

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

## FOREWORD

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

This second edition cancels and replaces the first edition published in 2013 and Amendment 1:2015. This edition constitutes a technical revision. It is based on the IEC 61970 UML CIM16 version 33.

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

- a) The Steady State Hypothesis (SSH) profile has been added in new Subclause 8.2.
- b) Clause 5 "Overview" has been extended to better describe the relation between different profiles and aligned with the current nomenclature used with profiles, e.g. "data set" and "network part".

- c) The former Clause 6 "Architecture" has been shrunk and merged with Clause 6 "Use cases".
- d) The former Clause 7 "Applying the standard to business problems" has been split and merged with Clause 6 "Use cases" and Clause 7 "Data model with CIMXML examples".
- e) Clause 6 "Use cases" description of the use cases has been extended.
- f) The former Clause 8 "Data model with CIMXML examples" has become section 7 "Data model with CIMXML examples".
- g) The CIMXML document examples in Clause 7 "Data model with CIMXML examples" has been updated to match with IEC 61970-552:2016.
- h) Clause 8 "Profiles" describe the actual profile data.
- i) Subclause 8.1 "Comments and notes" gives additional information on the use some profile data.

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

| FDIS         | Report on voting |
|--------------|------------------|
| 57/1951/FDIS | 57/1963/RVD      |

Full information on the voting for the approval of this International Standard can be found in the report on voting indicated in the above table.

This document has been drafted in accordance with the ISO/IEC Directives, Part 2.

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 "<http://webstore.iec.ch>" in the data related to the specific document. At this date, the document will be

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- withdrawn,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

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## 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. This document assumes and recommends that the exchanged data is formatted in XML based on the resource description framework (RDF) schema as specified in IEC 61970-552 CIM XML model exchange standard.

IEC 61970-456 specifies three profiles:

- The Steady State Hypothesis (SSH) profile that describe power flow application input variables such as voltage set points, switch statuses etc..
- The topology profile that describe a bus-branch model. A topology model may be created by a network model builder from a node-breaker model and SSH inputs or by a tool where a user interactively builds a topology model. A topology model is input to power flow applications.
- State variables solution from a power system case such as is produced by power flow or state estimation applications.

IEC 61970-456 describes the dynamic value inputs and solutions 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, define at an abstract level the content and exchange mechanisms used for data transmitted between power system analyses applications, control centers and/or control center 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 standard.

This document is intended for two distinct audiences, data producers and data recipients, and may be read from those two perspectives. From the standpoint of model export software used by a data producer, the document describes 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 describes 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, 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 61970-452:2017, *Energy management system application program interface (EMS-API) – Part 452: CIM static transmission network model profiles*

IEC 61970-453:2014, *Energy management system application program interface (EMS-API) – Part 453: Diagram layout profile*

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

#### 3 Terms and definitions

No terms and definitions are listed in this document.

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>

## 4 Profile information

The profiles defined in this document are based on the UML version CIM16v33.

The profiles are listed in Table 1.

**Table 1 – Profiles defined in this document**

| Name                        | Version | URI                                                                                                                               |
|-----------------------------|---------|-----------------------------------------------------------------------------------------------------------------------------------|
| SteadyStateHypothesis (SSH) | 1       | <a href="http://iec.ch/TC57/2013/61970-456/SteadyStateHypothesis/1">http://iec.ch/TC57/2013/61970-456/SteadyStateHypothesis/1</a> |
| Topology (TP)               | 4       | <a href="http://iec.ch/TC57/2013/61970-456/Topology/4">http://iec.ch/TC57/2013/61970-456/Topology/4</a>                           |
| StateVariables (SV)         | 4       | <a href="http://iec.ch/TC57/2013/61970-456/StateVariables/4">http://iec.ch/TC57/2013/61970-456/StateVariables/4</a>               |

## 5 Overview

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 so as 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.

In order to meet these 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'. Data set payloads are typically compressed to a zip archive.

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 of 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 by Model Authority Sets (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.

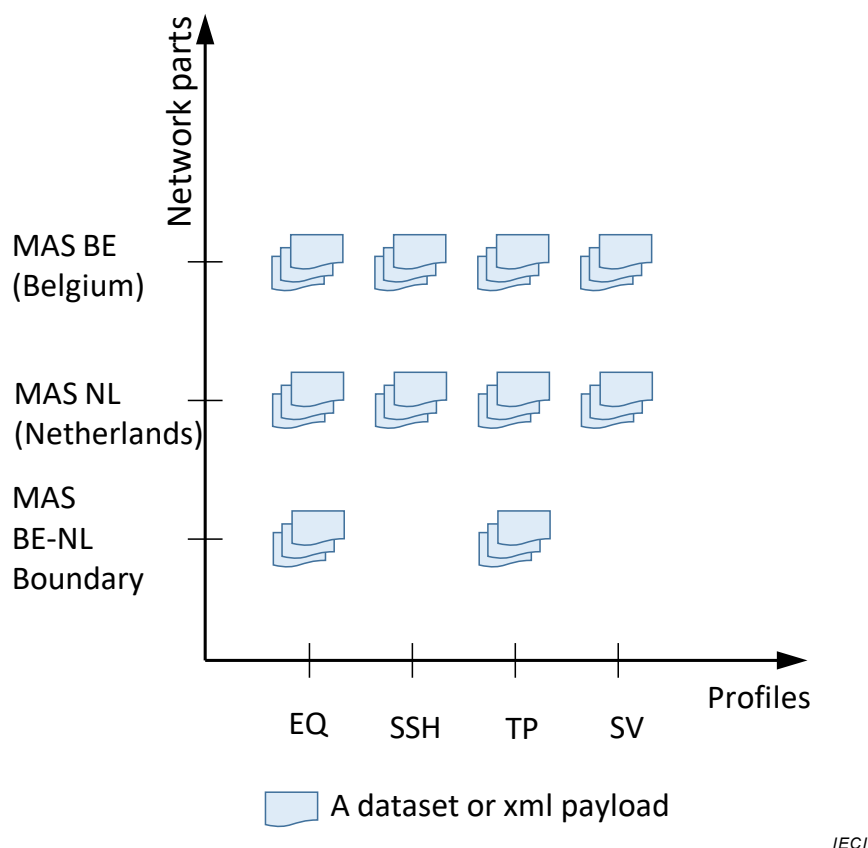


**Figure 1 – Relations between MAS, profile and dataset**

Different IEC 61970 profiles are listed along the horizontal axis:

- EQ for equipment as described in IEC 61970-452.
- SSH for power flow initial data as described in this document.
- TP for topology data as described in this document.
- SV for state variables data as described in this document.

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

- MAS BE represent 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 represent 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 describe a dataset packaged as a payload, e.g. a CIMXML document as described in IEC 61970-552.

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 contain 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..

This document is flexible and designed to satisfy a wide range of analytical scenarios in the planning and operating business environments. We expect that where parties are using it to collaborate in some business process, those parties will often want to create additional business agreements that describe any restrictions and customizations of the document that are deemed necessary for their process. In most cases, these additional agreements will be local agreements and will not be IEC industry standards.

This document does not specify a serialization format on its own but does so in companion with specification for CIMXML payloads is defined in IEC 61970-552. This method of serialization has the several useful characteristic

- The serialization format for a profile is defined by rules in IEC 61970-552 that describe the format based on the semantic model from the profile.
- Valid XML describing a complete model could be achieved simply by concatenating the CIMXML documents for each partial or profile document. Thus 'merge' and 'extract' of pieces of the modeling require no separate 'stitching' instructions and is conceptually a very simple process.
- IEC 61970-552 also describes how payload headers provide information as to how payloads fit together.

Figure 2 shows some of the profiles that are covered by the IEC 61970-450 to IEC 61970-499 series and depicts the relationships between them. The profiles are defined in different IEC 61970-450 specifications where each specification defines a group of profiles:

- Static network model profiles defined in IEC 61970-452
  - Equipment profile. The static modelling information describing power system physical elements and their electrical connections;
  - Measurement profile that defines the existence of measurements and their relations to power system equipment.
- Schematic display layout exchange profiles defined in IEC 61970-453
  - Schematic layout exchange profile. Describe the elements of schematic or geographic displays that typically shall be amended when new elements are added to a network model.
- Initial and solved power system state profiles defined in IEC 61970-456 (this document)
  - Steady State Hypothesis profile that provide the initial conditions to power flow. This profile have numerous sources, e.g. State Estimator or cases set up in a study;
  - Topology profile. The topology result as is produced by a network model builder;
  - State Variables profile. The result of a power flow calculation.

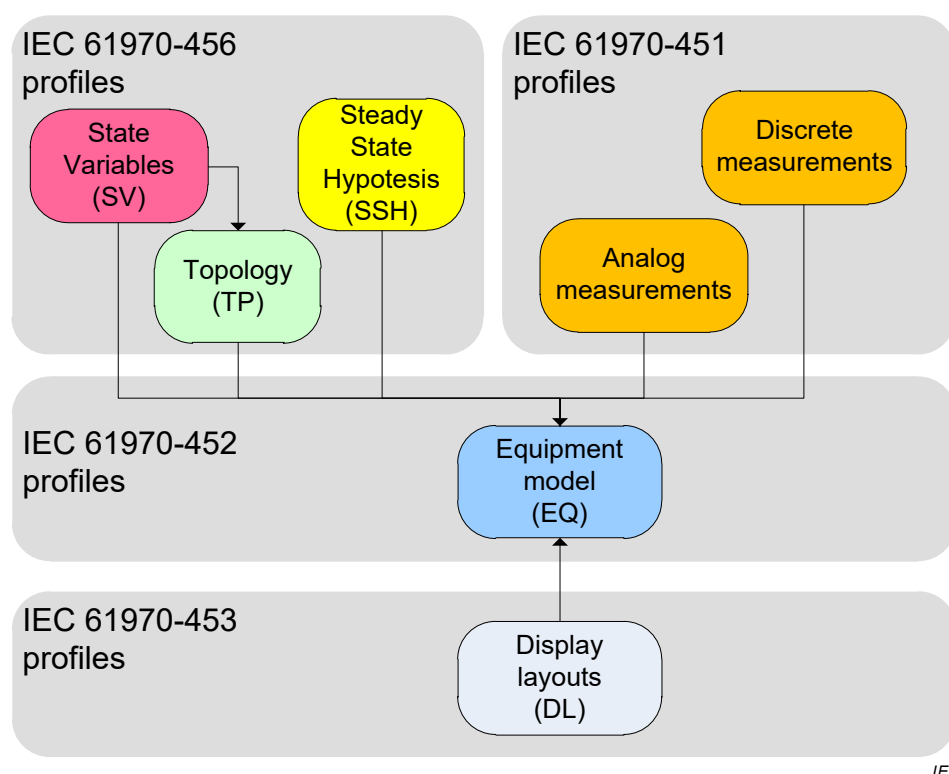


**Figure 2 – Profile relationships**

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.

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 (TopologicalNodes) from switching device statuses the power flow buses are maintained manually.

It assumed that node-breaker and bus-branch models will be combined in the future to enable sharing of the same models between operations and planning.

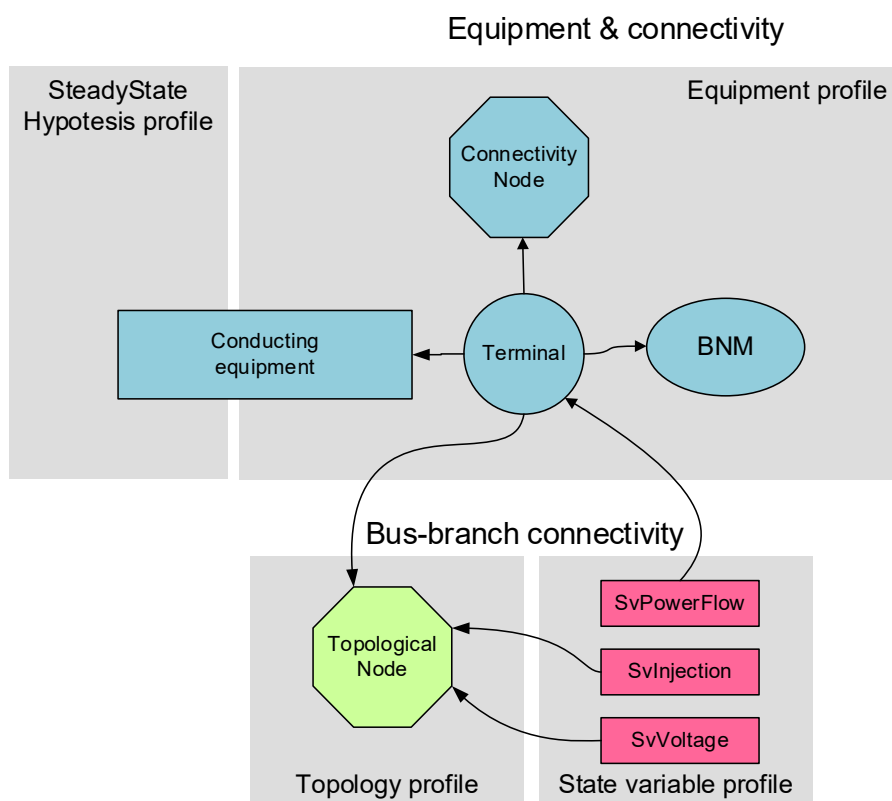
In Figure 2, an arrow between profiles indicates that there are relationships defined between classes in the two profiles. The directionality indicates that classes in the “from” profile depend on classes in the “to” profile. For data this means that “from” class data refers to or depends on “to” class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

In IT-systems, datasets corresponding to the profiles in Figure 2, are exchanged between functions and/or applications. Some examples of applications and their dataset exchange are described in Clauses 6 and 7.

The equipment model has equipment connectivity described by the ConnectivityNode and Terminal classes, refer to Figure 3. The Terminal class is central in that it support Equipment, Topology, State Variables, Steady State Hypothesis and Diagram Layout profiles. Within the Equipment profile the Terminal associate ConnectivityNodes with ConductingEquipment and

provide multi Terminal equipment (e.g. Switches, ACLinesegments 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 describe power flow busses, TopologicalNodes that are used as input by a power flow calculation. TopologicalNodes are created in a step preceding the actual power flow solution and can be the result of a network model builder using ConnectivityNodes as input or by manual editing in a bus-branch model editor. The state variables profile describes the result of a power flow application, refer to Figure 3.



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**Figure 3 – Connectivity model example**

The arrows in Figure 3 describe references between the CIM objects. For a node-breaker model the TopologicalNodes are computed from switching devices connecting ConnectivityNodes and for a bus-branch model the TopologicalNodes are manually maintained.

A node-breaker model use ConnectivityNodes to describe how conducting equipment are connected. In topology processing all conducting equipment connected with each other through closed Switches are identified and conducting equipment Terminals are assigned to a TopologicalNode.

A bus-branch model use TopologicalNodes to describe how conducting equipment are connected. In this case the TopologicalNodes are manually maintained and the assignment of conducting equipment Terminals to TopologicalNodes is also manually maintained. The manually maintained TopologicalNodes have well known identifiers or “Bus numbers” that enables comparison of different studies on the same network.

In the case of a node-breaker models the TopologicalNodes are created by topology processing. BusNameMarkers (BNM) are used to avoid an arbitrary naming of TopologicalNodes resulting from topology processing, as described in 7.1.1. The TopologicalNodes in a bus-branch model imply that the Switches in a corresponding node-breaker model have specified Switch statuses (Switch.open). By creating BusNameMarkers for one or more such sets of Switch statuses and use the BusNameMarker names to name the TopologicalNodes generated by topology processing it is possible to preserve the TopologicalNode names. Variations in Switch statuses is managed by adding as many BusNameMarkers as needed to support the wanted variations.

This use of BusNameMarkers preserve TopologicalNode names but not the mRID (the `rdf:ID/rdf:about` in IEC 61970-552). Hence TopologicalNode mRIDs will vary between different topology processing runs. In version 17 of the canonical UML the information model has been modified to support preserving the TopologicalNode mRIDs (this version of the profile is based on version 16 of the canonical UML).

An equipment model using ConnectivityNodes may not necessarily have any switches. A simplified equipment model can initially be created without switches similar to a bus-branch model. This enables mixing detailed node-breaker models having switches with simplified bus-branch style models without switches as both describe connectivity using ConnectivityNodes. 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 where all zero impedance elements have been removed is created. 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 neighboring regions including both EQ and SSH data. Figure 4 shows an example from Europe.

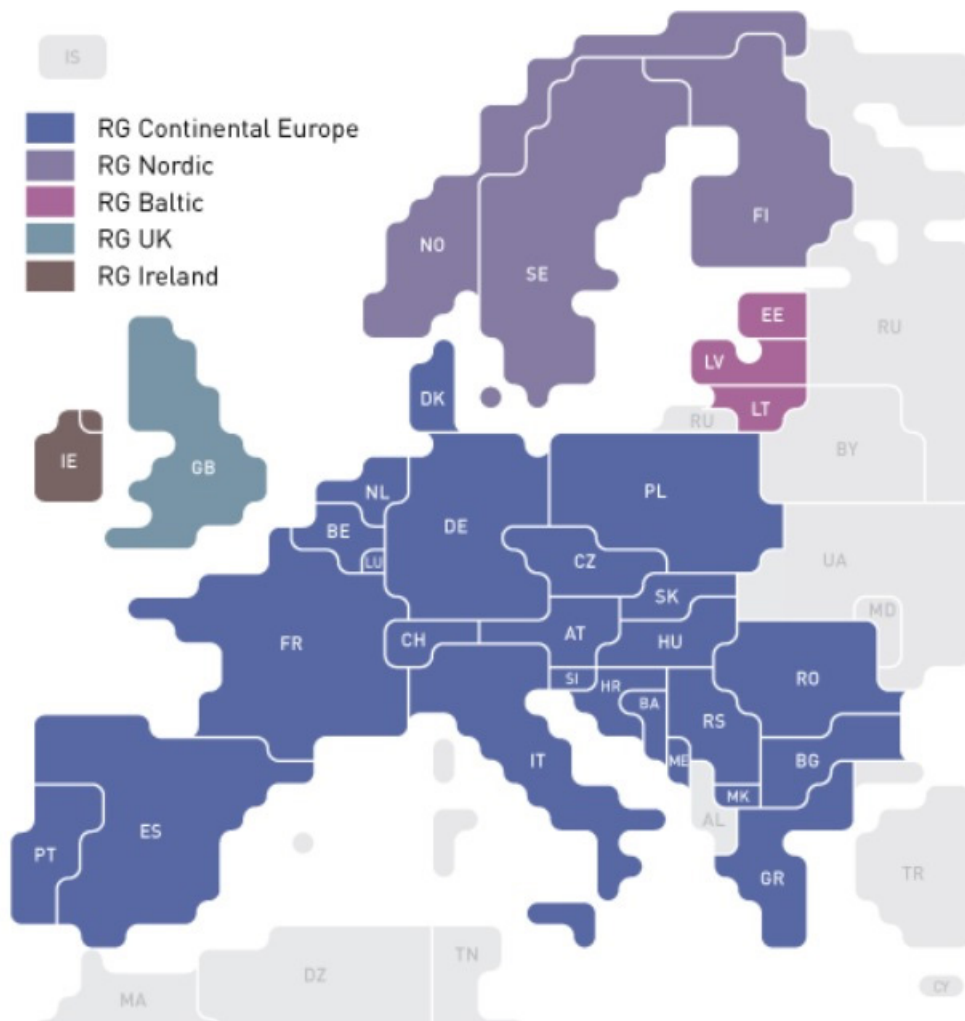
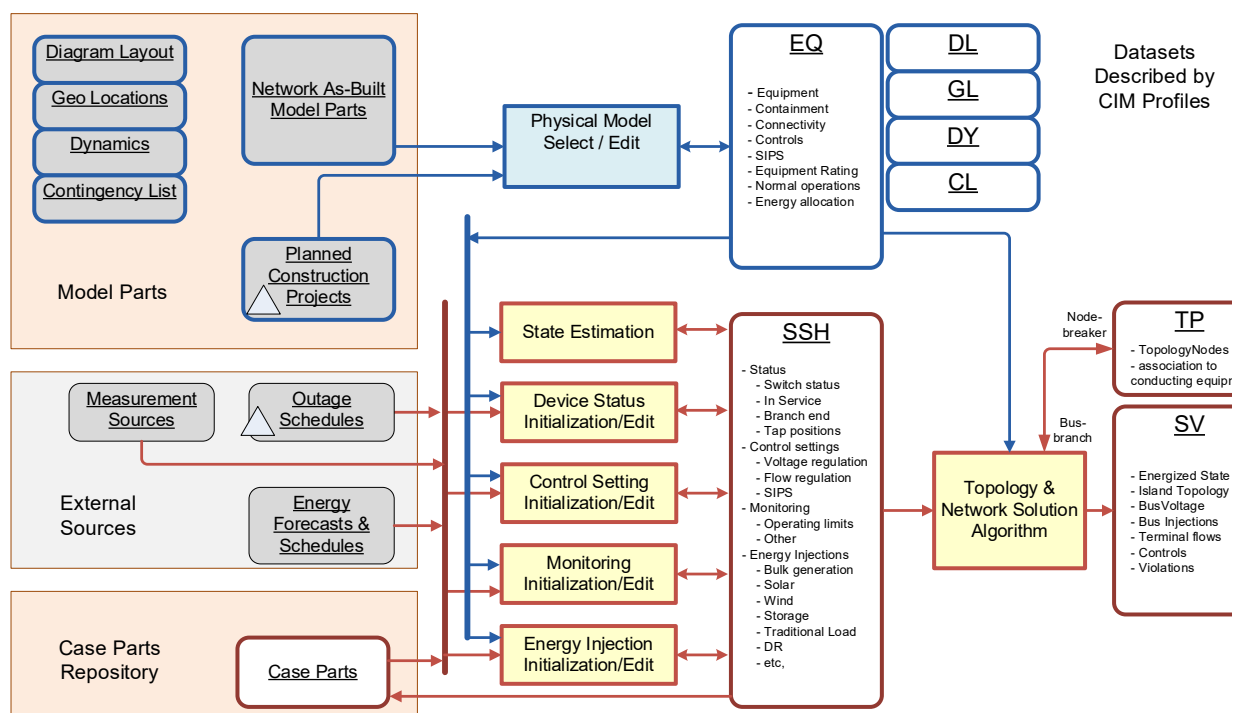


**Figure 4 – The European power system with regions**

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



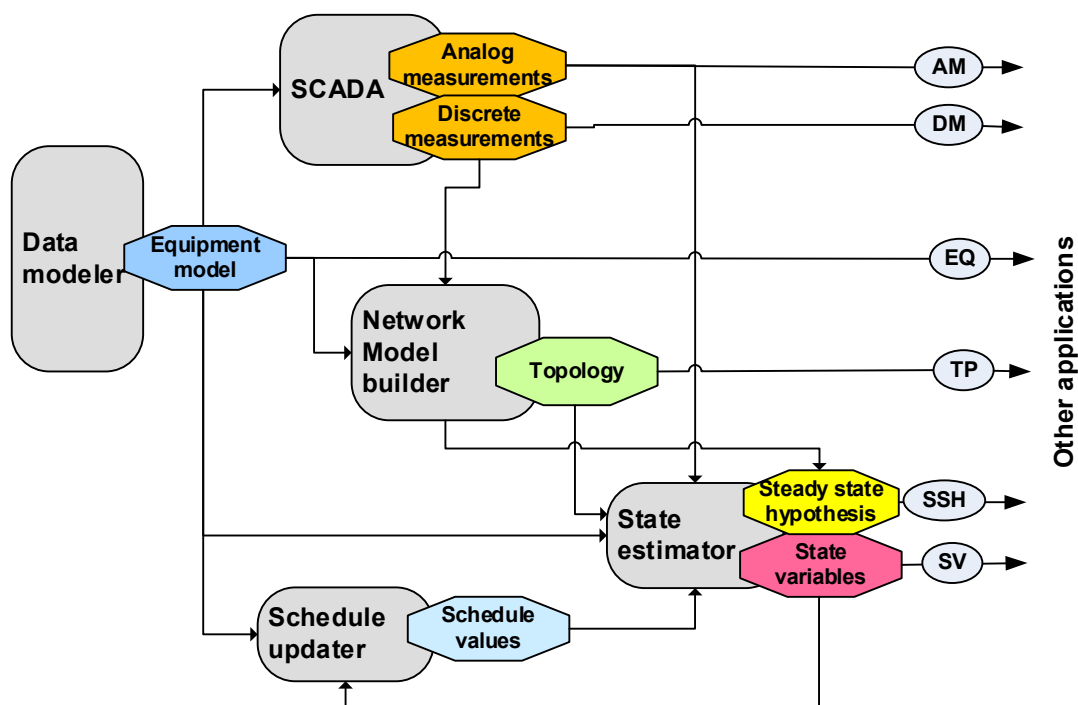
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**Figure 5 – Information exchange in power flow and sharing of results**

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.



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**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.

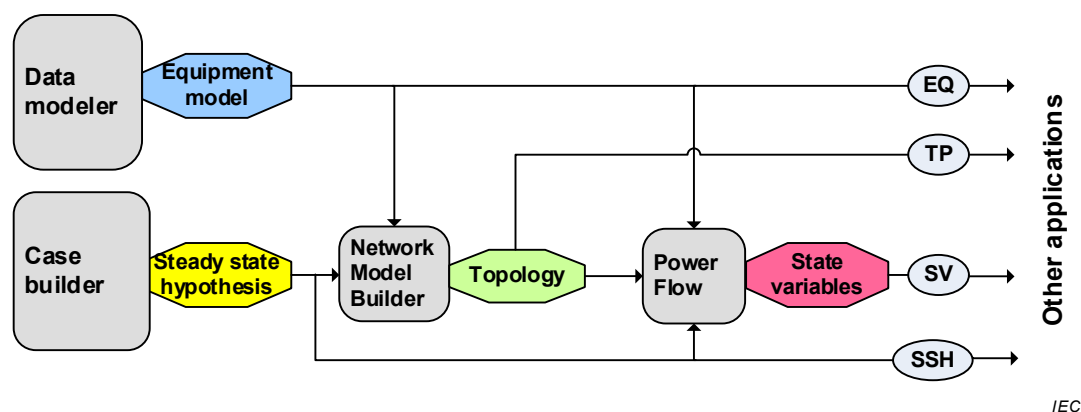


**Figure 7 – Node-breaker power flow Integration architecture**

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.

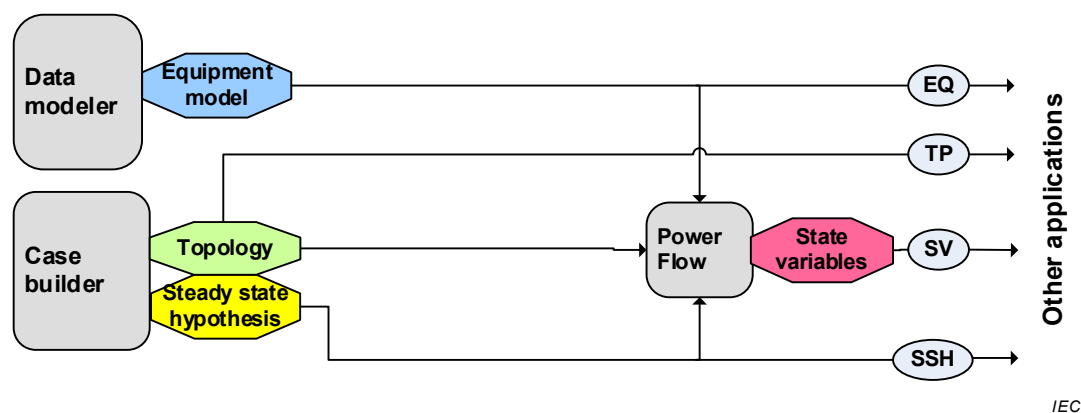


**Figure 8 – Bus-branch power flow Integration architecture**

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. 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.

A way to solve the power flow for a regional network part without the neighbouring network parts is to represent the neighbours with equivalent injections connected to the boundary network part as shown in Figure 9.

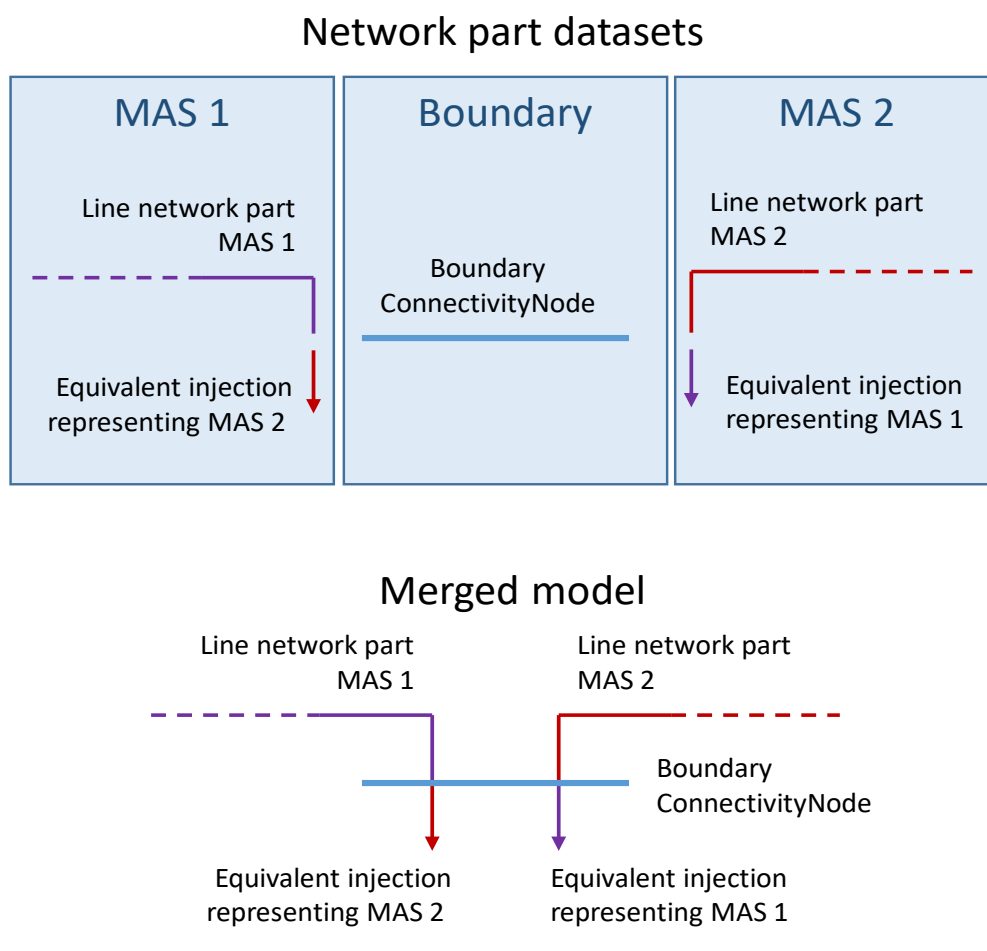


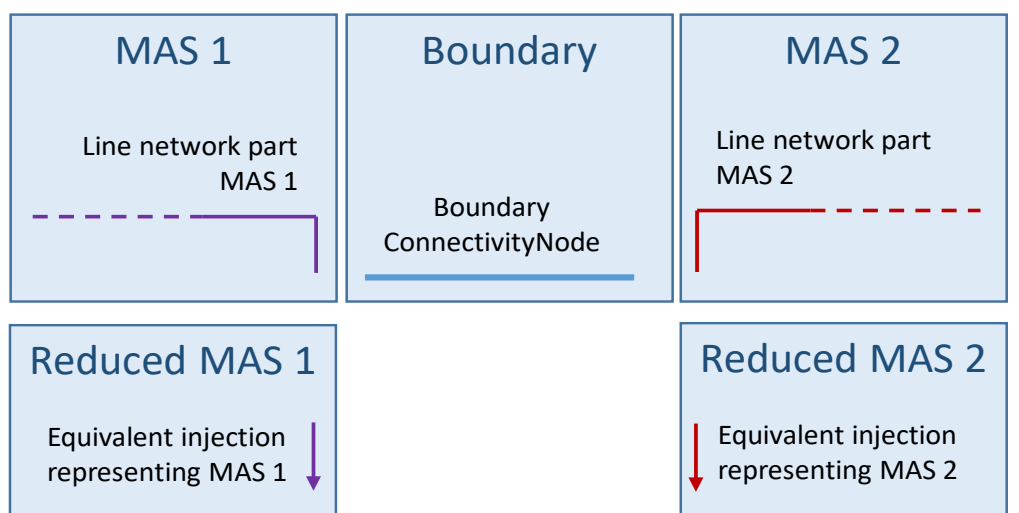
**Figure 9 – Boundary injection model**

Note that the two equivalent injections in Figure 9 are always present and integral parts of the model authority sets describing the regional network parts. The upper part in Figure 9 show the regional network parts before merging and the lower part show the assembled network model.

The equivalent injections in the boundary are used to verify that it is possible to solve the power flow for the regional network without the neighbouring network parts. In an assembled network model the boundary injections are ignored to avoid errors from differences in SSH injection values between the two equivalent injections. It is not described in data being exchanged (e.g. EQ or SSH data) whether to ignore the boundary injections. Instead the context for the data being exchanged decides when to ignore the boundary injections, e.g. data exchanges for congestion forecasting in Europe.

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 10.

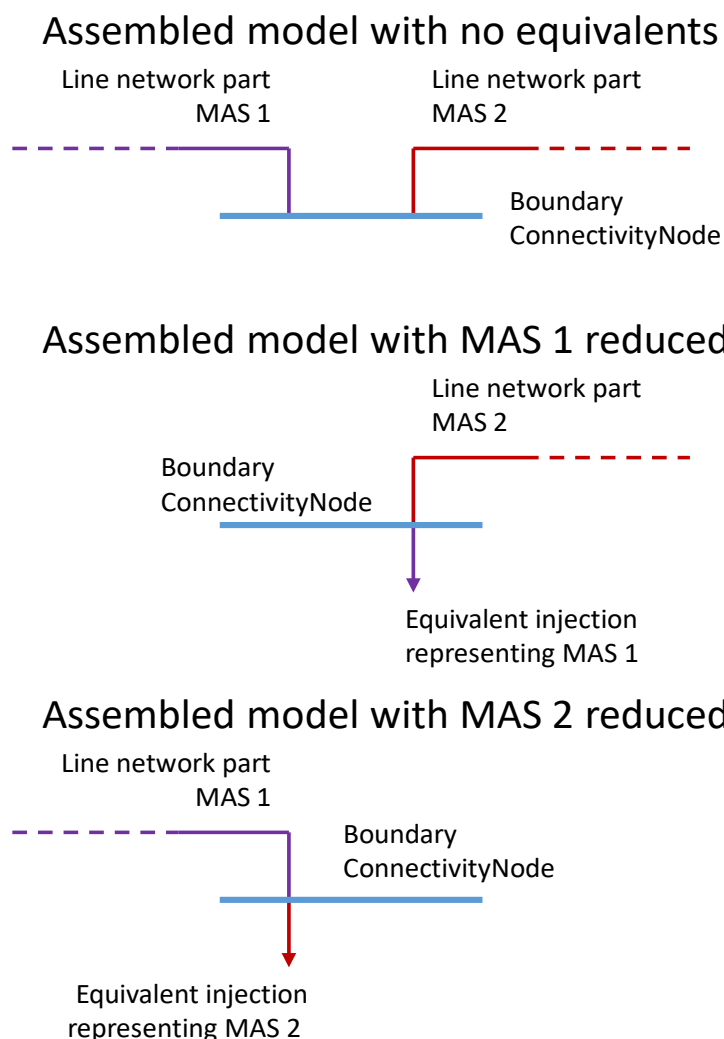
## Network part datasets



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**Figure 10 – Alternate boundary modelling**

In Figure 10 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 10 can then be combined as shown in Figure 11.



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**Figure 11 – Assembled model alternatives**

When regional model authority sets MAS 1 and MAS 2 are assembled, refer to upper part of Figure 11, 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 11.

The use of equivalent injections as shown in Figure 9 violates the original and intended use of equivalent injections. In this case a power flow needs to recognize an assembled case and then ignore the equivalent injections. Hence it is recommended not to use this modeling practice.

The use of equivalent injections as shown in Figure 10 complies with the original and intended use of equivalent injections and is the recommended usage.

The use cases described in this clause overlap with IEC 61970-452 and the EQ profile. As this document is intended for TP, SV and SSH profiles the next edition (Edition 3) will be better coordinated with IEC 61970-452.

## 7 Data model with CIMXML examples

### 7.1 Use of the interfaces

#### 7.1.1 Overview

Input to Network model building is the Equipment model data and Steady State Hypothesis data. The output is Topology data that is addressed in this clause. Its purpose is to provide a bus-branch model described by TopologicalNodes needed by state estimation or any other power flow based application as input. ConnectivityNode in the Equipment model is the input to the Network model building for creation of the TopologicalNodes.

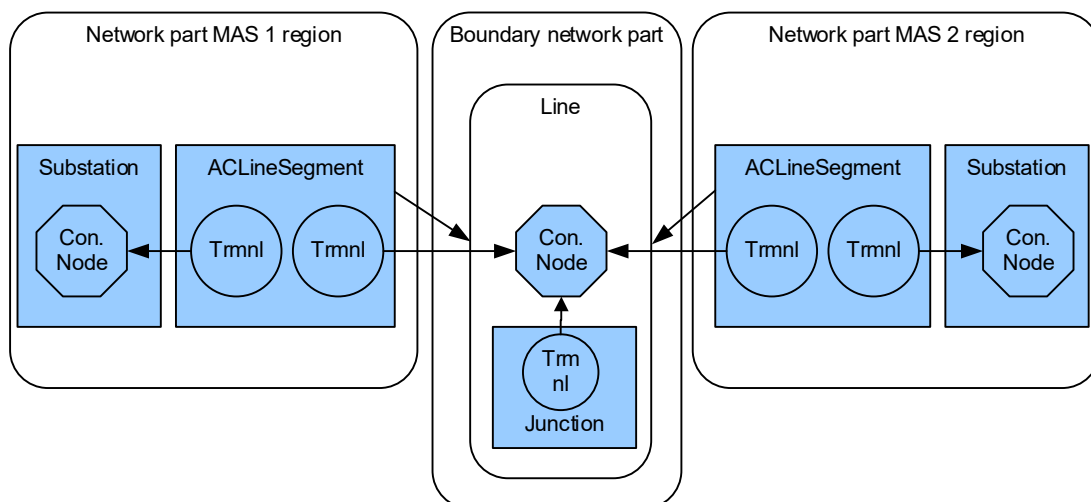
A Topology dataset always depends on an Equipment dataset. Hence a Topology dataset refers to the Equipment dataset on which it is based, and in most use cases, this is the Equipment dataset that the consumer will want to use. This does not prevent its attempted use with other Equipment datasets, which 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 TopologicalNodes 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 modeling allows the modeler 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 BusNameMarkers. If modelers provide BusNameMarkers, and establish multiple main buses separated by retained Switches wherever bus splits are common, then the TopologicalNodes can have consistent names from one Topology dataset to another. The CIM BusNameMarker class provides a way to give a persistent name to TopologicalNodes. 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 BusNameMarkers 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.
- BusNameMarkers that may appear at the same TopologicalNode must have strict priority ordering to provide over time consistent naming of TopologicalNodes.
- The BusNameMarker mRID cannot be copied to the TopologicalNode as this will break the uniqueness requirement for mRIDs if TopologicalNodes are not persistent in the exchangedocument.

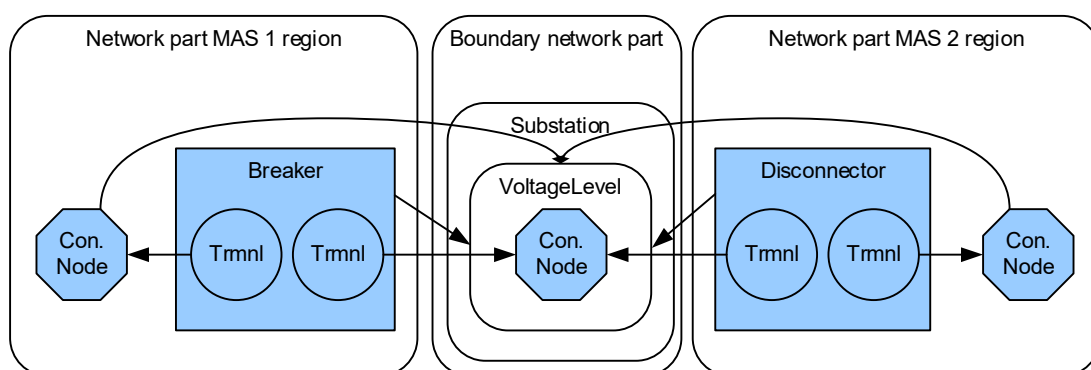
#### 7.1.2 Network model boundaries

ConnectivityNodes also form the interface point in boundary datasets between network parts as shown in Figure 12 and Figure 13.



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**Figure 12 – Line boundary dataset example**



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**Figure 13 – Substation boundary dataset example**

The following abbreviated CIM class names are used in Figure 12 and Figure 13:

- Con.Node = CIM ConnectivityNode;
- Top.Node = CIM TopologicalNode;
- Tmnl = CIM 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.

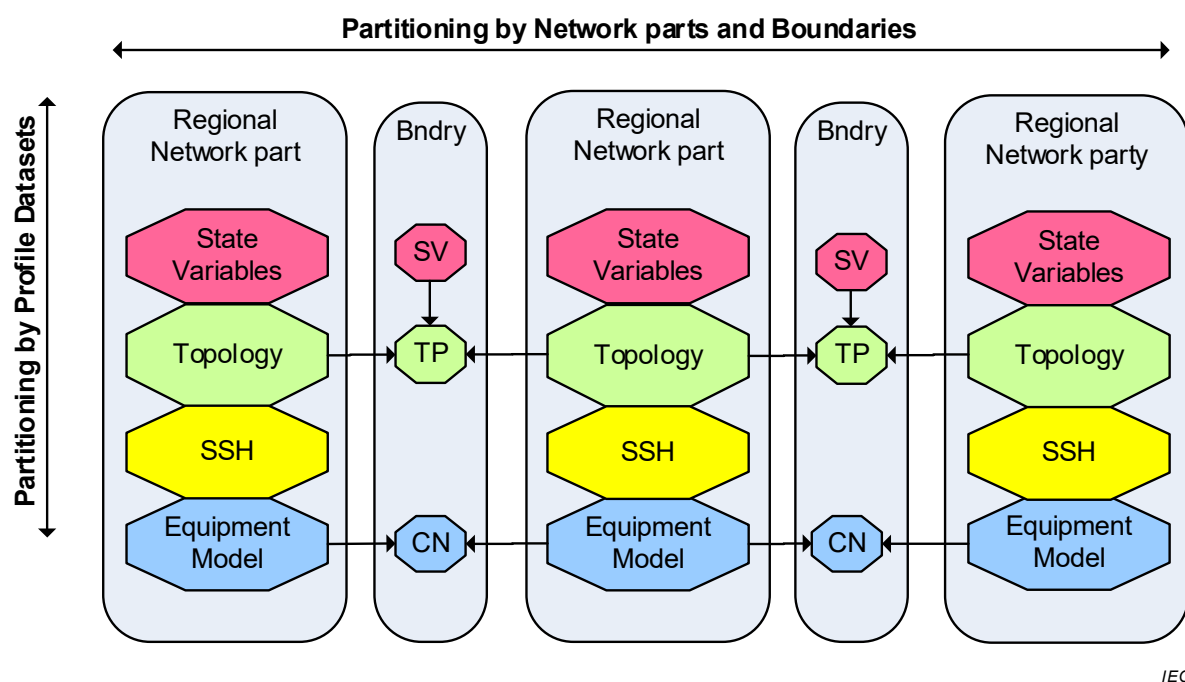
Figure 12 shows a Line between two Substations in different regional network parts named “Network part MAS 1” and “Network part MAS 2”. The boundary network part is described with a Line and a ConnectivityNode. To describe the physical location of the ConnectivityNode as

Junction may be added to the ConnectivityNode. The ACLineSegments 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 13. 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.

Figure 14 shows how an assembled Power Flow case is partitioned in two ways:

- Regions 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.



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**Figure 14 – Power Flow on an assembled model**

Figure 15 show the same partitioning as shown in Figure 14 but for a single regional network part. Steady State Hypothesis injections in the boundary representing the regional network parts are indicated with "BI" for boundary injection. As described in Figure 11 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.

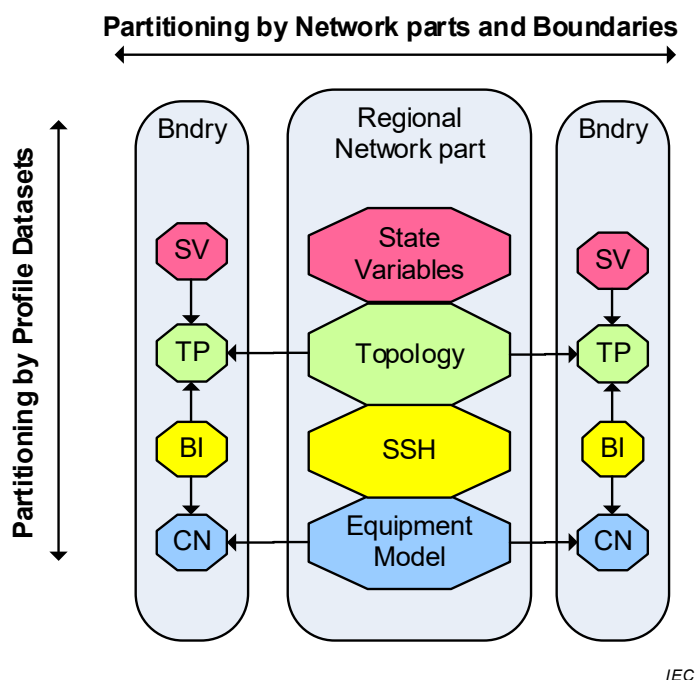


Figure 15 – Power Flow on a regional network part

### 7.1.3 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 TopologicalNodes for connectivity ConnectivityNodes while node-breaker models have use ConnectivityNodes separated by Switches (Breakers, Disconnectors). Network model building involves reducing away Switches based on the inputs Switch.open, Equipment.normallyInService, ACDCTerminal.connected and creating corresponding TopologicalNodes. By using BusNameMarkers the names of the TopologicalNodes resulting from Network model building can be made persistent with TopologicalNodes in a bus-branch model. Persistency of the TopologicalNode itself and its mRID is not supported however.

One of the inventions in CIM is the support of mixed bus-branch and node-breaker models. This is made possible by the linkage between ConnectivityNode and TopologicalNode as shown in Figure 16.

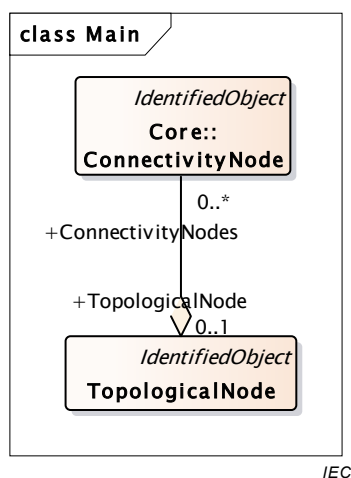


**Figure 16 – CIM relation between ConnectivityNode and TopologicalNode**

When a Network model builder creates a bus-branch model from a node-breaker model the TopologicalNodes and the link ConnectivityNode to TopologicalNode are created. There are several methods to do this:

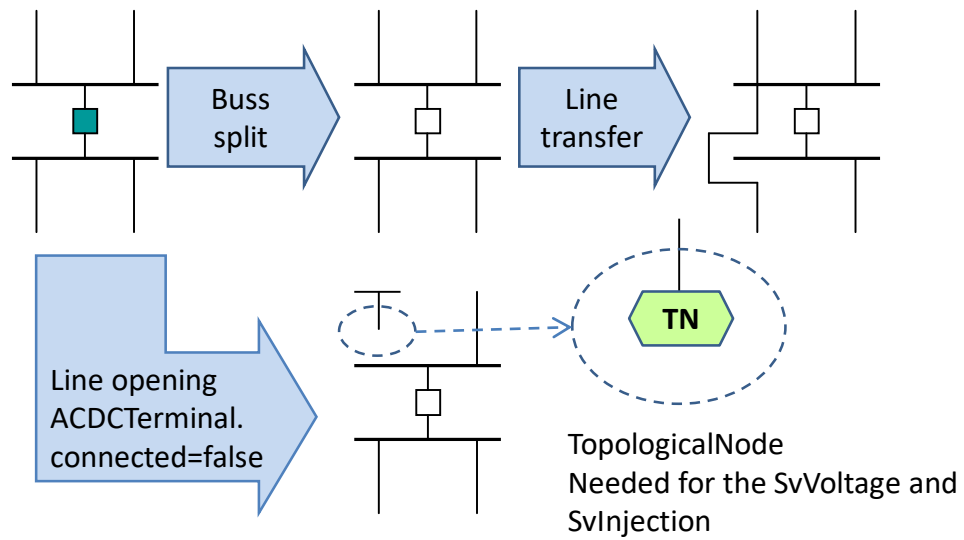
- Use the BusNameMarker names from node-breaker model to match the bus-branch model TopologicalNodes and merge the Topology models at the time of Network model building. Note that using names is an insecure way of merging TopologicalNodes. Preferably persistent TopologicalNodes should be used instead. This will be possible once TopologicalNodes are made persistent.
- Convert bus-branch equipment and topology models to node-breaker equipment models and assemble the equipment models. This is done by creating ConnectivityNodes and BusNameMarkers from the TopologicalNodes in the bus-branch models.

The rules for the Network model building are

- Calculate TopologicalNodes from ConnectivityNodes by processing Switch.open and ACDCTerminal.connected. An open ended branch results in a TopologicalNode at the open end to keep the voltage and angle.
- Exclude all equipment where Equipment.normallyInService=false from power flow.

In a bus-branch model, a bus split and transfer of a line between split buses is illustrated in Figure 17. This can be modeled as follows:

- A voltage level should be represented with two busses (ConnectivityNodes) 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 17.
- 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 that represents the voltage at the open ACLineSegment end is needed.



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**Figure 17 – Bus-branch modeling of bus coupler and line transfer**

## 7.2 Topology (TP) interface

The CIM for topology is shown in Figure 18. For the TP profile refer to Clause 8.

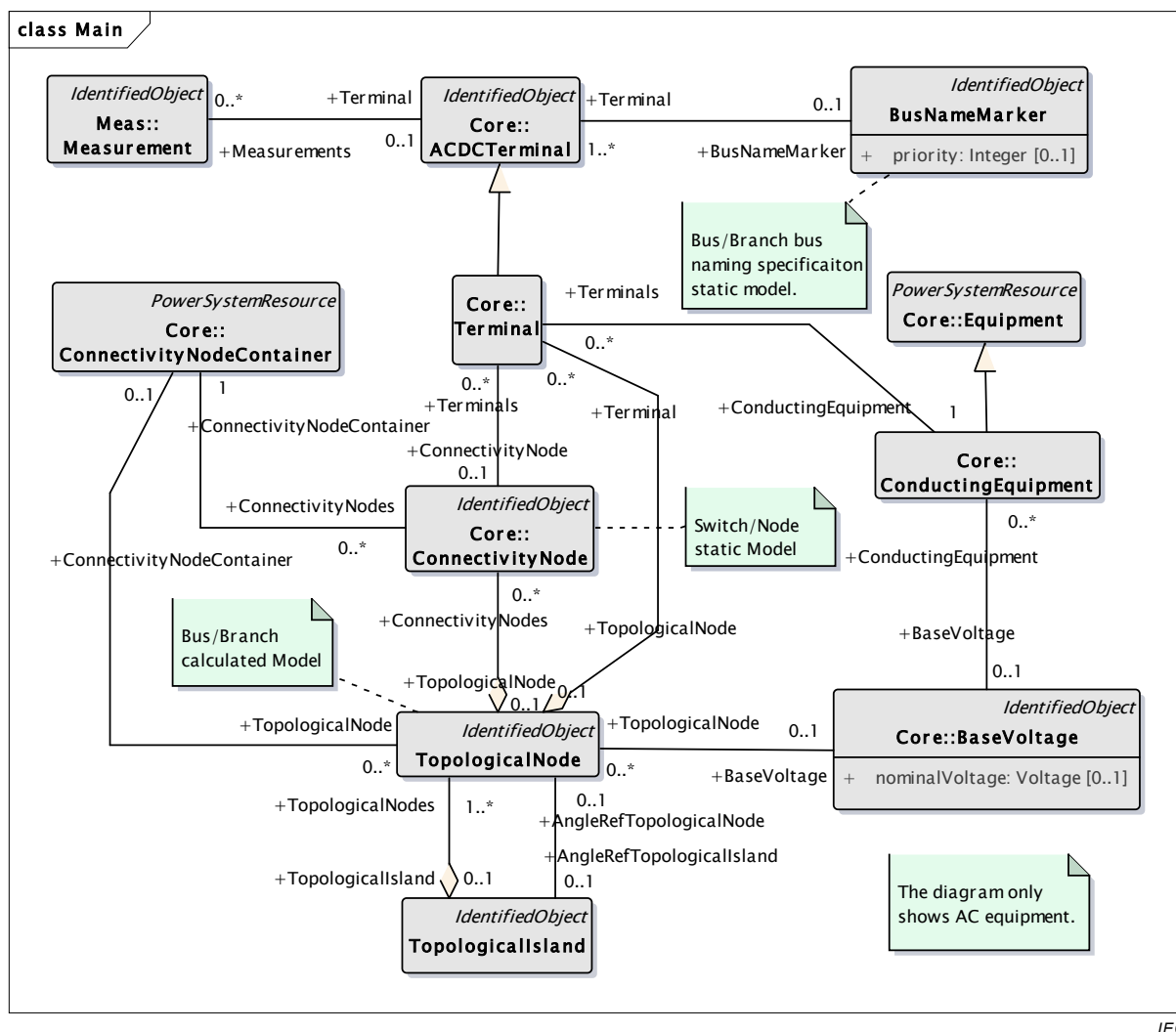


**Figure 18 – CIM topology model**

Figure 18 shows the CIM UML for the Topology interface.

A dataset example based on the model in Figure 18 and the corresponding Topology profile is shown in Figure 19.

```

<rdf:RDF xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#" xmlns:cim="
http://iec.ch/TC57/2013/CIM-schema-cim16#">

  <cim:TopologicalNode rdf:ID="_fe3b0741-0393-4f3f-9863-7658d6e61a60">
    <cim:IdentifiedObject.name>BLO0400SUBNET_7048</cim:IdentifiedObject.name>
    <cim:TopologicalNode.BaseVoltage rdf:resource="#_f9872320-6d88-43d1..."/>
    <cim:TopologicalNode.ConnectivityNodeContainer rdf:resource="#_8837228a..."/>
  </cim:TopologicalNode>

  <cim:TopologicalNode rdf:ID="_aled01d2-700c-4360-92cd-c4961eacd1eb">
    <cim:IdentifiedObject.name>BLO0220SUBNET_7067</cim:IdentifiedObject.name>
    <cim:TopologicalNode.BaseVoltage rdf:resource="#_f9872320-6d88-43d1..."/>
    <cim:TopologicalNode.ConnectivityNodeContainer rdf:resource="#_8837228a..."/>
  </cim:TopologicalNode>

  <cim:TopologicalNode rdf:ID="_325a0d99-4e2c-4456-8ed5-3af7cad51df6">
    <cim:IdentifiedObject.name>BLO0220SUBNET_7082</cim:IdentifiedObject.name>
    <cim:TopologicalNode.BaseVoltage rdf:resource="#_8b09c1fa-447a-4a0b-baca..."/>
    <cim:TopologicalNode.ConnectivityNodeContainer rdf:resource="#_f06f9c19-3123..."/>
  </cim:TopologicalNode>

  ...

  <cim:Terminal rdf:about="#_caec8e6b-6936-4926-89d5-76910fdae26b">
    <cim:Terminal.TopologicalNode rdf:resource="#_fe3b0741-0393-4f3f-98..."/>
  </cim:Terminal>

  <cim:Terminal rdf:about="#_da219c6a-d43b-4ac1-ab52-4212e9283c08">
    <cim:Terminal.TopologicalNode rdf:resource="#_fe3b0741-0393-4f3f-98....."/>
  </cim:Terminal>

  <cim:Terminal rdf:about="#_fe6773e3-14dc-4539-8899-2ceaed0ff46a">
    <cim:Terminal.TopologicalNode rdf:resource="#_fe3b0741-0393-4f3f-....."/>
  </cim:Terminal>

  <cim:Terminal rdf:about="#_b8bd4d23-c102-4d8e-8acc-1cd5b138119a">
    <cim:Terminal.TopologicalNode rdf:resource="#_aled01d2-700c-4360-....."/>
  </cim:Terminal>

  ...

  <cim:ConnectivityNode rdf:about="#_e6250f56-230d-4be8-a0e7-b8a0d91679b1">
    <cim:ConnectivityNode.TopologicalNode rdf:resource="#_aled01d2-70....."/>
  </cim:ConnectivityNode>

  ...

</rdf:RDF>

```

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Figure 19 – Topology solution interface

### 7.3 State Variables (SV) interface

The state variables CIM UML is shown in Figure 20. For the SV profile refer to Clause 8.

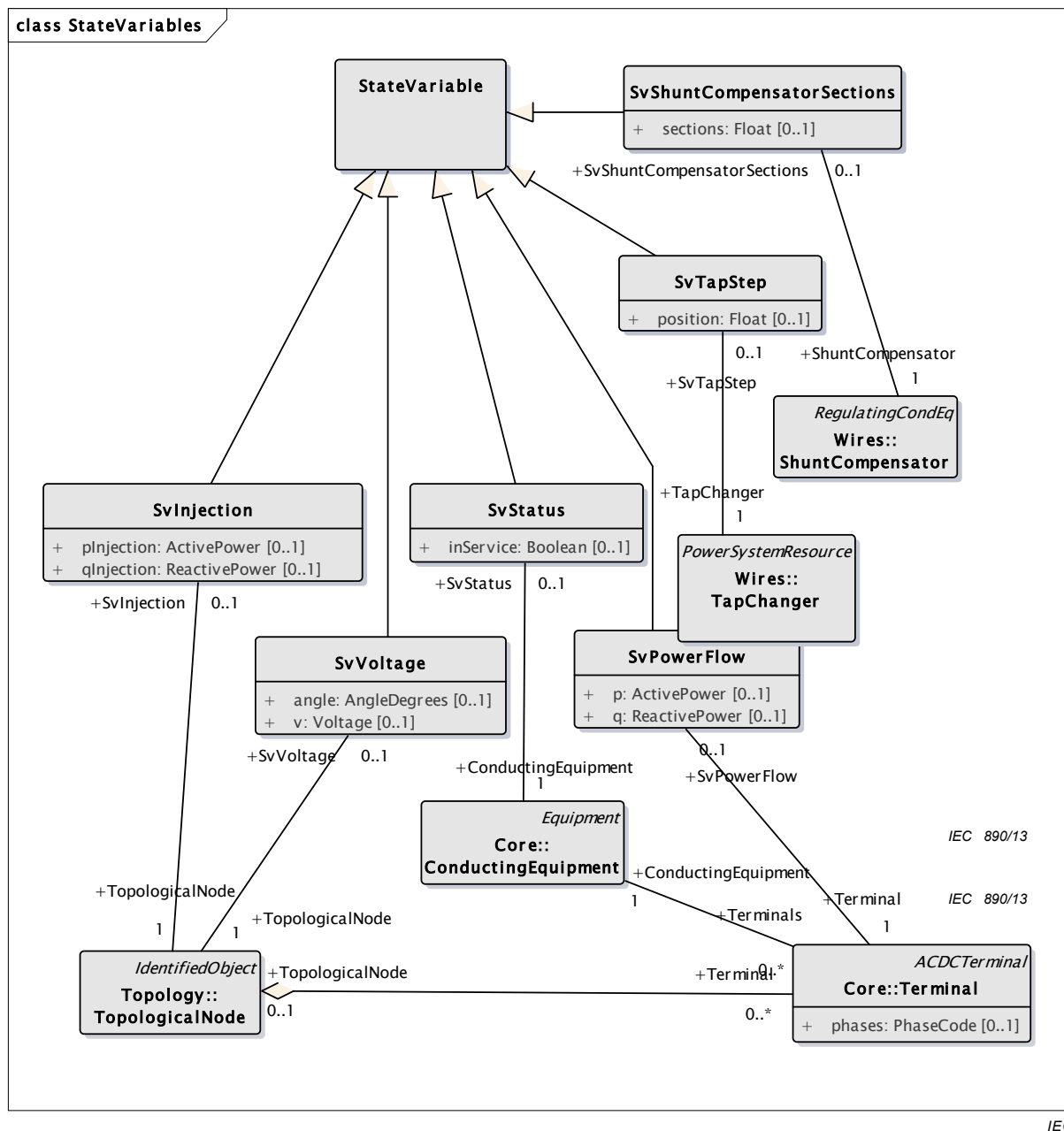


Figure 20 – CIM state variable solution model

The state variables are identified by the objects they belong to and their lifetime depends on that object, i.e. the objects TopologicalNode, ConductingEquipment, Terminal, TapChanger, etc. State variable mRIDs are required to be unique within a message only and their mRIDs cannot be correlated between messages.

The steady state solution is based on the class StateVariable that is specialized into a set of state variables as shown in Figure 20. Note that StateVariable does not inherit from IdentifiedObject as it is fully identified by the object it is attached to.

A CIM XML example based on the model in Figure 20 is shown in Figure 21.

```
<rdf:RDF xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#"
xmlns:cim="http://iec.ch/TC57/2013/CIM-schema-cim16#">

  <cim:TopologicalIsland rdf:ID="_20e3b9de-5d6e-4f36-9435-6fd02e234e67">
    <cim:IdentifiedObject.localName>_1001</cim:IdentifiedObject.localName>
    <cim:TopologicalIsland.TopologicalNode rdf:resource="#_fe3b0741-0393-4f3f-98...>
    <cim:TopologicalIsland.TopologicalNode rdf:resource="#_325a0d99-4e2c-4456-8e...>
    ...
    <cim:TopologicalIsland.AngleRefTopologicalNode rdf:resource=#_20e3b9de-5d6e...>
  </cim:TopologicalIsland>

  ...

  <cim:SvInjection rdf:ID="_e7a35941-f376-47c4-950e-41cf06e3b838">
    <cim:SvInjection.TopologicalNode rdf:resource="#_fe3b0741-0393-4f3f-98...>
    <cim:SvInjection.pInjection>123</cim:SvInjection.pInjection>
    <cim:SvInjection.qInjection>456</cim:SvInjection.qInjection>
  </cim:SvInjection>

  <cim:SvInjection rdf:ID="_85f1c150-7308-41b0-bb7e-25ed518cc67d">
    <cim:SvInjection.TopologicalNode rdf:resource="#_325a0d99-4e2c-4456-8e...>
    <cim:SvInjection.pInjection>123</cim:SvInjection.pInjection>
    <cim:SvInjection.pInjection>123</cim:SvInjection.pInjection>
    <cim:SvInjection.qInjection>456</cim:SvInjection.qInjection>
  </cim:SvInjection>

  ...

  <cim:SvVoltage rdf:ID="_e3a9aac0-2b0c-404b-929a-f30299fb2dc5">
    <cim:SvVoltage.TopologicalNode rdf:resource="#_325a0d99-4e2c-4456-8e...>
    <cim:SvVoltage.v>400</cim:SvVoltage.v>
    <cim:SvVoltage.angle>11.2</cim:SvVoltage.angle>
  </cim:SvVoltage>

  <cim:SvVoltage rdf:ID="_85f1c150-7308-41b0-bb7e-25ed518cc67d">
    <cim:SvVoltage.TopologicalNode rdf:resource="#_fe3b0741-0393-4f3f-98...>
    <cim:SvVoltage.v>400</cim:SvVoltage.v>
    <cim:SvVoltage.angle>10.3</cim:SvVoltage.angle>
  </cim:SvVoltage>

  ...

  <cim:SvPowerFlow rdf:ID="_85464e5f-2011-4d8c-89b1-0355de6eac53">
    <cim:SvPowerFlow.Terminal rdf:resource="#_caec8e6b-6936-4926-89d5_...>
    <cim:SvPowerFlow.p>123</cim:SvPowerFlow.p>
    <cim:SvPowerFlow.q>456</cim:SvPowerFlow.q>
  </cim:SvPowerFlow>

  ...
</rdf:RDF>
```

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Figure 21 – State solution interface example

## 7.4 Steady State Hypothesis (SSH) interface

The SSH profile is a subset of control variables located at the equipment CIM classes. As SSH just have attributes and no relations a UML diagram will show classes with a few attributes in them. Hence no UML diagram showing the profile is included; instead, refer to Clause 8.

## 8 Profiles

### 8.1 Comments and notes

The CIMXML data format described in IEC 61970-552 uses the XML attributes `rdf:ID` and `rdf:about` for object identification. Generally for IEC 61970 profiles the `IdentifiedObject.mRID` UML attribute is mapped to the `rdf:ID` and `rdf:about` XML attributes, hence the `IdentifiedObject.mRID` is not needed in CIMXML based exchanges. However `IdentifiedObject.mRID` is optionally included for the purpose of better compatibility with XML Schema based datasets that rely on the `mRID` attribute for object identification.

Note that the `IdentifiedObject.mRID` is only included in profiles for classes where objects are created with a full description, e.g. `TopologicalIslands` that are created when connectivity for `TopologicalNodes` are analysed in a power flow.

Notes on the profiles

#### a) SSH EquivalentInjection

- 1) `EquivalentInjection.regulationStatus` and `EquivalentInjection.regulationTarget` are required attributes if the `EquivalentInjection` is connected to a non-Boundary node.

#### b) SSH Generating unit

- 1) The active power slack is specified by using the multiple generator slack participation factor in CIM. In case `GeneratingUnit.normalPF` is set to one and all other generating units have a zero participation factor the `GeneratingUnit` which has `normalPF` equal to one will be the active power slack for the `ControlArea` to which it belongs. In case of multiple generators all these `GeneratingUnit(s)` have non-zero `normalPF`, but there must be one `GeneratingUnit` per control area that have maximum participation factor (`GeneratingUnit.normalPF`).
- 2) In case of exchange of steady state hypothesis (non-solved model) or solved model `normalPF` can be non-zero only for generators which are in operation (participate in the load flow).
- 3) In case of exchange of steady state hypothesis (non-solved model, i.e. SV profile is not exchanged) the tools should assign the slack node.

#### c) SSH RegulatingControl

- 1) Note that `RegulatingControl.targetDeadband` is primarily used if the `RegulatingControl.discrete` is set to "true". Tools should handle cases in which `RegulatingControl.targetDeadband` has a value if `RegulatingControl.discrete` is set to "false" or cases in which `RegulatingControl.targetDeadband` equals zero.
- 2) Note that for instance, if the `targetValue` is 100 kV and the `targetDeadband` is 2 kV the range is from 99 to 101 kV."

#### d) SSH VsConverter

- 1) Note that for `ACDCConverter.targetPpcc` load sign convention is used, i.e. positive sign means flow out from a node.
- 2) Note that for `VsConverter.targetQpcc` load sign convention is used, i.e. positive sign means flow out from a node.

#### e) SSH ACDCConverter

- 1) Note that for `ACDCConverter.targetPpcc` load sign convention is used, i.e. positive sign means flow out from a node.

- f) Simple\_Float, all profiles
  - 1) Value type is IEEE 754 simple precision floating point.
- g) TP TopologicalNode
  - 1) ConnectivityNodeContainer is an abstract class. It is used in the TopologicalNode to generate the TopologicalNode. ConnectivityNodeContainer association that is a pointer to ConnectivityNodeContainer concrete subclasses in the Equipment Profile.
  - 2) BaseVoltage is an abstract class. It is used in the TopologicalNode to generate the TopologicalNode.BaseVoltage association that is a pointer to BaseVoltage concrete class in the Equipment Profile.
- h) IdentifiedObject, all profiles
  - 1) IdentifiedObject.name is 32 characters maximum. It shall be consistent with the name of the object used in companies, in daily operation (e. g. in SCADA systems), in planning processes or in asset related systems and should allow inter-communicating of TSO, using general names.
  - 2) IdentifiedObject.name is inherited by many classes and is not required to be unique. Software developers should not count on this to link the power system mode.
  - 3) IdentifiedObject.description is 256 characters maximum.
- i) SV SvPowerFlow
  - 1) The active power flow into the ConductingEquipment. If the associated Terminal.connected status is "false", the flow specified in the SvPowerFlow.p should be zero.
  - 2) The reactive power flow into the ConductingEquipment. If the associated Terminal.connected status is "false", the flow specified in the SvPowerFlow.q should be zero.
  - 3) SvPowerFlow class is required to be instantiated for the following classes: subclasses of the RotatingMachine, subclasses of the EnergyConsumer, EquivalentInjection, ShuntCompensator, StaticVarCompensator and EnergySource.
- j) Conflicts between Equipment and SteadyStateHypothesis
  - 1) Some revisions of some equipment profiles (e.g. IEC 61970-452:2017) may include attributes that are also included in the SteadyStateHypothesis profile. When using an equipment profile that contains this duplication, the duplicate attributes in the SteadyStateHypothesis profile shall be considered optional. If the duplicated attributes are included in a SteadyStateHypothesis instance, then the values in the SteadyStateHypothesis shall override the corresponding values in the Equipment profile.

Subclauses 8.2, 8.3 and 8.4 contain tabular descriptions of the profile information model. All tables have the same structure that is shown below.

| Attribute or role name | Cardinality | Data type | Description |
|------------------------|-------------|-----------|-------------|
|------------------------|-------------|-----------|-------------|

## 8.2 SteadyStateHypothesis profile

### 8.2.1 General

A Steady State Hypothesis dataset 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.

Profile URI: <http://iec.ch/TC57/2013/61970-456/SteadyStateHypothesis/1#>

## 8.2.2 Concrete Classes

### 8.2.2.1 ACDCConverterDCTerminal

Package: DC

A DC electrical connection point at the AC/DC converter. The AC/DC converter is electrically connected also to the AC side. The AC connection is inherited from the AC conducting equipment in the same way as any other AC equipment. The AC/DC converter DC terminal is separate from generic DC terminal to restrict the connection with the AC side to AC/DC converter and so that no other DC conducting equipment can be connected to the AC side.

Inherited Members

|           |      |         |                  |
|-----------|------|---------|------------------|
| connected | 1..1 | boolean | see ACDCTerminal |
|-----------|------|---------|------------------|

### 8.2.2.2 ActivePowerLimit

Package: OperationalLimits

Limit on active power flow.

Native members

|       |      |             |                              |
|-------|------|-------------|------------------------------|
| value | 1..1 | ActivePower | Value of active power limit. |
|-------|------|-------------|------------------------------|

### 8.2.2.3 ApparentPowerLimit

Package: OperationalLimits

Apparent power limit

Native members

|       |      |               |                           |
|-------|------|---------------|---------------------------|
| value | 1..1 | ApparentPower | The apparent power limit. |
|-------|------|---------------|---------------------------|

### 8.2.2.4 AsynchronousMachine

Package: Wires

A rotating machine whose shaft rotates asynchronously with the electrical field. Also known as an induction machine with no external connection to the rotor windings, e.g squirrel-cage induction machine.

Native members

|                         |      |                         |                                            |
|-------------------------|------|-------------------------|--------------------------------------------|
| asynchronousMachineType | 1..1 | AsynchronousMachineKind | Indicates the type of Asynchronous Machine |
|-------------------------|------|-------------------------|--------------------------------------------|

## Inherited Members

|                |      |               |                      |
|----------------|------|---------------|----------------------|
| p              | 1..1 | ActivePower   | see RotatingMachine  |
| q              | 1..1 | ReactivePower | see RotatingMachine  |
| controlEnabled | 1..1 | boolean       | see RegulatingCondEq |

**8.2.2.5 Breaker**

Package: Wires

A mechanical switching device capable of making, carrying, and breaking currents under normal circuit conditions and also making, carrying for a specified time, and breaking currents under specified abnormal circuit conditions e.g. those of short circuit.

## Inherited Members

|      |      |         |            |
|------|------|---------|------------|
| open | 1..1 | boolean | see Switch |
|------|------|---------|------------|

**8.2.2.6 ConformLoad**

Package: LoadModel

ConformLoad represent loads that follow a daily load change pattern where the pattern can be used to scale the load with a system load.

## Inherited Members

|   |      |               |                    |
|---|------|---------------|--------------------|
| p | 1..1 | ActivePower   | see EnergyConsumer |
| q | 1..1 | ReactivePower | see EnergyConsumer |

**8.2.2.7 ControlArea**

Package: ControlArea

A control area is a grouping of generating units and/or loads and a subset of tie lines (as terminals) which may be used for a variety of purposes including automatic generation control, powerflow solution area interchange control specification, and input to load forecasting. Note that any number of overlapping control area specifications can be superimposed on the physical model.

## Native Members

|                |      |             |                                                                                                             |
|----------------|------|-------------|-------------------------------------------------------------------------------------------------------------|
| netInterchange | 1..1 | ActivePower | The specified positive net interchange into the control area, i.e. positive sign means flow in to the area. |
| pTolerance     | 0..1 | ActivePower | Active power net interchange tolerance                                                                      |

**8.2.2.8 CsConverter**

Package: DC

DC side of the current source converter (CSC).

## Native Members

|               |      |                     |                                                                                                        |
|---------------|------|---------------------|--------------------------------------------------------------------------------------------------------|
| operatingMode | 1..1 | CsOperatingModeKind | Indicates whether the DC pole is operating as an inverter or as a rectifier. CSC control variable used |
| pPccControl   | 1..1 | CsPpccControlKind   | Kind of active power control.                                                                          |
| targetAlpha   | 1..1 | AngleDegrees        | Target firing angle. CSC control variable used in power flow.                                          |
| targetGamma   | 1..1 | AngleDegrees        | Target extinction angle. CSC control variable used in power flow.                                      |
| targetIdc     | 1..1 | CurrentFlow         | DC current target value. CSC control variable used in power flow.                                      |

## Inherited Members

|            |      |               |                    |
|------------|------|---------------|--------------------|
| p          | 1..1 | ActivePower   | see ACDCCConverter |
| q          | 1..1 | ReactivePower | see ACDCCConverter |
| targetPpcc | 1..1 | ActivePower   | see ACDCCConverter |
| targetUdc  | 1..1 | Voltage       | see ACDCCConverter |

**8.2.2.9 CurrentLimit**

Package: OperationalLimits

Operational limit on current.

## Native members

|       |      |             |                        |
|-------|------|-------------|------------------------|
| value | 1..1 | CurrentFlow | Limit on current flow. |
|-------|------|-------------|------------------------|

**8.2.2.10 DCTerminal**

Package: DC

An electrical connection point to generic DC conducting equipment.

## Inherited Members

|           |      |         |                  |
|-----------|------|---------|------------------|
| connected | 1..1 | boolean | see ACDCTerminal |
|-----------|------|---------|------------------|

### 8.2.2.11 Disconnecter

Package: Wires

A manually operated or motor operated mechanical switching device used for changing the connections in a circuit, or for isolating a circuit or equipment from a source of power. It is required to open or close circuits when negligible current is broken or made.

Inherited Members

|      |      |         |            |
|------|------|---------|------------|
| open | 1..1 | boolean | see Switch |
|------|------|---------|------------|

### 8.2.2.12 EnergyConsumer

Package: Wires

Generic user of energy – a point of consumption on the power system model.

Native Members

|   |      |               |                                                                                                                                                                                                                               |
|---|------|---------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| p | 1..1 | ActivePower   | Active power of the load. Load sign convention is used, i.e. positive sign means flow out from a node.<br><br>For voltage dependent loads the value is at rated voltage.<br><br>Starting value for a steady state solution.   |
| q | 1..1 | ReactivePower | Reactive power of the load. Load sign convention is used, i.e. positive sign means flow out from a node.<br><br>For voltage dependent loads the value is at rated voltage.<br><br>Starting value for a steady state solution. |

### 8.2.2.13 EnergySource

Package: Production

A generic equivalent for an energy supplier on a transmission or distribution voltage level.

## Native Members

|               |      |               |                                                                                                                                                                        |
|---------------|------|---------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| activePower   | 1..1 | ActivePower   | High voltage source active injection. Load sign convention is used, i.e. positive sign means flow out from a node.<br><br>Starting value for steady state solutions.   |
| reactivePower | 1..1 | ReactivePower | High voltage source reactive injection. Load sign convention is used, i.e. positive sign means flow out from a node.<br><br>Starting value for steady state solutions. |

**8.2.2.14 EquivalentInjection**

Package: Equivalents

This class represents equivalent injections (generation or load). Voltage regulation is allowed only at the point of connection.

## Native Members

|                  |      |               |                                                                                                                                                                     |
|------------------|------|---------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| p                | 1..1 | ActivePower   | Equivalent active power injection. Load sign convention is used, i.e. positive sign means flow out from a node.<br><br>Starting value for steady state solutions.   |
| q                | 1..1 | ReactivePower | Equivalent reactive power injection. Load sign convention is used, i.e. positive sign means flow out from a node.<br><br>Starting value for steady state solutions. |
| regulationStatus | 0..1 | boolean       | Specifies the default regulation status of the EquivalentInjection. True is regulating. False is not regulating.                                                    |
| regulationTarget | 0..1 | Voltage       | The target voltage for voltage regulation.                                                                                                                          |

**8.2.2.15 ExternalNetworkInjection**

Package: Wires

This class represents external network and is used for IEC 60909 calculations.

#### Native Members

|                   |      |               |                                                                                                                                                               |
|-------------------|------|---------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------|
| p                 | 1..1 | ActivePower   | Active power injection. Load sign convention is used, i.e. positive sign means flow out from a node.<br><br>Starting value for steady state solutions.        |
| q                 | 1..1 | ReactivePower | Reactive power injection. Load sign convention is used, i.e. positive sign means flow out from a node.<br><br>Starting value for steady state solutions.      |
| referencePriority | 1..1 | integer       | Priority of unit for use as powerflow voltage phase angle reference bus selection. 0 = don't care (default) 1 = highest priority. 2 is less than 1 and so on. |

#### Inherited Members

|                |      |         |                      |
|----------------|------|---------|----------------------|
| controlEnabled | 1..1 | boolean | see RegulatingCondEq |
|----------------|------|---------|----------------------|

### 8.2.2.16 GeneratingUnit

Package: Generation

A single or set of synchronous machines for converting mechanical power into alternating-current power. For example, individual machines within a set may be defined for scheduling purposes while a single control signal is derived for the set. In this case there would be a GeneratingUnit for each member of the set and an additional GeneratingUnit corresponding to the set.

#### Native Members

|          |      |              |                                                |
|----------|------|--------------|------------------------------------------------|
| normalPF | 1..1 | Simple_Float | Generating unit economic participation factor. |
|----------|------|--------------|------------------------------------------------|

### 8.2.2.17 GroundDisconnector

Package: Wires

A manually operated or motor operated mechanical switching device used for isolating a circuit or equipment from ground.

#### Inherited Members

|      |      |         |            |
|------|------|---------|------------|
| open | 1..1 | boolean | see Switch |
|------|------|---------|------------|

### 8.2.2.18 HydroGeneratingUnit

Package: Generation

A generating unit whose prime mover is a hydraulic turbine (e.g., Francis, Pelton, Kaplan).

Inherited Members

|          |      |              |                    |
|----------|------|--------------|--------------------|
| normalPF | 1..1 | Simple_Float | see GeneratingUnit |
|----------|------|--------------|--------------------|

### 8.2.2.19 LinearShuntCompensator

Package: Wires

A linear shunt compensator has banks or sections with equal admittance values.

Inherited Members

|                |      |              |                      |
|----------------|------|--------------|----------------------|
| sections       | 1..1 | Simple_Float | see ShuntCompensator |
| controlEnabled | 1..1 | boolean      | see RegulatingCondEq |

### 8.2.2.20 LoadBreakSwitch

Package: Wires

A mechanical switching device capable of making, carrying, and breaking currents under normal operating conditions.

Inherited Members

|      |      |         |            |
|------|------|---------|------------|
| open | 1..1 | boolean | see Switch |
|------|------|---------|------------|

### 8.2.2.21 NonConformLoad

Package: LoadModel

NonConformLoad represent loads that do not follow a daily load change pattern and changes are not correlated with the daily load change pattern.

Inherited Members

|   |      |             |                    |
|---|------|-------------|--------------------|
| p | 1..1 | ActivePower | see EnergyConsumer |
| q | 1..1 | ActivePower | see EnergyConsumer |

### 8.2.2.22 NonlinearShuntCompensator

Package: Wires

A non-linear shunt compensator has bank or section admittance values that differs.

Inherited Members

|                |      |              |                      |
|----------------|------|--------------|----------------------|
| sections       | 1..1 | Simple_Float | see ShuntCompensator |
| controlEnabled | 1..1 | boolean      | see RegulatingCondEq |

### 8.2.2.23 NuclearGeneratingUnit

Package: Generation

A nuclear generating unit.

Inherited Members

|          |      |              |                    |
|----------|------|--------------|--------------------|
| normalPF | 1..1 | Simple_Float | see GeneratingUnit |
|----------|------|--------------|--------------------|

### 8.2.2.24 PhaseTapChangerAsymmetrical

Package: Wires

Describes the tap model for an asymmetrical phase shifting transformer in which the difference voltage vector adds to the primary side voltage. The angle between the primary side voltage and the difference voltage is named the winding connection angle. The phase shift depends on both the difference voltage magnitude and the winding connection angle.

Inherited Members

|                |      |         |                |
|----------------|------|---------|----------------|
| controlEnabled | 1..1 | boolean | see TapChanger |
| step           | 1..1 | float   | see TapChanger |

### 8.2.2.25 PhaseTapChangerLinear

Package: Wires

Describes a tap changer with a linear relation between the tap step and the phase angle difference across the transformer. This is a mathematical model that is an approximation of a real phase tap changer.

The phase angle is computed as stepPhaseShiftIncrement times the tap position.

The secondary side voltage magnitude is the same as at the primary side.

Inherited Members

|                |      |         |                |
|----------------|------|---------|----------------|
| controlEnabled | 1..1 | boolean | see TapChanger |
| step           | 1..1 | float   | see TapChanger |