European Network of
Transmission System Operators
for Electricity

QUALITY OF CGMES DATASETS AND CALCULATIONS

FOR SYSTEM OPERATIONS

SECOND EDITION

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PT COMMON GRID MODEL
CGMES RELATED TOPICS

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SUMMARY

The document “Quality of Datasets and Calculations” aims to increase the quality of data that is exchanged in order to support the following processes:

- Coordinated security assessment
- Flow-based and NTC based capacity calculations
- Unavailability planning coordination
- Inter-TSO compensation for the use of national transmission systems by cross-border trade
- After-the-fact analysis of events
- Ad-hoc system studies

Quality is a concept that can be expressed as the “fitness for purpose” for a particular process. This document contains the following sections:

- Introduction
- File name convention
- Validation rules for structure and syntax
- Completeness of the model
- Consistency rules of IGMs
- Robustness constraints
- Cross IGM consistency
- Plausibility of the input data and calculated results

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INTRODUCTION

The purpose of this document is to discuss the quality criteria and quality indicators that are applicable to the Individual Grid Models, Common Grid Models and associated information required for the merging process in order to obtain plausible Common Grid Models that can be used as a starting point for subsequent business processes, such as:

- Coordinated security analysis (n-k)
- Network Sensitivity (determination of critical network elements for flow-based capacity calculation)
- Dynamic Stability Assessment
- Impact of planned unavailabilities
- Short term adequacy

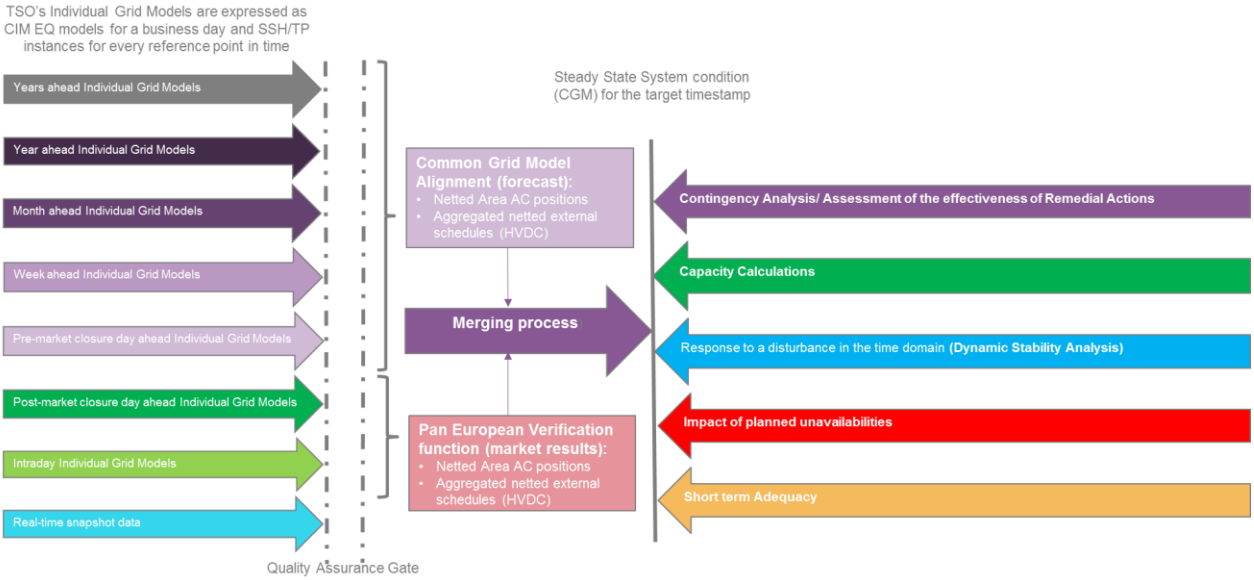

Figure 1. Context of the operational data exchanges

The network models will be exchanged in the CGMES (Common Grid Model Exchange Standard). The CGMES is based on the following existing or expected International Electrotechnical Commission (IEC) Common Information Model (CIM) standards valid for the CIM16:

- IEC 61970-301: Common Information Model (CIM) Base
- IEC 61970-302: Common Information Model (CIM) for Dynamics Specification
- IEC 61970-452: CIM Static Transmission Network Model Profiles
- IEC 61970-453: Diagram Layout Profile
- IEC 61970-456: Solved Power System State Profiles
- IEC 61970-457: Common Information Model (CIM) for Dynamics Profile
- IEC 61970-501: Common Information Model Resource Description Framework (CIM RDF) schema

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- IEC 61970-552: CIM XML Model Exchange Format

AC netted area 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.

READING GUIDE

- Rules are preceded by a level type and rule number, e.g. 0_1, and are in Calibri 11 in blue.
- Examples are displayed in a text box (italic font):

This is an example

- **The messages that are to be generated when a rule is violated are specified in bold font and have a message number, identified by the prefix "Msg"**
- Quality levels are expressed in either "Error" (data will be rejected) or "Warning" (data will be used in further processing, but impacts the quality of the calculation results)

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1 LEVEL 1 VALIDATION: FILE NAMES AND PACKAGING

According to [R4.6.2] of the CGMES Requirement Specification "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." This section defines the file name convention which is applied for Individual Grid Models and Common Grid Models exchanged in CGMES for the purpose of the operational planning.

1.1 GENERAL RULES

1_1. The ISO 8601:2004 standard will be used for designating dates and times

1_2. The days and times that are referred to in the filenames and the Model.scenarioTime attribute in the file headers will be associated with the UTC 00:00-23:59, regardless of the time zone of origin and Day Light Saving time schedules, e.g. for <md:Model.scenarioTime> 2015-01-15T17:00:00.000Z</md:Model.scenarioTime> corresponds with a DateTime reference of "20150115T1700Z" in the filename[1].

1_3. The days and times that are referred to in Model.created attribute in the file headers will be associated with the local machine's time.

1_4. Model part references have no predefined restrictions other than allowed characters[2], but the use of TSO names or HVDC link names is recommended[3]

1_5. Packages (zipped instance data) are based on the "smallest unit" that can be consumed separately. This is a separate profile instance, except for the boundary data

1_6. An Individual Grid Model (IGM) is defined by SSH, TP and SV instances that refer to a particular EQ model (an EQ model can be valid for multiple IGMs)

1_7. Common grid models are exchanged as Solved Cases (SV instances on a synchronous area level and on a pan-European level) and via updated SSH instance files in which the original data is referenced (Supersede statement) and in which the merging entity is identified in the file header

1_8. The common grid model zip file contains one of the following:

- SV for whole pan-European region (Model part reference "CGMEU")
- SV for CE area (Model part reference "CGMCE")
- SV for Nordic area (Model part reference "CGMNO")
- SV for Baltic area (Model part reference "CGMBA")
- SV for UK area (Model part reference "CGMUK")
- SV for I/NI area (Model part reference "CGMIN")

1_9. The information in the file headers contain sufficient information for the automatic assembly process.

1_10. Version identifiers always use three digits

[1] Note that the DateTime inside the file headers use the ISO 8601 extended format, whereas the filename use the ISO 8601 basic format

[2] Note that for the Model part reference only US ASCII characters are allowed

[3] Note that Denmark has two model parts, one for each Synchronous area

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1_11. The version number of the merged SV file is increased every time a merge sequence has been performed and a new file is exported consequently.

1_12. The same version number is used for both merged SV files and updated SSH files produced by the merging function.

1_13. The XML files have the same name as the zipped packages, except for the boundary data, which is zipped as a package of EQ_BD and TP_BD.

1_14. Files that do not respect the file name convention rules will not be used in the further processing.

MSG 1. ERROR: Invalid filename <filename**>**

1.2 YEAR AHEAD MODELS

The following file name convention is applied for the EQ model that includes the projects that are to be effective that in the relevant season:

1_15. <YYYYMMDD>T0030Z_YR_<Model part reference>_EQ_<version number>.zip

20160101T0030Z_YR_TTN_EQ_001.zip

The following file name convention is applied for each year ahead scenario (defined in SSH, TP and SV):

1_16. <YYYYMMDD>T<hhmm>Z_YR_<Model part reference>_<profile>_<version number>.zip

20160120T0930Z_YR_TTN_SSH_001.zip

The following file name convention is applied for year ahead common grid models (SV):

1_17. <YYYYMMDD>T<hhmm>Z_YR_<Model part reference>_SV_<version number>.zip

20160120T0930Z_YR_CGMEU_SV_001.zip

1.3 MONTH AHEAD MODELS

The following file name convention is applied for the EQ model that includes the projects that are to be effective that month:

1_18. <YYYYMMDD>T0030Z_MO_<Model part reference>_EQ_<version number>.zip

20150701T0030Z_MO_50Hertz_EQ_002.zip

The following file name convention is applied for each month ahead scenario (defined in SSH, TP and SV):

1_19. <YYYYMMDD>T<hhmm>Z_MO_<Model part reference>_<profile>_<version number>.zip

20150715T0930Z_MO_50Hertz_TP_002.zip

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The following file name convention is applied for month ahead common grid models (SV):

1_20. <YYYYMMDD>T<hhmm>Z_MO_<Model part reference>_SV_<version number>.zip

20150715T0930Z_MO_CGMEU_ SV_002.zip

1.4 WEEK AHEAD MODELS

The following file name convention is applied for the EQ model that includes the projects that are to be effective that week:

1_21. <YYYYMMDD>T0030Z_WK_<Model part reference>_EQ_<version number>.zip

20150720T0030Z_WK_RTE_EQ_001.zip

The following file name convention is applied for each week ahead scenario (defined in SSH, TP and SV):

1_22. <YYYYMMDD>T<hhmm>Z_WK_<Model part reference>_<profile>_<version number>.zip

20150722T07930Z_WK_RTE_SV_002.zip

The following file name convention is applied for week ahead common grid models (SV):

1_23. <YYYYMMDD>T<hhmm>Z_WK_<Model part reference>_SV_<version number>.zip

20150722T0930Z_WK_CGMEU_ SV_001.zip

1.5 MODELS THAT REFER TO AN ENERGY DELIVERY DAY

The following file name convention is applied for the EQ model that is defining the energy delivery day:

1_24. <YYYYMMDD>T<hhmm>[4]Z_<Model part reference>_EQ_<version number>.zip

20150720T0030Z_APG_EQ_001.zip

Subsequent changes that are valid during the day, e.g. when other operational limits[5] are used or when a different equivalent model is used to model DSO grids, can be exchanged via Equipment difference models:

1_25. <YYYYMMDD>T<hhmm>Z_<Model part reference>_EQ_DIFF_<version number>.zip[6]

[4] By Default the value 0030 will be used, however if multiple full EQ models are to be exchanged for the same day, other values can be used.

[5] Note: In the next version of CGMES, changed limit sets (e.g. in case of dynamic line rating) are being exchanged via the SSH profiles

[6] If the changes are only valid for one hour, we have to reverse the changes for the next hour, e.g. have two EQ_DIFF files – one for the start of the hours the new changes are valid for and the second for the next hours

20150720T0830Z_APG_EQ_DIFF_001.zip

when it goes back to default. This is not the same as Forward and Reverse dataset/statement. For only one change will forward and reverse dataset change place in the two EQ_DIFF.

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The following file name convention is applied for the individual models (SSH, TP and SV):

1_26. <YYYYMMDD>T<hhmm>Z_<time horizon>[7]_<Model part reference>_<profile>_<version number>.zip

20160401T0830Z_1D_TERNA_SSH_001.zip

The following file name convention is applied for common grid models (SV) that refer to an energy delivery day:

1_27. <YYYYMMDD>T<hhmm>Z_<time horizon>_<Model part reference>_SV_<version number>.zip

20150722T0930Z_2D_CGMNO_ SV_001.zip

1.6 BOUNDARY DATA

The following file name convention is applied for the boundary data:

1_28. <YYYYMMDD>T0000Z_ENTSO-E_BD_<version number>.zip

20150720T0000Z_ENTSO-E_BD_301.zip

This zip file contains both the EQ_BD and the TP_BD instance files, which carry the file names:

1_29. <YYYYMMDD>T0000Z_ENTSO-E_EQ_BD_<version number>.xml
1_30. <YYYYMMDD>T0000Z_ENTSO-E_TP_BD_<version number>.xml

respectively.

1.7 MASKS FOR AUTOMATED PROCESSING

To summarize, the following six masks are allowed in order to have a valid file names:

A. <YYYYMMDD>T<hhmm>Z_<time horizon>_<model part reference>_<profile>_<version nr>

[7] Defined as:

- 2D two days ahead
- 1D one day ahead
- 23 twenty three hours ahead
- ..
- 06 six hours ahead
- 05 five hours ahead
- 04 four hours ahead
- 03 three hours ahead
- 02 two hours ahead
- RT real-time snapshot (i.e. after-the-fact)

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B. <YYYYMMDD>T<hhmm>Z_<model part reference>_EQ_<version nr>
C. <YYYYMMDD>T<hhmm>Z_<model part reference>_EQ_DIFF_<version nr>
D. <YYYYMMDD>T<hhmm>Z_<time horizon>_<Model part reference>_SV_<version nr>
E. <YYYYMMDD>T<hhmm>Z_ENTSO-E_EQ_BD_<version nr>
F. <YYYYMMDD>T<hhmm>Z_ENTSO-E_TP_BD_<version nr>
G. <YYYYMMDD>T<hhmm>Z_ENTSO-E_DB_<version nr>

The following values are valid:

File name part	Meaning	Type	Allowed values
<YYYYMMDD>T<hhmm>Z	Valid from date and time	datetime	20000101T0000Z..21001231T2359Z
<time horizon>	Business process	string	• YR • MO • WK • 2D • 1D • 23 • 22 • .. • 01 • RT
<profile>	Type of data	string	• EQ • EQ_DIFF • SSH • TP • SV • DL • GL • DY
<Model part reference>	Scope	string	• CGMEU • CGMCE • CGMNO • CGMBA • CGMUK • CGMIN • Agreed TSO names
<version nr>	Version	string	000..999

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2 LEVEL 2 VALIDATION: XML STRUCTURE

CGMES data is exchanged as CIM RDF[8] XML[9] files, as specified in IEC 61970-552. The Resource Description Framework is an XML schema used to provide a framework for data in an XML format by allowing relationships to be defined between XML nodes. The first level of syntax validation is to check if the document is well formed according to the XML rules[10].

An instance file is considered to be *well-formed*[11] if the following rules are respected[12]:

2_1. The CGMES files ***can*** have an XML prolog that declares the version of the XML and in which the encoding is set to UTF-8. If the prolog is missing, XML version 1.0 and UTF-8 are assumed by default.

```
<?xml version="1.0" encoding="UTF-8"?>
```

2_2. XML documents must contain one **root** element that is the **parent** of all other elements

```
<root>
  <child>
    <subchild>.....</subchild>
  </child>
</root>
```

MSG 2. ERROR: XML - Invalid parent-child structure

2_3. In XML, it is illegal to omit the closing tag[13]. All elements must have a closing tag. The closing tag is the same as the opening tag, preceded by a forward slash (/).

MSG 3. ERROR: XML - Closing tag missing

2_4. XML tags are case sensitive. The tag <Letter> is different from the tag <letter>. Opening and closing tags must be written with the same case.

---

8 Resource Description Framework, i.e. a language recommended by the W3C for expressing metadata that machines can process easily

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

10 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

11 Note: well-formed doesn't mean valid

12 Errors in XML documents will stop your 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.

13 The XML prolog does not have a closing tag. This is not an error. The prolog is not a part of the XML document

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```
<Message>This is incorrect</message>
<message>This is correct</message>
```

MSG 4. ERROR: XML – Closing and end tags don't match

2_5. In XML, all elements must be properly nested within each other.

Incorrect:

```
<b><i>This text is bold and italic</b></i>
```

Correct:

```
<b><i>This text is bold and italic</i></b>
```

MSG 5. ERROR: XML – Incorrect nesting

2_6. XML elements can have attributes in name/value pairs just like in HTML. In XML, the attribute values must always be quoted.

Incorrect:

```
<note date=12/11/2007>
 <to>Tove</to>
 <from>Jani</from>
</note>
```

Correct:

```
<note date="12/11/2007">
  <to>Tove</to>
  <from>Jani</from>
</note>
```

MSG 6. ERROR: XML – Invalid attribute value

2_7. Entity references[14] are to be used for special characters[15]

MSG 7. ERROR: XML – Illegal characters in document

[14] The following entity references are pre-defined in XML:

- < < less than
- > > greater than
- & & ampersand
- ' ' apostrophe
- " " quotation mark

[15] Note: Only < and & are strictly illegal in XML, but it is a good habit to replace > with > as well.

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3 LEVEL 3 VALIDATION: RDF SPECIFICATION

3.1 INTRODUCTION

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

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

The simplified syntax is for exchanging power system models between utilities. The aim of the IEC 61970-551 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.

3.2 NAME SPACE

3_1. The element type is rdf:RDF. The namespaces are entered as attributes of the rdf:RDF element.

3_2. The mandatory RDF namespace (attribute xmlns:rdf) must be declared as http://www.w3.org/1999/02/22-rdf-syntax-ns#.

MSG 8. ERROR: Invalid RDF namespace

3_3. The mandatory CIM namespace (attribute xmlns:cim) must be declared as http://iec.ch/TC57/2013/CIM-schema-cim16#.

MSG 9. ERROR: Invalid CIM namespace

3_4. The mandatory namespace for ENTSO-E extensions (attribute xmlns:entsoe) must be declared as http://entsoe.eu/CIM/SchemaExtension/3/1#.

MSG 10. ERROR: Invalid ENTSO-E namespace

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3_5. The mandatory namespace for the model description (attribute xmlns:md) must be declared as http://iec.ch/TC57/61970-552/ModelDescription/1#.

MSG 11. ERROR: Invalid model description namespace

3_6. The optional namespace for difference models (attribute xmlns:dm) must be declared as http://iec.ch/TC57/61970-552/DifferenceModel/1#.

MSG 12. ERROR: Invalid difference model namespace

3_7. Other name spaces are optional.

3.3 FILE HEADERS

Model exchange typically involves the exchange of a collection of documents, each of which contains instance data, referred to as a model, and a header. The structure and semantics of each model as well as the header are described by a profile, which is not included in the exchanged data. The overall exchange is governed by a collection of profiles in a Profile Document.

3_8. A CIM XML document consists of a header and a model section.

MSG 13. ERROR: File header missing

A header section describes the content of the model section contained in a document e.g. the date the model was created, description etc. The header may also identify other models and their relationship to the present model. 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 model succeeds and/or depends on another.

3_9. A CIM XML document is described by a single header. Multiple headers in a CIM XML document are not allowed.

MSG 14. ERROR: Multiple file headers found

3_10. The header section shall always be the first element in a CIM XML document.

The header section elements are:

- FullModel element
- DifferenceModel element

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

Elements in a CIM XML document may have references to elements (resources) in other CIM XML documents.

3_11. As a single header element is allowed in a CIMXML document the model section may only contain elements that the header can describe. If multiple headers are needed a CIMXML document shall be created for each header.

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3_12. The file header of an EQ instance file must identify which TSO is responsible for the model by means of the attribute Model.modelingAuthoritySet.

MSG 15. ERROR: Missing attribute Model.modelingAuthoritySet in file header.

3.4 VALIDATION

As mentioned before, CGMES data is exchanged as CIM RDF XML files, as specified in IEC 61970-552. In the RDFS[16] files, generated from the UML, the CGMES classes and properties are expressed using RDF to describe resources and their properties, including how resources are related to other resources, which is used to specify an application-specific schema.

The RDFS files can be downloaded from:
https://www.entsoe.eu/Documents/CIM_documents/Grid_Model_CIM/ENTSOE_CGMES_v2.4.15_16Feb2016_RDFS.zip .

The RDFS validation (level 3) is to be done to check the correctness of the file headers and to check for the correct classes and attributes and their associations as defined in the respective profiles.

MSG 16. ERROR: RDF schema validation error (invalid class or attribute) <*value of rdf:Description rdf:about* ***attribute>***

[16] The RDF Schema provides a data-modelling vocabulary for RDF data. RDF Schema is an extension of the basic RDF vocabulary. Version 1.1, 25 February 2014, can be downloaded from: http://www.w3.org/TR/rdf-schema/

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4 LEVEL 4 VALIDATION: OBJECT CONSTRAINTS

This level of validation can be done *after* the document has been parsed and stored into an internal database of the validation module.

4.1 CONSTRAINTS DERIVED FROM THE UML

In the CGMES exchange profiles the cardinality of attributes is defined: Classes may have mandatory attributes or optional attributes, some are only mandatory for a specific stereotype and some are only mandatory when a specific flag is set. The cardinality can be validated through the OCLderivedFromUMLrules files, which can be found at: https://www.entsoe.eu/Documents/CIM_documents/Grid_Model_CIM/ENTSOE_CGMES_v2.4.15_7Aug2014_OCL.zip. These files are written in the Object Constraint Language, a language that specifies the class with a so-called ***context*** declaration, comments with two leading dashes ("**--** "), the name of the rule with an "***inv***[17]" statement and the attribute starting with a ***self.*** Prefix:

```
context IEC61970::Base::Generation::Production::GeneratingUnit
-- initialP must be set.
-- Default initial active power which is used to store a powerflow result for the initial active power for this unit in this network configuration.
inv GeneratingUnit_initialP: (self.initialP <> null)
-- maxOperatingP must be set.
-- This is the maximum operating active power limit the dispatcher can enter for this unit.
inv GeneratingUnit_maxOperatingP: (self.maxOperatingP <> null)
-- minOperatingP must be set.
-- This is the minimum operating active power limit the dispatcher can enter for this unit.
inv GeneratingUnit_minOperatingP: (self.minOperatingP <> null)
```

In the example above we refer to the Class "GeneratingUnit", which is packaged in the Equipment profile under Production. We can identify three mandatory attributes from the UML after the "***inv***" statements with the name of the rules:

- initial
- maxOperatingP
- minOperatingP

This can be verified in the UML diagram below:

[17] Inv is short for invariant

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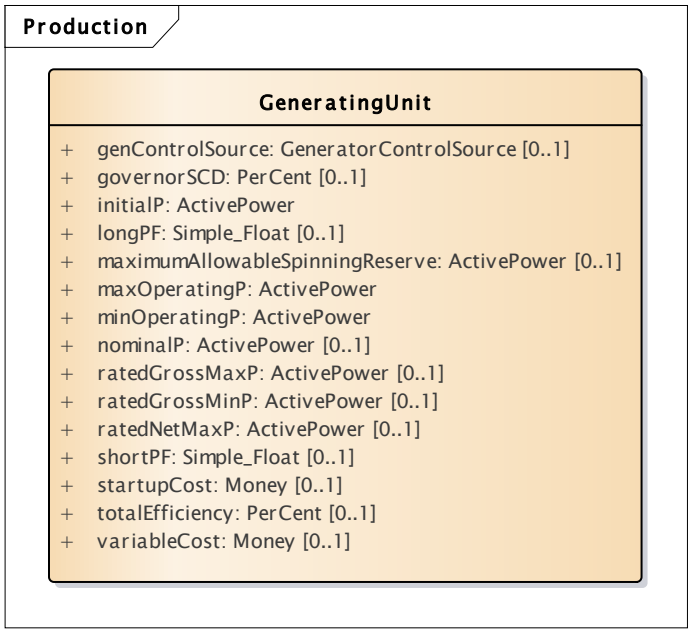

Figure 2. Class GeneratingUnit

4_1. All mandatory attributes for an exchanged CGMES class must be provided for the profile(s) declared in the file header.

MSG 17. ERROR: <*rule name*>[18] - <*diagnostic*>[19]

4.2 CGMES LENGTH CONSTRAINTS AND CONDITIONAL CONSTRAINTS

Additional length constraints are specified in the CGMES specifications document (https://www.entsoe.eu/Documents/CIM_documents/Grid_Model_CIM/140807_ENTSOE_CGMES_v2.4.15.pdf). Conditional constraints, can be found in the UML as OCL constraints. Both are specified in the OCLrulesAdded files, which can also be found at: https://www.entsoe.eu/Documents/CIM_documents/Grid_Model_CIM/ENTSOE_CGMES_v2.4.15_7Aug2014_OCL.zip.

```
context IEC61970::Base::Core::IdentifiedObject
-- R.4.10.11. Description length restriction (optional).
inv topologyDescriptionLength: self.description = null or self.description->size() <= 256
-- R.4.10.11. Energy Ident Code length restriction (optional).
inv topologyEnergyIdentCodeEicLength: self.energyIdentCodeEic = null or self.energyIdentCodeEic->size() = 16
-- R.4.10.11. Name length restriction.
inv topologyNameLength: self.name->size() <= 32 or name = null
-- R.4.10.11. ShortName length restriction (optional).
inv topologyShortNameLength: self.shortName = null or self.shortName->size() <= 12
```

[18] Specified in the OCL rule after the “inv” statement

[19] Specified in the OCL rule after the leading dashes

```
-- R.4.10.13. Name is required for all classes except ACDCTerminal.
inv tpNameRequirement: if (not self.oclIsKindOf(IEC61970::Base::Core::ACDCTerminal))
then (self.name <> null) else (self.name = null or self.name <> null) endif
```

The example above specifies name length restrictions for the IdentifiedObject Class within the Topology profile. The first four attributes are optional (**= *null***), but if provided the length is defined by the ***size*** statement.

4_2. If the class, for which additional constraints have been defined, is exchanged, it must fulfil the constraint.

MSG 18. ERROR: <*rule name***>[20] - <***diagnostic***>[21]**

4.3 PRECONDITIONS FOR THE MERGING PROCESS

The following quality checks (EQ profile only) refer to control area identification, which is necessary for area interchange enforcement using Aggregated Netted AC positions. Note that these checks are not defined in OCL as they refer to the business process.

5_1. ControlArea must be defined in EQ profile.

MSG 19. ERROR: ControlArea cannot be found.

5_2. IdentifiedObject.energyIdentCodeEic attribute must be provided for each ControlArea in EQ profile.

MSG 20. ERROR: ControlArea energyIdentCodeEic attribute cannot be found.

[20] Specified in the OCL rule after the “inv” statement

[21] Specified in the OCL rule after the leading dashes

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5 LEVEL 5 VALIDATION: CONSISTENCY

5.1 MODEL ASSEMBLY

Model assembly refers to the process of fulfilling the dependencies as specified in the file headers of instance files, starting with the EquipmentBoundary and TopologyBoundary instances, followed by the EQ, SSH and TP instances of a MA or multiple MAs.

As RDF allows associations across profiles, the fulfilment of all references and cross profile consistencies can only be checked after performing model assembly.

The following picture shows the dependencies between the individual profiles:

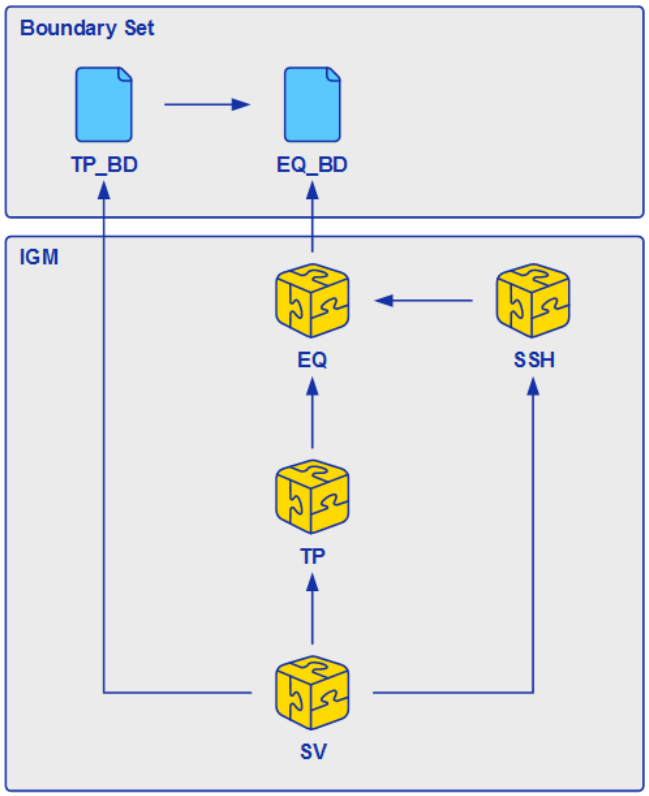

Figure 3. Profile dependencies

Note that in this picture SV is dependent on SSH, although the classes in SV only refer to EQ profile classes Terminal, ShuntCompensator, TapChanger, ConductingEquipment and TP profile class TopologicalNode. The dependency to SSH is necessary for initiating the validation and merging process, because the Power Flow results expressed in SV are the **result** of the data, expressed in EQ, TP **and** SSH.

5_3. The SV instance file must contain a dependency to specify which SSH data was used in the Power Flow calculation

MSG 21. ERROR: Reference to SSH data is missing.

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5.2 DANGLING REFERENCES

5_4. Taking into account the dependencies, provided in the file headers, all rdf:about references must be fulfilled

MSG 22. ERROR: Dangling reference for class <*classname*>, rdf:ID <*rdf:about*> cannot be found.

5.3 CONSISTENCY OF ATTRIBUTES OF ASSOCIATED CLASSES

5_5. All equipment associated with a specific Line container must have the same BaseVoltage.nominalVoltage value.

MSG 23. WARNING: BaseVoltage.nominalVoltage <*Voltage1, Voltage2*> detected for the line <*IdentifiedObject.name*>

5_6. GeneratingUnit.maxOperatingP must be greater than or equal to GeneratingUnit.minOperatingP

MSG 24. ERROR: Invalid generator active power limits detected for Generating Unit <*IdentifiedObject.name*>

5_7. SynchronousMachine.maxQ must be greater than or equal to SynchronousMachine.minQ

MSG 25. ERROR: Invalid reactive power limits for Synchronous Machine <*IdentifiedObject.name*>

5.4 CROSS PROFILE CONSISTENCY

The following consistency checks apply to transformers[22]:

5_8. If TapChanger.ltcFlag is true (EQ profile), TapChanger.TapChangerControl values (SSH profile) are expected.

MSG 26. WARNING: A real and fixed tap has been detected for Power Transformer <*IdentifiedObject.name*> that is not controlled, but can be moved manually under load. Power flow cannot be set to change the tap for voltage control during the calculation.

5_9. If TapChanger.ltcFlag is false (EQ profile), TapChanger.TapChangerControl values (SSH profile) are not expected.

MSG 27. WARNING: An artificial tap changer has been detected for Power Transformer <*IdentifiedObject.name*> that can be used to simulate control behaviour in power flow.

5_10. SvTapStep (SV profile) is expected for all TapChangers, defined in EQ profile.

MSG 28. ERROR: SvTapStep has not been provided for Power Transformer <*IdentifiedObject.name*>, this is required for all TapChangers.

[22] These rules have been derived from the document "Implementation guidelines – CGMES v2.4.15 – 15 March 2016"

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5_11. RegulatingControl.targetValue (SSH) must be smaller than or equal to (1+RatioTapChanger.stepVoltageIncrement*(TapChanger.highStep - TapChanger.neutralStep))* PowerTransformerEnd.ratedU

MSG 29. WARNING: RegulatingControl.targetValue out of range for Power Transformer <*IdentifiedObject.name*> [23]

5_12. RegulatingControl.targetValue (SSH) must be greater than or equal to (1-RatioTapChanger.stepVoltageIncrement*(TapChanger.neutralStep - TapChanger.lowStep))* PowerTransformerEnd.ratedU

MSG 30. WARNING: RegulatingControl.targetValue out of range for Power Transformer <*IdentifiedObject.name*> [24]

The following consistency checks apply to Generating Units:

5_13. Negated value[25] of RotatingMachine.p must be greater than or equal to GeneratingUnit.minOperatingP

MSG 31. WARNING: Generating Unit active power out of range for Generating Unit <*IdentifiedObject.name*> [26]

5_14. Negated value[27] of RotatingMachine.p must be smaller than or equal to GeneratingUnit.maxOperatingP

MSG 32. WARNING: Generating Unit active power out of range for Generating Unit <*IdentifiedObject.name*> [28]

5_15. If RegulatingControl.enabled is false[29] for a SynchronousMachine, while its RegulatingControl.mode equals “voltage” or “reactivePower”, the negated value of RotatingMachine.q must be greater than or equal to the minimum of (SynchronousMachine.minQ and ReactiveCapabilityCurve.y1value at ReactiveCapabilityCurve.xvalue[30])

[23] Note: the receiving application shall interpret the target value as PowerTransformerEnd.ratedU*(1+TapChanger.highStep*RatioTapChanger.stepVoltageIncrement)

[24] Note: the receiving application shall interpret the target value as PowerTransformerEnd.ratedU*(1-TapChanger.lowStep*RatioTapChanger.stepVoltageIncrement)

[25] Due to the sign convention (the p value is negative for production)

[26] Note: the receiving application shall interpret the value as GeneratingUnit.minOperatingP

[27] Due to the sign convention (inductive infeed is negative for production)

[28] Note: the receiving application shall interpret the value as GeneratingUnit.maxOperatingP

[29] Note that if the synchronous machine is in PV mode (i.e. RegulatingControl.enabled = true, while the control mode is voltage or reactive power), the value of Q in SSH is of less importance: it will be set during the power flow calculation, but if the synchronous machine is in PQ mode (i.e. the RegulatingControl.enabled = false), the value of q must be within the operating limits of the machine.

[30] The xvalue here is equal to the value of RotatingMachine.p

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MSG 33. **WARNING: Unrealistic reactive power value for Generating Unit <*IdentifiedObject.name*>**[31]

5_16. If RegulatingControl.enabled is false[32] for a SynchronousMachine, while its RegulatingControl.mode equals “voltage” or “reactivePower”, the negated value of RotatingMachine.q must be smaller than or equal to the maximum of (SynchronousMachine.maxQ and ReactiveCapabilityCurve.y2value at ReactiveCapabilityCurve.xvalue[33])

MSG 34. **WARNING: Unrealistic reactive power value for Generating Unit <*IdentifiedObject.name*>**[34]

[31] Note: the receiving application shall interpret the value as SynchronousMachine.minQ

[32] Note that if the synchronous machine is in PV mode (i.e. RegulatingControl.enabled = true, while the control mode is voltage or reactive power), the value of Q in SSH is of less importance: it will be set during the power flow calculation, but if the synchronous machine is in PQ mode (i.e. the RegulatingControl. enabled = false), the value of q must be within the operating limits of the machine.

[33] The xvalue here is equal to the value of RotatingMachine.p

[34] Note: the receiving application shall interpret the value as SynchronousMachine.maxQ

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6 LEVEL 6 VALIDATION: ROBUSTNESS

6.1 INTRODUCTION

In this category we focus on modelling assumptions that impact convergence behaviour. From experience we have identified the following root causes:

- 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)
- Tap positions of transformers that operate in parallel are not the same, causing loop flows
- Impact of cables not modelled
- Low impedance equipment (short cables or low impedance transformers)

6.2 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)

6.3 EXPECTED POWER FLOW SETTINGS

The Individual grid models are expected to be based on a solved case in the local tool, which is expressed in the operating assumptions and topology derived from this solved case. The following power flow settings are to be used when preparing the IGM:

- Full Newton Raphson power flow algorithm
- Q limits shall be respected (also for slack node/swing bus)
- Transformer tap adjustment is set to enabled
- Switched shunt adjustment is set to enabled
- Distributed load slack is set to enabled
- Flat start (i.e. nominal voltages and zero angles) is set to disabled (i.e. run on previous solution)
- Area interchange control is set to disabled

- Solution tolerance is set to 0.5 MW and 0.5 MVAr
- Voltage angle violation limit is set to 16 degrees

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6.4 DIAGNOSTIC RULES (IGM, BEFORE LOAD FLOW CALCULATION)

6_1. At least one voltage control node has to be available for each electrical island (SynchronousMachine.referencePriority > 0, or RegulatingControl.enabled is true[35] for a SynchronousMachine, while its RegulatingControl.mode equals “voltage” or “reactivePower”).

MSG 35. ERROR: Voltage phase angle reference bus cannot be selected

6_2. TapChanger.step value of RatioTapChangers that are operated in parallel shall be the same[36].

MSG 36. WARNING: Unbalanced TapChanger.step values detected for parallel RatioTapChangers <*IdentifiedObject.name*> and <*IdentifiedObject.name*>[37]

6_3. RegulatingControl.targetValue for voltage control (SynchronousMachines or RatioTapChanger with TapChanger.ltcFlag enabled) shall be smaller than or equal to the VoltageLimit.value for OperationalLimitType.limitType=highVoltage

MSG 37. WARNING: Target voltage not feasible for <*IdentifiedObject.name*>[38]

6_4. RegulatingControl.targetValue for voltage control (SynchronousMachines or RatioTapChanger with TapChanger.ltcFlag enabled) shall be greater than or equal to the VoltageLimit.value for OperationalLimitType.limitType=lowVoltage

MSG 38. WARNING: Target voltage not feasible for <*IdentifiedObject.name*>[39]

6_5. EnergyConsumer.p should not be negative.

MSG 39. WARNING: Distributed energy resources should not be modelled as EnergyConsumers

6_6. The sum of the EquivalentInjection.p values for all AC BoundaryPoints **is not allowed to** deviate from the aggregated netted AC position[40] by more than 500 MW.

MSG 40. ERROR: Sum of the AC tie-line flows is invalid (deviates more than 500 MW from Aggregated netted AC position)

6_7. The sum of the EquivalentInjection.p values for all AC BoundaryPoints **shall not** deviate from the aggregated netted AC position[41] by more than 50 MW.

---

35 Note that if a synchronous machine is in PV mode (i.e. RegulatingControl.enabled = true, while the control mode is voltage or reactive power), it can be used as voltage phase angle reference bus in case all synchronous machines in the electrical island have a zero SynchronousMachine.referencePriority value.

36 Note that tapchanger tap positions of parallel transformers could deviate in case of different electrical parameters of the two transformers

37 This message is included for diagnostic purposes as a potential cause of non-convergence

38 Note: The receiving application shall interpret the highvoltage value as target value instead

39 Note: The receiving application shall interpret the lowvoltage value as target value instead

40 Note that losses are expected to be compensated inside the IGM (sum of Production = -(sum of consumption and losses) – aggregated netted AC position

41 Note that losses are expected to be compensated inside the IGM (sum of Production = -(sum of consumption and losses) – aggregated netted AC position

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MSG 41. **WARNING: Unrealistic sum of AC tie-line flows (deviates more than 50 MW from Aggregated netted AC position)**

6_8. The same TopologicalNode shall not be associated with multiple[42] Regulating Controls at the same time[43].

MSG 42. **WARNING: Redundant regulation of the voltage for the TopologicalNode <***IdentifiedObject.name***> may complicate convergence behaviour**

6_9. The value of ACLineSegment.x is expected to be greater than or equal to 0.05 Ohms.

MSG 43. **WARNING: ACLineSegment <***IdentifiedObject.name***> - small reactance values (smaller than 0.05 Ohms) may complicate convergence behaviour**

6_10. The value of PowerTransformerEnd.x is expected to be greater than or equal to 0.05 Ohms.

MSG 44. **WARNING: PowerTransformerEnd <***IdentifiedObject.name***> - small reactance values (smaller than 0.05 Ohms) may complicate convergence behaviour**

6_11. If RotatingMachine.ratedS is smaller than or equal to 10 MVA, its RegulatingControl.enabled flag is expected to be set to “false”, if exchanged.

MSG 45. **WARNING: RotatingMachine <***IdentifiedObject.name***> is smaller than 10 MVA, its regulation control will be ignored as too many regulating controls may complicate convergence behaviour.**

[42] I.e. separate regulating controls associated with e.g. ShuntCompensator, a SynchronousMachine, TapChanger operating on the same target value (voltage, active power, ….)

[43] It is allowed to associate multiple devices to a single regulating control (a station controller)

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6.5 DIAGNOSTIC RULES (IGM, SV PROFILE AND EQ PROFILE)

6_12. For all TopologicalNodes, associated with synchronous machines (including slack generator), the negated value of SvInjection.qInjection value must be greater than or equal to the minimum of (SynchronousMachine.minQ and ReactiveCapabilityCurve.y1value at ReactiveCapabilityCurve.xvalue[44]), summed for each SynchronousMachine that is associated with this TopologicalNode.

MSG 46. ERROR: SvInjection.qInjection out of bound for TopologicalNode <*IdentifiedObject.name***>**

6_13. For all TopologicalNodes, associated with synchronous machines (including slack generator), the negated value of SvInjection.qInjection value must be smaller than or equal to the maximum of (SynchronousMachine.maxQ and ReactiveCapabilityCurve.y2value at ReactiveCapabilityCurve.xvalue[45]), summed for each SynchronousMachine that is associated with this TopologicalNode.

MSG 47. ERROR: SvInjection.qInjection out of bound for TopologicalNode <*IdentifiedObject.name***>**

6_14. For all TopologicalNodes, the value of SvVoltage.v shall be smaller than or equal to the VoltageLimit.value for OperationalLimitType.limitType=highVoltage.

MSG 48. WARNING: Calculated voltage at TopologicalNode <*IdentifiedObject.name***> is too high.**

6_15. For all TopologicalNodes, the value of SvVoltage.v shall be greater than or equal to the VoltageLimit.value for OperationalLimitType.limitType=lowVoltage.

MSG 49. WARNING: Calculated voltage at TopologicalNode <*IdentifiedObject.name***> is too low.**

[44] The xvalue here is equal to the value of RotatingMachine.p

[45] The xvalue here is equal to the value of RotatingMachine.p

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7 LEVEL 7 VALIDATION: CROSS IGM CONSISTENCY

This section focusses on consistency between information provided by two TSOs that share a common border.

7_1. If the absolute value of the SVPowerflow.p value is equal to zero at both terminals of the ACLineSegment of which one of the terminals is associated with a BoundaryPoint for one IGM, it is **expected** that this is find the also the case for the second IGM with the same BoundaryPoint.

MSG 50. WARNING: Tie-line <*IdentifiedObject.description*> opened at one side

7_2. The value of CurrentLimit.value is expected to be the same on both sides of a tie-line.

MSG 51. WARNING: Inconsistent monitoring values on the Tie-line <*IdentifiedObject.description*>[46]

[46] Note: the receiving application shall use the lowest value

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8 LEVEL 8 VALIDATION: PLAUSIBILITY

8.1 CONVERGENCE BEHAVIOUR OF IGM

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

8_1. It shall be possible to calculate the power flow of an IGM[47] with the power flow settings provided in 6.3[48].

MSG 52. ERROR: IGM for <md:ModelingAuthoritySet>*value*</md:ModelingAuthoritySet> didn't converge.

8.2 PLAUSIBILITY OF CGM

In this section we focus 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.

8_2. No substituted IGMs are expected to be used in the CGM

MSG 53. WARNING: IGM for <md:ModelingAuthoritySet>*value*</md:ModelingAuthoritySet> has been substituted

8_3. For all TopologicalNodes, the value of SvVoltage.v shall be smaller than or equal to the VoltageLimit.value for OperationalLimitType.limitType=highVoltage.

MSG 54. WARNING: Calculated voltage at TopologicalNode <*IdentifiedObject.name*> is too high.

8_4. For all TopologicalNodes, the value of SvVoltage.v shall be greater than or equal to the VoltageLimit.value for OperationalLimitType.limitType=lowVoltage.

MSG 55. WARNING: Calculated voltage at TopologicalNode <*IdentifiedObject.name*> is too low.

8_5. There shall be no base case violations with respect to PATL.

MSG 56. WARNING: Base case violation detected for monitored element <*IdentifiedObject.name*>

8_6. For all TopologicalNodes, associated with synchronous machines (including slack generator), the negated value of SvInjection.qInjection value must be greater than or equal to the minimum of (SynchronousMachine.minQ and ReactiveCapabilityCurve.y1value at ReactiveCapabilityCurve.xvalue[49]).

[47] A consistent set of EQ, SSH, TP, EQ-BD and TP-BD profiles

[48] The EMF will substitute the SSH data in accordance with the rules set forth in the EMF requirements specification

[49] The xvalue here is equal to the value of RotatingMachine.p

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MSG 57. **WARNING: SvInjection.qInjection bound for SynchronousMachine <*IdentifiedObject.name*> (low Qlimit has been reached)**

8_7. For all TopologicalNodes, associated with synchronous machines (including slack generator), the negated value of SvInjection.qInjection value must be smaller than or equal to the maximum of (SynchronousMachine.maxQ and ReactiveCapabilityCurve.y2value at ReactiveCapabilityCurve.xvalue[50]).

MSG 58. **WARNING: SvInjection.qInjection bound for SynchronousMachine <*IdentifiedObject.name*> (high Qlimit has been reached)**

8_8. It shall be possible to calculate the power flow of a CGM with the power flow settings provided in 6.3 for all synchronous areas.

MSG 59. **WARNING: CGM didn't converge for synchronous area <*Synchronous area*> with default power flow settings, calculation results may not be realistic.**

8_9. It shall be possible to calculate the power flow of a CGM with the power flow settings provided in 6.3, after relaxing the reactive power limits for all synchronous areas.

MSG 60. **ERROR: CGM didn't converge for synchronous area <*Synchronous area*> with relaxed power flow settings, calculation results not available.**

[50] The xvalue here is equal to the value of RotatingMachine.p

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