# IEC 61970-457

Edition 1.0 2021-03

# INTERNATIONAL STANDARD

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## Energy management system application program interface (EMS-API) – Part 457: Dynamics profile

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

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

## Part 457: Dynamics profile

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International Standard IEC 61970-457 has been prepared by IEC technical committee 57: Power systems management and associated information exchange.

The text of this standard is based on the following documents:

| FDIS | Report on voting |
|---|---|
| 57/2331/FDIS | 57/2344/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.

It is based on the IEC 61970 UML version 'IEC61970CIM17v40', dated '2020-08-24'.

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A list of all parts of the IEC 61970 series, 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- withdrawn,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.

**IMPORTANT – The 'colour inside' logo on the cover page of this publication 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.**

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# INTRODUCTION

The IEC 61970-300 series of documents specify 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 document does not include the method of exchange, and therefore is applicable to a variety of exchange implementations. All examples provided in this document are serialised according to in the IEC 61970-552:2016.

This document specifies the profile (or subset) of the CIM required to describe the exchanged dynamic model information needed 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 in this series of related standards. Thus, equipment and other related power flow model data is not repeated in the information exchanged with this document. The schema(s) for expressing the dynamic model information are derived directly from the CIM, more specifically from IEC 61970-302.

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

# Part 457: Dynamics profile

## 1 Scope

This part of IEC 61970 specifies a standard interface for exchanging dynamic model information needed 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 schema(s) for expressing the dynamic model information are derived directly from the CIM, more specifically from IEC 61970-302.

The scope of this document includes only the dynamic model information that needs to be exchanged as part of a dynamic study, namely the type, description and parameters of each control equipment associated with a piece of power system equipment included in the steady state solution of a complete power system network model. Therefore, this profile is dependent upon other standard profiles for the equipment as specified in IEC 61970-452, CIM static transmission network model profiles, the topology, the steady state hypothesis and the steady-state solution (as specified in IEC 61970-456, *Solved power system state profiles*) of the power system, which bounds the scope of the exchange. The profile information described by this document needs to be exchanged in conjunction with IEC 61970-452 and IEC 61970-456 profiles' information to support the data requirements of transient analysis tools. IEC 61970-456 provides a detailed description of how different profile standards can be combined to form various types of power system network model exchanges.

This document supports the exchange of the following types of dynamic models:

- standard models: a simplified approach to exchange, where models are contained in predefined libraries of classes interconnected in a standard manner that represent dynamic behaviour of elements of the power system. The exchange only indicates the name of the model along with the attributes needed to describe its behaviour.
- proprietary user-defined models: an exchange that would provide users the ability to exchange the parameters of a model representing a vendor or user proprietary device where an explicit description of the model is not described in this document. The connections between the proprietary models and standard models are the same as described for the standard models exchange. Recipient of the data exchange will need to contact the sender for the behavioural details of the model.

This document builds on IEC 61970-302, CIM for dynamics which defines the descriptions of the standard dynamic models, their function block diagrams, and how they are interconnected and associated with the static network model. This type of model information is assumed to be pre-stored by all software applications hence it is not necessary to be exchanged in real-time or as part of a dynamics model exchange.

## 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*

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IEC 61970-302:2018, *Energy management system application program interface (EMS-API) - Part 302: Common information model (CIM) dynamics*

IEC 61970-452:2017, *Energy management system application program interface (EMS-API) - Part 452: CIM static transmission network model profiles*

IEC 61970-456:2018, *Energy management system application program interface (EMS-API) - Part 456: Solved power system state profiles*

## 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 specification

### 4.1 General

This document is applicable for both CIM16 and CIM17 base models; however, if exchanged with CIM16 related standards some types of wind models cannot be exchanged due to lack of power electronics related classes in IEC 61970-452:2017 and IEC 61970-456:2018.

The profile defined in this document has the following version related information:

- Title: Dynamics Vocabulary
- Keyword: DY
- Description: This vocabulary is describing the dynamics profile from IEC 61970-457.
- Version IRI: http://iec.ch/TC57/ns/CIM/Dynamic/1.0
- Version info: 1.0.0
- Prior version:
- Conforms to: urn:iso:std:iec:61970-457:ed-1|urn:iso:std:iec:61970-301:ed-7:amd1|urn:iso:std:iec:61970-301:ed-1|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:892c090f-a121-4e11-bede-e47a2be990ff

### 4.2 Requirements and constraints

This clause 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 the machine processing and for the moment it is 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 part, e.g. 452 for IEC 61970-452.

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rule.Profile: the abbreviation of the profile, e.g. TP for Topology profile. If set to “ALL” the constraint is applicable to all 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:452:EQ:IdentifiedObject.name:StringLength.

- C:457:DY:GovSteamSGO.pmin:datatype

There is a mistake in IEC 61970-302. The datatype of the attribute GovSteamSGO.pmin is given there as Seconds. The value exchanged with this attribute shall be PU as it is for GovSteamSGO.pmax.

- C:457:DY:mwbase:equation

The vast majority of turbine-governor models have mwbase as a parameter. The parameter is specified explicitly in the turbine-governor models to support use of a different value by transient analysis tools, if needed. If this parameter is present it shall correspond to RotatingMachine.ratedPowerFactor * RotatingMachine.ratedS.

- C:457:DY:IdentifiedObject.name:stringLength

The string IdentifiedObject.name has a maximum of 128 characters.

- C:457:DY:IdentifiedObject.description:stringLength

The string IdentifiedObject.description has a maximum of 256 characters.

- C:457:DY:ExcitationSystemDynamics.SynchronousMachineDynamics:reference

ExcitationSystemDynamics.SynchronousMachineDynamics cannot point to an object of type SynchronousMachineSimplified.

- C:457:DY:TurbineGovernorDynamics:deltaomega

Some turbine governors diagrams have deltaomega as an input others just omega. In cases where deltaomega is an input, the following relation with the speed is defined: deltaomega = (speed – 1) in pu.

- C:457:DY:RotatingMachineDynamics:modelType-SubtransientRoundRotorSimplified

Annex A specifies the usage of different attributes related to the model type.

If SynchronousMachineTimeConstantReactance.modelType is subtransientSimplified and .rotorType is roundRotor the following optional attributes are not exchanged or set to 0:

  – SynchronousMachineDetailed.saturationFactorQAxis
  – SynchronousMachineDetailed.saturationFactor120QAxis.

RotatingMachineDynamics.statorResistance is set to 0.

- C:457:DY:RotatingMachineDynamics:modelType-SubtransientSalientPole

Annex A specifies the usage of different attributes related to the model type.

If SynchronousMachineTimeConstantReactance.modelType is subtransient and .rotorType is salientPole the following optional attributes are not exchanged or set to 0:

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  - SynchronousMachineDetailed.saturationFactorQAxis
  - SynchronousMachineDetailed.saturationFactor120QAxis.
- C:457:DY:RotatingMachineDynamics:modelType-SubtransientRoundRotor

Annex A specifies the usage of different attributes related to the model type.

If SynchronousMachineTimeConstantReactance.modelType is subtransient and .rotorType is roundRotor the following optional attributes are required:

  - SynchronousMachineTimeConstantReactance.xQuadTrans
  - SynchronousMachineTimeConstantReactance.tpqo
  - SynchronousMachineDetailed.saturationFactorQAxis
  - SynchronousMachineDetailed.saturationFactor120QAxis
  - RotatingMachineDynamics.saturationFactor
  - RotatingMachineDynamics.saturationFactor120.
- R:457:NA:float

An attribute that is defined as float (e.g. has a type Float or a type which is a Datatype with .value attribute of type Float) shall support ISO/IEC 60559:2020 for floating-point arithmetic using single precision floating point. A single precision float supports 7 significant digits where the significant digits are described as an integer, or a decimal number with 6 decimal digits. Two float values are equal when the significant with 7 digits are identical, e.g. 1234567 is equal 1.234567E6 and so are 1.2345678 and 1.234567E0.

- R:457:DY: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.

- R:457:DY: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:457:DY:NA:uniqueIdentifier

All IdentifiedObject-s shall have a persistent and globally unique identifier (Master Resource Identifier – mRID).

- R:457:DY:NA:exchange

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

- R:457:DY: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:457:DY: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

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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 61970-457. This provides flexibility for the business processes to adapt to different business requirements and base the exchanges on IEC 61970-457-compliant applications.

- R:457:DY: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 8.

## 5 Overview

This document describes an interface standard in which payloads are used to exchange dynamic model information of prime mover response, controls and other data needed to support the analysis of the steady state stability (small-signal stability) and/or transient stability of a power system.

The primary objective is to enable interoperability among different software vendors used by utilities and regional or national reliability entities to help ensure bulk power system reliability and security of supply through the exchange of the dynamic models needed to conduct small signal stability and transient stability analysis studies. These studies are also utilized in system development processes where new interconnections or other grid reinforcements are studied.

IEC 61970-302 extends the CIM standard information model by adding new standard power system dynamic models to the static power system network model described by IEC 61970-301, IEC 61970-452 and IEC 61970-456. The scope of the standard models is defined to include the vast majority of models commonly implemented by vendors or commonly used by utilities today.

This document defines a standard model exchange format (a profile) based on the extended CIM information model to accommodate the data requirements that shall be exchanged to completely specify a particular dynamic case, including association of these dynamic models to static load flow model elements for some specific point in time. The current practice is to use vendor proprietary formats and a converter to transform from one proprietary format to another depending on the software products sending and receiving the dynamic case files.

The modelling approach sought to minimize the amount of information that had to be actually exchanged by leveraging commonly understood information about the individual dynamic model subsystems, such as the specific model behaviour, equations, interconnection patterns, input/output signals, and initialization procedures that can be pre-stored and thus do not need to be exchanged. The only information required in the exchange is the identity of the specific standard or user-defined (proprietary) models, an association to a specific equipment instance in the static network model, the parameter values that are dependent on the behavior of the physical equipment, the electromechanical and electronic controls, and the small signal behavioural aspects of the equipment.

In some cases, the purpose of the exchange is to include all data necessary to perform a small signal stability analysis of a specific scenario. In this case, the entire electrical model as defined in IEC 61970-452 and the data describing the solved state as defined in IEC 61970-456 will be required. The solved state will be based on the study conditions such as equipment outages and generator output levels.

How to read this document:

- The ‘Use cases’ clause (Clause 6) gives examples of business problems that this document is intended to address.

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- The ‘Architecture’ clause (Clause 7) summarizes how the models described in this document work with parts described in other IEC 61970 series standards.
- The ‘Detailed profile specification’ clause (Clause 8) defines the kinds of datasets controlled by this document.
- Annex A provides implementation clarifications related to the models inherited from RotatingMachineDynamics class.
- Annex B provides some examples when using IEC 61970-552 serialisation.

# 6 Use cases

## 6.1 General

The use case clause presents some of the business problems that were considered in the design of this document and discusses how the document is expected to provide value to the industry.

Dynamics models exchange supplies data for one of the most complex analyses of a power system. The requirements of the data exchanges are directly related to the level of detail of the power system modelling applied in a given area. This document (dynamics profile) supports the exchange of dynamic behaviour models used by software applications which perform analysis of the steady state stability (small-signal stability) and/or transient stability of a power system as defined by IEEE / CIGRE Standard Terms and Definitions for Power System Stability Analysis.

Dynamics models are typically described using both graphics and text. Therefore, there is a high level of complexity and room for interpretation, which this document is designed to minimize.

## 6.2 Dynamic assessment studies

Small signal stability and transient stability analysis studies are used by utilities and regional or national reliability entities to help ensure bulk power system reliability and security of supply. These studies are utilized in the scope of system development processes where new interconnections or other grid reinforcements are studied. Sharing of dynamics behaviour information is not just useful, but crucial, for grid operations entities (utilities, regional reliability organizations, transmission system operators) that need to do system-wide studies utilizing different applications. These studies are generally over very large portions of the network, if not the entire interconnection, and each entity studying the dynamic stability of its system needs to acquire dynamics data from each of its neighbouring systems.

The standard models library (see IEC 61970-302) is based on numerous common models (some IEEE standards, some IEC standards and some models widely used by the utilities or organizations), which have been defined for various components of the power system. Since dynamic stability studies performed at both utilities and reliability entities require model definitions of each component, exchange of dynamic models in a standardized format benefits overall grid reliability and grid planning by eliminating manual entry errors and facilitating timely data sharing.

Dynamic assessment studies require a full steady state electrical equipment model including topology and a solved state. The source of this data may vary.

- In the case of long-term studies, planning models are typically used. These models reflect the equipment in place at the time of the study. The steady state hypothesis, topology, and solution state reflect normal or adverse conditions based on the purpose of the study.
- Current conditions are usually studied by using an electrical model from a state estimator along with a topology based on current switch positions and a solved state reflecting current generation and load.

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- For historic events which warrant small signal analysis or reproduction of the behaviour of generators during the event, previous state estimator models and solutions are typically used in providing equipment, topology and state of the study period.
- New generation or area-to-area interconnections are mostly studied using small signal stability studies. In these cases, planning models are often used.

# 7 Architecture

## 7.1 General

The main architectural feature of this document is the reduction in complexity of how the different models connect to one another and to the electrical equipment they are related to. In order to study the dynamic behaviour of a generator, a model describing the transient behaviour of the generator, prime mover, governor, exciter, power system stabilizer, voltage regulator, and any other equipment must be defined. In addition, similar detail of all generators in the region shall be modelled in the same detail.

All of the models covered in IEC 61970-302 are included in this profile. The document lists all concrete and abstract classes used by the dynamics profile. However only concrete classes are present in the exchange of dynamics model data as they include all of the data inherited from the abstract classes. This document augments IEC 61970-302 with examples of how the dynamics data is organized and dependant on other profiles. Some examples of payload are included in this document.

Details of the descriptions of the individual models found in IEC 61970-302 are further amended in this document in order to describe the usage of the models. IEC 61970-302 lists typical values to assist understanding of the magnitude of the quantities used for each of the attributes. These values do not replace or reflect any real data, hence shall not be interpreted as default values and shall not be used in real data exchange as a substitute of unknown values for the parameters. The untended use of typical values is to indicate a potential set of parameters that can be used during development and testing of applications supporting the standard models defined in the standard. The attributes used in the payload of any CIM transfer shall normally reflect commissioning data or results from subsequent testing of the machines being studied in order to provide reliable results. This document specifies the required attributes for each class in the profile as well as the directions of the associations. Therefore, the profile is designed to augment the equipment model with additional transient model data. The associations between the classes in the equipment model and the classes covered under this profile shall be defined within the instances of the classes included in this profile. Persistence in identifiers shall be maintained for these types of exchanges.

Figure 1 gives an example of linkage between dynamics profile and a SynchronousMachine defined in equipment profile (IEC 61970-452).

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```
<cim:SynchronousMachineTimeConstantReactance rdf:ID="_99d08548-89cf-11e3-8aa9-2c44fd6790f2">
 <cim:IdentifiedObject.name>GENROU</cim:IdentifiedObject.name>
 <cim:DynamicsFunctionBlock.enabled>true</cim:DynamicsFunctionBlock.enabled>
...
<cim:SynchronousMachineDynamics.SynchronousMachine rdf:resource="#_caca0471-89ce-11e3-8aa9-
2c44fd6790f2" />
...
</cim:SynchronousMachineTimeConstantReactance>
```

**Figure 1 – SynchronousMachineDynamics association**

## 7.2 Profile architecture

Every generator in the equipment model shall have all of its dynamic components modelled. Some of the dynamic components feed signals to other components. Some generators share controls, which shall be modelled. Many of the component models are standardized throughout the industry. The standard component models are generally connected together in a standard way based on the type of generator. Several types of these standard model interconnections are outlined in IEC 61970-302. The diagram shown in Figure 2 is one of those and specifies how to trace signals through the different standard component models of a synchronous generator.

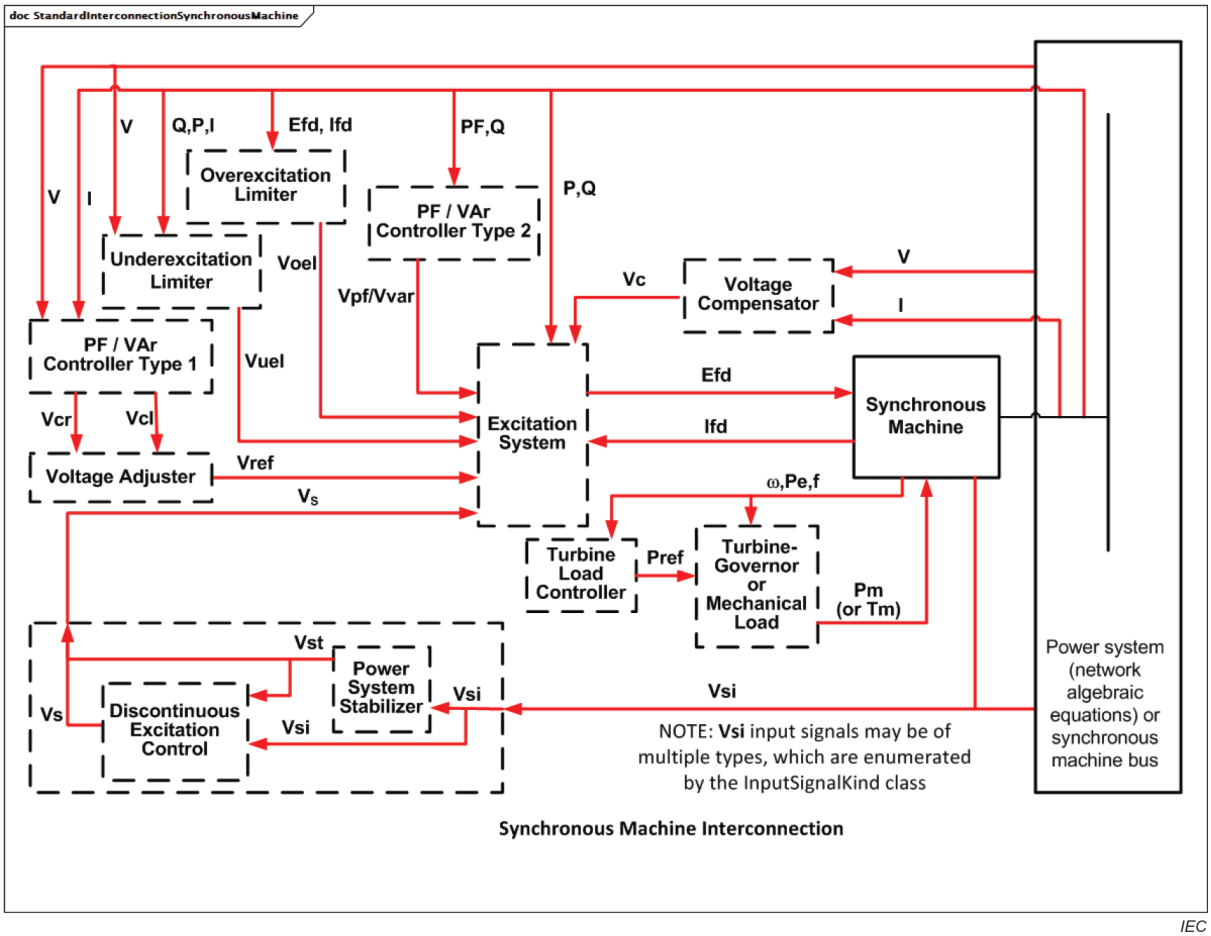



**Figure 2 – Interconnection diagram for a synchronous machine**

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There are CIM classes representing each type of component and the associations between them reflect the possible combinations of components that can be used to represent a specific type of interconnection. For example, the synchronous machine, whose interconnection diagram is shown in Figure 3, is represented by the CIM classes and associations shown in Figure 2. The cardinality of the associations reflects how many of which components can be used in describing a given synchronous machine.

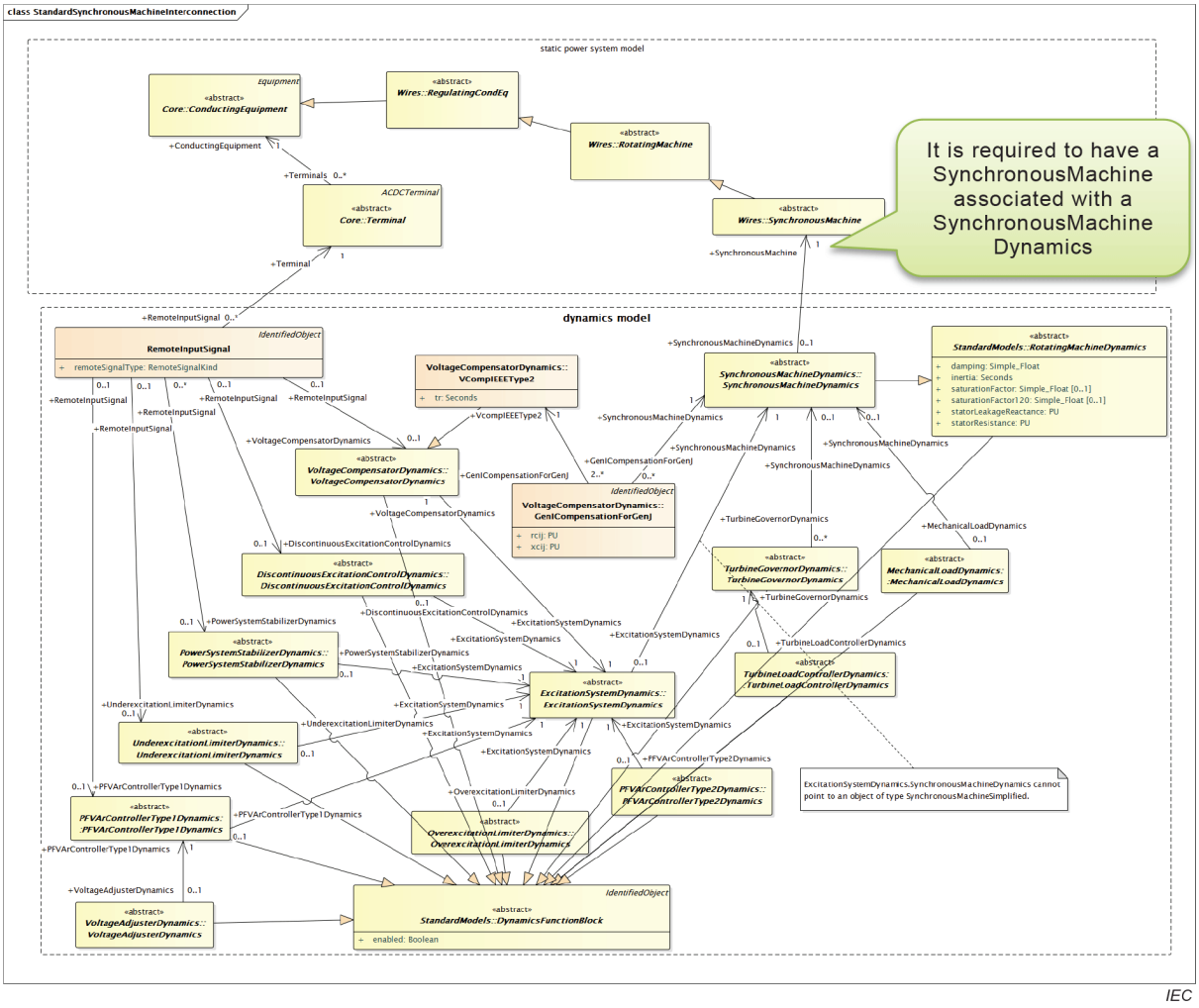



**Figure 3 – Standard connections for a synchronous machine**

Specifying the signal connectivity between models is not necessary for the standard models. A dynamic model for a specific generator shall include all of the components necessary to simulate its response to the electrical system. For example, if a generator does not have specific components installed such as limiters on the excitation controllers then the UnderexcitationLimiterDynamics and OverexcitationLimiterDynamics instances shall be excluded from the payload. The output signals from these components are not passed to the exciter component. In some cases, such as with a voltage adjuster, the input signal shall be passed through to the excitation system.

The exchange of dynamics data for use in simulations depends on data from other exchanges as defined in other IEC documentation and shown in the profile relationships in Figure 4.

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- Static network model profiles defined in IEC 61970-452 include the Equipment Model profile, which contains static modelling information describing power system physical elements and their electrical connections. Associations from Dynamics Models profile classes to equipment profile classes allow dynamic models to be associated with the specific equipment they represent. For example, there is an association from SynchronousMachineDynamics to SynchronousMachine which ties SynchronousMachineDynamics, along with all of its associated components, to the equipment model. This is illustrated in Figure 3.
- The steady-state solution profiles (Topology and State Variables) defined in IEC 61970-456 provide the topological connectivity of the model and the solved state of the model, which is used as a starting condition of the dynamics simulation. The steady-state solution information is accessible to the dynamics simulation because the classes of those profiles also refer to Equipment Model profile classes.
- The Schematic Layout profile defined in IEC 61970-453 describes the elements of schematic or geographic displays. Exchange of graphics data is not required to support dynamic simulation studies, but may be helpful in diagnosing or analyzing problem in the study.

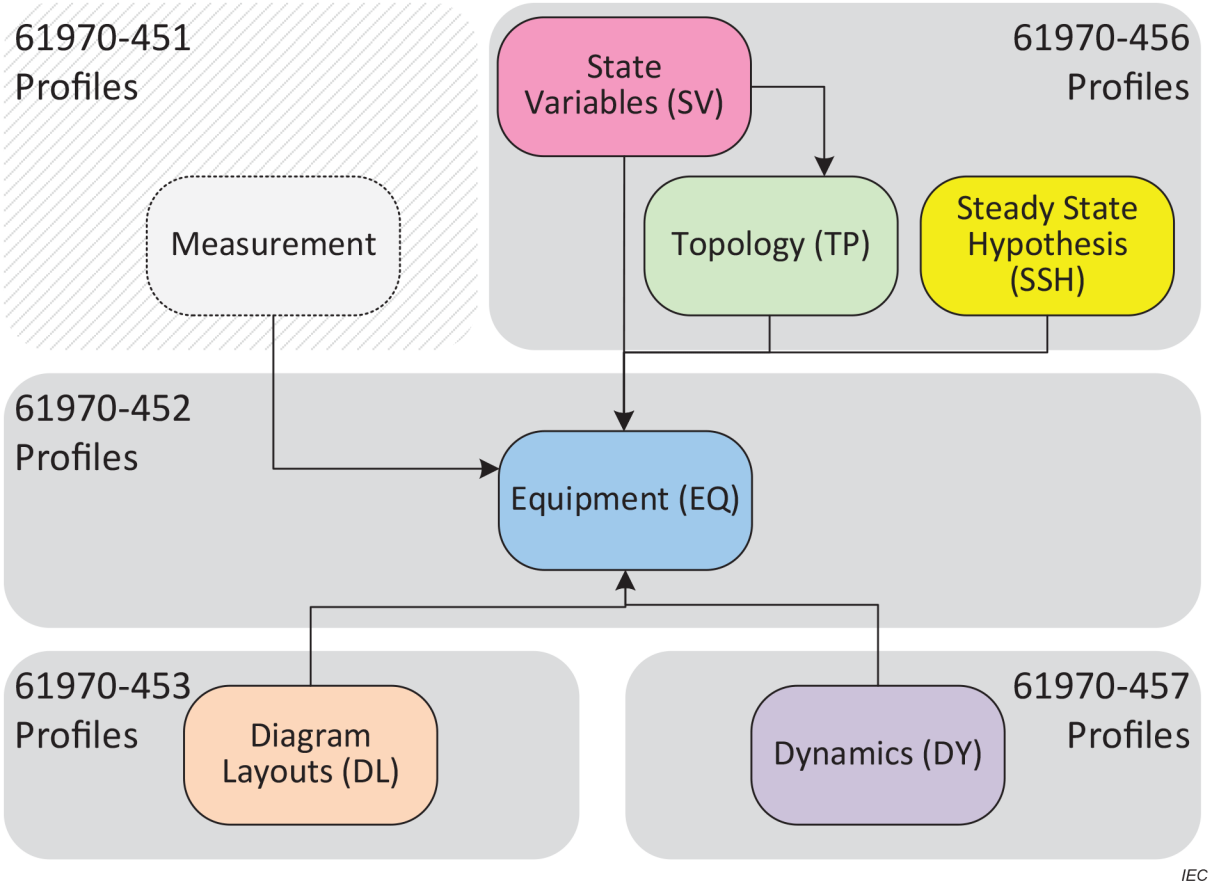



**Figure 4 – Profile relationships**

## 8 Detailed profile specification

### 8.1 General

This clause contains the detailed specification for the dynamics profile.

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## 8.2 Package DynamicsProfile

### 8.2.1 General

This is the IEC 61970-457 profile.

### 8.2.2 (abstract) DynamicsProfileVersion root class

Version details.

Table 1 shows all attributes of DynamicsProfileVersion.

**Table 1 – Attributes of DynamicsProfile::DynamicsProfileVersion**

| name | mult | type | description |
|---|---|---|---|
| baseUML | 1..1 | String | (const=iec61970cim17v38_iec61968cim13v12_iec62325cim03v17a) Base UML provided by CIM model manager. |
| baseURI | 1..1 | String | (const=http://iec.ch/TC57/CIM/Dynamics/1/0) Profile URI used in the Model Exchange header and defined in IEC standards. It uniquely identifies the Profile and its version. The last two elements in the URI (e.g. http://iec.ch/TC57/61970-452/CoreEquipment/yy/zzz) indicate major and minor versions where:<br>– yy – indicates a major version;<br>– zzz – indicates a minor version. |
| date | 1..1 | Date | (const=2020-05-14) Profile creation date. The form is YYYY-MM-DD. For example, for 5 January 2009 it is 2009-01-05. |
| differenceModelURI | 1..1 | String | (const=http://iec.ch/TC57/61970-552/DifferenceModel/1#) Difference model URI defined by IEC 61970-552. |
| profileUML | 1..1 | String | (const=FDIS09-iec61970-600-CGMES-v3_0_0) UML which contains the profile. |
| modelDescriptionURI | 1..1 | String | (const=http://iec.ch/TC57/61970-552/ModelDescription/1#) Model Description URI defined by IEC 61970-552. |
| namespaceRDF | 1..1 | String | (const=http://www.w3.org/1999/02/22-rdf-syntax-ns#) RDF namespace. |
| namespaceUML | 1..1 | String | (const=http://iec.ch/TC57/CIM100#) CIM UML namespace. |
| shortName | 1..1 | String | (const=DY) The short name of the profile used in profile documentation. |

### 8.2.3 Package Base

#### 8.2.3.1 General

Content of the base CIM published as IEC 61970-301.

#### 8.2.3.2 Package Domain

##### 8.2.3.2.1 General

The domain package defines primitive datatypes that are used by classes in other packages. Stereotypes are used to describe the datatypes. The following stereotypes are defined:

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– <<enumeration>> A list of permissible constant values.

– <<Primitive>> The most basic data types used to compose all other data types.

– <<CIMDatatype>> A datatype that contains a value attribute, an optional unit of measure and a unit multiplier. The unit and multiplier may be specified as a static variable initialized to the allowed value.

– <<Compound>> A composite of Primitive, enumeration, CIMDatatype or other Compound classes, as long as the Compound classes do not recurse.

For all datatypes both positive and negative values are allowed unless stated otherwise for a particular datatype.

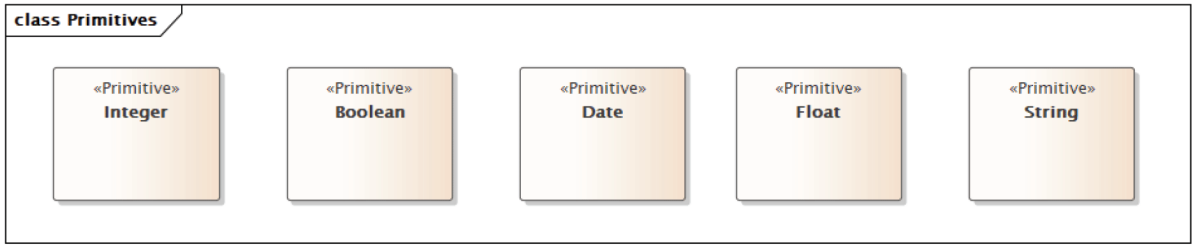



**Figure 5 – Class diagram Domain::Primitives**

Figure 5: This diagram lists the primitives defined in the CIM and used in this document.

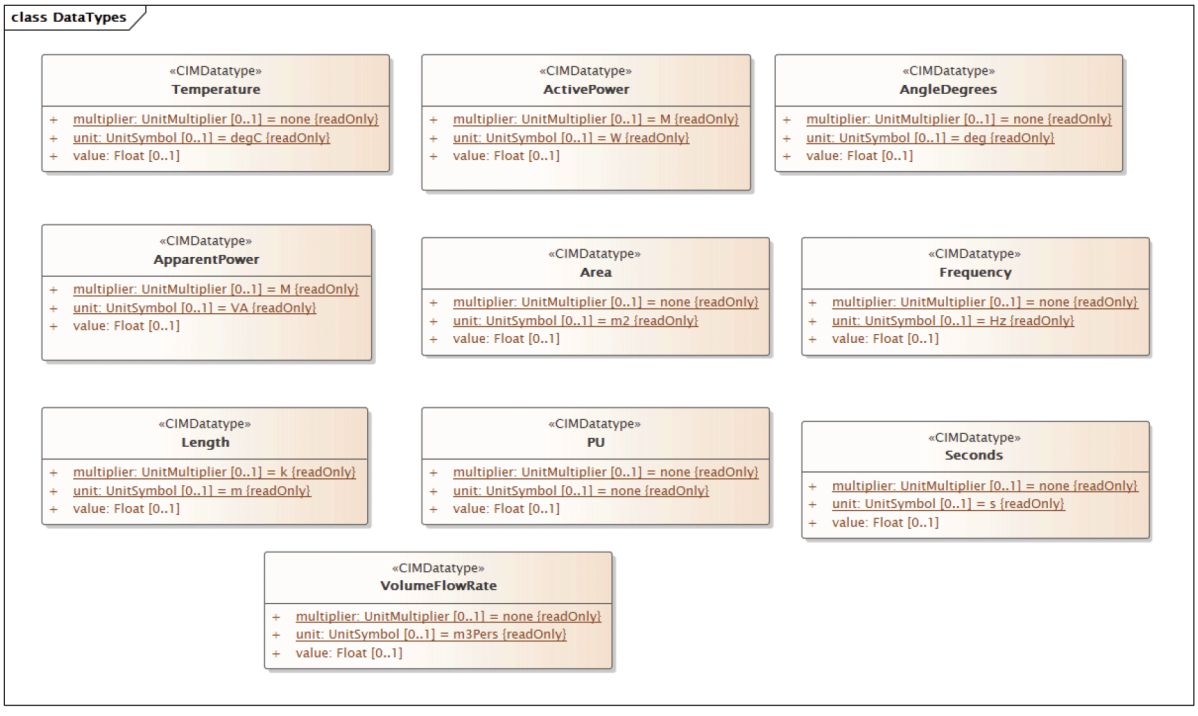



**Figure 6 – Class diagram Domain::DataTypes**

Figure 6: This diagram illustrates the data types supported by the CIM and used in this document.

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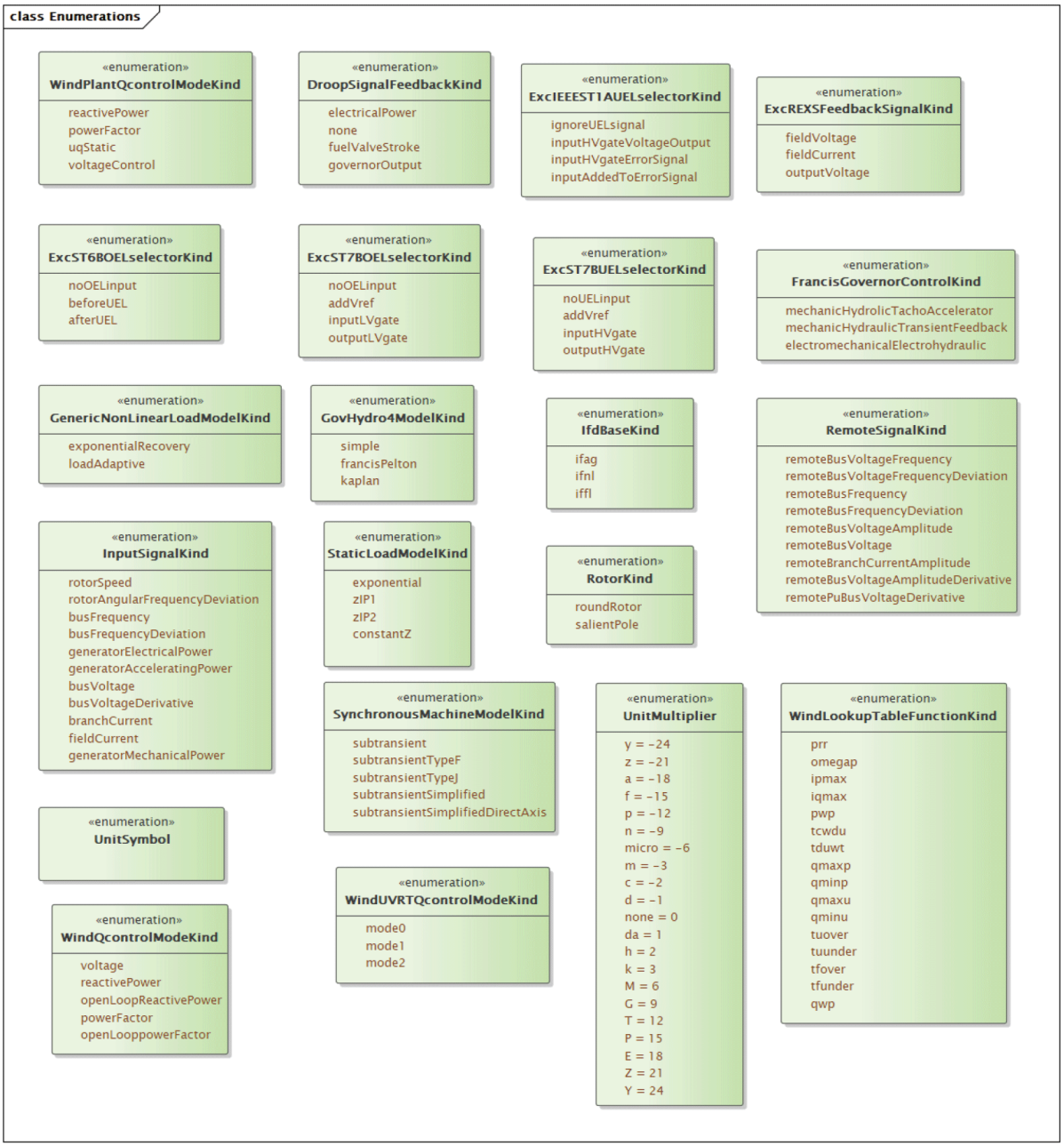



**Figure 7 – Class diagram Domain::Enumerations**

Figure 7: This diagram provides information on the enumerations defined in the CIM and used in this document.

#### 8.2.3.2.2 ActivePower datatype

Product of RMS value of the voltage and the RMS value of the in-phase component of the current.

Table 2 shows all attributes of ActivePower.

**Table 2 – Attributes of Domain::ActivePower**

| name | mult | type | description |
|---|---|---|---|
| value | 0..1 | Float | |

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| name | mult | type | description |
|---|---|---|---|
| multiplier | 0..1 | UnitMultiplier | (const=M) |
| unit | 0..1 | UnitSymbol | (const=W) |

#### 8.2.3.2.3 AngleDegrees datatype

Measurement of angle in degrees.

Table 3 shows all attributes of AngleDegrees.

**Table 3 – Attributes of Domain::AngleDegrees**

| name | mult | type | description |
|---|---|---|---|
| value | 0..1 | Float | |
| unit | 0..1 | UnitSymbol | (const=deg) |
| multiplier | 0..1 | UnitMultiplier | (const=none) |

#### 8.2.3.2.4 ApparentPower datatype

Product of the RMS value of the voltage and the RMS value of the current.

Table 4 shows all attributes of ApparentPower.

**Table 4 – Attributes of Domain::ApparentPower**

| name | mult | type | description |
|---|---|---|---|
| value | 0..1 | Float | |
| multiplier | 0..1 | UnitMultiplier | (const=M) |
| unit | 0..1 | UnitSymbol | (const=VA) |

#### 8.2.3.2.5 Area datatype

Area.

Table 5 shows all attributes of Area.

**Table 5 – Attributes of Domain::Area**

| name | mult | type | description |
|---|---|---|---|
| value | 0..1 | Float | |
| unit | 0..1 | UnitSymbol | (const=m2) |
| multiplier | 0..1 | UnitMultiplier | (const=none) |

#### 8.2.3.2.6 Frequency datatype

Cycles per second.

Table 6 shows all attributes of Frequency.

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**Table 6 – Attributes of Domain::Frequency**

| name | mult | type | description |
|---|---|---|---|
| value | 0..1 | Float | |
| unit | 0..1 | UnitSymbol | (const=Hz) |
| multiplier | 0..1 | UnitMultiplier | (const=none) |

#### 8.2.3.2.7 Length datatype

Unit of length. It shall be a positive value or zero.

Table 7 shows all attributes of Length.

**Table 7 – Attributes of Domain::Length**

| name | mult | type | description |
|---|---|---|---|
| value | 0..1 | Float | |
| unit | 0..1 | UnitSymbol | (const=m) |
| multiplier | 0..1 | UnitMultiplier | (const=k) |

#### 8.2.3.2.8 PU datatype

Per Unit – a positive or negative value referred to a defined base. Values typically range from -10 to +10.

Table 8 shows all attributes of PU.

**Table 8 – Attributes of Domain::PU**

| name | mult | type | description |
|---|---|---|---|
| value | 0..1 | Float | |
| unit | 0..1 | UnitSymbol | (const=none) |
| multiplier | 0..1 | UnitMultiplier | (const=none) |

#### 8.2.3.2.9 Seconds datatype

Time, in seconds.

Table 9 shows all attributes of Seconds.

**Table 9 – Attributes of Domain::Seconds**

| name | mult | type | description |
|---|---|---|---|
| value | 0..1 | Float | Time, in seconds |
| unit | 0..1 | UnitSymbol | (const=s) |
| multiplier | 0..1 | UnitMultiplier | (const=none) |

#### 8.2.3.2.10 Temperature datatype

Value of temperature in degrees Celsius.

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Table 10 shows all attributes of Temperature.

**Table 10 – Attributes of Domain::Temperature**

| name | mult | type | description |
|---|---|---|---|
| multiplier | 0..1 | UnitMultiplier | (const=none) |
| unit | 0..1 | UnitSymbol | (const=degC) |
| value | 0..1 | Float | |

#### 8.2.3.2.11 VolumeFlowRate datatype

Volume per time.

Table 11 shows all attributes of VolumeFlowRate.

**Table 11 – Attributes of Domain::VolumeFlowRate**

| name | mult | type | description |
|---|---|---|---|
| multiplier | 0..1 | UnitMultiplier | (const=none) |
| unit | 0..1 | UnitSymbol | (const=m3Pers) |
| value | 0..1 | Float | |

#### 8.2.3.2.12 Boolean primitive

A type with the value space "true" and "false".

#### 8.2.3.2.13 Float primitive

A floating point number. The range is unspecified and not limited.

#### 8.2.3.2.14 Date primitive

Date as "yyyy-mm-dd", which conforms with ISO 8601. UTC time zone is specified as "yyyy-mm-ddZ". A local timezone relative UTC is specified as "yyyy-mm-dd(+/-)hh:mm".

#### 8.2.3.2.15 Integer primitive

An integer number. The range is unspecified and not limited.

#### 8.2.3.2.16 String primitive

A string consisting of a sequence of characters. The character encoding is UTF-8. The string length is unspecified and unlimited.

#### 8.2.3.2.17 DroopSignalFeedbackKind enumeration

Governor droop signal feedback source.

Table 12 shows all literals of DroopSignalFeedbackKind.

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**Table 12 – Literals of Domain::DroopSignalFeedbackKind**

| literal | value | description |
|---|---|---|
| electricalPower | | Electrical power feedback (connection indicated as 1 in the block diagrams of models, e.g. GovCT1, GovCT2). |
| none | | No droop signal feedback, is isochronous governor. |
| fuelValveStroke | | Fuel valve stroke feedback (true stroke) (connection indicated as 2 in the block diagrams of model, e.g. GovCT1, GovCT2). |
| governorOutput | | Governor output feedback (requested stroke) (connection indicated as 3 in the block diagrams of models, e.g. GovCT1, GovCT2). |

#### 8.2.3.2.18 ExcIEEEST1AUELselectorKind enumeration

Types of connections for the UEL input used in ExcIEEEST1A.

Table 13 shows all literals of ExcIEEEST1AUELselectorKind.

**Table 13 – Literals of Domain::ExcIEEEST1AUELselectorKind**

| literal | value | description |
|---|---|---|
| ignoreUELsignal | | Ignore UEL signal. |
| inputHVgateVoltageOutput | | UEL input HV gate with voltage regulator output. |
| inputHVgateErrorSignal | | UEL input HV gate with error signal. |
| inputAddedToErrorSignal | | UEL input added to error signal. |

#### 8.2.3.2.19 ExcREXSFeedbackSignalKind enumeration

Types of rate feedback signals.

Table 14 shows all literals of ExcREXSFeedbackSignalKind.

**Table 14 – Literals of Domain::ExcREXSFeedbackSignalKind**

| literal | value | description |
|---|---|---|
| fieldVoltage | | The voltage regulator output voltage is used. It is the same as exciter field voltage. |
| fieldCurrent | | The exciter field current is used. |
| outputVoltage | | The output voltage of the exciter is used. |

#### 8.2.3.2.20 ExcST6BOELselectorKind enumeration

Types of connections for the OEL input used for static excitation systems type 6B.

Table 15 shows all literals of ExcST6BOELselectorKind.

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**Table 15 – Literals of Domain::ExcST6BOELselectorKind**

| literal | value | description |
|---|---|---|
| noOELinput | | No OEL input is used. Corresponds to OELin not = 1 and not = 2 on the ExcST6B diagram. Original ExcST6B model would have called this OELin = 0. |
| beforeUEL | | The connection is before UEL. Corresponds to OELin = 1 on the ExcST6B diagram. |
| afterUEL | | The connection is after UEL. Corresponds to OELin = 2 on the ExcST6B diagram. |

#### 8.2.3.2.21 ExcST7BOELselectorKind enumeration

Types of connections for the OEL input used for static excitation systems type 7B.

Table 16 shows all literals of ExcST7BOELselectorKind.

**Table 16 – Literals of Domain::ExcST7BOELselectorKind**

| literal | value | description |
|---|---|---|
| noOELinput | | No OEL input is used. Corresponds to OELin not = 1 and not = 2 and not = 3 on the ExcST7B diagram. Original ExcST7B model would have called this OELin = 0. |
| addVref | | The signal is added to Vref. Corresponds to OELin = 1 on the ExcST7B diagram. |
| inputLVgate | | The signal is connected into the input LVGate. Corresponds to OELin = 2 on the ExcST7B diagram. |
| outputLVgate | | The signal is connected into the output LVGate. Corresponds to OELin = 3 on the ExcST7B diagram. |

#### 8.2.3.2.22 ExcST7BUELselectorKind enumeration

Types of connections for the UEL input used for static excitation systems type 7B.

Table 17 shows all literals of ExcST7BUELselectorKind.

**Table 17 – Literals of Domain::ExcST7BUELselectorKind**

| literal | value | description |
|---|---|---|
| noUELinput | | No UEL input is used. Corresponds to UELin not = 1 and not = 2 and not = 3 on the ExcST7B diagram. Original ExcST7B model would have called this UELin = 0. |
| addVref | | The signal is added to Vref. Corresponds to UELin = 1 on the ExcST7B diagram. |
| inputHVgate | | The signal is connected into the input HVGate. Corresponds to UELin = 2 on the ExcST7B diagram. |
| outputHVgate | | The signal is connected into the output HVGate. Corresponds to UELin = 3 on the ExcST7B diagram. |

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#### 8.2.3.2.23 FrancisGovernorControlKind enumeration

Governor control flag for Francis hydro model.

Table 18 shows all literals of FrancisGovernorControlKind.

**Table 18 – Literals of Domain::FrancisGovernorControlKind**

| literal | value | description |
|---|---|---|
| mechanicHydrolicTachoAccelerator | | Mechanic-hydraulic regulator with tacho-accelerometer (Cflag = 1). |
| mechanicHydraulicTransientFeedback | | Mechanic-hydraulic regulator with transient feedback (Cflag=2). |
| electromechanicalElectrohydraulic | | Electromechanical and electrohydraulic regulator (Cflag=3). |

#### 8.2.3.2.24 GenericNonLinearLoadModelKind enumeration

Type of generic non-linear load model.

Table 19 shows all literals of GenericNonLinearLoadModelKind.

**Table 19 – Literals of Domain::GenericNonLinearLoadModelKind**

| literal | value | description |
|---|---|---|
| exponentialRecovery | | Exponential recovery model. |
| loadAdaptive | | Load adaptive model. |

#### 8.2.3.2.25 GovHydro4ModelKind enumeration

Possible types of GovHydro4 models.

Table 20 shows all literals of GovHydro4ModelKind.

**Table 20 – Literals of Domain::GovHydro4ModelKind**

| literal | value | description |
|---|---|---|
| simple | | Simple model. |
| francisPelton | | Francis or Pelton model. |
| kaplan | | Kaplan model. |

#### 8.2.3.2.26 IfdBaseKind enumeration

Excitation base system mode.

Table 21 shows all literals of IfdBaseKind.

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**Table 21 – Literals of Domain::IfdBaseKind**

| literal | value | description |
|---|---|---|
| ifag | | Air gap line mode. |
| ifnl | | No load system with saturation mode. |
| iffl | | Full load system mode. |

#### 8.2.3.2.27 InputSignalKind enumeration

Types of input signals. In dynamics modelling, commonly represented by the j parameter.

Table 22 shows all literals of InputSignalKind.

**Table 22 – Literals of Domain::InputSignalKind**

| literal | value | description |
|---|---|---|
| rotorSpeed | | Input signal is rotor or shaft speed (angular frequency). |
| rotorAngularFrequencyDeviation | | Input signal is rotor or shaft angular frequency deviation. |
| busFrequency | | Input signal is bus voltage frequency. This could be a terminal frequency or remote frequency. |
| busFrequencyDeviation | | Input signal is deviation of bus voltage frequency. This could be a terminal frequency deviation or remote frequency deviation. |
| generatorElectricalPower | | Input signal is generator electrical power on rated S. |
| generatorAcceleratingPower | | Input signal is generator accelerating power. |
| busVoltage | | Input signal is bus voltage. This could be a terminal voltage or remote voltage. |
| busVoltageDerivative | | Input signal is derivative of bus voltage. This could be a terminal voltage derivative or remote voltage derivative. |
| branchCurrent | | Input signal is amplitude of remote branch current. |
| fieldCurrent | | Input signal is generator field current. |
| generatorMechanicalPower | | Input signal is generator mechanical power. |

#### 8.2.3.2.28 RemoteSignalKind enumeration

Type of input signal coming from remote bus.

Table 23 shows all literals of RemoteSignalKind.

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**Table 23 – Literals of Domain::RemoteSignalKind**

| literal | value | description |
|---|---|---|
| remoteBusVoltageFrequency | | Input is voltage frequency from remote terminal bus. |
| remoteBusVoltageFrequencyDeviation | | Input is voltage frequency deviation from remote terminal bus. |
| remoteBusFrequency | | Input is frequency from remote terminal bus. |
| remoteBusFrequencyDeviation | | Input is frequency deviation from remote terminal bus. |
| remoteBusVoltageAmplitude | | Input is voltage amplitude from remote terminal bus. |
| remoteBusVoltage | | Input is voltage from remote terminal bus. |
| remoteBranchCurrentAmplitude | | Input is branch current amplitude from remote terminal bus. |
| remoteBusVoltageAmplitudeDerivative | | Input is branch current amplitude derivative from remote terminal bus. |
| remotePuBusVoltageDerivative | | Input is PU voltage derivative from remote terminal bus. |

#### 8.2.3.2.29 RotorKind enumeration

Type of rotor on physical machine.

Table 24 shows all literals of RotorKind.

**Table 24 – Literals of Domain::RotorKind**

| literal | value | description |
|---|---|---|
| roundRotor | | Round rotor type of synchronous machine. |
| salientPole | | Salient pole type of synchronous machine. |

#### 8.2.3.2.30 StaticLoadModelKind enumeration

Type of static load model.

Table 25 shows all literals of StaticLoadModelKind.

**Table 25 – Literals of Domain::StaticLoadModelKind**

| literal | value | description |
|---|---|---|
| exponential | | This model is an exponential representation of the load. Exponential equations for active and reactive power are used and the following attributes are required:<br>kp1, kp2, kp3, kpf, ep1, ep2, ep3<br>kq1, kq2, kq3, kqf, eq1, eq2, eq3. |
| zIP1 | | This model integrates the frequency-dependent load (primarily motors). ZIP1 equations for active and reactive power are used and the following attributes are required:<br>kp1, kp2, kp3, kpf<br>kq1, kq2, kq3, kqf. |

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| literal | value | description |
|---|---|---|
| zIP2 | | This model separates the frequency-dependent load (primarily motors) from other load. ZIP2 equations for active and reactive power are used and the following attributes are required:<br>kp1, kp2, kp3, kq4, kpf<br>kq1, kq2, kq3, kq4, kqf. |
| constantZ | | The load is represented as a constant impedance. ConstantZ equations are used for active and reactive power and no attributes are required. |

#### 8.2.3.2.31 SynchronousMachineModelKind enumeration

Type of synchronous machine model used in dynamic simulation applications.

Table 26 shows all literals of SynchronousMachineModelKind.

**Table 26 – Literals of Domain::SynchronousMachineModelKind**

| literal | value | description |
|---|---|---|
| subtransient | | Subtransient synchronous machine model. |
| subtransientTypeF | | WECC type F variant of subtransient synchronous machine model. |
| subtransientTypeJ | | WECC type J variant of subtransient synchronous machine model. |
| subtransientSimplified | | Simplified version of subtransient synchronous machine model where magnetic coupling between the direct- and quadrature- axes is ignored. |
| subtransientSimplifiedDirectAxis | | Simplified version of a subtransient synchronous machine model with no damper circuit on the direct-axis. |

#### 8.2.3.2.32 UnitMultiplier enumeration

The unit multipliers defined for the CIM. When applied to unit symbols, the unit symbol is treated as a derived unit. Regardless of the contents of the unit symbol text, the unit symbol shall be treated as if it were a single-character unit symbol. Unit symbols should not contain multipliers, and it should be left to the multiplier to define the multiple for an entire data type.

For example, if a unit symbol is "m2Pers" and the multiplier is "k", then the value is k(m**2/s), and the multiplier applies to the entire final value, not to any individual part of the value. This can be conceptualized by substituting a derived unit symbol for the unit type. If one imagines that the symbol "Þ" represents the derived unit "m2Pers", then applying the multiplier "k" can be conceptualized simply as "kÞ".

For example, the SI unit for mass is "kg" and not "g". If the unit symbol is defined as "kg", then the multiplier is applied to "kg" as a whole and does not replace the "k" in front of the "g". In this case, the multiplier of "m" would be used with the unit symbol of "kg" to represent one gram. As a text string, this violates the instructions in IEC 80000-1. However, because the unit symbol in CIM is treated as a derived unit instead of as an SI unit, it makes more sense to conceptualize the "kg" as if it were replaced by one of the proposed replacements for the SI mass symbol. If one imagines that the "kg" were replaced by a symbol "Þ", then it is easier to conceptualize the multiplier "m" as creating the proper unit "mÞ", and not the forbidden unit "mkg".

Table 27 shows all literals of UnitMultiplier.

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**Table 27 – Literals of Domain::UnitMultiplier**

| literal | value | description |
|---|---|---|
| y | -24 | Yocto 10**-24. |
| z | -21 | Zepto 10**-21. |
| a | -18 | Atto 10**-18. |
| f | -15 | Femto 10**-15. |
| p | -12 | Pico 10**-12. |
| n | -9 | Nano 10**-9. |
| micro | -6 | Micro 10**-6. |
| m | -3 | Milli 10**-3. |
| c | -2 | Centi 10**-2. |
| d | -1 | Deci 10**-1. |
| none | 0 | No multiplier or equivalently multiply by 1. |
| da | 1 | Deca 10**1. |
| h | 2 | Hecto 10**2. |
| k | 3 | Kilo 10**3. |
| M | 6 | Mega 10**6. |
| G | 9 | Giga 10**9. |
| T | 12 | Tera 10**12. |
| P | 15 | Peta 10**15. |
| E | 18 | Exa 10**18. |
| Z | 21 | Zetta 10**21. |
| Y | 24 | Yotta 10**24. |

#### 8.2.3.2.33 UnitSymbol enumeration

The derived units defined for usage in the CIM. In some cases, the derived unit is equal to an SI unit. Whenever possible, the standard derived symbol is used instead of the formula for the derived unit. For example, the unit symbol Farad is defined as "F" instead of "CPerV". In cases where a standard symbol does not exist for a derived unit, the formula for the unit is used as the unit symbol. For example, density does not have a standard symbol and so it is represented as "kgPerm3". With the exception of the "kg", which is an SI unit, the unit symbols do not contain multipliers and therefore represent the base derived unit to which a multiplier can be applied as a whole.

Every unit symbol is treated as an unparseable text as if it were a single-letter symbol. The meaning of each unit symbol is defined by the accompanying descriptive text and not by the text contents of the unit symbol.

To allow the widest possible range of serializations without requiring special character handling, several substitutions are made which deviate from the format described in IEC 80000-1. The division symbol "/" is replaced by the letters "Per". Exponents are written in plain text after the unit as "m3" instead of being formatted as "m" with a superscript of 3 or introducing a symbol as in "m^3". The degree symbol "°" is replaced with the letters "deg". Any clarification of the meaning for a substitution is included in the description for the unit symbol.

Non-SI units are included in list of unit symbols to allow sources of data to be correctly labelled with their non-SI units (for example, a GPS sensor that is reporting numbers that represent feet instead of meters). This allows software to use the unit symbol information correctly convert and scale the raw data of those sources into SI-based units.

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The integer values are used for harmonization with IEC 61850.

Table 28 shows all literals of UnitSymbol.

**Table 28 – Literals of Domain::UnitSymbol**

| literal | value | description |
|---|---|---|
| none | 0 | Dimension less quantity, e.g. count, per unit, etc. |
| m | 2 | Length in metres. |
| kg | 3 | Mass in kilograms. Note: multiplier “k” is included in this unit symbol for compatibility with IEC 61850-7-3. |
| s | 4 | Time in seconds. |
| A | 5 | Current in amperes. |
| K | 6 | Temperature in kelvins. |
| mol | 7 | Amount of substance in moles. |
| cd | 8 | Luminous intensity in candelas. |
| deg | 9 | Plane angle in degrees. |
| rad | 10 | Plane angle in radians (m/m). |
| sr | 11 | Solid angle in steradians (m2/m2). |
| Gy | 21 | Absorbed dose in grays (J/kg). |
| Bq | 22 | Radioactivity in becquerels (1/s). |
| degC | 23 | Relative temperature in degrees Celsius.<br>In the SI unit system the symbol is °C. Electric charge is measured in coulomb that has the unit symbol C. To distinguish degree Celsius from coulomb the symbol used in the UML is degC. The reason for not using °C is that the special character ° is difficult to manage in software. |
| Sv | 24 | Dose equivalent in sieverts (J/kg). |
| F | 25 | Electric capacitance in farads (C/V). |
| C | 26 | Electric charge in coulombs (A·s). |
| S | 27 | Conductance in siemens. |
| H | 28 | Electric inductance in henrys (Wb/A). |
| V | 29 | Electric potential in volts (W/A). |
| ohm | 30 | Electric resistance in ohms (V/A). |
| J | 31 | Energy in joules (N·m = C·V = W·s). |
| N | 32 | Force in newtons (kg·m/s$^2$). |
| Hz | 33 | Frequency in hertz (1/s). |
| lx | 34 | Illuminance in lux (lm/m$^2$). |
| lm | 35 | Luminous flux in lumens (cd·sr). |
| Wb | 36 | Magnetic flux in webers (V·s). |
| T | 37 | Magnetic flux density in teslas (Wb/m2). |
| W | 38 | Real power in watts (J/s). Electrical power may have real and reactive components. The real portion of electrical power (I$^2$R or VIcos(phi)), is expressed in Watts. See also apparent power and reactive power. |
| Pa | 39 | Pressure in pascals (N/m$^2$). Note: the absolute or relative measurement of pressure is implied with this entry. See below for more explicit forms. |

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