



BSI Standards Publication

Energy management system application program interface (EMS-API)

Part 456: Solved power system state profiles

National foreword

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The UK participation in its preparation was entrusted to Technical Committee PEL/57, Power systems management and associated information exchange.

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**Energy management system application program interface
(EMS-API) - Part 456: Solved power system state profiles
(IEC 61970-456:2021)**

Interface de programmation d'application pour système de
gestion d'énergie (EMS-API) - Partie 456: Profils d'état de
réseaux électriques résolus
(IEC 61970-456:2021)

Schnittstelle für Anwendungsprogramme für
Netzführungssysteme (EMS-API) - Teil 456: Gelöste
Zustandsprofile des Stromversorgungssystems
(IEC 61970-456:2021)

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European foreword

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- latest date by which the national standards conflicting with the document have to be withdrawn (dow) 2025-01-19

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In the official version, for Bibliography, the following notes have to be added for the standards indicated:

IEC 61970-1	NOTE	Harmonized as EN 61970-1
IEC/TS 61970-2	NOTE	Harmonized as CLC/TS 61970-2
IEC 61970-453	NOTE	Harmonized as EN 61970-453
IEC 61970-501	NOTE	Harmonized as EN 61970-501
IEC 61970-552	NOTE	Harmonized as EN 61970-552
IEC 61970-600-1	NOTE	Harmonized as EN IEC 61970-600-1
IEC 61970-600-2	NOTE	Harmonized as EN IEC 61970-600-2

Annex ZA (normative)

Normative references to international publications with their corresponding European publications

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

NOTE 1 Where an International Publication has been modified by common modifications, indicated by (mod), the relevant EN/HD applies.

NOTE 2 Up-to-date information on the latest versions of the European Standards listed in this annex is available here: www.cenelec.eu.

<u>Publication</u>	<u>Year</u>	<u>Title</u>	<u>EN/HD</u>	<u>Year</u>
IEC 61970-301	2020	Energy management system application program interface (EMS-API) - Part 301: Common information model (CIM) base	EN IEC 61970-301	2020
A1 ¹	—		A1 ²	—
IEC 61970-452	2021	Energy management system application program interface (EMS-API) - Part 452: CIM static transmission network model profiles	EN IEC 61970-452	2021

¹ Under preparation. Stage at the time of publication: IEC/RPVC 61970-301/AMD1:2021.

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INTERNATIONAL STANDARD

NORME INTERNATIONALE



**Energy management system application program interface (EMS-API) –
Part 456: Solved power system state profiles**

**Interface de programmation d'application pour système de gestion d'énergie
(EMS-API) –
Partie 456: Profils d'état de réseaux électriques résolus**



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INTERNATIONAL STANDARD

NORME INTERNATIONALE



**Energy management system application program interface (EMS-API) –
Part 456: Solved power system state profiles**

**Interface de programmation d'application pour système de gestion d'énergie
(EMS-API) –
Partie 456: Profils d'état de réseaux électriques résolus**

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

**ENERGY MANAGEMENT SYSTEM APPLICATION
PROGRAM INTERFACE (EMS-API) –****Part 456: Solved power system state profiles****FOREWORD**

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IEC 61970-456 has been prepared by IEC technical committee 57: Power systems management and associated information exchange. It is an International Standard.

This third edition cancels and replaces the second edition published in 2018. This edition constitutes a technical revision. It is based on the IEC 61970 UML version ‘IEC61970CIM17v40’, dated 2020-08-24.

This edition includes the following significant technical changes with respect to the previous edition:

- a) Updated to support CIM17 (IEC 61970-301:2020+AMD1) and align with IEC 61970-452:ED4.
- b) The classes `PowerElectronicsConnection`, `PowerElectronicsUnit` and `PowerElectronicsWindUnit` are added to the Steady State Hypothesis (SSH) profile to match the changes done for Edition 4 of IEC 61970-452, Core Equipment profile.
- c) Added relevant terms used in this document.

d) Clarified use of Equipment.inService and Equipment.normallyInService.

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

Draft	Report on voting
57/2406/FDIS	57/2440/RVD

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

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

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

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

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

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

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

INTRODUCTION

This document is one of several parts of the IEC 61970 series that defines common information model (CIM) datasets exchanged between application programs in energy management systems (EMS).

The IEC 61970-300 series specifies the common information model (CIM). The CIM is an abstract model that represents the objects in an electric utility enterprise typically needed to model the operational aspects of a utility.

This document is one of the IEC 61970-400 series of component interface standards that specify the semantic structure of data exchanged between components (or applications) and/or made publicly available data by a component. This document describes the payload that would be carried if applications are communicating via a messaging system, but the standard does not include the method of exchange, and therefore is applicable to a variety of exchange implementations. The examples in this document are based on the exchanged data formatted specified in IEC 61970-552 CIM XML model exchange standard.

This document specifies three profiles:

- The Steady State Hypothesis (SSH) profile that describes power flow application input variables such as voltage set points, switch statuses etc.
- The topology profile (TP) that describes a bus-branch model. A topology model may be created by a network model builder from a node-breaker model with SSH as inputs using topology processing or by a tool where a user interactively builds a topology model. Therefore, a topology model is defined as an output.
- State variables profile (SV) that describes the solution of a power system case such as is produced by power flow or state estimation applications.

This document describes the inputs and solutions (outputs) with reference to a power system model that conforms to IEC 61970-452 in this series of related standards. The separation of information into profiles also enables separation of data into documents corresponding to the profiles. In this way the profiles defined in this document generate small data documents compared with traditional bus-branch or node-breaker formats that include the network, the initial conditions and the result.

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

Part 456: Solved power system state profiles

1 Scope

This part of IEC 61970 belongs to the IEC 61970-450 to IEC 61970-499 series that, taken as a whole, defines at an abstract level the content and exchange mechanisms used for data transmitted between power system analyses applications, control centres and/or control centre components.

The purpose of this document is to rigorously define the subset of classes, class attributes, and roles from the CIM necessary to describe the result of state estimation, power flow and other similar applications that produce a steady-state solution of a power network, under a set of use cases which are included informatively in this document.

This document is intended for two distinct audiences, data producers and data recipients, and can be read from those two perspectives. From the standpoint of model export software used by a data producer, the document defines how a producer may describe an instance of a network case in order to make it available to some other program. From the standpoint of a consumer, the document defines what that importing software must be able to interpret in order to consume power flow cases.

There are many different use cases for which use of this document is expected and they differ in the way that the document will be applied in each case. Implementers are expected to consider what use cases they wish to cover in order to know the extent of different options they must cover. As an example, the profiles defined in this document will be used in some cases to exchange starting conditions rather than solved conditions, so if this is an important use case, it means that a consumer application needs to be able to handle an unsolved state as well as one which has met some solution criteria.

2 Normative references

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

IEC 61970-301:2020, *Energy management system application program interface (EMS-API) – Part 301: Common information model (CIM) base*
IEC 61970-301:2020/AMD1:—¹

IEC 61970-452:2021, *Energy management system application program interface (EMS-API) – Part 452: CIM static transmission network model profiles*

3 Terms and definitions

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

¹ Under preparation. Stage at the time of publication: IEC/RPVC 61970-301/AMD1:2021

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

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

3.1

assembled model

model of a Model Authority Set with internal references resolved

3.2

boundary set

set containing all boundary points necessary for a merge model

3.3

CIM XML document/distribution

instance file which is serialised according to IEC 61970-552

3.4

distribution

specific representation of a dataset

Note 1 to entry: A dataset might be available in multiple serializations that may differ in various ways, including natural language, media-type or format, schematic organization, temporal and spatial resolution. The level of detail in the distribution is defined by one or more profiles to which the dataset conforms.

3.5

external references resolved

state in which no dangling references are present across the models of Model Authority Sets

3.6

header references resolved

state in which the references defined in model header are resolved

3.7

internal references resolved

state in which no dangling references are present within the model of a Model Authority Set

3.8

merged model

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

3.9

profile

data model to describe instance file for exchange of CIM data

Note 1 to entry: A profile is a subset of classes, associations and attributes needed to accomplish a specific type of interface and based upon a CIM data model. Profiles may impose stricter rules on original classes and associations. A profile is usually converted to schema (XSD, RDF, OWL, etc.) that can be used to create, read and validate instance files for data exchange.

Note 2 to entry: This term may be used to define either the semantic model for an instance data payload or the syntactic schema for an instance data payload. A profile may be expressed in XSD, RDF, and/or OWL files. An instance data conforming to a profile can be tested in exchanges between applications. A profile is necessary in order to “use” the canonical model.

3.10

solved model

model containing instance of State Variables (SV)

3.11

bus-branch model

simplified representation, which is a result from a topology processing of a node-breaker model

Note 1 to entry: It does not include a complete breaker and busbar configuration however retained breakers are allowed. This representation is used by power flow or state estimation algorithms.

3.12

node-breaker model

detailed representation that includes a complete breaker and busbar configuration.

3.13

power system case

model which is describing a steady state power system situation including equipment status, control targets and energy interchange

Note 1 to entry: It can be a state estimator case or a power flow case.

3.14

base case

power system case that forms the basis for other studies like short circuit, dynamic stability or contingency analysis

4 Profile specification

4.1 General

4.1.1 General

The profiles defined in this document have the following version information.

4.1.2 Steady state hypothesis profile

- Title: Steady State Hypothesis Vocabulary
- Keyword: SSH
- Description: This vocabulary is describing the steady state hypothesis profile from IEC 61970-456.
- Version IRI: <http://iec.ch/TC57/ns/CIM/SteadyStateHypothesis/2.0>
- Version info: 2.0.0
- Prior version: <http://iec.ch/TC57/2013/61970-456/SteadyStateHypothesis/1>
- Conforms to: [urn:iso:std:iec:61970-456:ed-3|urn:iso:std:iec:61970-301:ed-7:amd1|file:///iec61970cim17v40_iec61968cim13v13a_iec62325cim03v17a.eap|urn:iso:std:iec:61970-401:draft:ed-1|urn:iso:std:iec:61970-501:draft:ed-2](#)
- Identifier: [urn:uuid:527c4385-0429-4987-9b1c-495be6e3ef63](#)

4.1.3 Topology profile

- Title: Topology Vocabulary
- Keyword: TP
- Description: This vocabulary is describing the topology profile from IEC 61970-456.
- Version IRI: <http://iec.ch/TC57/ns/CIM/Topology/5.0>
- Version info: 5.0.0
- Prior version: <http://iec.ch/TC57/2013/61970-456/Topology/4>
- Conforms to: urn:iso:std:iec:61970-456:ed-3|urn:iso:std:iec:61970-301:ed-7:amd1|file://iec61970cim17v40_iec61968cim13v13a_iec62325cim03v17a.eap|urn:iso:std:iec:61970-401:draft:ed-1|urn:iso:std:iec:61970-501:draft:ed-2
- Identifier: urn:uuid:e36dcb99-2368-4eac-88ac-0be58a44af63

4.1.4 State variables profile

- Title: State Variables Vocabulary
- Keyword: SV
- Description: This vocabulary is describing the state variables profile from IEC 61970-456.
- Version IRI: <http://iec.ch/TC57/ns/CIM/StateVariables/5.0>
- Version info: 5.0.0
- Prior version: <http://iec.ch/TC57/2013/61970-456/StateVariables/4>
- Conforms to: urn:iso:std:iec:61970-456:ed-3|urn:iso:std:iec:61970-301:ed-7:amd1|file://iec61970cim17v40_iec61968cim13v13a_iec62325cim03v17a.eap|urn:iso:std:iec:61970-401:draft:ed-1|urn:iso:std:iec:61970-501:draft:ed-2
- Identifier: urn:uuid:f9744f43-258c-49cd-8d8d-449ab427a490

4.2 Requirements and constraints

This subclause defines requirements and constraints that shall be fulfilled by applications that conform to this document. The naming of the rules shall not be used for machine processing. The rule names are just a string. The naming convention of the constraints is as follows.

“{rule.Type}:{rule.Standard}:{rule.Profile}:{rule.Property}:{rule.Name}”

where

- rule.Type: C – for constraint; R – for requirement
- rule.Standard: the number of the standard e.g. 456 for IEC 61970-456, 452 for IEC 61970-452.
- rule.Profile: the abbreviation of the profile, e.g. TP for Topology profile. If set to “ALL” the constraint is applicable to all IEC 61970-456 profiles.
- rule.Property: for UML classes, the name of the class, for attributes and associations, the name of the class and attribute or association end, e.g. EnergyConsumer, IdentifiedObject.name, etc. If set to “NA” the property is not applicable to a specific UML element.
- rule.Name: the name of the rule. It is unique for the same property.

Example: C:456:TP:IdentifiedObject.name:stringLength

This subclause includes rules and constraints that are defined in IEC 61970-452, tagged "452". They are included to make the validation self-contained. The rule and constraints that are tagged "456" are mastered in this document.

- R:452:ALL:NA:exchange

Optional and required attributes and associations must be imported and exported if they are in the model file prior to import.

- R:452:ALL:NA:exchange1

If an optional attribute does not exist in the imported file, it does not have to be exported in case exactly the same data set is exported, i.e. the tool is not obliged to automatically provide this attribute. If the export is resulting from an action by the user performed after the import, e.g. data processing or model update the export can contain optional attributes.

- R:452:ALL:NA:exchange2

In most of the profiles the selection of optional and required attributes is made so as to ensure a minimum set of required attributes without which the exchange does not fulfil its basic purpose. Business processes governing different exchanges can require mandatory exchange of certain optional attributes or associations. Optional and required attributes and associations shall therefore be supported by applications which claim conformance with certain functionalities of IEC 61970-452. This provides flexibility for the business processes to adapt to different business requirements and base the exchanges on IEC 61970-452 compliant applications.

- R:452:ALL:NA:exchange3

An exporter may, at his or her discretion, produce a serialization containing additional class data described by the CIM Schema but not required by this document provided these data adhere to the conventions established in Clause 5.

- R:452:ALL:NA:exchange4

From the standpoint of the model import used by a data recipient, the document describes a subset of the CIM that importing software shall be able to interpret in order to import exported models. Data providers are free to exceed the minimum requirements described herein as long as their resulting data files are compliant with the CIM Schema and the conventions established in Clause 5. The document, therefore, describes additional classes and class data that, although not required, exporters will, in all likelihood, choose to include in their data files. The additional classes and data are labelled as required (cardinality 1..1) or as optional (cardinality 0..1) to distinguish them from their required counterparts. Please note, however, that data importers could potentially receive data containing instances of any and all classes described by the CIM Schema.

- R:452:ALL:NA:cardinality

The cardinality defined in the CIM model shall be followed, unless a more restrictive cardinality is explicitly defined in this document. For instance, the cardinality on the association between VoltageLevel and BaseVoltage indicates that a VoltageLevel shall be associated with one and only one BaseVoltage, but a BaseVoltage can be associated with zero to many VoltageLevels.

- R:452:ALL:NA:associations

Associations between classes referenced in this document and classes not referenced here are not required regardless of cardinality.

- R:452:ALL:IdentifiedObject.name:rule

The attribute "name" inherited by many classes from the abstract class IdentifiedObject is not required to be unique. It must be a human readable identifier without additional embedded information that would need to be parsed. The attribute is used for purposes such as User Interface and data exchange debugging. The MRID defined in the data exchange format is the only unique and persistent identifier used for this data exchange. The attribute IdentifiedObject.name is, however, always required for CoreEquipment profile and Short Circuit profile.

- R:452:ALL:IdentifiedObject.description:rule
The attribute “description” inherited by many classes from the abstract class IdentifiedObject must contain human readable text without additional embedded information that would need to be parsed.
- R:452:ALL:NA:uniqueIdentifier
All IdentifiedObject-s shall have a persistent and globally unique identifier (Master Resource Identifier – mRID).
- R:452:ALL:NA:unitMultiplier
For exchange of attributes defined using CIM Data Types (ActivePower, Susceptance, etc.) a unit multiplier of 1 is used if the UnitMultiplier specified in this document is “none”.
- R:456:SV:SvPowerFlow:instance
As a minimum there shall be an instance of SvPowerFlow associated with the Terminal for all the following classes and their specialisation (subclass) that is part of an energized TopologicalIsland: RotatingMachine, EnergyConsumer, EquivalentInjection, ShuntCompensator, StaticVarCompensator, ExternalNetworkInjection, PowerElectronicsConnection and EnergySource. Additional instances of SvPowerFlow may optionally be available for other in service (SvStatus.inService=true) and energised equipment (equipment connected to a TopologicalNode part of the TopologicalIsland).
- C:456:SSH:ACDCConverter:targets
The target values and related attributes for ACDCConverter and its subclasses are optional in SSH. However, depending on the control mode of the converter some of the attributes shall be considered as required. The description of the control modes in the enumerations CsPpccControlKind, VsPpccControlKind and VsQpccControlKind provide information on necessary attributes which are then considered required attributes for each control mode in SSH.
- C:456:SSH:EnergyConsumer.p:ValueRange
EnergyConsumer.p shall be zero or positive value. Energy production shall be modelled as an energy producer class (e.g. GeneratingUnit) or an Equivalent classes.
- C:456:SSH:EnergyConsumer.q:ValueRange
EnergyConsumer.q shall be zero or positive value. Energy production shall be modelled as an energy producer class (e.g. GeneratingUnit) or an Equivalent classes.
- C:456:SSH:EnergySource:EnergySourcePQ
The attributes voltageAngle and voltageMagnitude shall not be used when the EnergySource is representing a constant active and reactive power injection (PQ injection), i.e. they shall only be used when the EnergySource is modelling a voltage source.
- C:456:SSH:EquivalentInjection.p:limits
The negated value (necessary due to sign convention) of EquivalentInjection.p shall be less than or equal to EquivalentInjection.maxP and shall be greater than or equal to EquivalentInjection.minP.
- C:456:SSH:EquivalentInjection.q:limits
The negated value (necessary due to sign convention) of EquivalentInjection.q shall be less than or equal to EquivalentInjection.maxQ and shall be greater than or equal to EquivalentInjection.minQ.
- C:456:SSH:EquivalentInjection:regulation
If EquivalentInjection.regulationCapability in EQ is true, then EquivalentInjection.regulationStatus and EquivalentInjection.regulationTarget are required in SSH. If EquivalentInjection.regulationCapability in EQ is false, then EquivalentInjection.regulationStatus and EquivalentInjection.regulationTarget are not exchanged in SSH.

- C:456:SSH:ExternalNetworkInjection.p:limits
The negated value (necessary due to sign convention) of ExternalNetworkInjection.p shall be less than or equal to ExternalNetworkInjection.maxP and shall be greater than or equal to ExternalNetworkInjection.minP.
- C:456:SSH:ExternalNetworkInjection.q:limits
The negated value (necessary due to sign convention) of ExternalNetworkInjection.q shall be less than or equal to ExternalNetworkInjection.maxQ and shall be greater than or equal to ExternalNetworkInjection.minQ.
- C:456:SSH:GeneratingUnit.normalPF:values
GeneratingUnit.normalPF is normally zero for generators which are non-energized (do not participate in the load flow). It can have a number in case of activating the GeneratingUnit is a remedial action. As .normalPF values are not normalized across different MAS, the application that imports a model shall have a power flow calculation logic setup to be able to normalize normalPF values for the purpose of the distributed slack and preserve the original values of GeneratingUnit.normalPF in case of export.
- C:456:SSH:NA:angleReference
Angle reference: In cases where it is required to exchange a solved model and compare power flow results (assuming identical/comparable calculation methods and initial conditions) it is required that the angle reference slack is placed within the exported model. The slack generator is the SynchronousMachine connected to the TopologicalNode referenced by TopologicalIsland.AngleRefTopologicalNode and which has the highest SynchronousMachine.referencePriority in the exported MAS's SSH.
- C:456:SSH:NA:distributedActivePowerSlack
Active power slack by multiple generators per ControlArea: all GeneratingUnit(s) have non-zero normalPF, but there must be one GeneratingUnit per ControlArea that have maximum (the highest) participation factor (GeneratingUnit.normalPF) so that this GeneratingUnit is used as a single active power slack in case the tooling does not support active power slack by multiple generators per ControlArea.
- C:456:SSH:NA:notSolvedModel
In case of exchange of non-solved model (i.e. SV profile is not exchanged) the tools shall assign the angle reference node using the information from SSH (the highest SynchronousMachine.referencePriority or GeneratingUnit.normalPF in the exported MAS's SSH).
- C:456:SSH:NA:singleActivePowerSlack
Active power slack by a single generator per ControlArea: one generator has GeneratingUnit.normalPF set to a highest value (non-zero) and all other generating units have a zero GeneratingUnit.normalPF.
- C:456:SSH:RegulatingControl.targetValue:value
RegulatingControl.targetValue shall be positive value in cases where the RegulatingControl.mode is set to voltage in EQ profile.
- C:456:SSH:RotatingMachine.p:limits
The negated value (necessary due to sign convention) of RotatingMachine.p shall be less than or equal to GeneratingUnit.maxOperatingP and shall be greater than or equal to GeneratingUnit.minOperatingP of the associated GeneratingUnit. This applies regardless if the Equipment in service or not.
- C:456:SSH:RotatingMachine.q:limits
In case there is no ReactiveCapabilityCurve associated with the SynchronousMachine, the negated value (necessary due to sign convention) of RotatingMachine.q shall be less than or equal to SynchronousMachine.maxQ and shall be greater than or equal to SynchronousMachine.minQ. This applies regardless if the Equipment in service or not.

- C:456:SSH:RotatingMachine:pCapabilityCurve
In cases where a ReactiveCapabilityCurve is associated, the RotatingMachine.p shall be less than or equal to the maximum active power value defined by the curve and it shall be greater than or equal to the minimum active power value defined by the curve. NOTE: The machine operating mode (e.g. motor, generator etc) shall be taken into consideration.
- C:456:SSH:RotatingMachine:qCapabilityCurve
In cases where a ReactiveCapabilityCurve is associated, the RotatingMachine.q shall be less than or equal to the maximum reactive power value defined by the curve and it shall be greater than or equal to the minimum reactive power value defined by the curve. NOTE: The machine operating mode (e.g. motor, generator etc) shall be taken into consideration.
- C:456:SSH:ShuntCompensator.sections:value
In cases where RegulatingControl.discrete is true and RegulatingControl.enabled is true, ShuntCompensator.sections shall be integer.
- C:456:SSH:SynchronousMachine.operatingMode:matchType
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"].
- C:456:SSH:TapChanger.step:value
In cases where RegulatingControl.discrete is true and RegulatingControl.enabled is true, TapChanger.step shall be integer.
- C:456:SV:IdentifiedObject.name:stringLength
The string IdentifiedObject.name has a maximum of 128 characters.
- C:456:SV:SvPowerFlow.p:synchronousMachine
The SvPowerFlow.p that is given by the steady state power flow solution for a SynchronousMachine shall normally be within the capability of the machine defined in the ReactiveCapabilityCurve or GeneratingUnit.maxOperatingP and GeneratingUnit.minOperatingP when ReactiveCapabilityCurve is not present. Active power can be outside the capability as part of start-up or shutdown of the generator. CIM cannot represent different operation mode so this constraint will only give a warning. Note that different data exchange processes can assign more restrictive severity depending on the business needs and power flow algorithm applied by the business process.
- C:456:SV:SvPowerFlow.q:synchronousMachine
The SvPowerFlow.q that is given by the steady state power flow solution for a SynchronousMachine shall normally be within the capability of the machine defined in the ReactiveCapabilityCurve or SynchronousMachine.maxQ, SynchronousMachine.minQ when ReactiveCapabilityCurve is not present. Reactive power can be outside the capability if powerflow excludes reactive restriction. CIM cannot represent this so this contains will also give a warning. Note that different data exchange processes can assign more restrictive severity depending on the business needs and power flow algorithm applied by the business process.
- C:456:SV:SvShuntCompensatorSections.sections:value
In cases where RegulatingControl.discrete is true and RegulatingControl.enabled is true, SvShuntCompensatorSections.sections shall be integer.

- C:456:SV:SvSwitch:instance
SvSwitch shall be exchanged for all switching devices. It is expected that in most cases the SvSwitch.open in SV instance data will be identical with Switch.open in SSH instance data. However, in cases where a regulating control is modifying the connection state of the controlled device a difference between SvSwitch.open and Switch.open can occur.
- C:456:SV:SvTapStep.position:value
In cases where RegulatingControl.discrete is true and RegulatingControl.enabled is true, SvTapStep.position shall be integer.
- C:456:SV:SvVoltage.v:absoluteLimit
SvVoltage.v shall be greater than 0,4 pu in cases where associated voltage limits are not defining different limit range.
- C:456:SV:SvVoltage.v:limits
The SvVoltage.v shall be less than or equal to VoltageLimit.value associated with OperationalLimitType.limitType=highVoltage and greater than or equal to VoltageLimit.value associated with OperationalLimitType.limitType=lowVoltage.
- C:456:SV:TopologicalIsland:instance
At least one TopologicalIsland instance shall be present per SV instance.
The TopologicalIsland-s for a merged model which are defined in the state variables instance file for the merged model are created with the solving on the power flow of the merged model, i.e. there are no TopologicalIsland-s defined per MAS in a merged model. In case a solved merged model is exchanged for a single MAS the state variables instance file shall include at least one instance of TopologicalIsland.
- C:456:TP:IdentifiedObject.description:stringLength
The string IdentifiedObject.description is maximum 256 characters.
- C:456:TP:IdentifiedObject.name:instance
Name is required for all classes in the profile except ACDCTerminal.
- C:456:TP:IdentifiedObject.name:stringLength
The string IdentifiedObject.name has a maximum of 128 characters.
- C:456:TP:Terminal:switch
The Terminal-s of the two sides of a retained Switch (Switch.retained=true) or any of its subclasses shall not be connected to the same TopologicalNode.
- C:456:TP:TopologicalNode:containment
The association TopologicalNode.ConnectivityNodeContainer is required however CGMES does not specify to which type of EquipmentContainer the association shall point to. Therefore the association TopologicalNode.ConnectivityNodeContainer shall point to any type of EquipmentContainer given by the connecting equipment (that is linked to the associated Terminal). Machine based validation is not performed. It is required that import and export shall not make any changes to this association.

5 Overview

5.1 General

This document describes an interface standard in which XML payloads are used to transfer initial conditions and results created during typical steady-state network analysis processes (e.g. state estimation or power flow solutions). Major requirements/objectives driving the design of this document include:

- Power flow solution algorithms and outputs are virtually the same whether run in operations or planning contexts. State estimator output shares a common core with power flow. A single standard is desired to minimize software development and enable use cases that cross between environments.

- While some users of this standard might only be interested in the output state, the more general situation is that users continue to perform follow-on analyses (e.g. security analysis, voltage stability) and require both the input on which the solution was based and the output result.
- Real life analytical processes often involve a series of solutions in which most of the input data remains the same from one solution to the next, and the standard must support these processes in a way that does not repeat data unnecessarily.
- Power flow solutions tend to drift if the result from a power flow run is used as input to a subsequent power flow run. By preserving the initial conditions between power flow runs the solutions do not drift.

This document is flexible and designed to satisfy a wide range of analytical scenarios in the planning and operating business environments. It enables parties that collaborate in some business process to create additional business agreements that describe any restrictions and customizations of the document that are deemed necessary for the business process. In most cases, these additional agreements are local agreements hence they are not included in IEC standards.

5.2 Modelling authorities

In order to meet the requirements, this document depends on modularizing the potentially voluminous overall input and output data into subsets that would each be realized as smaller, XML payloads. An instance of one of these subsets is referred to herein as a 'dataset'.

Two types of partitioning into datasets are utilized. In the first, the data is modularized according to what kind of data is produced (which generally corresponds with what kind of application produces the data). CIM 'profiles' (subsets of the complete CIM) define the classes and attributes that make up each kind of modularization. The second type of partitioning is by network parts, which divides data into sets of instances according to which utility or entity in an interconnection is responsible for the data. The party responsible for data is called the Model Authority of the data and the network parts are defined as belonging to a Model Authority Set (MAS). This partitioning occurs at the instance level and produces multiple datasets governed by a profile and network part. Datasets from different MAS combine to form the complete set of data for that profile, Figure 1 illustrates this.

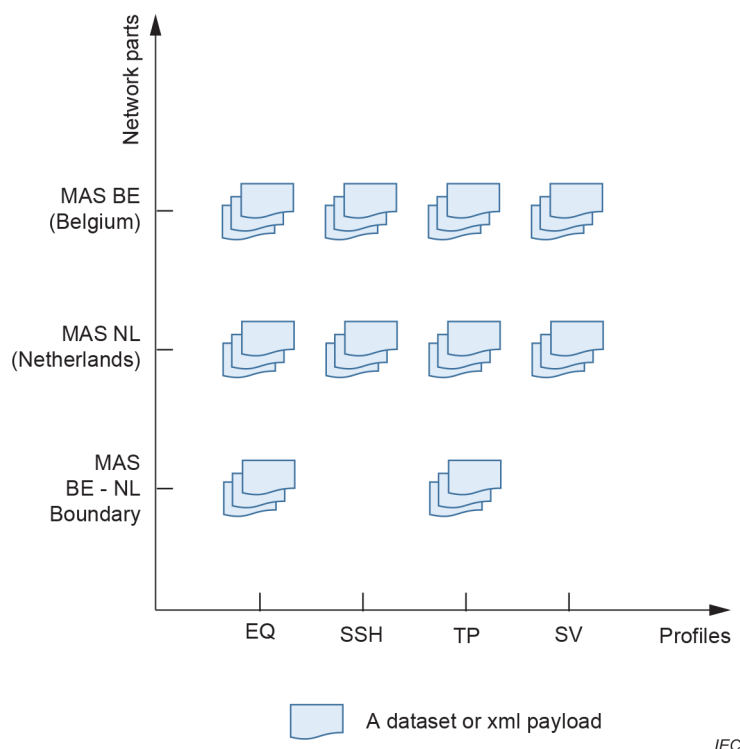


Figure 1 – Relations between MAS, profile and dataset

Different IEC 61970 profiles are listed along the horizontal axis:

- EQ for equipment are defined in IEC 61970-452.
- SSH for power flow initial data, TP for topology data and SV for state variables data are defined in this document.

A few examples of Model Authority Sets are listed along the vertical axis:

- MAS BE represents a regional Model Authority Set for Belgium that is a network part defined by a Model Authority BE, e.g. the Belgian TSO.
- MAS NL represents a regional Model Authority Set for Netherlands that is a network part defined by another Model Authority NL, e.g. the Netherlands TSO.
- MAS BE-NL Boundary represent a Model Authority Set that is a network part for the boundary between MAS BE and MAS NL. The boundary network part is typically agreed mutually between Model Authority BE and NL.

The document symbol in Figure 1 describes a dataset packaged as a payload.

The Model Authority Sets along the vertical axis in Figure 1 define parts of a network. Datasets belong to a Model Authority Set and this is indicated in Figure 1 by the horizontally aligned datasets at each MAS.

The profiles along the horizontal axis in Figure 1 describe a subset of the CIM canonical data used for a particular purpose. A dataset Figure 1 contains data for a specific profile and this is indicated in Figure 1 by the vertically aligned datasets at each profile.

At each crossing point between a Model Authority Set and profile there is a stack of datasets meaning that for this particular Model Authority Set and profile there may be many datasets e.g. representing different points in time or different study cases. The ways datasets can be created and combined is dependent on the use case. Specifications that better support use cases on how to combine datasets an explicit CIM model for Model Authority Sets is being developed and will be released in the future.

5.3 Profile relationships

Figure 2 illustrates some of the profiles that are defined by the IEC 61970-450 to IEC 61970-499 series and depicts the relationships between them.

Network models used in operations include detailed descriptions of measurements and their location in the network and switching devices, such models are called node-breaker models. Network models used in planning may not have this level of detail and typically exclude measurements and switching devices. Instead of computing the power flow buses (TopologicalNode-s) from switching device statuses the power flow buses are maintained manually in legacy bus-branch tools.

Node-breaker and bus-branch model representations can be combined in an assembled or a merged model and this is ensured by building of models using ConnectivityNode-s.

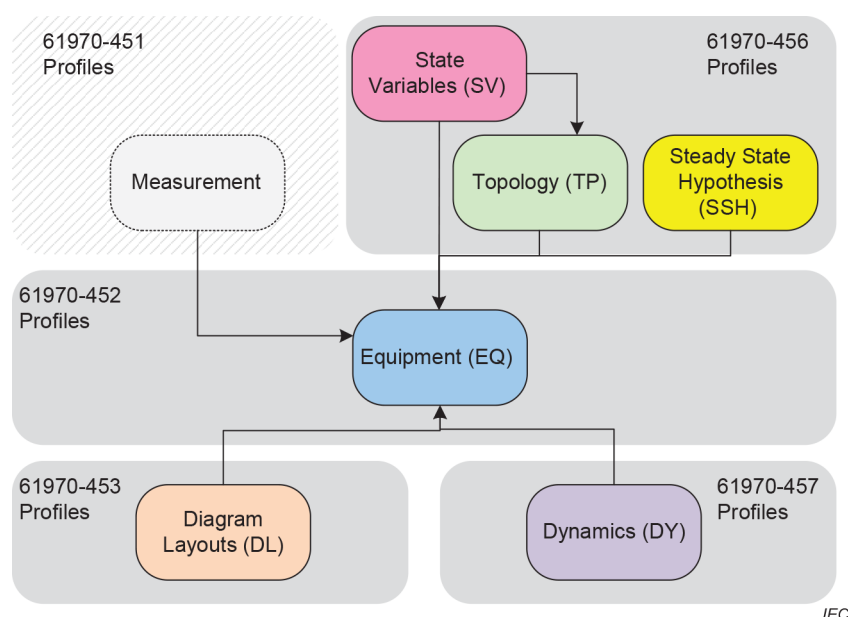


Figure 2 – Profile relationships

These modules satisfy the needs of network analysis business processes used in operations, in planning studies, as well as for transfers between operations and planning. The IEC 61970-451 profiles that support transfer of SCADA measurements to EMS applications do not yet exist and is planned work.

IEC 61970-452 defines specific profiles (or subsets) of the CIM for exchange of static power system data between utilities, security coordinators and other entities participating in an interconnected power system, such that all parties have access to the modelling of their neighbour's systems that is necessary to run state estimation or power flow applications. Currently three profiles, the Equipment Core profile, the Operation profile and the Short Circuit profile, have been defined.

Energy Management Systems and various network modelling and simulation tools employ a variety of schematic and quasi-geographic presentations in their user interfaces. These are sometimes generated automatically, but more often are hand-drawn and require considerable labour to create and maintain. Most of this labour goes into the arrangement, or 'layout' of the power system elements within the overall diagram. The IEC 61970-453 specifies guidelines for the exchange of diagram layout information for schematic data.

IEC 61970-457 specifies a profile to support the analysis of the steady state stability (small-signal stability) and/or transient stability of a power system or parts of it. The information is described with reference to a power system model that conforms to IEC 61970-452 and IEC 61970-456. Thus, equipment and other related power flow model data are not repeated in the information exchanged with this document. The schema(s) for expressing the dynamic model information are derived from IEC 61970-302.

In Figure 2, an arrow between profiles indicates that there are relationships defined between data in the two datasets. The directionality indicates that the data in the “from” dataset depends on classes in the “to” dataset. For data this means that “from” class data refers to or depends on “to” class data. Example: a dataset of an equipment model may have many Topology, State Variable and Steady State Hypothesis datasets that refer to it.

5.4 Connectivity model

Figure 3 illustrates an example of the equipment model in which the equipment connectivity is described by the ConnectivityNode and Terminal classes. The Terminal class is central in that and it supports Equipment, Topology, State Variables, Steady State Hypothesis and Diagram Layout profiles. Within the Equipment profile the Terminal is associated ConnectivityNode-s with ConductingEquipment and provides the multi Terminal equipment (e.g. Switch-es, ACLineSegment-s, etc.) with well-defined equipment “sides”.

The Equipment and Steady State Hypothesis profiles are the basis for network model building and power flow calculation. The Topology profile describes power flow busses that are an output of a topology processing of the equipment model, i.e. the TopologicalNode-s that are used as input by a power flow calculation. The State Variables profile describes the result of a power flow application.

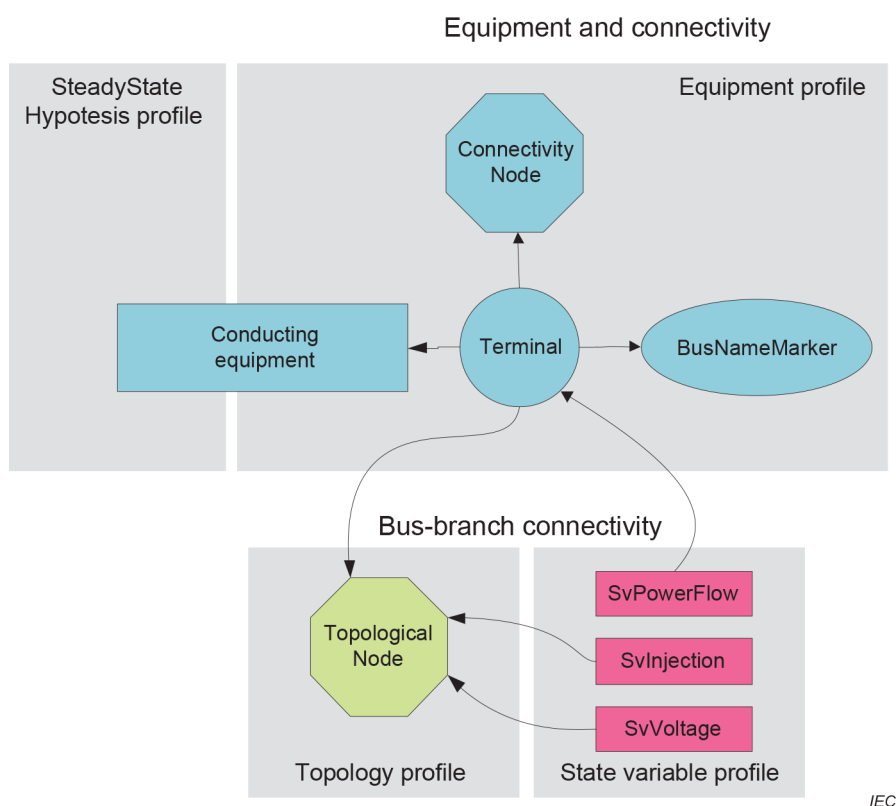


Figure 3 – Connectivity and solution model

The arrows in Figure 3 describe references between the CIM objects. TopologicalNode-s are computed from switching devices connecting ConnectivityNode-s.

A model uses `ConnectivityNode`-s to describe how `ConductingEquipment`-s are connected. In topology processing all `ConductingEquipment`-s connected with each other through closed `Switch`-es are identified and the `Terminal`-s of `ConductingEquipment`-s are assigned to a `TopologicalNode`.

`BusNameMarker`-s are used to avoid an arbitrary naming of `TopologicalNode`-s resulting from topology processing, as described in 7.1.1. It is possible to preserve the `TopologicalNode` names by creating `BusNameMarker`-s for one or more such sets of `Switch.open` and usage of the `BusNameMarker` names to name the `TopologicalNode`-s generated by topology processing.

This usage of `BusNameMarker`-s preserves `TopologicalNode` names but not the mRID (the `rdf:ID/rdf:about` in IEC 61970-552). Hence, `TopologicalNode` mRID-s will vary between different topology processing runs.

An equipment model using `ConnectivityNode`-s may not necessarily have any switches. A simplified equipment model can initially be created without switches. As the connectivity is described using `ConnectivityNode`-s it is possible to have a hybrid modelling representation where a detailed node-breaker model having switches is combined with a simplified bus-branch style model without switches. This is useful when operational models are to be combined with planning models to verify that the planned extensions work with existing operational models.

6 Use cases

6.1 Overview

This clause describes how the standard should be applied in business problems and gives examples of some scenarios.

Network applications use a bus-branch model in the basic power flow calculation where the branches are non-zero impedance elements. Real power systems have measurements and switching devices that are not described in bus-branch models but in node-breaker models. So, to run network calculations on a node-breaker model, a bus-branch model is created, where all zero impedance elements have been removed. In many study situations, it is impractical to deal with all the details in a node-breaker model, hence studies often use a bus-branch model for building study cases. The Steady State Hypothesis profile describes the data, e.g. switch statuses, needed to transform a node-barker model into a bus-branch model.

A large interconnected power network is typically divided into regions with a system operator that is responsible for operating the power network within a region. With increased and stronger interconnections between the regions the mutual dependency between the regions increases. A consequence is that a power flow set up for a particular region must also include a substantial part of the neighbouring regions including both EQ and SSH data. Figure 4 shows an example from Europe.

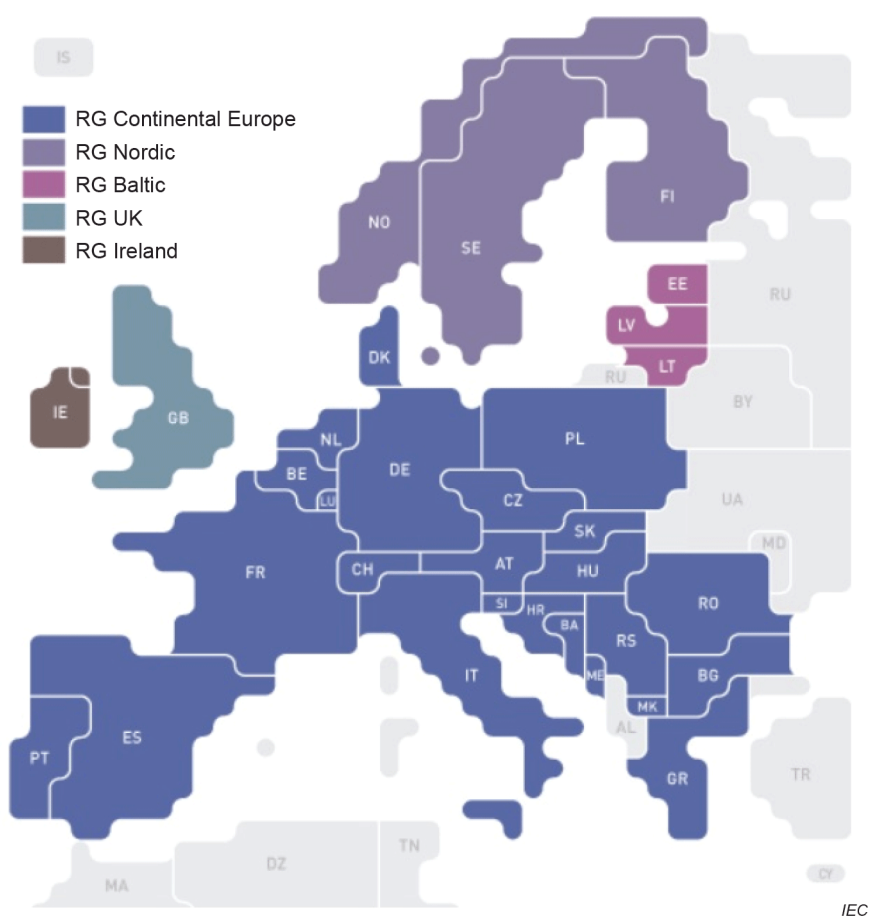


Figure 4 – The European power system with regions

The Case building process includes many sources of SSH data, as shown in Figure 5.

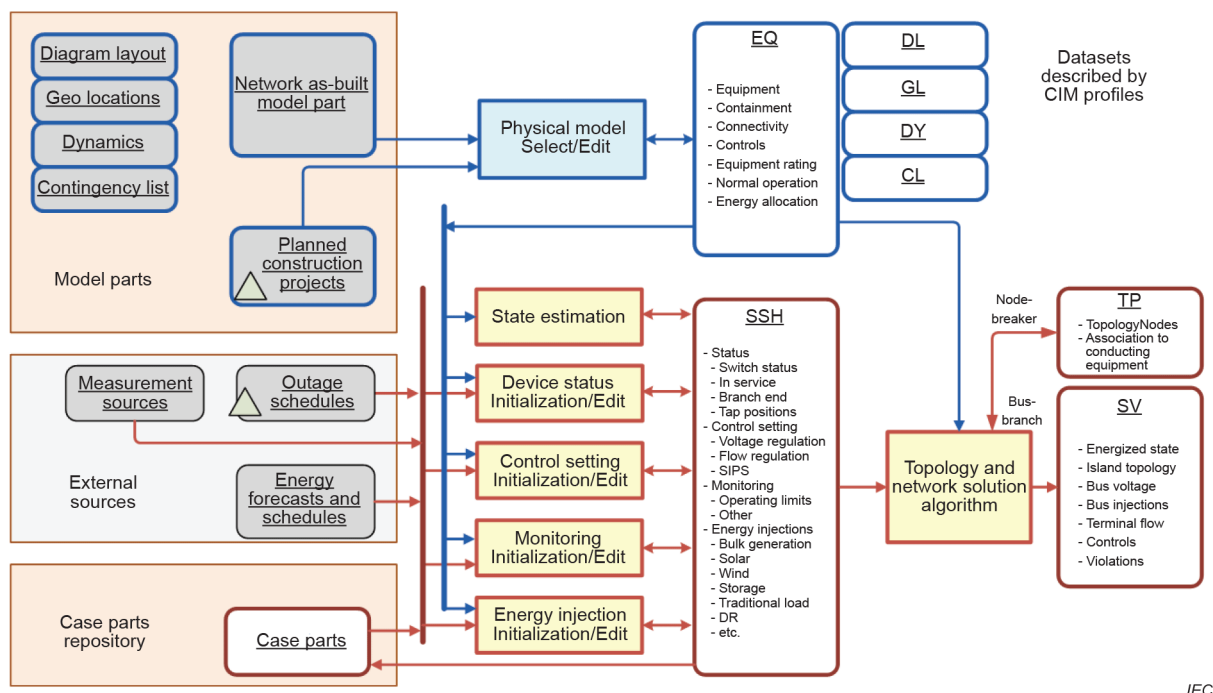


Figure 5 – Information exchange in power flow and sharing of results

Figure 5 describes how input to power flow calculation has many different possible sources. State Estimation and measurements create SSH data as input to power flow calculations. Case building includes selecting and combining data from different sources to form a complete input to a power flow study. The Steady State Hypothesis (SSH), Topology (TP) and State Variables (SV) are in scope of this specification. Other interfaces indicated in Figure 5 are outside the scope of this specification.

6.2 EMS network analysis integration

An architecture for transfer of data from a SCADA/EMS to other applications is shown in Figure 6.

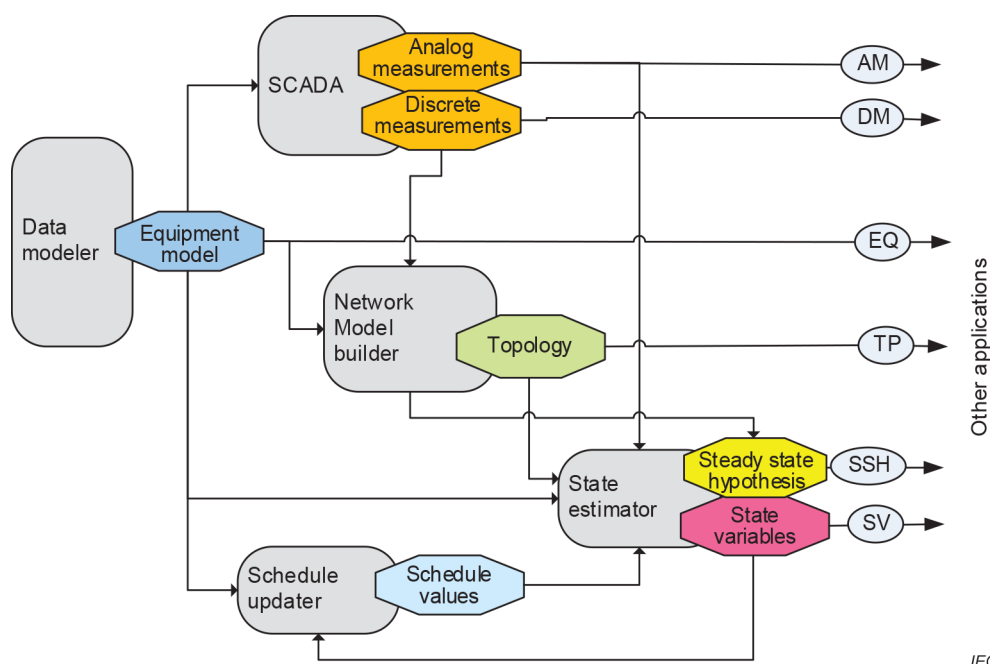


Figure 6 – EMS datasets to an external client

The following interfaces are shown in Figure 6:

- EQ: Equipment model data as described in IEC 61970-452;
- DM: network discrete measurements dataset;
- AM: network analog measurements dataset;
- TP: Topology dataset from network model builder;
- SV: State Variables dataset from state estimator;
- SSH: Steady State Hypothesis from the network model builder and state estimator is an output that can be used as input to power flow calculations as shown in Figure 7.

6.3 Power flow based network analysis

Architecture for power flow based applications on node-breaker models is presented in Figure 7.

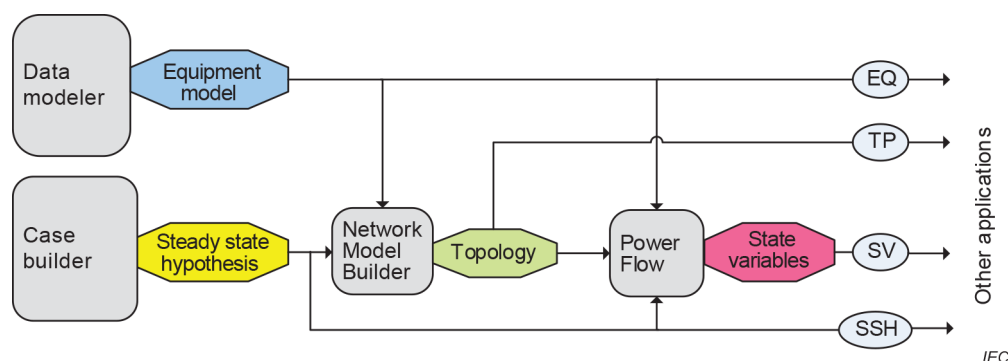


Figure 7 – Node-breaker power flow integration architecture

SSH and EQ data are the result of the Case builder activity. The Case builder activity produces all inputs needed for the Power Flow in addition to the Equipment model. SSH data may also be provided by the State Estimator as in Figure 6.

Architecture for power flow based applications on bus-branch models is presented in Figure 8.

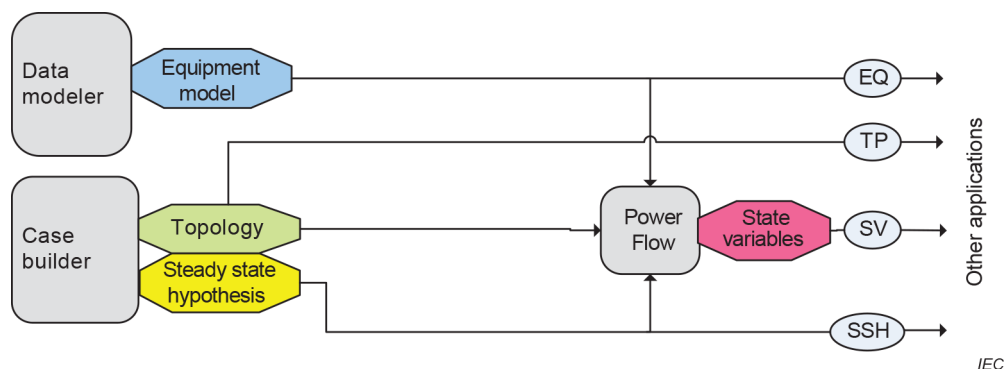


Figure 8 – Bus-branch power flow integration architecture

SSH, TP and EQ data are the result of the Case builder activity. The Case builder activity produces all inputs needed for the Power Flow in addition to the Equipment model.

Figure 7 and Figure 8 describe the case when all inputs to the power flow are known.

6.4 Model partitioning and boundary modelling

6.4.1 General

This subclause describes a method of partitioning a large power network. It is not necessary the recommended method of doing it, but it should be one of the methods that applications shall support. The text in 6.4 is planned to be moved to other documents which will distinguish between best practices and specific use cases.

For a large power network with many interconnected regions this may mean that data for many of the regions is collected and assembled to form the study case. In many study situations, a large number of power flow calculations are run, e.g. congestion forecast, and the case set up is automated without requirement for human intervention. This implies that the regional network models are described such that they can be assembled automatically. This is done with a method where the boundaries between the regions are described by separate boundary model authority sets that are used as an interface between the regions.

6.4.2 Network model boundaries

ConnectivityNode-s also form the interface point in boundary datasets between network parts as shown in Figure 9 and Figure 10.

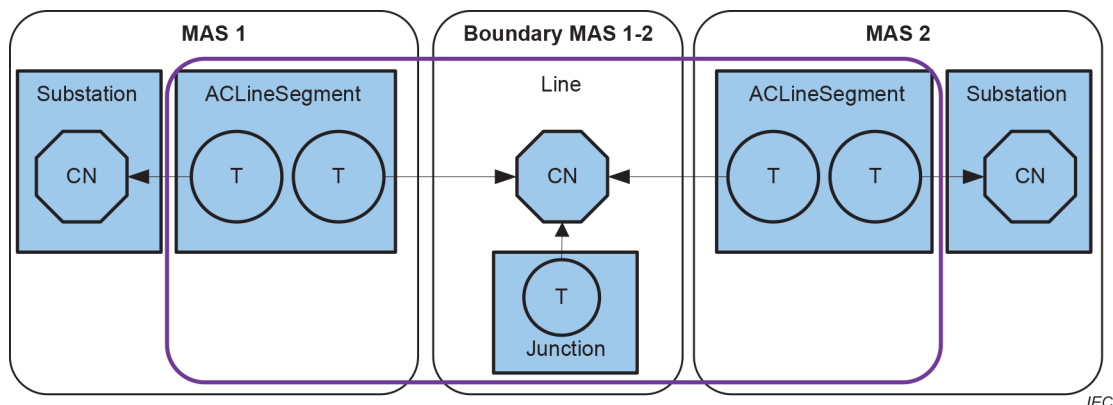


Figure 9 – Line boundary dataset example

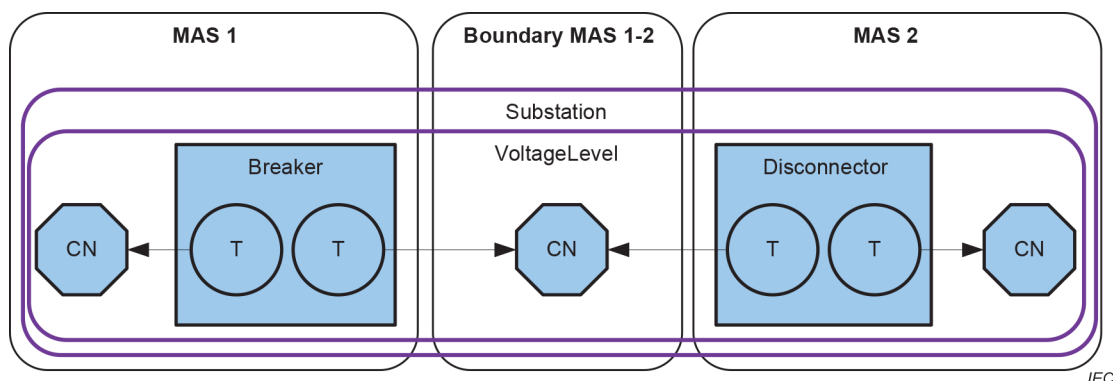


Figure 10 – Substation boundary dataset example

The following abbreviated CIM class names are used in Figure 9 and Figure 10:

- CN = ConnectivityNode;
- TN = TopologicalNode;
- T = Terminal.

The arrows reflect the directions of references as defined in the profile documents and instantiated in datasets. All references are going from the regional network parts into the boundary network part and the boundary network part has no references outside itself. Hence the boundary network parts are self-contained and not dependent on any other network parts.

Figure 9 shows a Line between two Substations in different regional network parts named “Network part MAS 1” and “Network part MAS 2”. The boundary network part is described with a Line and a ConnectivityNode. To describe the physical location of the ConnectivityNode a Junction may be added to the ConnectivityNode. The ACLineSegment-s are described in the regional network parts but are contained by the Line in the boundary as well as being connected to the ConnectivityNode in the boundary. A boundary network part may also have a Substation instead of a Line as shown in Figure 10. In this case the Substation, a VoltageLevel and a ConnectivityNode is in the boundary network part while the rest of the Substation equipment is defined within the regional network parts.

6.4.3 Network parts and model merge

A way to solve the power flow for an assembled model without the neighbouring network parts is to represent the neighbours with equivalent injections connected to the boundary ConnectivityNode as shown in Figure 11.

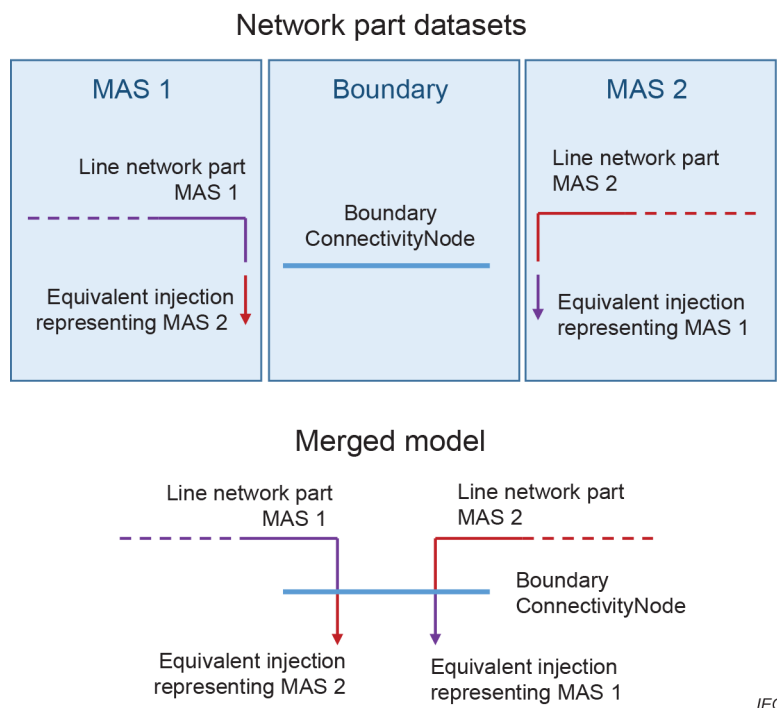


Figure 11 – Merged model

Note that the two equivalent injections in Figure 11 are always present and integral parts of the model authority sets describing the regional network parts (MAS 1 and MAS 2). The upper part in Figure 11 shows the regional network parts before merging and the lower part shows the merged network model.

The equivalent injections associated with the boundary ConnectivityNode are used to represent the power flow for the regional network when the neighbouring network parts are not connected. In a merged network model, the boundary injections are normally ignored (when the interconnection is complete) to avoid errors from differences in SSH injection values between the two equivalent injections which belong to a ConnectivityNode. It is not described in data being exchanged (e.g. EQ or SSH data) whether to ignore the boundary injections or not. Instead the context for the data being exchanged decides when to ignore the boundary injections.

Another way to manage injections at boundaries is to treat the reduced representation of the network at the other side of the boundary as separate model authority sets as shown in Figure 12.

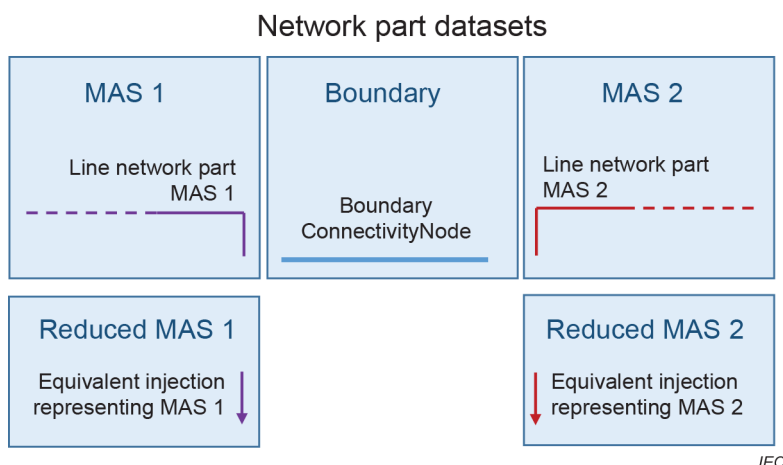


Figure 12 – Alternate boundary modelling

In Figure 12 the two model authority sets “Reduced MAS 1” and “Reduced MAS 2” have simplified equivalents. More complex equivalents than this are of course possible. The model authority sets in Figure 12 can then be combined as shown in Figure 13.

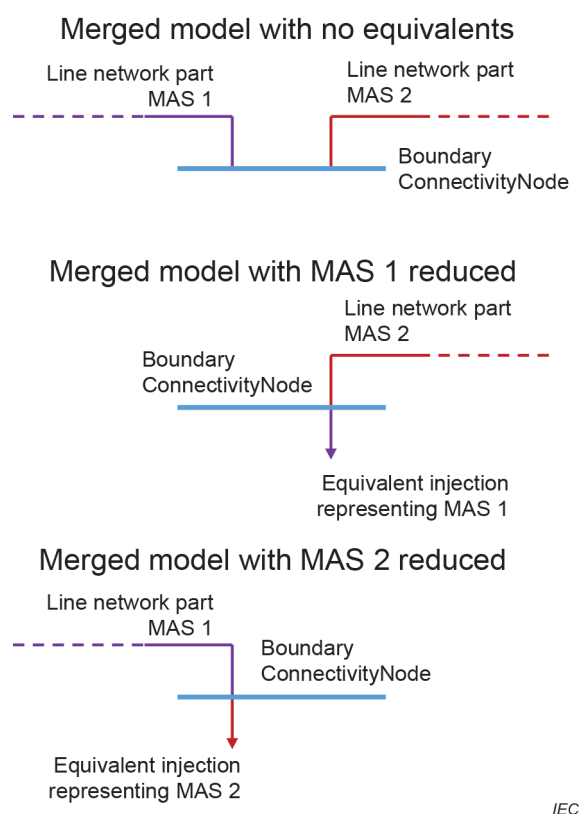


Figure 13 – Merged model alternatives

When regional model authority sets MAS 1 and MAS 2 are merged, refer to upper part of Figure 13, no equivalents are included that need special treatment when solving a power flow. When power flow is run for a regional network without the neighbouring networks the equivalent injections are used instead as shown in the lower part of Figure 13.

The use of equivalent injections as shown in Figure 11 violates the original and intended use of equivalent injections. In this case a power flow needs to recognize a merged model and then ignore the equivalent injections. Hence it is recommended not to use this modelling practice.

The use of equivalent injections as shown in Figure 12 complies with the original and intended use of equivalent injections and is the recommended usage.

6.4.4 Partitioning of a merged model

Figure 14 shows how a merged model is partitioned in two ways:

- Network parts separated by boundaries.
- Data sets according to CIM profiles.

In splitting CIMXML documents corresponding to the cross section between regions and profile data sets a large network can be described by many smaller XML documents as shown in Figure 14.

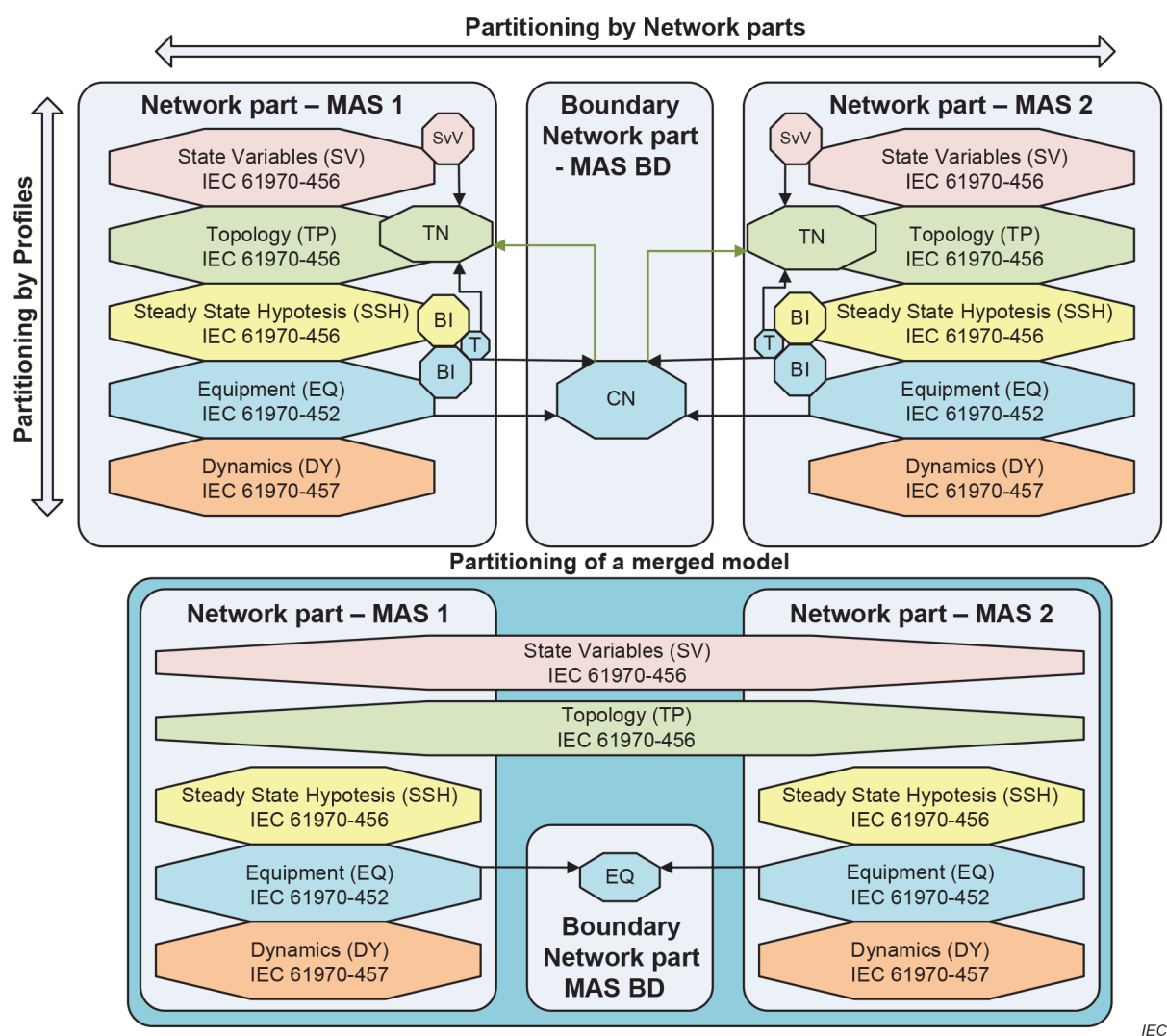


Figure 14 – Partitioning of a merged model

Steady State Hypotesis injections in the boundary representing the regional network parts are indicated with “BI” for boundary injection. The boundary injections are only used when power flow is solved for a single regional network part. When solving power flow for multiple regional network parts the boundary injections between them are ignored.

7 Data model with CIMXML examples

7.1 Topology processing

7.1.1 Overview

The equipment model data and steady state hypothesis data are input to the network model building. The output is topology data that is addressed in this clause. The purpose of the topology data is to provide a bus-branch model described by TopologicalNode-s needed by state estimation or any other power flow based application as input for the purpose of power flow calculation.

A Topology dataset always depends on an Equipment dataset and SSH dataset. Hence, a Topology dataset refers to the Equipment dataset on which it is based, and in most use cases, this is the Equipment dataset that the consumer will want to use. This does not prevent its attempted use with other Equipment datasets, which may make sense in some use cases. Basically, the only software requirement is that all the external references from the Topology dataset resolve to objects in the Equipment dataset that it is used with. If a Topology dataset was created by a network model builder using switch statuses from a Steady State Hypothesis dataset the Topology dataset may have a reference to the Steady State Hypothesis dataset.

A network model builder will generate the TopologicalNode-s at each run and with potentially different switch statuses from the Steady State Hypothesis dataset. To enable the comparison of network topologies the identity associated with the main buses of each substation shall be the same and stable. CIM modelling allows the modeller to provide input data to identify the main buses and provide direction as to how bus identity is to be created in the topology processing algorithm by the use of BusNameMarker-s. If modelers provide BusNameMarker-s, and establish multiple main buses separated by retained Switch-es wherever bus splits are common, then the TopologicalNode-s can have consistent names from one Topology dataset to another. The CIM BusNameMarker class provides a way to give a persistent name to TopologicalNode-s. A network model builder can copy the name from a BusNameMarker to the TopologicalNode given that a BusNameMarker is present at a Terminal linked to the TopologicalNode. In cases where multiple BusNameMarker-s are present at the same TopologicalNode, a priority is used to select the BusNameMarker. Note that:

- A BusNameMarker is related to Terminal which means that a ConductingEquipment must be present to allow placement of a BusNameMarker.
- BusNameMarker-s that may appear at the same TopologicalNode must have strict priority ordering to provide over time consistent naming of TopologicalNode-s.
- The BusNameMarker mRID cannot be copied to the TopologicalNode as this will break the uniqueness requirement for mRIDs if TopologicalNode-s are not persistent in the exchange document.

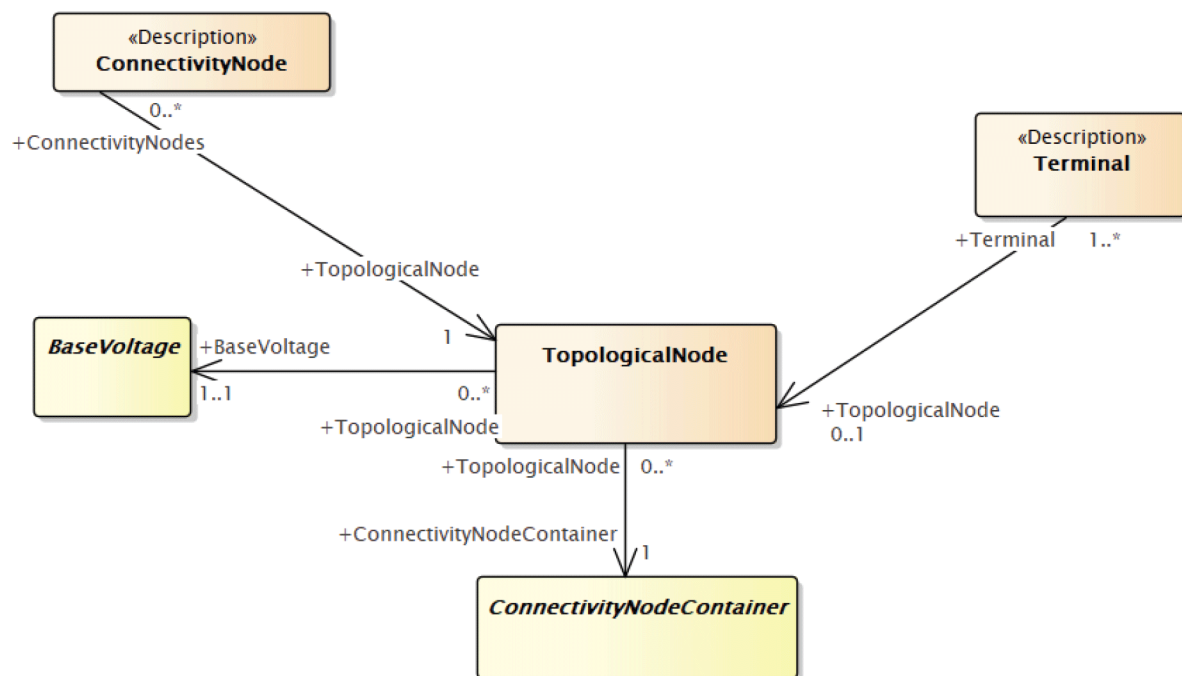
7.1.2 Bus-branch and node-breaker models

A network model can be described in two different levels of detail:

- Bus-branch model without any substation details;
- Node-breaker model with switches and measurement details.

Bus-branch models use TopologicalNode-s for connectivity while node-breaker models use ConnectivityNode-s separated by Switch-es (Breaker-s, Disconnectors). Network model building (also known as topology processing) involves reducing Switch-es based on the inputs Switch.open, Switch.retained, Equipment.inService and creating corresponding TopologicalNode-s. By using BusNameMarker-s the names of the TopologicalNode-s resulting from network model building can be made persistent with TopologicalNode-s in a bus-branch model. However, persistency of the TopologicalNode itself and its mRID is not supported.

CIM supports a hybrid bus-branch and node-breaker models. This is made possible by the linkage between `ConnectivityNode` and `TopologicalNode` and the requirement to have all models build by using `ConnectivityNode`-s. The Topology profile requires the association between `ConnectivityNode` and `TopologicalNode` to be exchanged as shown in Figure 15.



IEC

Figure 15 – Relation between ConnectivityNode and TopologicalNode

The rules for the network model building are as follows:

- Calculate `TopologicalNode`-s from `ConnectivityNode`-s by processing `Switch.open` and `Switch.retained`. An open-ended branch results in a `TopologicalNode` at the open end to keep the voltage and angle.
- Exclude all equipment where `Equipment.inService=false` (or `Equipment.normallyInService` in case SSH data is not present).

In a bus-branch model, a bus split and transfer of a line between split buses is illustrated in Figure 16. This can be modelled as follows:

- A voltage level should be represented with two busses (`ConnectivityNode`-s) with a retained switch (`Switch.retained=true`) between them with the bus tie closed. The switch will be treated as a zero-impedance logical branch within the power flow.
- The bus may then be split by opening the bus coupler switch, as shown in Figure 16.
- Transfer of a branch or other equipment between bus bars cannot be made with switching. Instead, the equipment model is updated so that branch/equipment terminal link to the `ConnectivityNode` is updated.
- Opening of an `ACLineSegment` end can be made by using the `ACDCTerminal.connected` flag. In this case a `TopologicalNode` at the open `ACLineSegment` end is needed. This is made to describe a fault case.

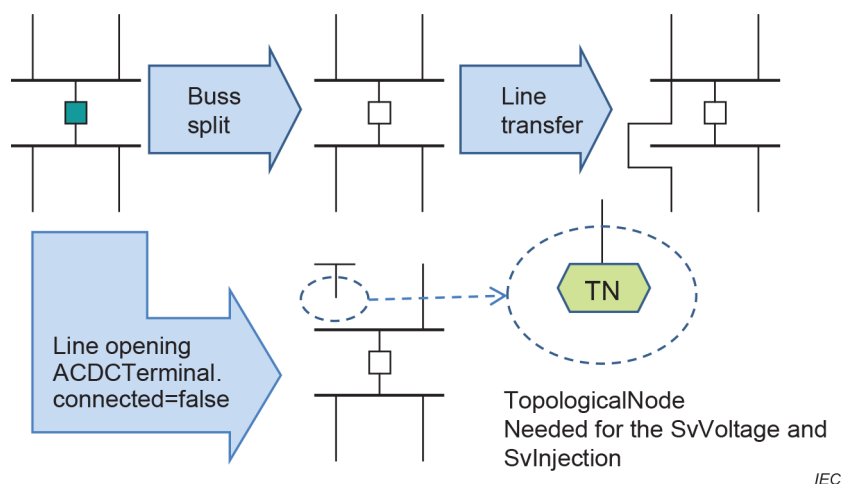


Figure 16 – Bus-branch modelling of bus coupler and line transfer

8 Detailed Profile specification

8.1 General

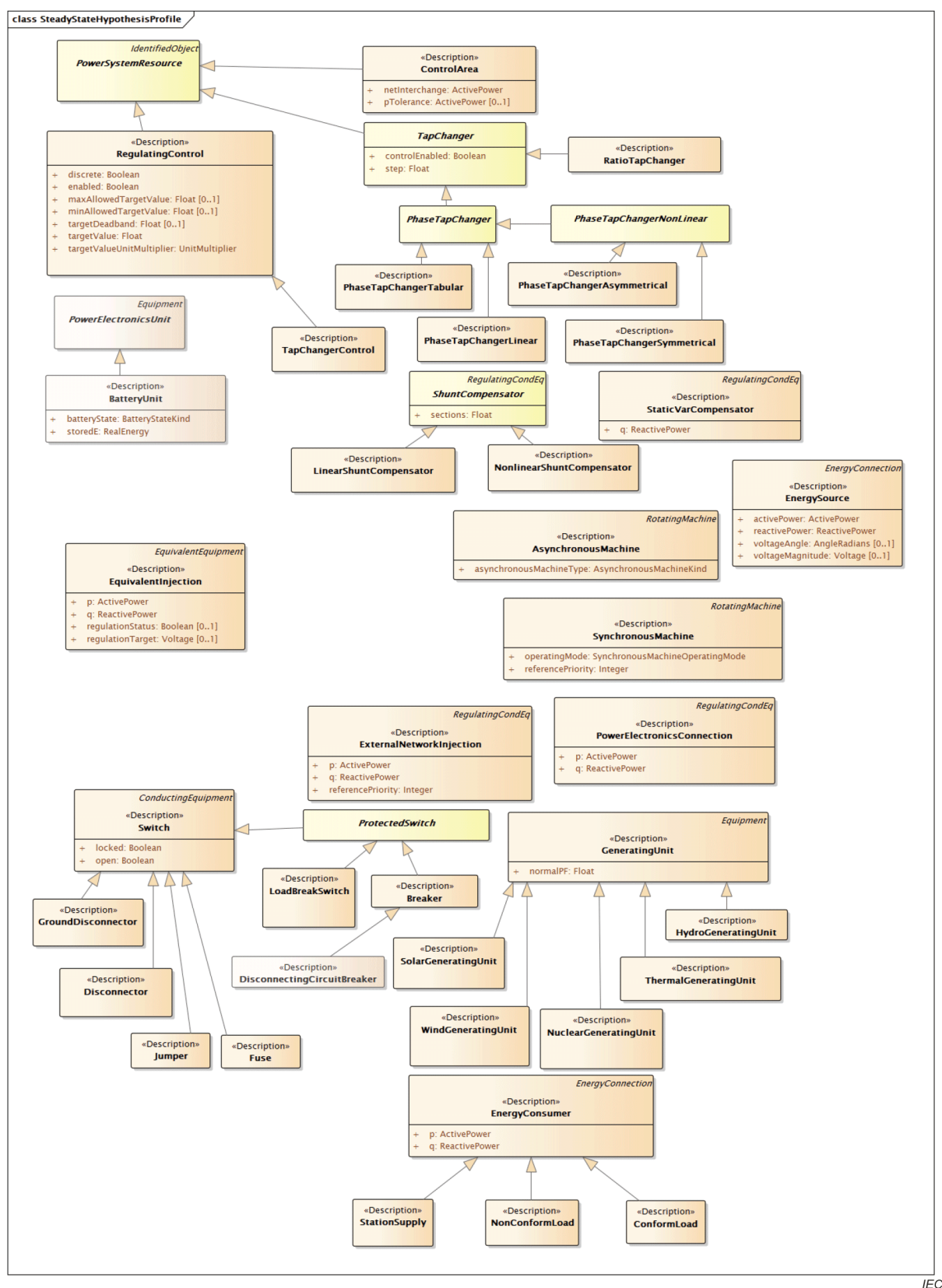
Subsequent subclauses contain tabular descriptions of the profile information model. All tables have the same structure that is shown below.

name (attribute or role)	mult (multiplicity)	type	description
--------------------------	---------------------	------	-------------

8.2 Package SteadyStateHypothesisProfile

8.2.1 General

A steady state hypothesis dataset which conforms to the IEC 61970-456 steady state hypothesis profile contains all objects required to exchange input parameters to be able to perform load flow simulations. Due to the nature of the SSH profile, all objects in a Steady State Hypothesis instance file should have persistent mRIDs.



IEC

Figure 17 – Class diagram SteadyStateHypothesisProfile::SteadyStateHypothesisProfile

Figure 17: The diagram illustrates most of the classes in steady state hypothesis profile.

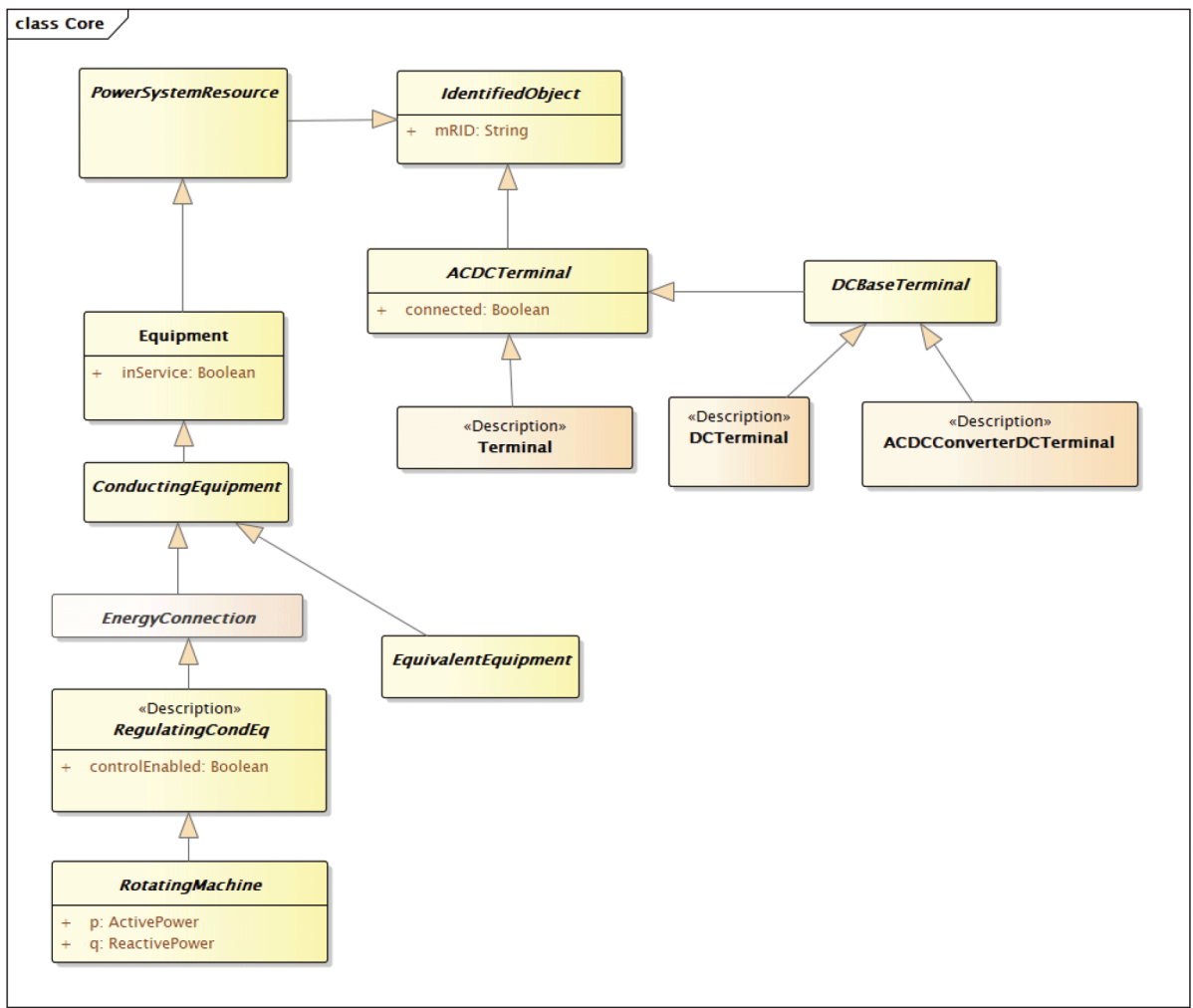


Figure 18 – Class diagram SteadyStateHypothesisProfile::Core

Figure 18: The diagram shows main classes from Core package in the canonical CIM used in this profile.

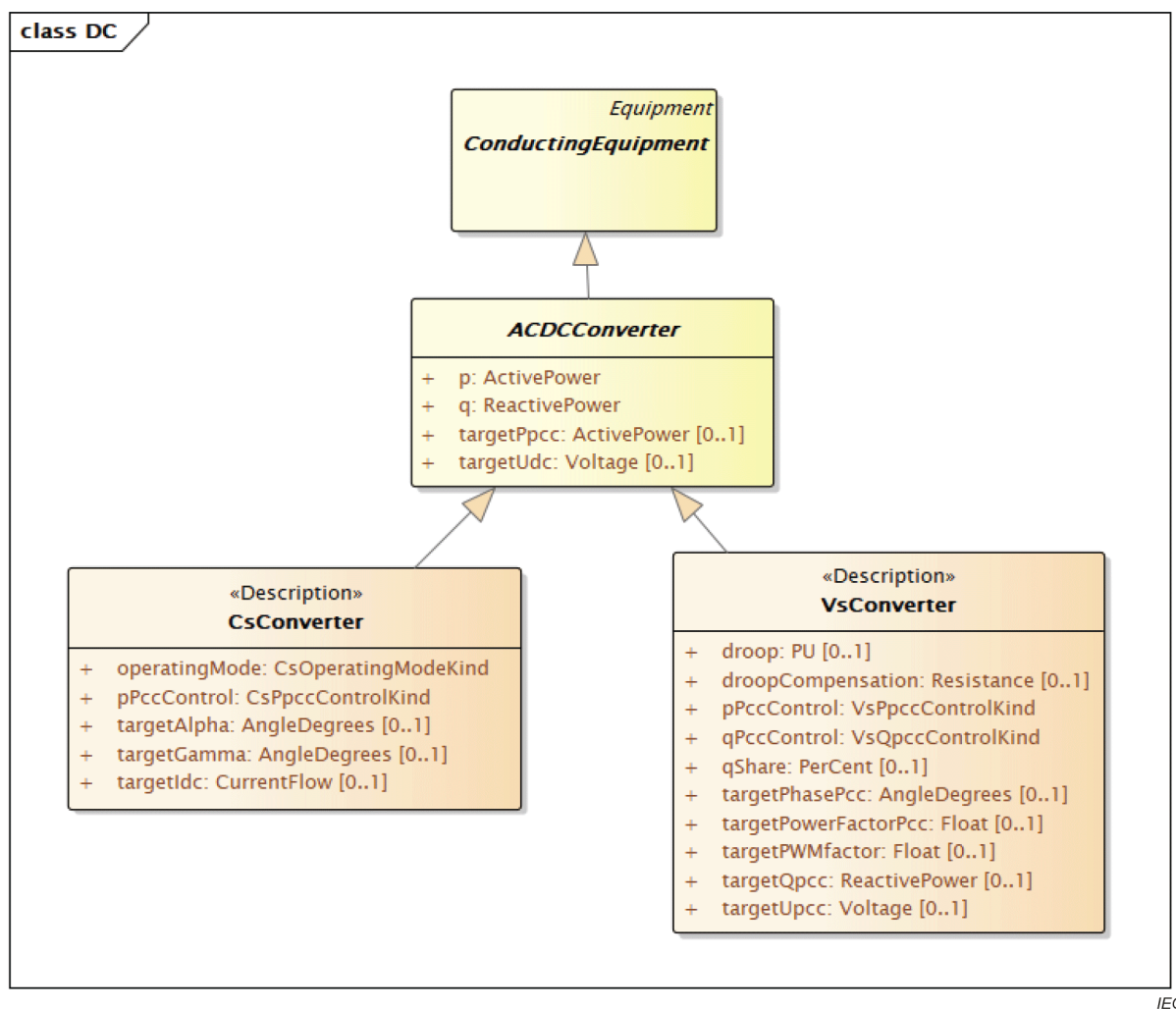


Figure 19 – Class diagram SteadyStateHypothesisProfile::DC

Figure 19: The diagram shows DC related classes included in the profile.

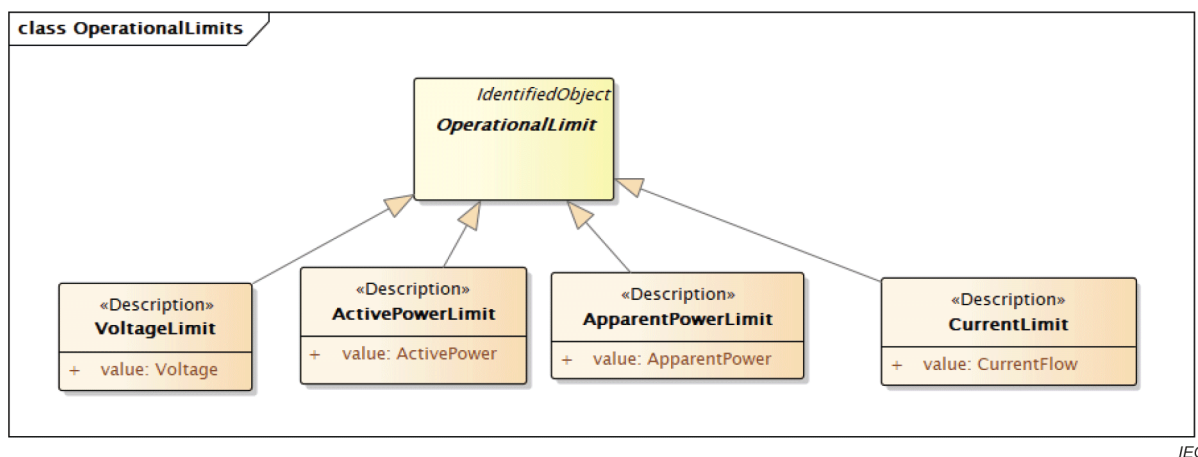
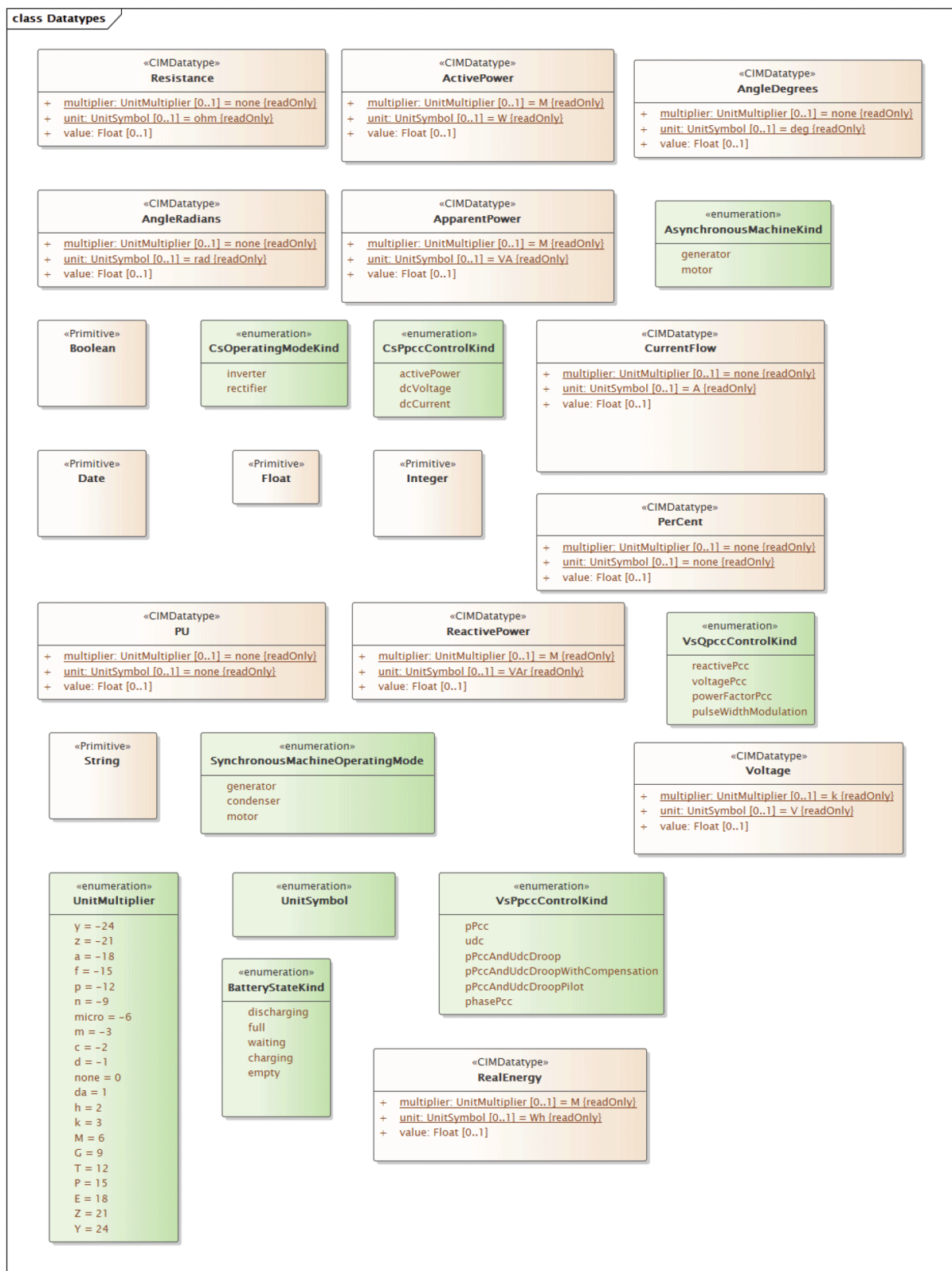


Figure 20 – Class diagram SteadyStateHypothesisProfile::OperationalLimits

Figure 20: This diagram shows operational limits as they tie back into the core model.



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Figure 21 – Class diagram SteadyStateHypothesisProfile::Datatypes

Figure 21: The diagram shows datatypes that are used by classes in the profile. Stereotypes are used to describe the datatypes. The following stereotypes are defined:

- <<enumeration>> A list of permissible constant values.
- <<Primitive>> The most basic data types used to compose all other data types.