilityCurve data.
2911
2912        Usage: #IGMRuleSet
2913
2914    Rule: VSCXValues  Level: 3  Severity: ERROR
2915
2916        Details:
2917        For every instance of cim:CurveData, for which the cim:CurveData.Curve
```

refers to a cim:VSCapabilityCurve, at least two instances of the cim:CurveData are associated.

Justification:
A curve consists of at least two curve points.

Message:
Invalid cim:VSCapabilityCurve data.

Usage: #IGMRuleSet

Rule: PhaseCodeGround Level: 3 Severity: ERROR

Details:
Multiple cim:ConductingEquipment-s are typically connected to the same cim:TopologicalNode via their cim:Terminal-s.
The phase codes of the cim:Terminal-s of the following grounding equipment shall be N:
- cim:PetersenCoil
- cim:Ground
- cim:GroundingImpedance
Note that cim:GroundDisconnector will have phase code N at the two sides.

Justification:
Ohm’s and Kirchhoff’s laws.

Message
Grounding equipment does not have phase code N.

Usage: #IGMRuleSet

Rule: ControlAreaInstance Level: 3 Severity: ERROR

Details:
Exactly one cim:ControlArea instance per IGM with following attributes must be defined:
- cim:ControlArea.type is cim:ControlAreaTypeKind.Interchange
- an entsoe:IdentifiedObject.energyIdentCodeEic shall be one of the codes defined in the QoCDC Reference Data document in column “RegionEic”.

Justification:
The cim:ControlArea of type interchange is the model equivalent of a SchedulingArea.

Message:
cim:ControlArea instance of type cim:ControlAreaTypeKind.Interchange is missing or does not have correct entsoe:IdentifiedObject.energyIdentCodeEic.

Usage: #IGMRuleSet

Rule: DCEquipmentContainerMapping Level: 3 Severity: ERROR

Details:
For each cim:DCConverterUnit and cim:DCLine instance the attribute entsoe:IdentifiedObject.energyIdentCodeEic is required. The third character of the

```
2974          EIC code shall be 'T'.
2975
2976          Justification:
2977          The mapping of reference schedules for HVDC links is done via
2978          the EIC T codes. The EIC T code is also used to identify DC equipment
2979          containers that belong to the same HVDC pole.
2980
2981          Message:
2982          EIC code for cim:DCConverterUnit or cim:DCLine is either not provided or it is not
2983          a 'T' code.
2984
2985          Usage: #IGMRuleSet
2986
2987    Rule: RCandTCCcontrollingObjects  Level: 3  Severity: WARNING
2988
2989          Details:
2990          A cim:RegulatingControl or cim:TapChangerControl shall have at least one
2991          controlling object. The cardinality
2992          - cim:RegulatingControl[0..1]-[0..*]cim:RegulatingCondEq
2993          - cim:TapChangerControl[0..1]-[0..*]cim:TapChanger
2994          are currently allowing no controlling objects.
2995
2996          Justification:
2997          A cim:RegulatingControl or cim:TapChangerControl without controlling objects
2998          cannot perform control.
2999          It is important for IGMs quality and CGM creation process to indicate
3000          these occurrences.
3001
3002          Message:
3003          cim:RegulatingControl or cim:TapChangerControl without controlling objects.
3004
3005          Usage: #IGMRuleSet
3006
3007    Rule: SMRatedSunrealistic  Level: 3  Severity: WARNING
3008
3009          Details:
3010          If a cim:SynchronousMachine has a rated power way beyond the specified
3011          active and reactive limit values or way outside the reactive capability curve
3012          the rated power value is not realistic.
3013          A EQ_RATEDS_REASONABILITY_FACTOR (RSRF) is used to determine if a rated power
3014          is reasonable.
3015          To be realistic and reasonable the cim:RotatingMachine.ratedS shall if an active
3016          or reactive power limit is present be less than
3017          - max(abs(cim:SynchronousMachine.minQ),
3018             abs(cim:SynchronousMachine.maxQ),
3019             abs(cim:GeneratingUnit.minOperatingP,
3020             abs(cim:GeneratingUnit.maxOperatingP))*RSRF
3021          - max(abs(CurveData.xvalue),
3022             abs(CurveData.y1value),
3023             abs(CurveData.y2value))*RSRF
3024          for all x, y1 and y2 values.
3025
3026          Justification:
3027          Rated powers may be given a large and unrealistic value that will impact other
3028          rules which may result in erroneous reporting by them.
3029
```

```
3030        Message:
3031        Unrealistic cim:RotatingMachine.ratedS is specified.
3032
3033        Usage: #IGMRuleSet
3034
3035    Rule: TargetDeadbandOutOfRange  Level: 3  Severity: WARNING
3036
3037        Details:
3038        If the cim:RegulatingControl.targetDeadband has a value similar to the
3039        cim:RegulatingControl.targetValue this means that it has no effect and
3040        that the cim:RegulatingControl is in practice disabled. Disabling a
3041        cim:RegulatingControl this way shouldn't be used, instead use the
3042        cim:RegulatingControl.enabled flag.
3043        cim:RegulatingControl.targetDeadband/EQ_DB_REASONABILITY_FACTOR
3044        should be less than the cim:RegulatingControl.targetValue.
3045        With a value of 2 for the EQ_DB_REASONABILITY_FACTOR this means that
3046        if the cim:RegulatingControl.targetDeadband is greater than twice the
3047        cim:RegulatingControl.targetValue this means that the target will always stay
3048        inside the dead band.
3049        The rule is only activated when cim:RegulatingControl.discrete="true",
3050        cim:RegulatingControl.enabled="true" and
3051        cim:RegulatingControl.mode= RegulatingControlModeKind.voltage.
3052
3053        Justification:
3054        Using other ways than cim:RegulatingControl.enabled flag shouldn't be used.
3055
3056        Message:
3057        cim:RegulatingControl has been potentially disabled with a large
3058        cim:RegulatingControl.targetDeadband.
3059
3060        Usage: #IGMRuleSet
3061
3062    Rule: WindingConnectionAngle  Level: 3  Severity: WARNING
3063
3064        Details:
3065        The cim:PhaseTapChangerAsymmetrical.windingConnectionAngle attribute in real
3066        grids can only have the following values:
3067        - +/-150;
3068        - +/-120;
3069        - +/-90;
3070        - +/-60;
3071        - +/-30.
3072        Values can be expressed as integer or float. Non-zero decimals are not allowed in
3073        case the value is expressed as float.
3074        Justification:
3075        Asymmetrical phase tap changers are built for specific connection angles.
3076
3077        Message:
3078        cim:PhaseTapChangerAsymmetrical.windingConnectionAngle value is not
3079        one of the defined values.
3080
3081        Usage: #IGMRuleSet
3082
3083    Rule: VoltageLimitDirection  Level: 3  Severity: WARNING
3084
3085        Details:
```

```
3086          A cim:VoltageLimit should be specified with a direction high or low, i.e. the
3087          cim:OperationalLimitType.direction value should be one of
3088          - cim:OperationalLimitDirectionKind.high
3089          - cim:OperationalLimitDirectionKind.low
3090
3091          Justification:
3092          If the direction is missing it is not possible to check the voltage value.
3093
3094          Message:
3095          cim:OperationalLimitType.direction is either 1) not provided or 2) it is not set
3096          to cim:OperationalLimitDirectionKind.high or
3097          cim:OperationalLimitDirectionKind.low.
3098
3099          Usage: #IGMRuleSet
3100
3101    Rule: VoltageLimitsConsistency  Level: 3  Severity: WARNING
3102
3103          Details:
3104          cim:VoltageLimit within a given cim:OperationalLimitSet with direction
3105          cim:OperationalLimitDirectionKind.high should be
3106          greater than cim:VoltageLimit with direction
3107          cim:OperationalLimitDirectionKind.low.
3108
3109          Justification:
3110          cim:VoltageLimit not consistent with the specified direction are meaningless.
3111
3112          Message:
3113          cim:VoltageLimit values are not consistent with the specified directions.
3114
3115          Usage: #IGMRuleSet
3116
3117    Rule: FlowLimitsDirectionConsistency  Level: 3  Severity: WARNING
3118
3119          Details:
3120          Branch flow limits cim:CurrentLimit, cim:ApparentPowerLimit and
3121          cim:ActivePowerLimit should have a cim:OperationalLimitType.direction with value
3122          cim:OperationalLimitDirectionKind.absoluteValue.
3123
3124          Justification:
3125          Branch flow can go in both directions on the branch. Hence the direction should be
3126          specified as an absoluteValue.
3127
3128          Message:
3129          Branch flow limits with other direction than absoluteValue.
3130
3131          Usage: #IGMRuleSet
3132
3133    Rule: AsymmetricalEquivalent  Level: 3  Severity: WARNING
3134
3135          Details:
3136          cim:EquivalentBranch with EquivalentBranch.r not equal to EquivalentBranch.r21 or
3137          EquivalentBranch.x not equal to EquivalentBranch.x21 should not be used.
3138
3139          Justification:
3140          Equivalents with different impedance in different directions may result in poor
3141          convergence, hence reporting the difference support error tracing in data.
```

```
3142
3143          Message:
3144          cim:EquivalentBranch with asymmetrical impedances.
3145
3146          Usage: #IGMRuleSet
3147
3148
3149    Rule: PositiveTransformerB  Level: 3  Severity: WARNING
3150
3151          Details:
3152          Two-winding transformer with positive shunt (cim:PowerTransformerEnd.b > 0)
3153          that are not equivalenced (cim:Equipment.aggregate = false)
3154          shouldn't have positive PowerTransformerEnd.b.
3155
3156          Justification:
3157          Two winding transformers are reactive and should not have
3158          positive cim:PowerTransformerEnd.b.
3159
3160          Message:
3161          Two winding transformer with a positive shunt.
3162
3163          Usage: #IGMRuleSet
3164
3165    Rule: SubLoadAreaMissing  Level: 3  Severity: ERROR
3166
3167          Details:
3168          The reference cim:LoadGroup->cim:SubLoadArea is required. The class cim:LoadGroup
3169          in in EQ core while cim:SubLoadArea is in operation. Hence a BB model using
3170          classes cim:ConformLoad and cim:NonConformLoad will get an error if cim:SubLoadArea
3171          instances are missing. As a CGM may contain both NB and BB models the
3172          cardinality for the BB models need to be 0..1 but for the NB models 1.
3173          This is solved by making the reference cim:LoadGroup->cim:SubLoadArea optional
3174          and have this rule checking that NB models do have the references.
3175
3176          Justification:
3177          This is a bug fix of CGMES2.4.15.
3178
3179          Message:
3180          The reference cim:LoadGroup.SubLoadArea is missing.
3181
3182          Usage: #IGMRuleSet
3183
3184    Rule: EnergyAreaMissing  Level: 3  Severity: ERROR
3185
3186          Details:
3187          The reference cim:ControlArea->cim:EnergyArea is required for NB models
3188          but not for BB models.
3189
3190          Justification:
3191          Required for NB models according to diagram note in CGMES2.4.15.
3192
3193          Message:
3194          The reference cim:ControlArea.EnergyArea is missing.
3195
3196          Usage: #IGMRuleSet
3197
```

```
Rule: GeneratingUnitSM  Level: 3  Severity: ERROR

      Details:
      A cim:GeneratingUnit or any of its subclasses is not allowed to have more
      than one cim:RotatingMachine.

      Justification:
      Having more than one cim:RotatingMachine with a cim:GeneratingUnit will make
      active and reactive limits dynamically dependent of the number of operational
      cim:RotatingMachine-s which makes scheduling difficult as this information
      is missing.

      Message:
      More than one cim:RotatingMachine defined for a cim:GeneratingUnit.

      Usage: #IGMRuleSet

Rule: TooManyTapChangers  Level: 3  Severity: ERROR

      Details:
      Multiple tap changers can be combined within one power transformer. To avoid
      interpretation issues and to be close to real power transformer, the following is
      introduced.
      Only one phase shifting and one ratio changing tap changer can be modelled on a
      terminal of a cim:PowerTransformer.
      Maximum two cim:TapChanger-s are allowed per cim:PowerTransformerEnd as follows:
      - one subtype of cim:PhaseTapChanger
      - one cim:RatioTapChanger, being either:
          - OLTC cim:RatioTapChanger
          or
          - manually adjustable cim:RatioTapChanger.

      Justification:
      A real power transformer does not have more than one on-load tap changer of the
      same kind at the cim:PowerTransformerEnd or more than one manually adjustable.

      Message:
      More than allowed cim:TapChanger-s at a cim:PowerTransformerEnd.

      Usage: #IGMRuleSet

Rule: NoFlowControlAtNonRetainedSW  Level: 3  Severity: ERROR

      Details:
      cim:RegulatingControl.Terminal can reference a cim:Terminal of a non-retained
      cim:Switch (i.e. where cim:Switch.retained is set to false) only if
      cim:RegulatingControl.mode is cim:RegulatingControlModeKind.voltage.

      Justification:
      Non-retained cim:Switch-es are not included in a power flow solution, hence
      it is not possible for the power flow calculation to control their cim:Terminal-s.
      cim:Terminal-s of retained cim:Switch-es can be included in flow control.

      Message:
      A non-retained cim:Switch has flow control, i.e. cim:RegulatingControl.Terminal
      refers to a cim:Terminal of that cim:Switch.
```

```
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[9] 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.

[9] 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

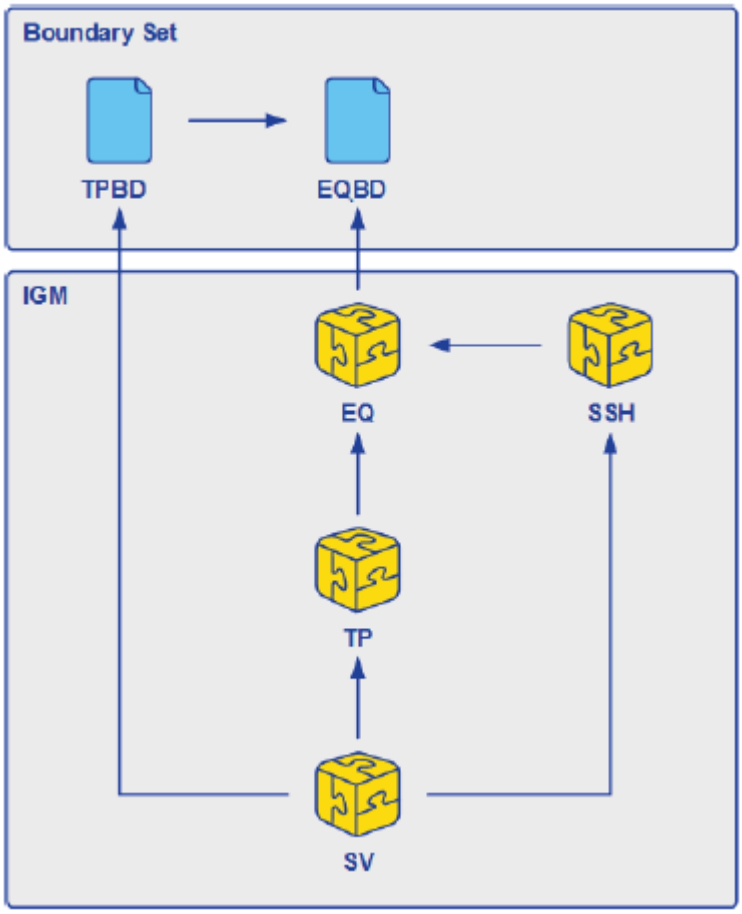

Figure 7 Dependencies of CGMES model instances

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

The references in 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, 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. The figure is described in more detail further down in the document.

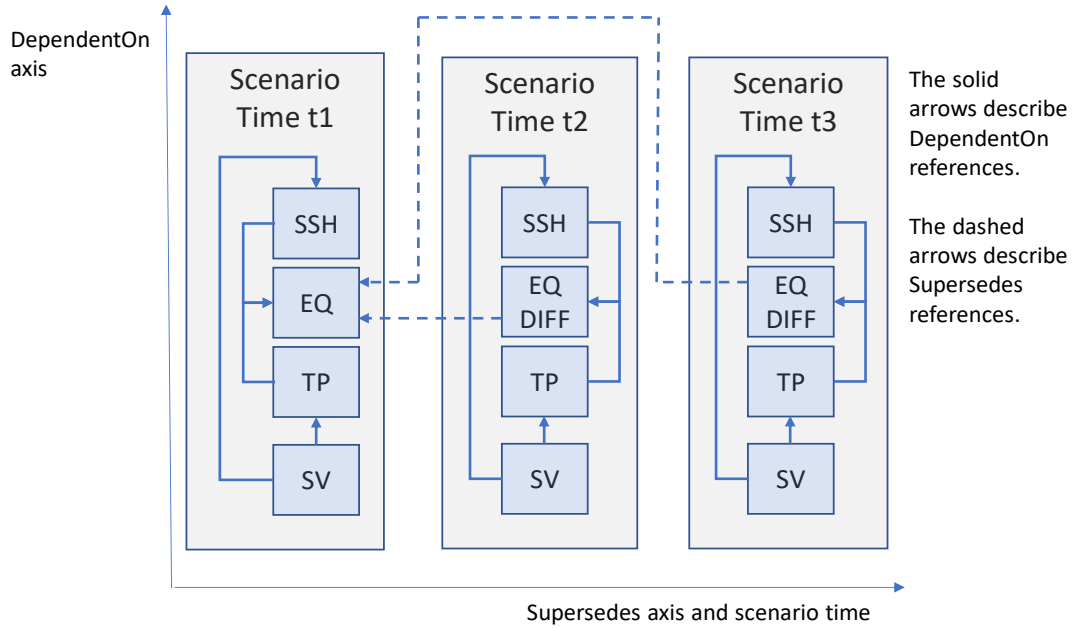

Figure 8 Use of DependentOn and Supersedes in IGMs

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.

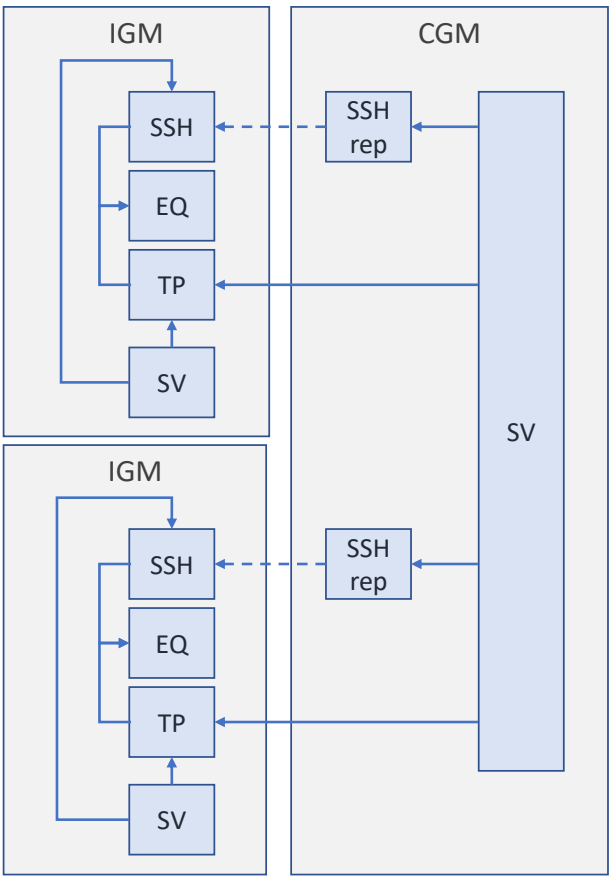

Figure 9 Example of relations between IGM and CGM files

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 and 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.

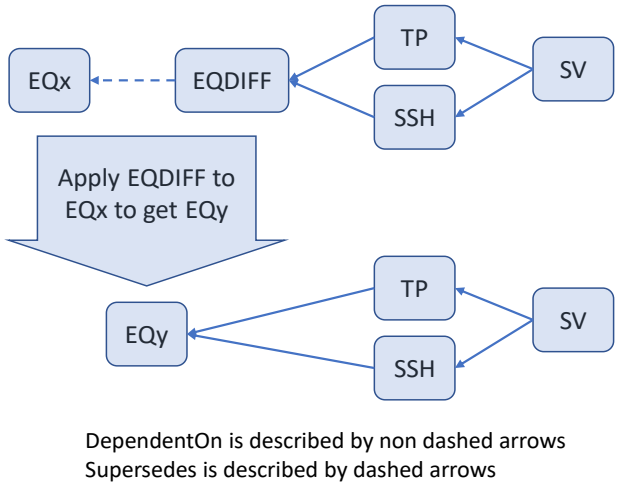

Figure 10 Application of DIFF files

In 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 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, the Receiver is the client using CIMXML files, e.g. an RSC) don't need to bother with EQDIFF files nor the Supersedes reference.

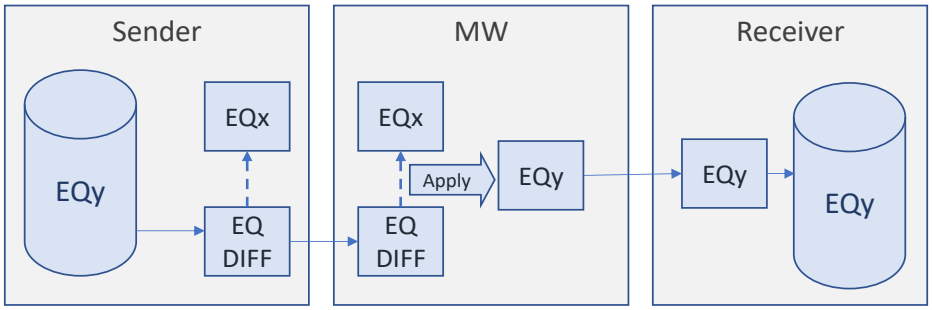

Figure 11 Applying the EQDIFF at the middleware

In Figure 11 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:
```

```
3400          Every SSH file shall have an
3401          'md:Model.DependentOn' reference to a EQ or EQDIFF file.
3402          Note: This is a minimum requirement so more references may be present.
3403
3404          Justification:
3405          IEC TS 61970-600-1:2017, requirement HREF2: "Dependent IDs refer to
3406          IDs of the dependent files at the time of the export".
3407          IEC TS 61970-600-1:2017, requirement PROF10.
3408
3409          Message:
3410          Invalid md:Model.DependentOn statement(s) in SSH.
3411
3412          Usage: #IGMRuleSet #CGMRuleSet
3413
3414    Rule: DY->EQ,DY->EQDIFF  Level: 4  Severity: ERROR
3415
3416          Details:
3417          Every DY file shall have an
3418          'md:Model.DependentOn' reference to a EQ or EQDIFF file.
3419          Note: This is a minimum requirement so more references may be present.
3420
3421          Justification:
3422          IEC TS 61970-600-1:2017, requirement HREF2: "Dependent IDs refer to
3423          IDs of the dependent files at the time of the export".
3424          IEC TS 61970-600-1:2017, requirement PROF10.
3425
3426          Message:
3427          Invalid md:Model.DependentOn statement(s) in DY.
3428
3429          Usage: #IGMRuleSet #CGMRuleSet
3430
3431    Rule: SV->SSH,SV->TP,SV->TPBD  Level: 4  Severity: ERROR
3432
3433          Details:
3434          Every SV file shall have 'md:Model.DependentOn' references to the files
3435          - SSH input files to the power flow calculation.
3436          - TP files with the power flow busses used in the power flow calculation.
3437          - TPBD files with the power flow busses in the boundary
3438          Note: This is a minimum requirement so more references may be present.
3439
3440          Justification:
3441          IEC TS 61970-600-1:2017, requirement HREF2: "Dependent IDs refer to
3442          IDs of the dependent files at the time of the export".
3443          IEC TS 61970-600-1:2017, requirement PROF10.
3444
3445          Message:
3446          Invalid md:Model.DependentOn statement(s), SV does not have reference to TP, SSH
3447          and TPBD (used as input data for the power flow calculations).
3448
3449          Usage: #IGMRuleSet #CGMRuleSet
3450
3451    Rule: GL->EQ,GL->EQBD  Level: 4  Severity: ERROR
3452
3453          Details:
3454          Every GL model file has 'md:Model.DependentOn'
3455          references to the EQ model file and EQBD model file that
```

```
3456          were used for the serialization. The reference to the EQ model file is required
3457          and EQBD model file is optional.
3458          Note: This is a minimum requirement so more references may be present.
3459
3460          Justification:
3461          IEC TS 61970-600-1:2017, requirement HREF2: "Dependent IDs refer to
3462          IDs of the dependent files at the time of the export".
3463          IEC TS 61970-600-1:2017, requirement PROF10.
3464
3465          Message:
3466          Invalid md:Model.DependentOn statement(s), GL does not have reference to EQ.
3467
3468          Usage: #IGMRuleSet #CGMRuleSet
3469
3470    Rule: DL->EQ,DL->EQDIFF,DL->TP,DL->DY  Level: 4  Severity: ERROR
3471
3472          Details:
3473          Every DL file shall have 'md:Model.DependentOn'
3474          references to the EQ or EQDIFF file, the TP file and to
3475          the DY file that were used for the serialization. The
3476          reference to the EQ model file is required and the references to
3477          TP and DY model files are optional.
3478          Note: This is a minimum requirement so more references may be present.
3479
3480          Justification:
3481          IEC TS 61970-600-1:2017, requirement HREF2: "Dependent IDs refer to
3482          IDs of the dependent files at the time of the export".
3483          IEC TS 61970-600-1:2017, requirement PROF10.
3484
3485          Message:
3486          Invalid md:Model.DependentOn statement(s), DL does not have reference to EQ.
3487
3488          Usage: #IGMRuleSet #CGMRuleSet
3489
3490    Rule: EQDIFF->EQ  Level: 4  Severity: ERROR
3491
3492          Details:
3493          Every EQDIFF file shall only have a md:Model.Supersedes
3494          references to the EQ file it updates as it is not correct to use
3495          md:Model.DependentOn for a CIMXML file that replaces or supersedes another.
3496          The elements of the following types are allowed in the EQDIFF document
3497          - cim:VoltageLimit
3498          - cim:CurrentLimit
3499          - cim:ActivePowerLimit
3500          - cim:ApparentPowerLimit
3501          This rule restricts use of difference models and is CGM_BP specific.
3502
3503          Justification:
3504          IEC TS 61970-600-1:2017 annex C.2.
3505          EMF meeting decision in Rome 2018-10-05.
3506
3507          Message:
3508          Invalid md:Model.Supersedes statement(s), only reference to EQ is allowed.
3509
3510          Usage: #IGMRuleSet #CGMRuleSet
3511
```

```
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 an attribute or a 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.

```
3615
3616          Justification:
3617          cim:GeographicalRegion is used to organise equipment geographically and regions
3618          that corresponds to a network model managed by a TSO which is also the
3619          ModelingAuthority for the network.
3620          Each IGM shall be described by one cim:GeographicalRegion.
3621          See also IEC TS 61970-600-1 E.13.
3622
3623          Message:
3624          More than one GeographicalRegion in IGM or cim:SubGeographicalRegion-s refer to
3625          multiple cim:GeographicalRegion-s.
3626
3627          Usage: #IGMRuleSet
3628
3629
3630    Rule: LineContainment  Level: 5  Severity: ERROR
3631
3632          Details:
3633          For every instance of cim:ACLineSegment, the cim:Equipment.EquipmentContainer
3634          referred to, if provided, must be of type cim:Line.
3635
3636          Justification:
3637          See Figure 15 (diagram Core notes) and
3638          section 6.9.16 of IEC TS 61970-600-2.
3639
3640          Message:
3641          cim:ACLineSegments is not contained in a cim:Line.
3642
3643          Usage: #IGMRuleSet
3644
3645    Rule: EquivalentInjectionContainment  Level: 5  Severity: ERROR
3646
3647          Details:
3648          Every cim:EquivalentInjection shall be contained by a
3649          - cim:VoltageLevel if not in a boundary point.
3650          - If in a boundary point, preferably it is contained in a cim:Line or
3651             not contained at all with provided association to cim:BaseVoltage.
3652
3653          Justification:
3654          All equipment shall be contained, also cim:EquivalentInjection, but as it is
3655          allowed not to have cim:EquivalentInjection contained this is
3656          allowed for backwards compatibility.
3657          See also IEC TS 61970-600-2 6.7.6.
3658
3659          Message:
3660          cim:EquivalentInjection containment error.
3661
3662          Usage: #IGMRuleSet
3663
3664
3665    Rule: DCLineContainment  Level: 5  Severity: ERROR
3666
3667          Details:
3668          For every instance of cim:DCLineSegment, the cim:Equipment.EquipmentContainer
3669          referred to, must be of type cim:DCLine. In the case of modelling back to back
3670          configuration the association shall point to EquipmentContainer of type
```

```
3671          cim:Substation. Missing containment is not allowed.
3672
3673          Justification:
3674          See section 6.3.15 of IEC TS 61970-600-2
3675
3676          Message:
3677          cim:DCLineSegment is not contained in either a cim:DCLine or a cim:Substation.
3678
3679          Usage: #IGMRuleSet
3680
3681
3682    Rule: BaseVoltageNotInBoundary  Level: 5  Severity: WARNING
3683
3684          Details:
3685          All cim:BaseVoltages should be agreed on by modeling authorities and
3686          be in the boundary.
3687          If a matching base voltage is already in the boundary it
3688          should be used.
3689          If a matching base voltage is not in the boundary, consider
3690          to add it in the boundary so that it can be reused by others.
3691
3692
3693          Justification:
3694          An agreement on the base voltages is required to get interoperability.
3695          Rule added at CGM_BP meeting in Zagreb 2019-05-23.
3696
3697          Message:
3698          cim:BaseVoltage not in boundary.
3699
3700          Usage: #IGMRuleSet
3701
3702
3703    Rule: SVCVoltage  Level: 5  Severity: ERROR
3704
3705          Details:
3706          The association end cim:RegulatingCondEq.RegulatingControl is required.
3707          cim:RequlatingControl.targetValue shall be greater than zero if
3708          cim:RequlatingControl.mode is RegulatingControlModeKind.voltage.
3709          The attributes cim:StaticVarCompensator.sVCControlMode and
3710          cim:StaticVarCompensator.voltageSetPoint are ignored at both model validation and
3711          control logic of the SVC.
3712
3713          Justification:
3714          The reactive power output of the SVC is proportional to the
3715          difference between the voltage at the regulated bus and the voltage
3716          setpoint. When the regulated bus voltage is equal to the voltage
3717          setpoint, the reactive power output is zero.
3718          RequlatingControl is used as it has capabilities missing from SVC,
3719          e.g. the controlled point.
3720          See IEC TS 61970-600-2:2017, section 6.9.44.
3721
3722          Message:
3723          cim:RegulatingCondEq.RegulatingControl is not provided or
3724          cim:RequlatingControl.targetValue is not greater than zero.
3725
3726
```

```
3727          Usage: #IGMRuleSet
3728
3729    Rule: TapChangerNeutralU  Level: 5  Severity: ERROR
3730
3731          Details:
3732          The cim:TapChanger.neutralU shall be the same as cim:PowerTransformerEnd.ratedU.
3733
3734          Justification:
3735          See section E.2.2. of IEC TS 61970-600-1:2017.
3736
3737          Message:
3738          The neutralU differs from ratedU.
3739
3740          Usage: #IGMRuleSet
3741
3742    Rule: ControlLinkedToTopology  Level: 5  Severity: WARNING
3743
3744          Details:
3745          The controlled cim:Terminal at a cim:RegulatingControl (RC) or
3746          cim:TapChangerControl (TCC) must be linkedto a cim:TopologicalNode (TN).
3747          In case cim:Switch cim:Terminals are not included in TP and if the
3748          controlled point is a cim:Switch cim:Terminal the controlled point is lost.
3749          The cardinality for cim:Terminal.TopologicalNode is 1 so it is required,
3750          hence all cim:Terminals must be present in TP regardless of the type of
3751          conducting equipment, it is linked to.
3752          This rule shouldn't be needed if all cim:Terminals where present in TP.
3753
3754          Justification:
3755          If a RC or TCC is not linked to a TN the changes in the control variables will not
3756          affect the target value in the power flow calculation.
3757          See section E.12 of IEC TS 61970-600-1:2017.
3758
3759          Message:
3760          Terminal controlled by cim:RegulatingControl or cim:TapChangerControl is not
3761          linked to a cim:TopologicalNode.
3762
3763          Usage: #IGMRuleSet
3764
3765    Rule: BranchBaseVoltage  Level: 5  Severity: ERROR
3766
3767          Details:
3768          Every instance of cim:ACLineSegment, cim: SeriesCompensator or cim:EquivalentBranch
3769          must have an association cim:ConductingEquipment.BaseVoltage.
3770
3771          Note: PowerTransformerEnd already has required association with
3772          cim:TransformerEnd.BaseVoltage.
3773
3774          Justification:
3775          See section 6.7.6, 6.10.42, 6.12.2 and 6.10.2 of IEC TS 61970-600-2.
3776
3777          Message:
3778          Either cim:ACLineSegment, cim:EquivalentBranch, or cim:SeriesCompensator has no
3779          BaseVoltage.
3780
3781          Usage: #IGMRuleSet
3782
```

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:
A boundary cim:EquivalentInjection representing AC network controls 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 cim:SvTapStep for a cim: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

3839 - cim:ExternalNetworkInjection
3840 - cim:ShuntCompensator
3841 - cim:StaticVarCompensator
3842 - cim:EnergySource.
3843
3844 Justification:
3845 See section 9.5.4 of IEC TS 61970-600-2.
3846
3847 Message:
3848 Missing cim:SvPowerFlow for an equipment.
3849
3850 Usage: #IGMRuleSet #CGMRuleSet
3851
3852
3853 Rule: SvPowerFlowBranchInstances Level: 5 Severity: ERROR
3854
3855 Details:
3856 The following shall conform:
3857 1) For cim:TieFlow, which association end cim:TieFlow.ControlArea refers to a
3858 cim:ControlArea with cim:ControlArea.type equal to
3859 cim:ControlAreaTypeKind.Interchange, the association end cim:TieFlow.Terminal
3860 shall refer to a cim:Terminal of either cim:ACLineSegment, cim:PowerTransformer or
3861 cim:Switch and its subclasses. The cim:Terminal referenced by the association end
3862 cim:TieFlow.Terminal shall be associated with a boundary cim:TopologicalNode that
3863 conforms to item 2).
3864 2) A boundary cim:TopologicalNode that is connected to an IGM shall have
3865 - One cim:EquivalentInjection
3866 - One of the following equipment: cim:ACLineSegment, cim:PowerTransformer or a
3867 retained cim:Switch (cim:Switch.retained=true) and its subclasses.
3868
3869 Justification:
3870 See BPPL1 of IEC TS 61970-600-1:2017.
3871 Normally, cim:EquivalentBranch-es result from a power system reduction process that
3872 depends on its state, e.g. connectivity. Therefore, cim:EquivalentBranch-es are
3873 not persistent over time as new ones may be created while previous ones deleted.
3874 Branches connected at the network boundary need to be well defined and unambiguously
3875 identifiable, as they are representing non-equivalent objects connected to a
3876 boundary point agreed between the two parties on a given border. The
3877 cim:EquivalentBranch is not meeting such criteria by nature hence, it shall not
3878 connect to a boundary point.
3879
3880 Message:
3881 One of the following occurs: 1) A cim:TieFlow with a cim:TieFlow.Terminal referring
3882 to either a cim:Terminal that is not connected to a boundary cim:TopologicalNode
3883 or it is not a cim:Terminal of one of the following: cim:ACLineSegment,
3884 cim:PowerTransformer or a retained cim:Switch and its subclasses; 2) A boundary
3885 cim:TopologicalNode connected to the IGM that does not have one
3886 cim:EquivalentInjection and one of the following: cim:ACLineSegment,
3887 cim:PowerTransformer, or a retained cim:Switch and its subclasses.
3888
3889 Usage: #IGMRuleSet #CGMRuleSet
3890
3891 Rule: SvPowerFlowBranchInstances2 Level: 5 Severity: ERROR
3892
3893 Details:
3894 Branches shall have cim:SvPowerFlow instantiated at its cim:Terminals for

```
3895          the following branch classes:
3896          - cim:SeriesCompensator
3897          - cim:ACLineSegment
3898          - cim:PowerTransformer
3899          - cim:EquivalentBranch
3900          - cim:Switch where cim:Switch.retained is true.
3901
3902          Justification:
3903          The power flow result for branches cannot be reviewed without cim:SvPowerFlow.
3904          This is needed when solutions for the same IGM or CGM computed by different
3905          tools are compared.
3906          Note that computing the flows by scripts based on solved voltages may not
3907          give the same result as the original power flow.
3908
3909          Message:
3910          Missing cim:SvPowerFlow for a branch.
3911
3912          Usage: #IGMRuleSet #CGMRuleSet
3913
3914    Rule: DisconnectedTerminal  Level: 5  Severity: ERROR
3915
3916          Details:
3917          If the associated cim:ACDCTerminal.connected status is false, the flow
3918          specified in the cim:SvPowerFlow.p and cim:SvPowerFlow.q shall be zero.
3919
3920          Justification:
3921          See section 9.5.4. of IEC TS 61970-600-2.
3922
3923          Message:
3924          Non-zero flow exchanged for a disconnected terminal.
3925
3926          Usage: #IGMRuleSet #CGMRuleSet
3927
3928    Rule: TopologicalIslandInstance  Level: 5  Severity: ERROR
3929
3930          Details:
3931          In case a solved model is exchanged for a single MAS the state variables
3932          profile must include at least one instance of cim:TopologicalIsland.
3933
3934          Justification:
3935          See section E.6 of IEC TS 61970-600-1:2017.
3936
3937          Message:
3938          Missing cim:TopologicalIsland.
3939
3940          Usage: #IGMRuleSet #CGMRuleSet
3941
3942    Rule: SmallTopologicalIsland  Level: 5  Severity: WARNING
3943
3944          Details:
3945          A small cim:TopologicalIsland with TNs having zero voltage is in most cases
3946          meaningless and should not be exchanged.
3947          A cim:TopologicalIsland with three or fewer cim:TopologicalNodes is small.
3948
3949          Justification:
3950          A small cim:TopologicalIsland is typically not energized and does not contribute
```

```
3951        to the interconnected network solution. The number of three cim:TopologicalNodes
3952        as a small island is selected to catch disconnected three winding transformers.
3953
3954        Message:
3955        Small cim:TopologicalIsland found.
3956
3957        Usage: #IGMRuleSet #CGMRuleSet
3958
3959  Rule: SlackNode  Level: 5  Severity: WARNING
3960
3961        Details:
3962        For every cim:TopologicalIsland the
3963        cim:TopologicalIsland.AngleRefTopologicalNode should refer to the
3964        cim:TopologicalNode with a cim:SynchronousMachine having the highest
3965        cim:SynchronousMachine.referencePriority. The priority values are
3966        - 0 not included in slack node determination.
3967        - 1 is the highest.
3968        - 2 and on are decreasing priorities. If no cim:SynchronousMachine with
3969           cim:SynchronousMachine.referencePriority specified is available the
3970           cim:TopologicalIsland.AngleRefTopologicalNode can be set to any
3971           cim:TopologicalNode.
3972
3973        Justification:
3974        See section E.4 of IEC TS 61970-600-1:2017
3975        If different power flow solutions have the same angle reference
3976        for the same network solutions are easier to compare.
3977        If not, the linear offset is to be expected.
3978
3979        Message:
3980        A cim:SynchronousMachine with valid ReferencePriority exists
3981        but is not used for defining the angle reference node in topological island.
3982
3983        Usage: #IGMRuleSet
3984
3985  Rule: SwitchTerminals  Level: 5  Severity: ERROR
3986
3987        Details:
3988        For every instance of cim:Switch, cim:Breaker, cim:Disconnector,
3989        cim:GroundDisconnector and cim:LoadBreakSwitch,
3990        it is not allowed to have its cim:Terminals connected to the
3991        same cim:ConnectivityNode.
3992
3993        Justification:
3994        See section E.17 of IEC TS 61970-600-1:2017.
3995
3996        Message:
3997        A switch that has its terminals connected to the same cim:ConnectivityNode.
3998
3999        Usage: #IGMRuleSet
4000
4001  Rule: SwitchVL  Level: 5  Severity: ERROR
4002
4003        Details:
4004        For every instance of cim:Switch, cim:Breaker, cim:Disconnector,
4005        cim:GroundDisconnector and cim:LoadBreakSwitch,
4006        it is not allowed to connect cim:ConnectivityNode or cim:TopologicalNode
```

```
4007          in different cim:VoltageLevels.
4008
4009          Justification:
4010          See section E.17 of IEC TS 61970-600-1:2017.
4011
4012          Message:
4013          A cim:Switch that connects to cim:ConnectivityNode-s or cim:TopologicalNode-s
4014          in different cim:VoltageLevel-s.
4015
4016          Usage: #IGMRuleSet
4017
4018    Rule: SwitchTN1  Level: 5  Severity: ERROR
4019
4020          Details:
4021          For every instance of cim:Switch, cim:Breaker, cim:Disconnector,
4022          cim:GroundDisconnector and cim:LoadBreakSwitch,
4023          with cim:Switch.retained is true,
4024          its cim:Terminals shall be associated with different cim:TopologicalNodes.
4025
4026          Justification:
4027          See section E.17 of IEC TS 61970-600-1:2017.
4028
4029          Message:
4030          A retained cim:Switch with cim:Terminal-s associated with the same
4031          cim:TopologicalNode.
4032
4033          Usage: #IGMRuleSet
4034
4035    Rule: SwitchOpenVsConnected  Level: 5  Severity: ERROR
4036
4037          Details:
4038          The attribute cim:ACDCTerminal.connected shall always be set to true for terminals
4039          of cim:Switch or its subclasses.
4040
4041          Justification:
4042          A cim:Terminal has switching capability due to the attribute
4043          cim:ACDCTerminal.connected flag, a cim:Equipment can be disconnected with this
4044          flag. For cim:Switch-es this means it is possible to break the conducting path at
4045          three places:
4046          - cim:ACDCTerminal.connected side 1 (cim:ACDCTerminal.sequenceNumber=1)
4047          - cim:Switch.open
4048          - cim:ACDCTerminal.connected side 2 (cim:ACDCTerminal.sequenceNumber=2)
4049          Evaluating switch status then means inspecting the three flags for every switch.
4050
4051          Message:
4052          cim:ACDCTerminal.connected is not set to true for a cim:Switch or its subclasses.
4053
4054          Usage: #IGMRuleSet
4055
4056    Rule: ParticipatingGeneratingUnit  Level: 5  Severity: WARNING
4057
4058          Details:
4059          This rule applies when generation slack is used.
4060          cim:GeneratingUnit-s that pick-up mismatch shall have a cim:GeneratingUnit.normalPF
4061          greater than 0. At least one such unit is required in every electrical island.
4062
```

```
4063          Justification:
4064          GeneratingUnits cannot pick-up mismatch if this data is unspecified.
4065
4066          Message:
4067          No GeneratingUnit with .normalPF greater than 0 in an island.
4068
4069          Usage: #IGMRuleSet
4070
4071    Rule: ControlOfAnotherIsland  Level: 5  Severity: WARNING
4072
4073          Details:
4074          A cim:RegulatingControl or cim:TapChangerControl should not control a
4075          cim:TopologicalNode in another cim:TopologicalIsland than its
4076          controlling equipment is located.
4077          The rule is applied for cim:RegulatingControl.enabled equal true. In addition, the
4078          rule applies to objects only within the IGM as references to objects in another
4079          MAS will be reported as dangling references.
4080
4081          Justification:
4082          There is no feedback loop to the control in this case.
4083
4084          Message:
4085          A controlled cim:TopologicalNode is in another cim:TopologicalIsland
4086          than the controlling equipment.
4087
4088          Usage: #IGMRuleSet
4089
4090    Rule: TapChangerTargetRange  Level: 5  Severity: WARNING
4091
4092          Details:
4093          A tap changer cannot reach a cim:RegulatingControl.targetValue outside its
4094          capability.
4095          The tap changer upper capability limit (TCUC) in per unit is
4096          - TCUC = 1+cim:RatioTapChanger.stepVoltageIncrement/100*
4097             (cim:TapChanger.highStep-cim:TapChanger.neutralStep)
4098          The tap changer lower capability limit (TCLC) in per unit is
4099          - TCLC = 1-cim:RatioTapChanger.stepVoltageIncrement/100*
4100             (cim:TapChanger.neutralStep-cim:TapChanger.lowStep)
4101          The TCUC and TCLC are in per unit (PU)
4102          The target value in PU is TargetValuePU =
4103          cim:RegulatingControl.targetValue/cim:BaseVoltage.nominalVoltage
4104          where the cim:BaseVoltage is from the controlled Terminal.
4105          The rule is
4106          - min(TCLC,TCUC) GreaterOrEqual TargetValuePU LessOrEqual max(TCLC,TCUC)
4107          Note1: The cim:TapChanger.controlEnabled and
4108          cim:RequlatingControl.enabled flags are to be considered.
4109          Note2: cim:TapChangerControlMode shall be set to voltage control.
4110
4111          Justification:
4112          The transformer cannot meet the requested target value.
4113
4114          Message:
4115          The cim:RegulatingControl.targetValue is outside the cim:TapChanger
4116          capability.
4117
4118          Usage: #IGMRuleSet #CGMRuleSet
```

```
4119
4120   Rule: IDuniqueness  Level: 5  Severity: ERROR
4121
4122         Details:
4123         All mRIDs (rdf:ID or rdf:about) in a model shall
4124         be unique.
4125
4126         Justification:
4127         All mRIDs (rdf:ID or rdf:about) shall be globally unique
4128         as stated in IEC 61970-552.
4129         See IEC TS 61970-600-1:2017 GENC1.
4130
4131         Message:
4132         mRID (rdf:ID or rdf:about) is not unique within model.
4133
4134         Usage: #IGMRuleSet #CGMRuleSet
4135
4136   Rule: TCCRemoteReactiveFlow  Level: 5  Severity: WARNING
4137
4138         Details:
4139         A cim:TapChangerControl (TCC) controlling reactive power flow should control the
4140         flow at one of the cim:Terminal-s belonging
4141         to cim:PowerTransformerEnd-s in the cim:PowerTransformer where the
4142         cim:TapChanger is located.
4143         Control a remote cim:Terminal (even if it is within the MAS) not belonging to the
4144         cim:PowerTransformer
4145         with the cim:TapChanger is not allowed.
4146         Note: A result of this is that multiple cim:TapChanger-s cannot be
4147         controlled by the same TCC.
4148
4149         Justification:
4150         A power transformer cannot efficiently control reactive power flow
4151         other than on its own terminals.
4152
4153         Message:
4154         A cim:TapChangerControl for reactive power flow is controlling a
4155         cim:Terminal that is not connected to one of the cim:PowerTransformerEnd-s.
4156
4157         Usage: #IGMRuleSet
4158
4159   Rule: SynchronousCondenserMode  Level: 5  Severity: WARNING
4160
4161         Details:
4162         For a synchronous condenser (cim:SynchronousMachine.type = condenser)
4163         there is no capability for real power output.
4164         In this case, the cim:SynchronousMachine.operationMode should be condenser.
4165
4166         Justification:
4167         The name plate ratings are used as a reference.
4168         See IEC TS 61970-600-2:2017, section 6.9.47.
4169
4170         Message:
4171         A synchronous condenser that does not have cim:SynchronousMachine.operatingMode
4172         set to condenser.
4173
4174         Usage: #IGMRuleSet #CGMRuleSet
```

Rule: SMOperatingModeConsistency Level: 5 Severity: ERROR

Details:
The SynchronousMachine.operatingMode shall be consistent with the SynchronousMachine.type.
– SynchronousMachine.operatingMode = “motor” shall be provided for SynchronousMachine.type in ["motor", "generatorOrMotor", "motorOrCondenser", "generatorOrCondenserOrMotor"],
– SynchronousMachine.operatingMode = “condenser" shall be provided for SynchronousMachine.type in ["condenser", "generatorOrCondenser", "motorOrCondenser", "generatorOrCondenserOrMotor"], and
– SynchronousMachine.operatingMode = “generator” shall be provided for SynchronousMachine.type in ["generator", "generatorOrMotor", "generatorOrCondenser", "generatorOrCondenserOrMotor"].

Justification:
A cim:SynchronousMachine can only operate with the modes it is built for.

Message:
The cim:SynchronousMachine.operatingMode is inconsistent with cim:SynchronousMachine.type.

Usage: #IGMRuleSet

Rule: ControlOfIslandIsMissing Level: 5 Severity: ERROR

Details:
A cim:TopologicalIsland shall have at least one equipment controlling the voltage, e.g.:
- cim:EquivalentInjection with cim:EquivalentInjection.regulationStatus=true, nonzero cim:EquivalentInjection.regulationTarget and valid reactive power limits
- cim:SynchronousMachine with
    - control enabled for both cim:SynchronousMachine and cim:RegulatingControl
    - cim:SynchronousMachine.operatingMode = generator or condenser
- cim:StaticVarCompensator with control enabled for both SVC and cim:RegulatingControl

Justification:
Power flow calculation will not converge if an island does not have equipment controlling the voltage. Hence at least one controlling equipment must be present. If the island has the voltage controlled by resources in another IGM the EquivalentInjection at the boundary shall have its control enabled.

Message:
The island does not have any equipment controlling the voltage.

Usage: #IGMRuleSet #CGMRuleSet

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
2. Mean value of pairwise Q values, see Figure 13.
3. Max of pairwise negative Q values and min of pairwise positive Q values, see Figure 14.

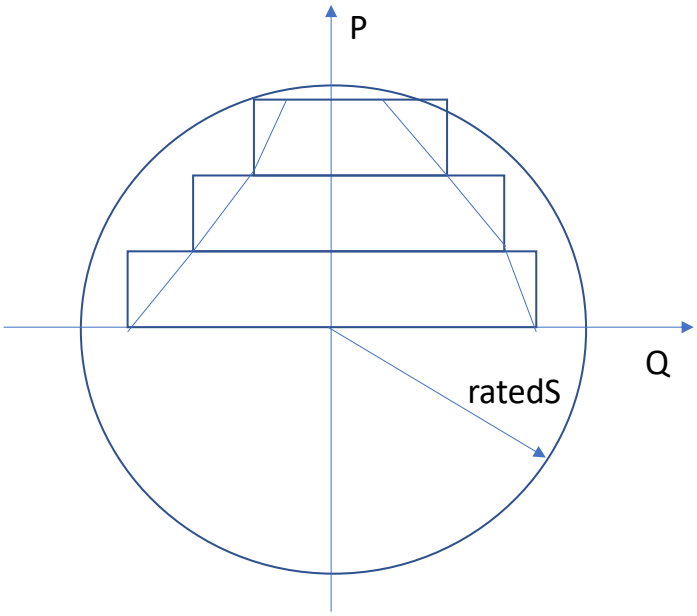

Figure 12 Pairwise max Value

The corners in the boxes in 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.

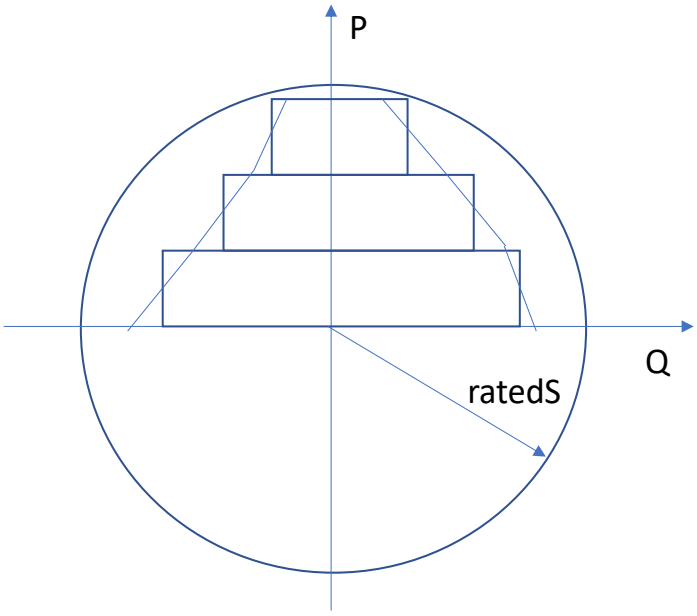

Figure 13 Pairwise Mean Value

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

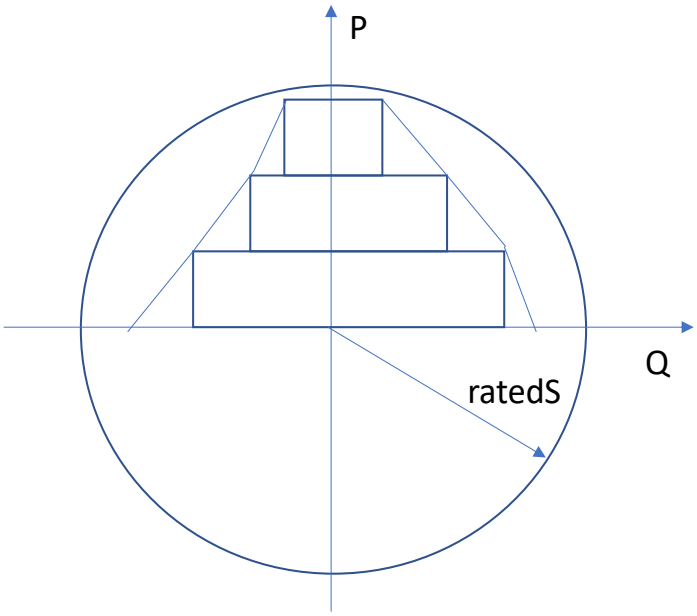

Figure 14 Pairwise Min Value

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 is 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,
```

```
4346        the values in SSH (input) and SV (calculation results) should not be far away.
4347
4348        Message:
4349        Assumed aggregated active power generation infeed deviates from calculated
4350        generation infeed more than SSH_SV_TOT_P_DIFF MW.
4351
4352        Usage: #IGMRuleSet #CGMRuleSet
4353
4354  Rule: GenReactivePowerInfeedDiffW  Level: 6  Severity: WARNING
4355
4356        Details:
4357        For every instance of cim:SynchronousMachine, the value of
4358        cim:RotatingMachine.q should not deviate more than SSH_SV_MAX_Q_DIFF MVAr
4359        from the value of cim:SvPowerFlow.q for the associated terminal.
4360        Note that disconnected synchronous machines should have zero values in SSH.
4361
4362        Justification:
4363        Considering the Power Flow settings, the reactive power shift
4364        should be minimal.
4365
4366        Message:
4367        Potential reactive power problem located for cim:SynchronousMachine, assumed
4368        reactive power generation of cim:SynchronousMachine deviates from calculated
4369        more than SSH_SV_MAX_Q_DIFF MVAr.
4370
4371        Usage: #IGMRuleSet #CGMRuleSet
4372
4373  Rule: GenReactivePowerInfeedLim  Level: 6  Severity: WARNING
4374
4375        Details:
4376        The reactive power provided to the network by a cim:SynchronousMachine shall
4377        stay within limits regardless if it is controlling or not
4378        - negated cim:RotatingMachine.q greater or equal than cim:SynchronousMachine.minQ
4379          if provided
4380        - negated cim:RotatingMachine.q less or equal than cim:SynchronousMachine.maxQ
4381          if provided
4382        Note1: cim:RotatingMachine.q shall be negated due to the load sign convention.
4383        The rule is applied for all cim:SynchronousMachine-s with and without associated
4384        cim:ReactiveCapabilityCurve.
4385
4386
4387        Justification:
4388        The reactive power infeed at PQ nodes should be within limits.
4389
4390        Message:
4391        Generation reactive power infeed is out of range.
4392
4393        Usage: #IGMRuleSet #CGMRuleSet
4394
4395  Rule: GenRCCPowerInfeed  Level: 6  Severity: WARNING
4396
4397        Details:
4398        The power provided to the network by a cim:SynchronousMachine should stay
4399        within limits regardless if it is controlling or not. This rule applies
4400        when a reactive capability curve is present. Active power is restricted as
4401        - RCCCD = RCC.mRID=CD[CD.Curve]
```

```
4402          - -RM.p LE max(RCCCD/CD.xvalue) and
4403          - -RM.p GE min(RCCCD/CD.xvalue)
4404          where
4405          - The notation above is an XPath expression
4406          - RCC = cim:ReactiveCapabilityCurve
4407          - RCCCD = The cim:CurveData points that belongs to the RCC
4408          - CD = cim:CurveData
4409          - RM = cim:RotatingMachine, note this is load sign convention
4410          - LE = Less or Equal
4411          - GE = Greater or Equal
4412          Reactive power is restricted as
4413          - CD1 = min(RCCCD[CD.xvalue LE -RM.p])
4414          - CD2 = min(RCCCD[CD.xvalue GE -RM.p])
4415          - RM.q LE interpolate(CD2/CD.y2value, CD2/CD.xvalue, CD1/CD.y2value,
4416                CD1/CD.xvalue, -RM.p)
4417          - RM.q GE interpolate(CD2/CD.y1value, CD2/CD.xvalue, CD1/CD.y1value,
4418                CD1/CD.xvalue, -RM.p)
4419          where
4420          - CD1 = nearest lower active power limit point
4421          - CD2 = nearest higher active power limit point
4422          - interpolate(w1, z1, w2, z2, w) is a function with parameters
4423             - w1 and z1 = the first coordinate point
4424             - w2 and z2 = the second coordinate point
4425             - w = the value along the w axis to interpolate the value along
4426                the z axis
4427             In case interpolation is not used, the mean value between w1
4428             and w2 should be used as limit.
4429
4430          Justification:
4431          The active and reactive power infeed at PQ nodes should be within limits.
4432
4433          Message:
4434          Generation active and/or reactive power infeed is out of range.
4435
4436          Usage: #IGMRuleSet #CGMRuleSet
4437
4438    Rule: ValidDER  Level: 6  Severity: WARNING
4439
4440          Details:
4441          For every instance of a DistributedEnergyResource (DER), e.g.
4442          cim:EnergySource, the value of cim:EnergySource.activePower
4443          should be lower than or equal to zero.
4444
4445          Justification:
4446          Due to the load sign convention, decentralized infeed must be
4447          negative or zero.
4448          See IEC TS 61970-600-2:2017 section 7.8.6.
4449
4450          Message:
4451          DER infeed acts as a load.
4452
4453          Usage: #IGMRuleSet #CGMRuleSet
4454
4455    Rule: DERActivePowerInfeedDiffW  Level: 6  Severity: WARNING
4456
4457          Details:
```

```
4458          For every instance of cim:EnergySource, the value of
4459          cim:EnergySource.activePower should not deviate more than SSH_SV_MAX_P_DIFF MW
4460          from the value of cim:SvPowerFlow.p for the associated terminal.
4461          Note that disconnected DER should have zero values in SSH.
4462
4463          Justification:
4464          The SSH data should be based on a solved power flow (CGMM) and as a consequence,
4465          the values in SSH (input) and SV (calculation results) should not be far away.
4466
4467          Message:
4468          Assumed generation infeed of cim:EnergySource deviates from calculated generation
4469          infeed more than SSH_SV_MAX_P_DIFF MW.
4470
4471          Usage: #IGMRuleSet #CGMRuleSet
4472
4473    Rule: DERActivePowerInfeedDiffE  Level: 6  Severity: ERROR
4474
4475          Details:
4476          The aggregated sum of the values of cim:EnergySource.activePower shall not
4477          deviate more than SSH_SV_TOT_P_DIFF MW from the aggregated sum of the values of
4478          cim:SvPowerFlow.p for the terminals connected to cim:EnergySource.
4479          Note that disconnected DER should have zero values in SSH.
4480
4481          Justification:
4482          The SSH data should
4483          be based on a solved power flow (CGMM) and as a consequence, the values in
4484          SSH (input) and SV (calculation results) should not be far away.
4485
4486          Message:
4487          Assumed aggregated active power generation infeed deviates from calculated
4488          generation infeed more than SSH_SV_TOT_P_DIFF MW.
4489
4490          Usage: #IGMRuleSet #CGMRuleSet
4491
4492    Rule: DERReactivePowerInfeedDiffW  Level: 6  Severity: WARNING
4493
4494          Details:
4495          For every instance of cim:EnergySource, the value of
4496          cim:EnergySource.reactivePower should not deviate more than SSH_SV_MAX_Q_DIFF MVAr
4497          from the value of cim:SvPowerFlow.q for the associated terminal.
4498          Note that disconnected DER should have zero values in SSH.
4499
4500          Justification:
4501          The SSH data should be based on a solved power flow (CGMM) and as a consequence,
4502          the values in SSH (input) and SV (calculation results) should not be far away.
4503
4504          Message:
4505          Assumed generation infeed of cim:EnergySource deviates from calculated generation
4506          infeed more than SSH_SV_MAX_Q_DIFF MVAr.
4507
4508          Usage: #IGMRuleSet #CGMRuleSet
4509
4510    Rule: ValidLoad  Level: 6  Severity: WARNING
4511
4512          Details:
4513          For every instance of cim:StationSupply, cim:ConformLoad and
```

```
4514          cim:NonConformLoad, the value of cim:EnergyConsumer.p should be greater
4515          than or equal to zero.
4516
4517          Justification:
4518          Due to the load sign convention, all loads should be
4519          positive or zero. Decentralized generation should be modelled explicitly.
4520          See IEC TS 61970-600-2:2017 section 7.8.5.
4521
4522          Message:
4523          Load infeed acts as a generator.
4524
4525          Usage: #IGMRuleSet #CGMRuleSet
4526
4527    Rule: LoadActivePowerInfeedDiffW  Level: 6  Severity: WARNING
4528
4529          Details:
4530          For every instance of cim:StationSupply, cim:ConformLoad and
4531          cim:NonConformLoad, the value of cim:EnergyConsumer.p should not deviate
4532          more than SSH_SV_MAX_P_DIFF MW from the value of cim:SvPowerFlow.p for the
4533          associated terminal. Note that disconnected loads should have zero values in SSH.
4534
4535          Justification:
4536          The SSH data should be based on a solved power flow (CGMM) and as a consequence,
4537          the values in SSH (input) and SV (calculation results) should not be far away.
4538
4539          Message:
4540          Assumed consumption deviates from calculated consumption more than
4541          SSH_SV_MAX_P_DIFF MW.
4542
4543          Usage: #IGMRuleSet #CGMRuleSet
4544
4545    Rule: LoadActivePowerInfeedDiffE  Level: 6  Severity: ERROR
4546
4547          Details:
4548          The aggregated sum of the values of cim:EnergyConsumer.p shall not
4549          deviate more than SSH_SV_TOT_P_DIFF MW from the aggregated sum of the values of
4550          cim:SvPowerFlow.p for the associated terminals. Note that disconnected
4551          loads should have zero values in SSH.
4552
4553          Justification:
4554          The SSH data should be based on a solved power flow (CGMM) and as a consequence,
4555          the values in SSH (input) and SV (calculation results) should not be far away.
4556
4557          Message:
4558          Assumed aggregated consumption deviates from calculated consumption
4559          more than SSH_SV_TOT_P_DIFF MW.
4560
4561          Usage: #IGMRuleSet #CGMRuleSet
4562
4563    Rule: LoadReactivePowerInfeedDiffW  Level: 6  Severity: WARNING
4564
4565          Details:
4566          For every instance of cim:StationSupply, cim:ConformLoad and
4567          cim:NonConformLoad, the value of cim:EnergyConsumer.q should not deviate
4568          more than SSH_SV_MAX_Q_DIFF MVAr from the value of cim:SvPowerFlow.q for the
4569          associated terminal. Note that disconnected loads should have zero values in SSH.
```

```
4570
4571          Justification:
4572          Considering the Power Flow settings, the reactive power shift
4573          should be minimal.
4574
4575          Message:
4576          Potential reactive power problem located for load instance, assumed reactive power
4577          deviates from calculated more than SSH_SV_MAX_Q_DIFF MVAr.
4578
4579          Usage: #IGMRuleSet #CGMRuleSet
4580
4581    Rule: ENIActivePowerInfeedLim  Level: 6  Severity: WARNING  Template: RuleModel
4582          Details:
4583          The negated value of cim:ExternalNetworkInjection.p should be within the range
4584          [cim:ExternalNetworkInjection.minP, cim:ExternalNetworkInjection.maxP]. The
4585          validation takes into account that both cim:ExternalNetworkInjection.minP and
4586          cim:ExternalNetworkInjection.maxP will be negative if the equivalent injection is
4587          representing load operating range as cim:ExternalNetworkInjection.minP and
4588          cim:ExternalNetworkInjection.maxP are following generator sign convention (i.e.
4589          positive sign when generating power).
4590          Note1: Negation is necessary due to the load sign convention.
4591          Note2: An instance with cim:ExternalNetworkInjection.p = 0
4592          is considered out of service.
4593
4594          Justification:
4595          Load sign convention is used for the power infeed. The operating point should be
4596          within defined limits.
4597
4598          Message:
4599          ExternalNetworkInjection active power infeed is out of range.
4600
4601          Usage: #IGMRuleSet #CGMRuleSet
4602
4603    Rule: ENIReactivePowerInfeedLim  Level: 6  Severity: WARNING
4604
4605          Details:
4606          The negated value of cim:ExternalNetworkInjection.q should be within the range
4607          [cim:ExternalNetworkInjection.minQ, cim:ExternalNetworkInjection.maxQ]. The
4608          validation takes into account that both cim:ExternalNetworkInjection.minQ and
4609          cim:ExternalNetworkInjection.maxQ will be negative if the equivalent injection is
4610          representing load operating range as cim:ExternalNetworkInjection.minQ and
4611          cim:ExternalNetworkInjection.maxQ are following generator sign convention (i.e.
4612          positive sign when generating power).
4613          Note1: Negation is necessary due to the load sign convention.
4614
4615          Justification:
4616          Load sign convention is used for the power infeed. The operating point should be
4617          within defined limits.
4618
4619          Message:
4620          ExternalNetworkInjection reactive power infeed is out of range.
4621
4622          Usage: #IGMRuleSet #CGMRuleSet
4623
4624    Rule: ENIActivePowerInfeedDiffW  Level: 6  Severity: WARNING
4625
```

```
        Details:
        For every instance of cim:ExternalNetworkInjection, the value of
        cim:ExternalNetworkInjection.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:ExternalNetworkInjection should not be used frequently considering its
        purpose.

        Message:
        Assumed external injection deviates from calculated
        more than SSH_SV_MAX_P_DIFF MW.

        Usage: #IGMRuleSet #CGMRuleSet

Rule: ENIActivePowerInfeedDiffE  Level: 6  Severity: ERROR

        Details:
        The aggregated sum of the values of cim:ExternalNetworkInjection.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 associated terminals

        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:ExternalNetworkInjection should not be used frequently considering its
           purpose.

        Message:
        Assumed aggregated sum of external injections deviates from calculated
        more than SSH_SV_TOT_P_DIFF MW

        Usage: #IGMRuleSet #CGMRuleSet

Rule: ENIReactivePowerInfeedDiffW  Level: 6  Severity: WARNING

        Details:
        For every cim:ExternalNetworkInjection the value of
        cim:ExternalNetworkInjection.q should not deviate
        more than SSH_SV_MAX_Q_DIFF MVAr from the value of cim:SvPowerFlow.q for the
        associated terminal.
        Note that disconnected loads should have zero values in SSH.

        Justification:
        Considering the Power Flow settings, the reactive power shift
        should be minimal.

        Message:
        Potential reactive power problem located for cim:ExternalNetworkInjection,
        assumed reactive power deviates from calculated more than
        SSH_SV_MAX_Q_DIFF MVAr

        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.

```
4738
4739          Message:
4740          Assumed non-boundary cim:EquivalentInjection injection deviates from calculated
4741          more than SSH_SV_MAX_P_DIFF MW.
4742
4743          Usage: #IGMRuleSet #CGMRuleSet
4744
4745    Rule: EIActivePowerInfeedDiffE  Level: 6  Severity: ERROR
4746
4747          Details:
4748          The aggregated sum of the values of non-boundary cim:EquivalentInjection.p
4749          shall not deviate more than SSH_SV_TOT_P_DIFF MW from the aggregated sum of
4750          the values of cim:SvPowerFlow.p for the associated terminals
4751
4752          Justification:
4753          The SSH data should be based on a solved power flow (CGMM) and as a consequence,
4754          the values in SSH (input) and SV (calculation results) should not be far away.
4755          Note: cim:EquivalentInjection should not be used frequently considering its
4756          purpose.
4757
4758          Message:
4759          Assumed non-boundary cim:EquivalentInjection aggregated injection deviates from
4760          calculated more than SSH_SV_TOT_P_DIFF MW.
4761
4762          Usage: #IGMRuleSet #CGMRuleSet
4763
4764    Rule: EIReactivePowerInfeedDiffW  Level: 6  Severity: WARNING
4765
4766          Details:
4767          For every instance of cim:EquivalentInjection, the value of
4768          cim:EquivalentInjection.q should not deviate more than SSH_SV_MAX_Q_DIFF Mvar
4769          from the value of cim:SvPowerFlow.q for the associated terminal.
4770
4771
4772          Justification:
4773          The SSH data should be based on a solved power flow (CGMM) and as a consequence,
4774          the values in SSH (input) and SV (calculation results) should not be far away.
4775
4776          Message:
4777          Assumed generation infeed of cim:EquivalentInjection deviates from calculated
4778          generation
4779          infeed more than SSH_SV_MAX_Q_DIFF Mvar.
4780
4781          Usage: #IGMRuleSet #CGMRuleSet
4782
4783
4784    Rule: NetInterchange1  Level: 6  Severity: WARNING
4785
4786          Details:
4787          For a cim:ControlArea of type interchange the aggregated sum of the values
4788          of cim:SvPowerFlow.p for cim:Terminals referenced by cim:TieFlow.Terminal shall
4789          not deviate from the value of cim:ControlArea.netInterchange with more than
4790          cim:ControlArea.pTolerance, if provided. In cases where cim:ControlArea.pTolerance
4791          is not provided the value of INTERCH_IMBALANCE_WARNING MW is used in the comparison.
4792
4793          There are some implications from other rules to be considered:
```

4794 1) According to level 5 rule SvPowerFlowBranchInstances the cim:Terminal referenced
4795 by a cim:TieFlow.Terminal is located at a boundary
4796 cim:TopologicalNode, hence the attribute cim:TieFlow.positiveFlowIn
4797 is always true.
4798 2) According to level 5 rule SvPowerFlowBranchInstances2 the cim:Terminal
4799 of cim:ACLineSegment, cim:PowerTransformer or retained cim:Switch, etc. should have
4800 a cim:SvPowerFlow.
4801 3) According to level 5 rule SvPowerFlowInstances every cim:EquivalentInjection
4802 has a cim:SvPowerFlow.
4803
4804 As a consequence cim:SvPowerFlow related to boundary cim:EquivalentInjection-s
4805 must be used in the summation but with negated value. cim:SvPowerFlow participates
4806 in the sum if the cim:Terminal is a terminal of cim:EquivalentInjection, which is
4807 connected to a boundary cim:TopologicalNode, referenced by a cim:Terminal, which
4808 is also associated to a cim:TieFlow through cim:TieFlow.Terminal.
4809
4810 Note1: cim:ControlArea.netInterchange include AC and DC exchanges.
4811 Note2: An HVDC Boundary cim:TopologicalNode has a cim:IdentifiedObject.description
4812 attribute with leading characters 'HVDC'.
4813
4814 Justification:
4815 Area interchange control uses ControlArea.netInterchange as
4816 set point, the TieFlow terminals as State Variables and the ConformLoad
4817 within the ControlArea as Control Variables.
4818
4819 Message:
4820 Netted Area position not respected more than INTERCH_IMBALANCE_WARNING MW or
4821 cim:ControlArea.pTolerance, if provided.
4822
4823 Usage: #IGMRuleSet #CGMRuleSet
4824
4825 Rule: NetInterchange2 Level: 6 Severity: ERROR
4826
4827 Details:
4828 For a cim:ControlArea of type interchange the aggregated sum of the values
4829 of cim:SvPowerFlow.p for cim:Terminals referenced by cim:TieFlow.Terminal
4830 shall not deviate from the value of cim:ControlArea.netInterchange with more
4831 than INTERCH_IMBALANCE_ERROR MW.
4832 There are some implications from other rules to be considered:
4833 1) According to level 5 rule SvPowerFlowBranchInstances the cim:Terminal
4834 referenced by a cim:TieFlow.Terminal is located at a boundary
4835 cim:TopologicalNode, hence the attribute cim:TieFlow.positiveFlowIn
4836 is always true.
4837 2) According to level 5 rule SvPowerFlowBranchInstances2 the cim:Terminal
4838 of cim:ACLineSegment, cim:PowerTransformer or retained cim:Switch, etc. should have
4839 a cim:SvPowerFlow.
4840 3) According to level 5 rule SvPowerFlowInstances every cim:EquivalentInjection
4841 has a cim:SvPowerFlow.
4842
4843 As a consequence cim:SvPowerFlow related to boundary cim:EquivalentInjection-
4844 s must be used in the summation but with negated value.
4845 cim:SvPowerFlow participates in the sum if the cim:Terminal is a terminal of
4846 cim:EquivalentInjection, which is connected to a boundary cim:TopologicalNode,
4847 referenced by a cim:Terminal, which is also associated to a cim:TieFlow through
4848 cim:TieFlow.Terminal.
4849 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 is 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

```
4962          and the cim:RegulatingControl.targetValues differ the power flow will
4963          have to pick a value. If different Power Flow applications use different
4964          strategies to pick a value the voltage
4965          solution will differ between them which is the reason to warn.
4966
4967          Message:
4968          Conflicting target values of cim:RegulatingControl regulating voltage at the same
4969          cim:TopologicalNode.
4970
4971          Usage: #IGMRuleSet #CGMRuleSet
4972
4973    Rule: VoltageTargetAndDeadbandAtTN  Level: 6  Severity: WARNING
4974
4975          Details:
4976          For all cim:RegulatingControl (including its subclass cim:TapChangerControl)
4977          instances at a cim:TopologicalNode with one or more cim:RegulatingControls that
4978          have:
4979          - cim:RegulatingControl.discrete set to true
4980          - cim:RegulatingControl.enabled set to true, and
4981          - cim:RegulatingControl.mode set to cim:RegulatingControlModeKind.voltage,
4982          shall have cim:RegulatingControl.targetValue within the intersection of regulating
4983          ranges formed by all discrete cim:RegulatingControl regulating a
4984          cim:TopologicalNode.
4985          The range for a discrete control (cim:RegulatingControl.discrete set to true) is
4986          {cim:RegulatingControl.targetValue - cim:RegulatingControl.targetDeadband/2,
4987          cim:RegulatingControl.targetValue + cim:RegulatingControl.targetDeadband/2}
4988
4989          Note: the rule is validating both if the ranges of discrete regulating control form
4990          intersection and if the target values of all regulating controls are within the
4991          intersection regulating range.
4992
4993          Justification:
4994          The power flow solver need a single deadband per cim:TopologicalNode
4995          and if the deadbands differ the power flow will have to pick a value. If different
4996          Power Flow applications use different strategies to pick a value the voltage
4997          solution will differ between them which is the reason to warn.
4998
4999          Message:
5000          Either 1) Regulating ranges of discrete regulating controls do not create
5001          intersection or 2) the target values of regulating controls are not within the
5002          intersection range.
5003
5004          Usage: #IGMRuleSet #CGMRuleSet
5005
5006    Rule: EnergizedBoundaryTN  Level: 6  Severity: ERROR
5007
5008          Details:
5009          A boundary cim:TopologicalNode with a non-zero cim:EquivalentInjection.p or
5010          cim:EquivalentInjection.q is supposed to be energized and shall have a
5011          solved voltage, i.e. cim:SvVoltage.v shall not be zero.
5012
5013          Justification:
5014          All boundary cim:TopologicalNodes in a power flow model shall have a
5015          solved voltage.
5016
5017          Message:
```

Boundary cim:TopologicalNode with injecting cim:EquivalentInjection without solved cim:SvVoltage.v.

Usage: #IGMRuleSet #CGMRuleSet

Rule: FakeVoltage Level: 6 Severity: WARNING

Details:
A cim:TopologicalNode with a solved voltage equal to the cim:BaseVoltage.nominalVoltage is suspected to copy that value rather than solving to power flow.

Justification:
This is to prevent from faking the voltage.

Message:
Voltage at cim:TopologicalNode reported in SV profile equals cim:BaseVoltage.nominalVoltage.

Usage: #IGMRuleSet #CGMRuleSet

Rule: InvalidVoltage Level: 6 Severity: ERROR

Details:
cim:SvVoltage.v shall be either 0 per unit or greater than 0.4 per unit.

Justification:
Voltage lower than 0.4 per unit is not reasonable. The 0 is allowed to cover situations such as deenergized nodes or non converging power flow.

Message:
Voltage magnitude is outside allowed range.

Usage: #IGMRuleSet #CGMRuleSet

Rule: DiscreteControl Level: 6 Severity: ERROR

Details:
For every instance of cim:RegulatingControl (SSH) for which the value of cim:RegulatingControl.discrete is true and cim:RegulatingControl.enabled is true the control variables must move in discrete steps. Hence the values of the following attributes shall not have non-zero decimals considering the precision of xsd:float:
- cim:ShuntCompensator.sections
- related cim:SvShuntCompensatorSections.sections
- cim:TapChanger.step
- related cim:SvTapStep.position.

Justification:
If cim:RegulatingControl.discrete is set to true it is not possible to move the control variables continuously.

Message:
A discrete control is declared, but the value has non-zero decimals.

Usage: #IGMRuleSet #CGMRuleSet

```
5074
5075   Rule: ContinuousControl  Level: 6  Severity: WARNING
5076
5077         Details:
5078         For every instance of cim:RegulatingControl (SSH) for which the value of
5079         cim:RegulatingControl.discrete is false and cim:RegulatingControl.enabled
5080         is true means continuous control. For devices natively being discrete this
5081         means an imprecise modelling of the behaviour for
5082         - cim:ShuntCompensator
5083         - cim:TapChanger.
5084
5085         Justification:
5086         If cim:RegulatingControl.discrete is false continuous control is used
5087         which is an imprecise model.
5088         For as built equipment the most precise model should be used.
5089
5090         Message:
5091         cim:ShuntCompensator or cim:TapChanger are used with a continuous control.
5092
5093         Usage: #IGMRuleSet #CGMRuleSet
5094
5095   Rule: RequiredSvVoltage  Level: 6  Severity: ERROR
5096
5097         Details:
5098         Instances of cim:SvVoltage is required for all cim:TopologicalNodes.
5099         If power flow didn't create a solution for a cim:TopologicalNode
5100         cim:SvVoltage angle and voltage shall be set to zero.
5101
5102         Justification:
5103         Instances of cim:SvVoltage is required to know where power flow managed
5104         to solve.
5105
5106         Message:
5107         cim:SvVoltage is missing for cim:TopologicalNode.
5108
5109         Usage: #IGMRuleSet #CGMRuleSet
5110
5111   Rule: RequiredSvSCSections  Level: 6  Severity: ERROR
5112
5113         Details:
5114         The following shall be satisfied for cim:ShuntCompensator:
5115         1) Each instance of cim:ShuntCompensator shall have cim:SvShuntCompensatorSections
5116         instantiated.
5117         2) For a cim:ShuntCompensator that is not used in control by power flow (no
5118         cim:RegulatingControl associated or if cim:RegulatingControl.enabled equals false)
5119         the value of SvShuntCompensatorSections.sections shall be the same as
5120         cim:ShuntCompensator.sections.
5121
5122         Justification:
5123         Instances of cim:SvShuntCompensatorSections is required to tell the number
5124         of sections that was used in the solution.
5125
5126         Message:
5127         cim:SvShuntCompensatorSections is missing for shunt compensator or the
5128         cim:SvShuntCompensatorSections.sections is not the same as
5129         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. The power flow in non-retained cim:Switch-es may not have been correctly computed and may 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.

Justification:
The sum of power flow into a node is zero according to Kirchhoffs first law.

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. In case there is no operational limit
defined at terminals connected to the boundary point, limit values assigned to other end
of the tie-line segment are considered for the comparison.
      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:
      A paired boundary cim:TopologicalNode should be consistent in terms of cim:TieFlow-
s associated with cim:Terminal-s connected to this cim:TopologicalNode. If one side of
the border has cim:TieFlow the other side should also have one, and vice versa.

      Note: An AC boundary cim:TopologicalNode which has two branches and two
      cim:EquivalentInjection-s   linking   two   IGMs   is   a   paired   boundary
cim:TopologicalNode.

      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 inconsistent cim:TieFlow.

      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
```

```
5231          - have a direct association to cim:BaseVoltage
5232          shall have a cim:BaseVoltage.nominalVoltage that deviates no more than
5233          BOUNDARY_BV_MAX_DIFF from the cim:BaseVoltage.nominalVoltage of the
5234          boundary point obtained from the association end cim:TopologicalNode.BaseVoltage.
5235          Note: An HVDC Boundary Point has a cim:IdentifiedObject.description
5236          attribute equal to 'HVDC'.
5237
5238          Justification:
5239          See section 6.10.2 of IEC TS 61970-600-2:2017.
5240
5241          Message:
5242          AC Tie line nominalVoltage deviates from the boundary point base voltage
5243          more than BOUNDARY_BV_MAX_DIFF.
5244
5245          Usage: #IGMRuleSet #CGMRuleSet
5246
5247    Rule: ACScheduleMatch1  Level: 7  Severity: WARNING
5248
5249          Details:
5250          The sum of cim:SvPowerFlow.p should match
5251          the value of the external AC schedule with the same cim:ControlArea EIC 'Y'
5252          code within INTERCH_IMBALANCE_WARNING MW threshold. The following conditions apply
5253          when creating the sum:
5254          - cim:SvPowerFlow related to boundary cim:EquivalentInjection-s  must be used in
5255            the summation but with negated value.
5256          - cim:SvPowerFlow participates in the sum if the cim:Terminal is a terminal of
5257            cim:EquivalentInjection which is connected to a boundary cim:TopologicalNode
5258            (HVDC Boundary TopologicalNode-s are excluded), referenced by a cim:Terminal,
5259            which is also associated to a cim:TieFlow through cim:TieFlow.Terminal.
5260
5261          Note: An HVDC Boundary cim:TopologicalNode has a cim:IdentifiedObject.description
5262          attribute with leading characters 'HVDC'.
5263
5264          Justification:
5265          In the Reporting Information Market Document, issued by PEVF or CGMA,
5266          the EIC 'Y' code is found in the domain.mRID, in the IGM it is the value
5267          of attribute entsoe:IdentifiedObject.EnergyIdentCodeEic for the ControlArea
5268          instance.
5269
5270          Message:
5271          AC tie flows does not match the scheduled interchange value
5272          more than INTERCH_IMBALANCE_WARNING MW.
5273
5274          Usage: #IGMRuleSet #CGMRuleSet
5275
5276    Rule: ACScheduleMatch2  Level: 7  Severity: ERROR
5277
5278          Details:
5279          The sum of cim:SvPowerFlow.p tie flows should match
5280          the value of the external AC schedule with the same cim:ControlArea
5281          EIC 'Y' code within INTERCH_IMBALANCE_ERROR MW threshold.
5282          The following conditions apply when creating the sum:
5283          - cim:SvPowerFlow related to boundary cim:EquivalentInjection-s  must be used in
5284            the summation but with negated value.
5285          - cim:SvPowerFlow participates in the sum if the cim:Terminal is a terminal of
5286            cim:EquivalentInjection which is connected to a boundary cim:TopologicalNode
```

```
5287          (HVDC Boundary TopologicalNode-s are excluded), referenced by a cim:Terminal
5288          which is also associated to a cim:TieFlow through cim:TieFlow.Terminal.
5289
5290        Note: An HVDC Boundary TopologicalNode has a cim:IdentifiedObject.description
5291        attribute with leading characters 'HVDC'.
5292
5293        Justification:
5294        In the Reporting Information Market Document, issued by PEVF or CGMA,
5295        the EIC 'Y' code is found in the domain.mRID, in the IGM it is the value
5296        of attribute entsoe:IdentifiedObject.EnergyIdentCodeEic for the ControlArea
5297        instance.
5298
5299        Message:
5300        AC tie flows does not match the scheduled interchange values
5301        more than INTERCH_IMBALANCE_ERROR MW.
5302
5303        Usage: #IGMRuleSet #CGMRuleSet
5304
5305
5306    Rule: HVDCScheduleMatch1  Level: 7  Severity: WARNING
5307
5308        Details:
5309        The cim:SvPowerFlow.p value should match the value
5310        of the external schedule for the same cim:ControlArea
5311        EIC 'Y' code and with the same connectingLine_RegisteredResource EIC 'T'
5312        code within INTERCH_IMBALANCE_WARNING MW threshold. The following conditions apply:
5313        - cim:SvPowerFlow related to boundary cim:EquivalentInjection-s   must be used but
5314          with negated value.
5315        - cim:SvPowerFlow participates in the comparison if the cim:Terminal is a terminal
5316          of cim:EquivalentInjection which is connected to a boundary cim:TopologicalNode
5317          (HVDC Boundary TopologicalNode), referenced by a cim:Terminal, which is also
5318          associated to a cim:TieFlow through cim:TieFlow.Terminal.
5319
5320        Note: An HVDC Boundary cim:TopologicalNode has a cim:IdentifiedObject.description
5321        attribute with leading characters 'HVDC'.
5322
5323        Justification:
5324        In the Reporting Information Market Document, issued by PEVF or CGMA,
5325        the EIC 'Y' code is found in the domain.mRID, in the IGM it is the value
5326        of attribute entsoe:IdentifiedObject.EnergyIdentCodeEic for the cim:ControlArea
5327        instance. The EIC 'T' code is found in the TimeSeries in the
5328        connectingLine_RegisteredResource.mRID, in the IGM it is the value of
5329        attribute entsoe:IdentifiedObject.EnergyIdentCodeEic for the Boundary
5330        point instance, the terminal is connected to.
5331
5332        Message:
5333        HVDC flow does not match the scheduled interchange value
5334        more than INTERCH_IMBALANCE_WARNING MW.
5335
5336        Usage: #IGMRuleSet #CGMRuleSet
5337
5338    Rule: HVDCScheduleMatch2  Level: 7  Severity: ERROR
5339
5340        Details:
5341        The cim:SvPowerFlow.p value shall match the value
5342        of the external schedule for the same cim:ControlArea
```

```
5343          EIC 'Y' code and with the same connectingLine_RegisteredResource EIC 'T'
5344          code within INTERCH_IMBALANCE_ERROR MW threshold. The following conditions apply:
5345          - cim:SvPowerFlow related to boundary cim:EquivalentInjection-s  must be used but
5346            with negated value.
5347          - cim:SvPowerFlow participates in the comparison if the cim:Terminal is a terminal
5348            of cim:EquivalentInjection which is connected to a boundary cim:TopologicalNode
5349            (HVDC Boundary TopologicalNode), referenced by a cim:Terminal, which is also
5350            associated to a cim:TieFlow through cim:TieFlow.Terminal.
5351
5352          Note: An HVDC Boundary cim:TopologicalNode has a cim:IdentifiedObject.description
5353          attribute with leading characters 'HVDC'.
5354
5355          Justification:
5356          In the Reporting Information Market Document, issued by PEVF or CGMA,
5357          the EIC 'Y' code is found in the domain.mRID, in the IGM it is the value
5358          of attribute entsoe:IdentifiedObject.EnergyIdentCodeEic for the cim:ControlArea
5359          instance. The EIC 'T' code is found in the TimeSeries in the
5360          connectingLine_RegisteredResource.mRID, in the IGM it is the value of
5361          attribute entsoe:IdentifiedObject.EnergyIdentCodeEic for the Boundary
5362          point instance, the terminal is connected to.
5363
5364          Message:
5365          HVDC flow does not match the scheduled interchange value
5366          more than INTERCH_IMBALANCE_ERROR MW
5367
5368          Usage: #IGMRuleSet #CGMRuleSet
5369
5370    Rule: NetInterchangeMatch1  Level: 7  Severity: WARNING
5371
5372          Details:
5373          For every cim:ControlArea of type interchange, the value of
5374          cim:ControlArea.netInterchange should
5375          not deviate more than INTERCH_IMBALANCE_WARNING MW from the sum of the
5376          netted area AC and DC positions in the aggregated netted external schedules
5377          (PEVF or CGMA) for the same scenarioTime and with the same EIC 'Y' code.
5378          If no netted area AC or DC positions or netted external schedule can be found for
5379          the control area this rule skipped.
5380
5381          Justification:
5382          In the Reporting Information Market Document, issued by PEVF or CGMA, the
5383          EIC 'Y' code is found in the domain.mRID, in the IGM it is the value of
5384          attribute entsoe:IdentifiedObject.EnergyIdentCodeEic for the cim:ControlArea
5385          instance.
5386
5387          Message:
5388          cim:ControlArea netInterchange deviates more than INTERCH_IMBALANCE_WARNING MW from
5389          netted area position.
5390
5391          Usage: #IGMRuleSet #CGMRuleSet
5392
5393    Rule: NetInterchangeMatch2  Level: 7  Severity: ERROR
5394
5395          Details:
5396          For every cim:ControlArea of type interchange, the value of
5397          cim:ControlArea.netInterchange should
5398          not deviate more than INTERCH_IMBALANCE_ERROR MW from the sum of the netted
```

```
5399        area AC and DC positions in the aggregated netted external schedules
5400        (PEVF or CGMA) for the same scenarioTime and with the same EIC 'Y' code.
5401        If no netted area AC or DC positions or netted external schedule can be found for
5402        the control area this rule skipped.
5403
5404        Justification:
5405        In the Reporting Information Market Document, issued by PEVF or CGMA,
5406        the EIC 'Y' code is found in the domain.mRID, in the IGM it is the value
5407        of attribute entsoe:IdentifiedObject.EnergyIdentCodeEic for the
5408        cim:ControlArea instance.
5409
5410        Message:
5411        cim:ControlArea netInterchange deviates more than INTERCH_IMBALANCE_ERROR MW from
5412        netted area position.
5413
5414        Usage: #IGMRuleSet #CGMRuleSet
5415
5416  Rule: InconsistentTnBaseVoltage  Level: 7  Severity: WARNING
5417
5418        Details:
5419        All equipment with a direct association to cim:BaseVoltage connected to a
5420        cim:TopologicalNode shall have a cim:BaseVoltage.nominalVoltage that deviates no
5421        more than BOUNDARY_BV_MAX_DIFF   from the cim:BaseVoltage.nominalVoltage of the
5422        cim:BaseVoltage referenced by the association end cim:TopologicalNode.BaseVoltage.
5423
5424
5425        Justification:
5426        If the cim:BaseVoltage.nominalVoltage differs this may indicate a topology error.
5427
5428        Message:
5429        cim:BaseVoltages.nominalVoltage at a cim:TopologicalNode differs
5430        more than BOUNDARY_BV_MAX_DIFF from the cim:BaseVoltage.nominalVoltage of the
5431        connected equipment.
5432
5433        Usage: #IGMRuleSet
5434
5435  Rule: PairedEICompatibility  Level: 7  Severity: ERROR
5436
5437        Details:
5438        The rule is checking SSH information of a paired boundary point in a CGM.
5439        The two cim:EquivalentInjection-s at a boundary cim:TopologicalNode shall have:
5440        - control disabled (cim:EquivalentInjection.regulationStatus = false);
5441        - the sum of their active power injections (cim:EquivalentInjection.p) shall be
5442  less than or equal to SV_INJECTION_LIMIT;
5443
5444        - the sum of their reactive power injections (cim:EquivalentInjection.q) shall be
5445  less than or equal to SV_INJECTION_LIMIT.
5446
5447
5448        Justification:
5449        A cim:EquivalentInjection represents the power flow towards a boundary
5450        cim:TopologicalNode.
5451        If the neighbouring IGM has voltage control capability this could be modelled by
5452        enabling the cim:EquivalentInjection control
5453         (cim:EquivalentInjection.regulationStatus set to true).
5454        When a CGM is built and both networks are connected at a boundary
```

```
        - the cim:EquivalentInjection control shall be disabled to avoid duplicate
          controls.
        - the sum of their active and reactive powers must be within the tolerance
SV_INJECTION_LIMIT.

        Message:
        Either any of the cim:EquivalentInjection-s at a paired boundary has control enabled
or the sum of active/reactive power is greater than SV_INJECTION_LIMIT.

        Usage: #CGMRuleSet
```

10 LEVEL 8 VALIDATION: CONVERGENCE BEHAVIOUR AND CGM PLAUSIBILITY

10.1 CONVERGENCE BEHAVIOUR OF IGM

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

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

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

10.2 PLAUSIBILITY OF CGM

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

10.3 VALIDATION RULES

```
Rule: IGMConvergence  Level: 8  Severity: ERROR

        Details:
        This rule applies to IGMs only.
        It shall be possible to solve the power flow with the following power
        flow settings:
        - Full Newton Raphson power flow algorithm.
        - Switched shunt adjustment must be set to enabled for shunts used for
          voltage regulation.
        - Transformer tap adjustment is set to enabled.
        - Q limits shall be respected for EquivalentInjection,
          ExternalNetworkInjection, SynchronousMachines, SVCs and
          SynchronousCondensers (also for slack node/swing bus).
        - Distributed generation slack is set to enabled
          (proportional to GeneratingUnit.normalPF).
        - Maximum mismatch is set to SV_INJECTION_LIMIT MW and SV_INJECTION_LIMIT MVAr per
          node.
        - Controlled node voltage error convergence tolerance = 0.0001 pu
```

```
5496          (The largest difference between actual and scheduled voltage magnitude in
5497          per unit at each node where voltage is subject to control to a set point,
5498          and for which at least one of the devices participating in the control of
5499          bus voltage to its set point is not at a reactive power limit, must be less
5500          than the controlled bus voltage error convergence tolerance).
5501
5502        Justification:
5503
5504        Message:
5505        Power flow could not be calculated for IGM with required settings.
5506        Check diagnostic messages.
5507
5508        Usage: #IGMRuleSet
5509
5510  Rule: CGMConvergence  Level: 8  Severity: WARNING
5511
5512        Details:
5513        This rule applies to CGMs only.
5514        It shall be possible to solve the power flow with the following power
5515        flow settings:
5516        - Full Newton Raphson power flow algorithm.
5517        - Switched shunt adjustment must be set to enabled for shunts used for
5518          voltage regulation.
5519        - Transformer tap adjustment is set to enabled.
5520        - Q limits shall be respected for EquivalentInjection,
5521          ExternalNetworkInjection, SynchronousMachines, SVCs and
5522          SynchronousCondensers (also for slack node/swing bus).
5523        - Area interchange control is set to enabled.
5524        - Maximum mismatch is set to SV_INJECTION_LIMIT MW and SV_INJECTION_LIMIT MVAr per
5525          node.
5526        - Controlled node voltage error convergence tolerance = 0.0001 pu
5527          (The largest difference between actual and scheduled voltage magnitude in
5528          per unit at each node where voltage is subject to control to a set point,
5529          and for which at least one of the devices participating in the control of
5530          bus voltage to its set point is not at a reactive power limit, must be less
5531          than the controlled bus voltage error convergence tolerance).
5532
5533        Justification:
5534
5535        Message:
5536        Power flow could not be calculated for CGM with required settings.
5537        Check diagnostic messages.
5538
5539        Usage: #CGMRuleSet
5540
5541  Rule: TIConvergenceStatMissing  Level: 8  Severity: WARNING
5542
5543        Details:
5544        This rule applies to both IGMs and CGMs. cim:IdentifiedObject.description is added
5545        to State Variables profile as required attribute. The
5546        cim:IdentifiedObject.description of cim:TopologicalIsland shall have one the
5547        following string values: “converged” and “diverged” which represents the
5548        convergence status of the cim:TopologicalIsland.
5549
5550        Justification:
5551        It should be possible to conclude if a cim:TopologicalIslands has diverged or
```

```
5552          converged.
5553
5554          Message:
5555          Convergence status (cim:IdentifiedObject.description) is not provided for
5556          cim:TopologicalIsland.
5557
5558          Usage: #IGMRuleSet #CGMRuleSet
5559
5560    Rule: TIConvergenceStatDiverged  Level: 8  Severity: WARNING
5561
5562          Details:
5563          This rule applies to both IGMs and CGMs. Convergence status for
5564          cim:TopologicalIsland is diverged. The
5565          cim:IdentifiedObject.description of the cim:TopologicalIsland shall then
5566          contain the text "diverged".
5567
5568          Justification:
5569          It should be possible to conclude if a cim:TopologicalIslands has diverged or
5570          converged.
5571
5572          Message:
5573          Convergence status is declared as diverged for cim:TopologicalIsland
5574
5575          Usage: #IGMRuleSet #CGMRuleSet
5576
5577    Rule: CGMConvergenceRelaxed  Level: 8  Severity: ERROR
5578
5579          Details:
5580          This rule applies to CGMs only.
5581          It shall be possible to solve the power flow with the following power
5582          flow settings:
5583          - Full Newton Raphson power flow algorithm.
5584          - Q limits shall be ignored (also for slack node/swing bus) meaning
5585            unlimited reactive resources.
5586          - Area interchange control is set to enabled.
5587          - Maximum mismatch is set to 0.5 MW and 0.5 MVAr per node.
5588          - Controlled node voltage error convergence mismatch = 0.0001 pu
5589            (The largest difference between actual and scheduled voltage magnitude in
5590            per unit at each node where voltage is subject to control to a setpoint,
5591            and for which at least one of the devices participating in the control of
5592            bus voltage to its setpoint is not at a reactive power limit, must be less
5593            than the controlled bus voltage error convergence mismatch).
5594
5595          Justification:
5596
5597          Message:
5598          Power flow could not be calculated for CGM with relaxed Q limits.
5599          Check diagnostic messages.
5600
5601          Usage: #CGMRuleSet
5602
5603    Rule: Congestion  Level: 8  Severity: WARNING
5604
5605          Details:
5606          This rule applies to both IGMs and CGMs.
5607          There should be no base case violations considering PATL limits.
```

```
5608        The rule is applied only for PATL limits in cases where there is a cim:SvPowerFlow
5609        at the terminal where the cim:OperationalLimitSet is.
5610
5611        Justification:
5612
5613        Message:
5614        Base case violation is present.
5615
5616        Usage: #IGMRuleSet #CGMRuleSet
5617
5618  Rule: CGMTieFlowImbalance  Level: 8  Severity: WARNING
5619
5620        Details:
5621        This rule applies to CGMs only.
5622        The sum of the solved tie flows for each cim:ControlArea of type
5623        interchange shall equal the cim:ControlArea.netInterchange plus/minus
5624        an INTERCH_IMBALANCE_EMF MW. i.e.
5625        o TFS less than or equal to cim:ControlArea.netInterchange +
5626              INTERCH_IMBALANCE_EMF MW
5627        o TFS greater than or equal to cim:ControlArea.netInterchange -
5628              INTERCH_IMBALANCE_EMF MW
5629        Where TFS (TieFlow sum) is computed as
5630        o TFS = sum(cim:SvPowerFlow.p) of cim:EquivalentInjection-s which cim:Terminal
5631        connects to the same boundary point (cim:TopologicalNode) where there is a
5632        cim:Terminal referenced by the association end cim:TieFlow.Terminal.
5633
5634        Note: This rule is built on the fact that the CGM SV instance file and the updated
5635        SSH instance files of IGMs are consistent hence contain updated values of
5636        cim:SvPowerFlow. i.e. cim:EquivalentInjection has the same output as the flow of
5637        the interconnection in the CGM SV instance file.
5638
5639        Justification:
5640
5641        Message:
5642        The sum of solved tie flows for a cim:ControlArea deviates from the cim:ControlArea
5643        interchange tolerance INTERCH_IMBALANCE_EMF MW.
5644
5645        Usage: #CGMRuleSet
5646
5647
```

5648 11 ANNEX A: SUPPORTING DOCUMENTS, FOR INFORMATION 5649 ONLY

5650 11.1 INTRODUCTION

5651 This section contains references to documents that support the rules.

11.2 QoCDC Reference Data document

The QoCDC Reference Data document provides all reference data e.g. enumerations and shared 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.

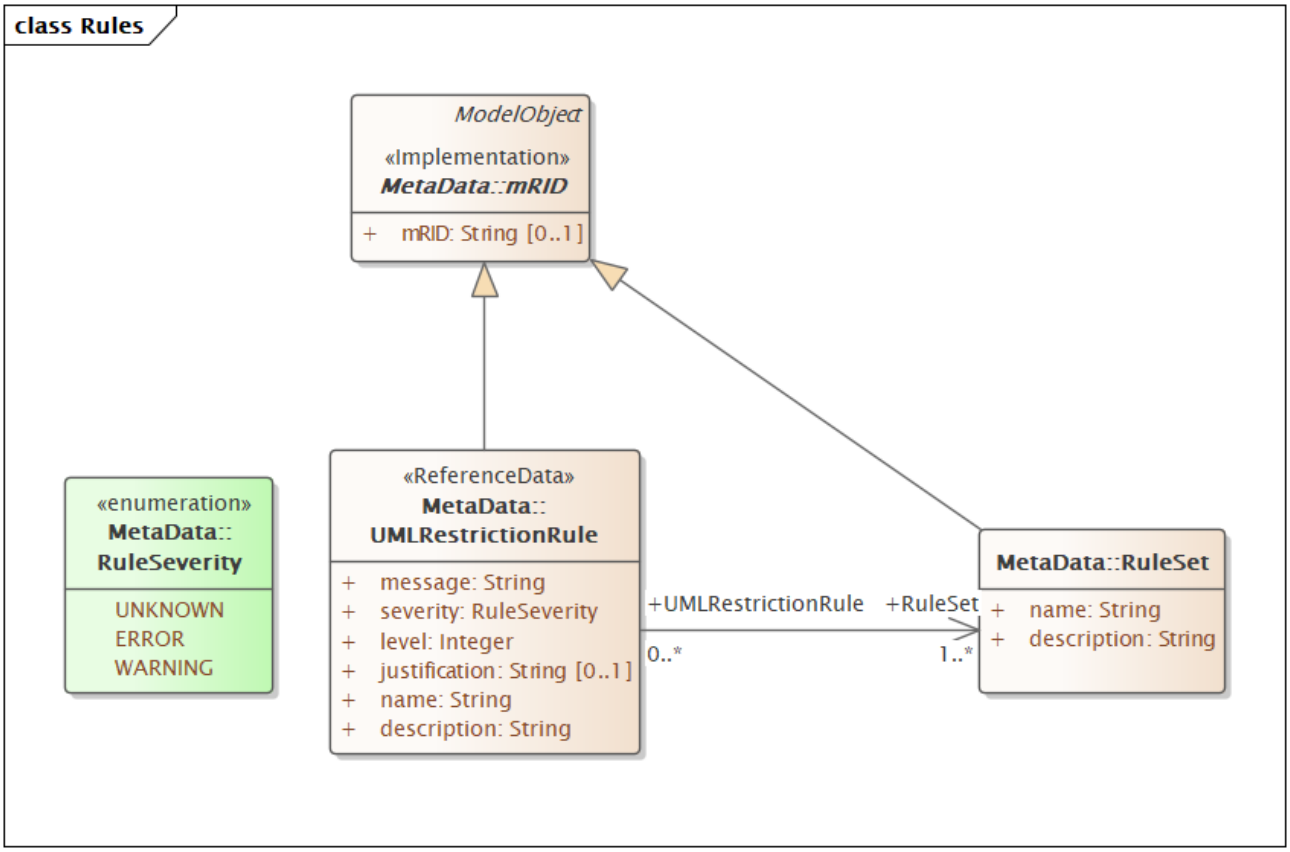

Figure 15 Rule Description Information Model

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. 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.