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Ersatz für
DIN EN 61970-452:2019-09
Siehe Anwendungsbeginn

**Schnittstelle für Anwendungsprogramme für Netzführungssysteme
(EMS-API) –****Teil 452: CIM-Statistische-Übertragungsnetzwerk-Modell-Profile
(IEC 61970-452:2021);****Englische Fassung EN IEC 61970-452:2021**

Energy management system application program interface (EMS-API) –

Part 452: CIM static transmission network model profiles

(IEC 61970-452:2021);

English version EN IEC 61970-452:2021

Interface de programmation d'application pour système de gestion d'énergie (EMS-API) –

Partie 452: Profils du modèle de réseau de transport statique CIM

(IEC 61970-452:2021);

Version anglaise EN IEC 61970-452:2021

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Anwendungsbeginn

Anwendungsbeginn für die von CENELEC am 2021-12-01 angenommene Europäische Norm als DIN-Norm ist 2024-03-01.

Für DIN EN 61970-452:2019-09 besteht eine Übergangsfrist bis 2024-12-01.

Nationales Vorwort

Vorausgegangener Norm-Entwurf: E DIN EN IEC 61970-452:2022-06.

Für dieses Dokument ist das nationale Arbeitsgremium DKE/K 952 „Netzleittechnik“ der DKE Deutsche Kommission Elektrotechnik Elektronik Informationstechnik in DIN und VDE (www.dke.de) zuständig.

Aktuelle Informationen zu diesem Dokument können über die Internetseiten von DKE (www.dke.de) und DIN (www.din.de) durch eine Suche nach der Dokumentennummer aufgerufen werden.

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Das Präsidium des DIN hat mit Präsidialbeschluss 1/2004 festgelegt, dass DIN-Normen, deren Inhalt sich auf internationale Arbeitsergebnisse der Informationsverarbeitung gründet, unter bestimmten Bedingungen allein in englischer Sprache veröffentlicht werden dürfen. Diese Bedingungen sind für die vorliegende Norm erfüllt.

Da sich die Benutzer der vorliegenden Norm der englischen Sprache als Fachsprache bedienen, wird die Englische Fassung der EN IEC 61970-452 veröffentlicht. Zu deren Einleitung und Abschnitt 1, der den Anwendungsbereich festlegt, und Abschnitt 3, der die Begriffe festlegt, wurde eine Übersetzung angefertigt und als informativer Nationaler Anhang NA der vorliegenden Norm hinzugefügt. Für die meisten der verwendeten Begriffe existieren keine gebräuchlichen deutschen Benennungen, da sich die deutschen Anwender in der Regel ebenfalls der englischen Benennungen bedienen. Diese Norm steht nicht in unmittelbarem Zusammenhang mit Rechtsvorschriften und ist nicht als Sicherheitsnorm anzusehen.

Das Original-Dokument enthält Bilder in Farbe, die in der Papierversion in einer Graustufen-Darstellung wiedergegeben werden. Elektronische Versionen dieses Dokuments enthalten die Bilder in der originalen Farbdarstellung.

Änderungen

Gegenüber DIN EN 61970-452:2019-09 wurden folgende Änderungen vorgenommen:

- a) die Klassen PowerElectronicsConnection, PowerElectronicsUnit und PowerElectronicsWindUnit werden zum Core Equipment-Profil hinzugefügt.

Frühere Ausgaben

DIN EN 61970-452: 2014-07, 2016-12, 2019-09

Nationaler Anhang NA (informativ)

Auszugsweise Übersetzung

Reihenfolge und Inhalt der folgenden Abschnitte sind identisch mit denen in den jeweiligen Abschnitten der Englischen Fassung.

EINLEITUNG

Dieser Teil von IEC 61970 gehört zur Reihe IEC 61970, die eine Anwendungsprogramm-Schnittstelle (API, en: application program interface) für ein Netzführungssystem (EMS, en: energy management system) definiert.

Die Reihe IEC 61970-300 legt ein allgemeines Informationsmodell (CIM, en: common information model) fest. Das CIM ist ein abstraktes Modell, das alle wichtigen Objekte in einem Energieversorgungsunternehmen darstellt, die in der Regel für die Betriebsaspekte einer Versorgungseinrichtung erforderlich sind. Es stellt die Semantik für die APIs aus IEC 61970 bereit, die in der Reihe IEC 61970-400 zu Komponenten-Schnittstellen-Normen (CIS, en: component interface standards) festgelegt sind. Die Reihe IEC 61970-300 enthält die Norm IEC 61970-301, *Allgemeines Informationsmodell (CIM) Basismodell* und den Norm-Entwurf IEC 61970-302, *Allgemeines Informationsmodell (CIM) Dynamik*.

Dieses Dokument gehört zur Reihe IEC 61970-400 mit Normen zu Komponenten-Schnittstellen, welche die funktionalen Anforderungen für Schnittstellen festlegen, die eine Komponente (oder Anwendung) bereitstellen muss, um Informationen mit anderen Komponenten (oder Anwendungen) austauschen und/oder mithilfe genormter Verfahren auf öffentlich zugängliche Daten zugreifen zu können. Die Komponenten-Schnittstellen beschreiben die spezifischen Nachrichteninhalte und -dienste, die von den Anwendungen zu diesem Zweck verwendet werden können. Die Implementierung dieser Nachrichten mithilfe einer bestimmten Technologie wird in der Reihe IEC 61970-500 beschrieben.

Dieses Dokument legt die spezifischen Profile (oder Teilmengen) des CIM fest, mit denen die statischen Daten aus Energieversorgungssystemen zwischen Versorgern, Sicherheitskoordinatoren und anderen Institutionen ausgetauscht werden, die an einem vernetzten Energiesystem beteiligt sind. Damit sollen alle Parteien Zugang zur Modellierung ihrer benachbarten Systeme erhalten, was zur Durchführung von Zustandsschätzungen oder Lastflussanwendungen erforderlich ist. Bisher wurden drei Profile definiert: „CoreEquipment“, „Operation“ und „ShortCircuit“. Die anwendungsbezogene Norm IEC 61970-552 legt das Austauschformat des CIM-XML-Modells auf der Grundlage der Schemafestlegungssprache des Ressourcen-Beschreibungssystems (RDF, en: resource description framework) fest. IEC 61970-552 ist der allgemeine Industrieansatz, dessen Verwendung bei der Übertragung von Modelldaten für Energieversorgungssysteme im Zusammenhang mit dem Profil aus IEC 61970-452 empfohlen wird.

1 Anwendungsbereich

Dieses Dokument gehört zu der Reihe IEC 61970-450 bis 499, welche auf einer abstrakten Ebene den Inhalt und die Austauschmechanismen derjenigen Daten definiert, die zwischen Netzleitstellen und/oder Teilen einer Netzleitstelle, wie beispielsweise Anwendungen von Energieversorgungssystemen, übertragen werden.

Ziel dieses Dokuments ist die Definition einer Teilmenge von Klassen, Klassenattributen und Assoziationen aus dem CIM, welche für die Ausführung von Zustandsschätzungen und Lastflussanwendungen benötigt werden. Die Data Exchange Working Group (DEWG) Common Power System Modeling group (CPSM) des North American Electric Reliability Council (NERC) hat die ursprünglichen Datenanforderungen erstellt; diese sind in Anhang F dargestellt. Diese Anforderungen beruhen auf bisherigen Vorgehensweisen der Industrie beim Austausch von Daten aus Energieversorgungsmodellen, die in erster Linie in Planungsstudien verwendet werden. Die Liste der erforderlichen Daten wurde jedoch gegenüber der ersten Ausgabe dieser Norm erweitert, um einen Austausch von Modellen zu erleichtern, der auch solche Parameter umfasst, die für Leistungsschalter-bezogene Anwendungen üblich sind. Wo nötig, erstellt dieses Dokument Grundsätze (dargestellt in Abschnitt 6), mit denen eine XML-Datei übereinstimmen muss, um als gültig für den Austausch von Modellen zu gelten.

Die Anwendungsfälle für den Datenaustausch, die dieser Standard unterstützen soll, sind in Anhang A beschrieben. Die Idee einer Modellierungs-Dienststelle (en: modelling authority) als die für die Modellierung einer bestimmten Region zuständige Quelle wird in Anhang B beschrieben. Das Konzept einer Grenze zwischen Regionen wird in Anhang C erläutert. In Anhang D wird die Verarbeitung mehrerer Profile, wie die drei in dieser Norm beschriebenen Profile, erläutert. Die Verwendung verschiedener Kurvenstile zur Definition von ReactiveCapabilityCurve-s wird in Anhang E erläutert.

Dieses Dokument richtet sich an zwei bestimmte Zielgruppen, Datenproduzenten und Datenempfänger, und kann daher aus zwei Blickwinkeln gelesen werden.

Aus Sicht der von dem Datenproduzenten verwendeten Software für den Modellexport beschreibt dieses Dokument eine Mindest-Teilmenge an CIM-Klassen, -Attributen und -Assoziationen, die in einer XML-formatierten Datei für den Austausch von Modellen vorhanden sein müssen. Dieses Dokument schreibt jedoch nicht vor, wie das Netzwerk zu modellieren ist. Es gibt lediglich vor, welche Klassen, Attribute und Assoziationen für die Beschreibung des bestehenden Quellenmodells zu verwenden sind.

3 Begriffe

In diesem Dokument werden keine Begriffe aufgeführt.

ISO und IEC stellen terminologische Datenbanken für die Verwendung in der Normung unter den folgenden Adressen bereit:

- IEC Electropedia: verfügbar unter <http://www.electropedia.org/>
- ISO Online Browsing Platform: verfügbar unter <http://www.iso.org/obp>

– Leerseite –

EUROPEAN STANDARD

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English version

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

Interface de programmation d'application pour système
de gestion d'énergie (EMS-API) – Partie 452: Profils
du modèle de réseau de transport statique CIM
(IEC 61970-452:2021)

Schnittstelle für Anwendungsprogramme für
Netzführungssysteme (EMS-API) – Teil 452: CIM-
Statische-Übertragungsnetzwerk-Modell-Profil
(IEC 61970-452:2021)

This European Standard was approved by CENELEC on 2021-12-01. CENELEC members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration.

Up-to-date lists and bibliographical references concerning such national standards may be obtained on application to the CEN-CENELEC Management Centre or to any CENELEC member.

This European Standard exists in three official versions (English, French, German). A version in any other language made by translation under the responsibility of a CENELEC member into its own language and notified to the CEN-CENELEC Management Centre has the same status as the official versions.

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European Committee for Electrotechnical Standardization
Comité Européen de Normalisation Electrotechnique
Europäisches Komitee für Elektrotechnische Normung

CEN-CENELEC Management Centre: Rue de la Science 23, B-1040 Brüssel

European Foreword

The text of document 57/2400/FDIS, future edition 4 of IEC 61970-452, prepared by IEC/TC 57 “Power systems management and associated information exchange” was submitted to the IEC-CENELEC parallel vote and approved by CENELEC as EN IEC 61970-452:2021.

The following dates are fixed:

- latest date by which the document has to be implemented at national level by publication of an identical national standard or by endorsement (dop): 2022-09-01
- latest date by which the national standards conflicting with the document have to be withdrawn (dow): 2024-12-01

This document supersedes EN 61970-452:2017 and all of its amendments and corrigenda (if any).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CENELEC shall not be held responsible for identifying any or all such patent rights.

Any feedback and questions on this document should be directed to the users’ national committee. A complete listing of these bodies can be found on the CENELEC website.

Endorsement notice

The text of the International Standard IEC 61970-452:2021 was approved by CENELEC as a European Standard without any modification.

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

IEC 61968-13	NOTE	Harmonized as EN IEC 61968-13
IEC 61970-1	NOTE	Harmonized as EN 61970-1
IEC/TS 61970-2	NOTE	Harmonized as CLC/TS 61970-2
IEC 61970-456	NOTE	Harmonized as EN IEC 61970-456
IEC 61970-501	NOTE	Harmonized as EN 61970-501
IEC 61970-552	NOTE	Harmonized as EN 61970-552

Annex ZA (normative)

Normative references to international publications with their corresponding European publications

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

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

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

<u>Publication</u>	<u>Year</u>	<u>Title</u>	<u>EN/HD</u>	<u>Year</u>
IEC 61970-301	2020	Energy management system application program interface (EMS-API) - Part 301: Common information model (CIM) base	EN IEC 61970-301	2020

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INTRODUCTION

This part of IEC 61970 is part of the IEC 61970 series that define an application program interface (API) for an energy management system (EMS).

The IEC 61970-300 series specifies a Common Information Model (CIM). The CIM is an abstract model that represents all of the major objects in an electric utility enterprise typically needed to model the operational aspects of a utility. It provides the semantics for the IEC 61970 APIs specified in the IEC 61970-400 series of Component Interface Standards (CIS). The IEC 61970-300 series includes IEC 61970-301, *Common Information Model (CIM) base* and draft standard IEC 61970-302, *Common Information Model (CIM) for Dynamics*.

This document is one of the IEC 61970-400 series of Component Interface Standards that specify the functional requirements for interfaces that a component (or application) shall implement to exchange information with other components (or applications) and/or to access publicly available data in a standard way. The component interfaces describe the specific message contents and services that can be used by applications for this purpose. The implementation of these messages in a particular technology is described in the IEC 61970-500 series.

This document specifies the specific profiles (or subsets) of the CIM for exchange of static power system data between utilities, security coordinators and other entities participating in an interconnected power system, such that all parties have access to the modelling of their neighbour's systems that is necessary to execute state estimation or power flow applications. Currently three profiles, the CoreEquipment Profile, the Operation Profile and the Short Circuit Profile, have been defined. A companion standard, IEC 61970-552, defines the CIM XML Model Exchange Format based on the Resource Description Framework (RDF) Schema specification language. IEC 61970-552 is the common industry approach and is recommended to be used to transfer power system model data for the IEC 61970-452 profile.

ENERGY MANAGEMENT SYSTEM APPLICATION PROGRAM INTERFACE (EMS-API) – Part 452: CIM static transmission network model profiles

1 Scope

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

The purpose of this document is to define the subset of classes, class attributes, and associations from the CIM necessary to execute state estimation and power flow applications. The North American Electric Reliability Council (NERC) Data Exchange Working Group (DEWG) Common Power System Modelling group (CPSM) produced the original data requirements, which are shown in Annex F. These requirements are based on prior industry practices for exchanging power system model data for use primarily in planning studies. However, the list of required data has been extended starting with the first edition of this standard to facilitate a model exchange that includes parameters common to breaker-oriented applications. Where necessary this document establishes conventions, shown in Clause 6, with which an XML data file must comply in order to be considered valid for exchange of models.

The data exchange use cases which this standard is meant to support are described in Annex A. The idea of a modelling authority as the source responsible for the modeling of a given region is described in Annex B. The concept of a boundary between regions is explained in Annex C. Annex D explains the processing of multiple profiles such as the three profiles described in this standard. The use of different curve styles to define ReactiveCapabilityCurve-s is explained in Annex E.

This document is intended for two distinct audiences, data producers and data recipients, and may be read from two perspectives.

From the standpoint of model export software used by a data producer, this document describes a minimum subset of CIM classes, attributes, and associations which must be present in an XML formatted data file for model exchange. This document does not dictate how the network is modelled, however. It only dictates what classes, attributes, and associations are to be used to describe the source model as it exists.

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.

NOTE For general glossary definitions, see IEC 60059, International Electrotechnical Vocabulary.

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

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 Application profile specification

4.1 General

An extensive discussion of the model exchange use cases can be found in Annex A. In all cases, the purposes of this document are:

- To improve the accuracy of power system models used in critical systems, particularly the representation of parts of the network outside the primary domain of the system in question.
- To achieve consistency among the models used by the various systems that play a role in operating or planning the interconnection.
- To reduce the overall cost of maintaining critical models used in operating or planning an interconnection.

The classes, attributes, and associations identified in IEC 61970-301 and specified in this document represent the minimum subset of the full CIM model necessary to exchange sufficient power system data to support state estimation and power flow for HV(high voltage) and MV (medium voltage) networks. IEC 61968-13 describes the profiles used to exchange distribution MV/LV (low voltage) network models.

4.2 Version information

4.2.1 Core equipment profile

- Title: Core Equipment Vocabulary
- Keyword: EQ
- Description: This vocabulary is describing the core equipment profile from IEC 61970-452.
- Version IRI: <http://iec.ch/TC57/ns/CIM/CoreEquipment/4.0>
- Version info: 4.0.0
- Prior version: <http://iec.ch/TC57/61970-452/CoreEquipment/3>
- Conforms to: urn:iso:std:iec:61970-452:ed-4|urn:iso:std:iec:61970-301:ed-7:amd1|file:///iec61970cim17v40_iec61968cim13v13a_iec62325cim03v17a.eap|urn:iso:std:iec:61970-401:draft:ed-1|urn:iso:std:iec:61970-501:draft:ed-2
- Identifier: urn:uuid:aa5a0075-82df-4e6a-8879-8e860deb4da9

4.2.2 Operation profile

- Title: Operation Vocabulary
- Keyword: OP
- Description: This vocabulary is describing the operation profile from IEC 61970-452.
- Version IRI: <http://iec.ch/TC57/ns/CIM/Operation/4.0>
- Version info: 4.0.0
- Prior version: <http://iec.ch/TC57/61970-452/Operation/3>
- Conforms to: urn:iso:std:iec:61970-452:ed-4|urn:iso:std:iec:61970-301:ed-7:amd1|file:///iec61970cim17v40_iec61968cim13v13a_iec62325cim03v17a.eap|urn:iso:std:iec:61970-401:draft:ed-1|urn:iso:std:iec:61970-501:draft:ed-2
- Identifier: urn:uuid:26cd507d-95c2-4003-95a8-6c148a8fcd71

4.2.3 Short-Circuit profile

- Title: Short Circuit Vocabulary
- Keyword: SC
- Description: This vocabulary is describing the short circuit profile from IEC 61970-452.
- Version IRI: <http://iec.ch/TC57/ns/CIM/ShortCircuit/4.0>
- Version info: 4.0.0
- Prior version: <http://iec.ch/TC57/61970-452/ShortCircuit/3>
- Conforms to: urn:iso:std:iec:61970-452:ed-4|urn:iso:std:iec:61970-301:ed-7:amd1|file:///iec61970cim17v40_iec61968cim13v13a_iec62325cim03v17a.eap|urn:iso:std:iec:61970-401:draft:ed-1|urn:iso:std:iec:61970-501:draft:ed-2
- Identifier: urn:uuid:e75168b4-6581-46ab-bc1c-fa7ef332558e

4.3 Requirements and constraints

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

rule.Profile: the abbreviation of the profile.

- EQ – Core Equipment Profile
- OP – Operation Profile
- SC – Short Circuit Profile
- ALL – All profiles (the constraint applies to all IEC 61970-452 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:ALL:IdentifiedObject.name:stringLength.

- C:452:ALL:NA:datatypes
According to 61970-501, datatypes are not exchanged in the instance data. The UnitMultiplier is 1 in cases none value is specified in the profile.
- R:452:ALL:NA:exchange
Optional and required attributes and associations must be imported and exported if they are in the model file prior to import.
- R:452:ALL:NA:exchange1
If an optional attribute does not exist in the imported file, it does not have to be exported in case exactly the same data set is exported, i.e. the tool is not obliged to automatically provide this attribute. If the export is resulting from an action by the user performed after the import, e.g. data processing or model update the export can contain optional attributes.

- R:452:ALL:NA:exchange2
In most of the profiles the selection of optional and required attributes is made so as to ensure a minimum set of required attributes without which the exchange does not fulfil its basic purpose. Business processes governing different exchanges can require mandatory exchange of certain optional attributes or associations. Optional and required attributes and associations shall therefore be supported by applications which claim conformance with certain functionalities of the IEC 61970-452. This provides flexibility for the business processes to adapt to different business requirements and base the exchanges on IEC 61970-452 compliant applications.
- R:452:ALL:NA:exchange3
An exporter may, at his or her discretion, produce a serialization containing additional class data described by the CIM Schema but not required by this document provided these data adhere to the conventions established in Clause 5.
- R:452:ALL:NA:exchange4
From the standpoint of the model import used by a data recipient, the document describes a subset of the CIM that importing software shall be able to interpret in order to import exported models. Data providers are free to exceed the minimum requirements described herein as long as their resulting data files are compliant with the CIM Schema and the conventions established in Clause 5. The document, therefore, describes additional classes and class data that, although not required, exporters will, in all likelihood, choose to include in their data files. The additional classes and data are labelled as required (cardinality 1..1) or as optional (cardinality 0..1) to distinguish them from their required counterparts. Please note, however, that data importers could potentially receive data containing instances of any and all classes described by the CIM Schema.
- R:452:ALL:NA:cardinality
The cardinality defined in the CIM model shall be followed, unless a more restrictive cardinality is explicitly defined in this document. For instance, the cardinality on the association between VoltageLevel and BaseVoltage indicates that a VoltageLevel shall be associated with one and only one BaseVoltage, but a BaseVoltage can be associated with zero to many VoltageLevels.
- R:452:ALL:NA:associations
Associations between classes referenced in this document and classes not referenced here are not required regardless of cardinality.
- C:452:ALL:NA:minMaxValues
Maximum values shall always be greater than or equal to minimum values if not specified otherwise explicitly.
- R:452:ALL:IdentifiedObject.name:rule
The attribute "name" inherited by many classes from the abstract class IdentifiedObject is not required to be unique. It must be a human readable identifier without additional embedded information that would need to be parsed. The attribute is used for purposes such as User Interface and data exchange debugging. The MRID defined in the data exchange format is the only unique and persistent identifier used for this data exchange. The attribute IdentifiedObject.name is, however, always required for CoreEquipment profile and Short Circuit profile.
- C:452:ALL:IdentifiedObject.name:stringLength
The string IdentifiedObject.name has a maximum of 128 characters.
- R:452:ALL:IdentifiedObject.description:rule
The attribute "description" inherited by many classes from the abstract class IdentifiedObject must contain human readable text without additional embedded information that would need to be parsed.
- R:452:ALL:NA:uniqueIdentifier
All IdentifiedObject-s shall have a persistent and globally unique identifier (Master Resource Identifier – mRID).

- R:452:ALL:ConductingEquipment:connectivity
All subtypes of ConductingEquipment are required to have associations to Terminals. The number of associated Terminals is specified in IEC 61970-301:2020, 4.8.2 "Number of terminals for ConductingEquipment objects." The associated Terminal(s) are not required to have associations to ConnectivityNodes, for instance a ShuntCompensator whose Terminal is not associated to a ConnectivityNode.
- R:452:ALL:NA:classes
Instance data to be exchanged must make use of the most detailed class possible within a profile, i.e. using sub-typed classes rather than general classes e.g. NuclearGeneratingUnit instead of GeneratingUnit.
- R:452:ALL:NA:ground
There shall not be any ground voltage level. The ConnectivityNode connected to the Ground instance belongs to the same containment instance as the grounding device. This means that the Ground instances are contained in the same voltage level where other switching devices are contained with a non-zero BaseVoltage.
- R:452:ALL:NA:unitMultiplier
For exchange of attributes defined using CIM Data Types (ActivePower, Susceptance, etc.) a unit multiplier of 1 is used if the UnitMultiplier specified in this document is "none".
- C:452:ALL: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.
- C:452:EQ:ACLineSegment.BaseVoltage:calculations
All implementations shall use association to a BaseVoltage for the purpose of any per unit calculations and shall not rely on the voltages (neither nominal nor actual values obtained by previous or current solution) at the nodes, which the ACLineSegment connects to.
- C:452:EQ:ACLineSegment.BaseVoltage:calculations2
In case there are interconnected ACLineSegments with different BaseVoltage for different parts of the networks (when assembling different model authority sets) the application needs to handle this to ensure accurate physical units.
- C:452:EQ:ACLineSegment.r:valueRange
ACLineSegment.r shall be a positive value or zero.
- C:452:EQ:ACLineSegment.x:valueRange
ACLineSegment.x shall be a positive value. As negative reactance values are not allowed for ACLineSegment-s it is recommended to model series compensators explicitly.
- C:452:EQ:AsynchronousMachine:aggregate
If one AsynchronousMachine is associated with one GeneratingUnit the flag Equipment.aggregate shall be consistent in case it is provided at both AsynchronousMachine and GeneratingUnit.
- C:452:EQ:AsynchronousMachine.ratedS:dynamicSimulation
RotatingMachine.ratedS is required in case of data exchange to support dynamic simulations.
- C:452:EQ:ConductingEquipment.BaseVoltage:whereRequired
The ConductingEquipment.BaseVoltage association is required for the following ConductingEquipment: ACLineSegment, EquivalentBranch and SeriesCompensator.
For all other Equipment-s, not contained in a VoltageLevel, the association ConductingEquipment.BaseVoltage can be provided (as it is optional), however the association to BaseVoltage coming from the container or transformer ends takes precedence.

- C:452:EQ:ConnectivityNode:containment

The association ConnectivityNode.ConnectivityNodeContainer is required however the type of EquipmentContainer the association shall point to is not specified. Therefore the association ConnectivityNode.ConnectivityNodeContainer shall point to any type of EquipmentContainer given by the connecting equipment (that is linked to the associated Terminal). Machine based validation is not performed. It is required that import and export shall not make any changes to this association.

- C:452:EQ:CurveData.Curve:equationY1

If CurveData.Curve is a ReactiveCapabilityCurve, each CurveData shall satisfy the following relation:

- $\text{CurveData.xvalue}^2 + \text{CurveData.y1value}^2$ shall be less than or equal to $\text{RotatingMachine.ratedS}^2$

- C:452:EQ:CurveData.Curve:equationY2

If CurveData.Curve is a ReactiveCapabilityCurve, each CurveData shall satisfy the following relation:

- $\text{CurveData.xvalue}^2 + \text{CurveData.y2value}^2$ shall be less than or equal to $\text{RotatingMachine.ratedS}^2$.

- C:452:EQ:CurveData.Curve:reactive

If CurveData.Curve is a ReactiveCapabilityCurve, the CurveData.y2value shall be greater than or equal to CurveData.y1value. It is not allowed that all CurveData.y2value values are equal to CurveData.y1value values.

- C:452:EQ:CurveData.Curve:reactiveCountP

For a SynchronousMachine with a ReactiveCapabilityCurve the number of CurveData instances depends on the attribute SynchronousMachine.type as follows:

- condenser, reactive capability limits are given by SynchronousMachine.maxQ and SynchronousMachine.minQ. There shall not be any association to ReactiveCapabilityCurve.
- generator or generatorOrCondenser, at least two CurveData instances with CurveData.xvalue greater than or equal to 0.
- motor or motorOrCondenser, at least two CurveData instances with CurveData.xvalue less than or equal to 0.
- generatorOrMotor or generatorOrCondenserOrMotor, at least three CurveData instances with at least one having CurveData.xvalue greater than or equal to 0 and one having CurveData.xvalue less than or equal to 0.

It is required that the points defining a ReactiveCapabilityCurve include at least two different values of xvalue (active power) and that the values of y1value and y2value (reactive minimum and maximum respectively) can not be equal except at the minimum and maximum values of xvalue.

- C:452:EQ:CurveData.Curve:VsCapabilityCurve

If CurveData.Curve is a VsCapabilityCurve, the CurveData.y2value shall be greater than CurveData.y1value.

- C:452:EQ:CurveData.Curve:VsCapabilityCurveCount

If CurveData.Curve is a VsCapabilityCurve at least two CurveData shall be associated.

- C:452:EQ:CurveData.xvalue:value

If CurveData.Curve is a ReactiveCapabilityCurve, the GeneratingUnit.minOperatingP shall be equal of the minimum of the CurveData.xvalue among all points defined for the ReactiveCapabilityCurve. The GeneratingUnit.maxOperatingP shall be equal of the maximum of the CurveData.xvalue among all points defined for the ReactiveCapabilityCurve.

- C:452:EQ:DayType.name:validValues

For DayType the name attribute indicates the days of the week that a given DayType represents. The name attribute is restricted to the following names: Monday, Tuesday, Wednesday, Thursday, Friday, Saturday, Sunday, Weekday, Weekend, All. If the name attribute is All, it represents all

seven days of the week. If the name attribute is Weekday, it represents Monday through Friday. If the name attribute is Weekend, it represents Saturday and Sunday.

- C:452:EQ:DCGround:instance
At least one DCGround shall be defined for each DC circuit.
- C:452:EQ:DCLineSegment.resistance:valueRange
The attribute DCLineSegment.resistance shall be a positive value.
- C:452:EQ:AuxiliaryEquipment:containment
For AuxiliaryEquipment (CurrentTransformer, PotentialTransformer, PostLineSensor, SurgeArrester, WaveTrap, FaultIndicator) the association Equipment.EquipmentContainer is required and shall point to EquipmentContainer of type Bay or Line.
- C:452:EQ:EnergyConnection:containment
For EnergyConnection (EnergySource, EnergyConsumer, NonConformLoad, ConformLoad, LinearShuntCompensator, NonlinearShuntCompensator, ExternalNetworkInjection, StaticVarCompensator, SynchronousMachine, AsynchronousMachine) the association Equipment.EquipmentContainer is required and shall point to EquipmentContainer of type VoltageLevel.
- C:452:EQ:ProtectedSwitch:containment
For ProtectedSwitch (Breaker, DisconnectingCircuitBreaker, LoadBreakSwitch) the association Equipment.EquipmentContainer is required and shall point to EquipmentContainer of type Bay, VoltageLevel or DCConverterUnit.
- C:452:EQ:Ground:containment
For Ground the association Equipment.EquipmentContainer is required and shall point to EquipmentContainer of type Bay or VoltageLevel.
- C:452:EQ:EarthFaultCompensator:containment
For EarthFaultCompensator (GroundingImpedance, PetersenCoil) the association Equipment.EquipmentContainer is required and shall point to EquipmentContainer of type VoltageLevel.
- C:452:EQ:Conductor:containment
For Conductor (ACLineSegment) the association Equipment.EquipmentContainer is required and shall point to EquipmentContainer of type Line.
- C:452:EQ:SeriesCompensator:containment
For SeriesCompensator the association Equipment.EquipmentContainer is required and shall point to EquipmentContainer of type VoltageLevel when in substation, DCConverterUnit or Line when outside substation.
- C:452:EQ:BusbarSection:containment
For BusbarSection the association Equipment.EquipmentContainer is required and shall point to EquipmentContainer of type VoltageLevel or Bay (when a disconnecter is splitting a busbar section in two).
- C:452:EQ:Junction:containment
For Junction the association Equipment.EquipmentContainer is required and shall point to EquipmentContainer of type Line (in case they model T-junction of a Line), or VoltageLevel or Bay (in case they model named join locations within a Substation).
- C:452:EQ:PowerTransformer:containment
For PowerTransformer the association Equipment.EquipmentContainer is required and shall point to EquipmentContainer of type Substation or DCConverterUnit. For the case of a transformer that connects two substations, the terminal of one of the PowerTransformerEnd-s can be connected to a ConnectivityNode defined in another substation.

- C:452:EQ:Disconnecter:containment
For Disconnecter the association Equipment.EquipmentContainer is required and shall point to EquipmentContainer of type Bay, VoltageLevel, DCConverterUnit or Line when outside substation.
- C:452:EQ:GroundDisconnecter:containment
For GroundDisconnecter the association Equipment.EquipmentContainer is required and shall point to EquipmentContainer of type Bay, VoltageLevel, DCConverterUnit or Line when outside substation.
- C:452:EQ:Fuse:containment
For Fuse the association Equipment.EquipmentContainer is required and shall point to EquipmentContainer of type Bay, VoltageLevel, DCConverterUnit or Line when outside substation.
- C:452:EQ:Jumper:containment
For Jumper the association Equipment.EquipmentContainer is required and shall point to EquipmentContainer of type Bay, VoltageLevel, DCConverterUnit or Line when outside substation.
- C:452:EQ:Cut:containment
For Cut the association Equipment.EquipmentContainer is required and shall point to EquipmentContainer of type Bay, VoltageLevel or DCConverterUnit or Line when outside substation.
- C:452:EQ:Clamp:containment
For Clamp the association Equipment.EquipmentContainer is required and shall point to EquipmentContainer of type Bay or Line when outside substation.
- C:452:EQ:GeneratingUnit:containment
For GeneratingUnit (SolarGeneratingUnit, NuclearGeneratingUnit, ThermalGeneratingUnit, HydroGeneratingUnit, WindGeneratingUnit) the association Equipment.EquipmentContainer is required and shall point to EquipmentContainer of type Substation.
- C:452:EQ:HydroPump:containment
For HydroPump the association Equipment.EquipmentContainer is required and shall point to EquipmentContainer of type Substation.
- C:452:EQ:EquivalentInjection:containment
For EquivalentInjection the association Equipment.EquipmentContainer is required and shall point to EquipmentContainer of type VoltageLevel or Line.
- C:452:EQ:EquivalentShunt:containment
For EquivalentShunt the association Equipment.EquipmentContainer is required and shall point to EquipmentContainer of type VoltageLevel.
- C:452:EQ:EquivalentBranch:containment
For EquivalentBranch the association Equipment.EquipmentContainer is required and shall point to EquipmentContainer of type VoltageLevel, Line or Substation.
- C:452:EQ:DCSwitch:containment
For DCSwitch (DCDisconnecter, DCBreaker) the association Equipment.EquipmentContainer is required and shall point to EquipmentContainer of type DCConverterUnit.
- C:452:EQ:DCGround:containment
For DCGround the association Equipment.EquipmentContainer is required and shall point to EquipmentContainer of type DCConverterUnit.
- C:452:EQ:DCBusbar:containment
For DCBusbar the association Equipment.EquipmentContainer is required and shall point to EquipmentContainer of type DCConverterUnit.

- C:452:EQ:DCChopper:containment
For DCChopper the association Equipment.EquipmentContainer is required and shall point to EquipmentContainer of type DCConverterUnit.
- C:452:EQ:DCShunt:containment
For DCShunt the association Equipment.EquipmentContainer is required and shall point to EquipmentContainer of type DCConverterUnit.
- C:452:EQ:DCTSeriesDevice:containment
For DCTSeriesDevice the association Equipment.EquipmentContainer is required and shall point to EquipmentContainer of type DCConverterUnit.
- C:452:EQ:DCLineSegment:containment
For DCLineSegment the association Equipment.EquipmentContainer is required and shall point to EquipmentContainer of type DCLine. In the case of modelling back to back configuration the association shall point to EquipmentContainer of type Substation.
- C:452:EQ:ACDCCConverter:containment
For ACDCCConverter (CsConverter, VsConverter) the association Equipment.EquipmentContainer is required and shall point to DCEquipmentContainer of type DCConverterUnit. In this case the association DCConverterUnit.Substation is required.
- C:452:EQ:Equipment:details
Instance data to be exchanged shall make use of the most detailed class possible based on the level of detailed information currently available about the equipment at the time of the exchange. The classes GeneratingUnit, Switch, and EnergyConsumer should only be used if the information to determine the more detailed class (ThermalGeneratingUnit, HydroGeneratingUnit, Breaker, Disconnecter, etc.) is not available.

If in the future the more detailed information becomes available, the instance data shall be exchanged with the more specific specialisation class. The more specific specialization class in the newer serialization shall be exchanged with the same MRID as the more generic class exchanged previously. (Note: Rules such as this pertaining to serialization shall be moved to a document pertaining to all IEC 61970 profiles when that document becomes available.)
- R:452:EQ:EnergySource:instance
The EnergySource class is a simplified representation of an energy supplier without regulation capability or the possibility of an associated ReactiveCapabilityCurve. Consequently it should only be used when the information to determine a more detailed class (GeneratingUnit, PhotoVoltaicUnit, etc) is not available.
- C:452:EQ:EquivalentInjection:instance
Using EquivalentInjection to model a distribution network equivalent is recommended practice instead of using ExternalNetworkInjection-s.
- C:452:EQ:GeneratingUnit:maxOperatingP:ratedS
GeneratingUnit.maxOperatingP shall be less than or equal to the sum of RotatingMachine.ratedS for RotatingMachine-s associated to the GeneratingUnit.
- R:452:EQ:GeneratingUnit:realPowerLimits
The net real power limits for a GeneratingUnit can be defined in three ways; 1) with the attributes "maxOperatingP" and "minOperatingP", or 2) with the attribute "ratedNetMaxP" or 3) with the attributes "ratedGrossMinP" and "ratedGrossMaxP" used in conjunction with an associated GrossToNetActivePowerCurve.
- C:452:EQ:GeneratingUnit:minOperatingP:valueRangePair
GeneratingUnit.maxOperatingP shall be greater than or equal to GeneratingUnit.minOperatingP.

- C:452:EQ:GrossToNetActivePowerCurve:values
For GrossToNetActivePowerCurve used in transmission system data exchanges where the x and y values will always be specified in MW, the xMultiplier and y1Multiplier attributes do not need to be supplied thus not included in the profile.
- C:452:EQ:HydroGeneratingUnit.energyConversionCapability:typeConsistency
If HydroGeneratingUnit.energyConversionCapability is "generator" the associated SynchronousMachine shall have SynchronousMachine.type set to "generator" or "generatorOrCondenser". If HydroGeneratingUnit.energyConversionCapability is "pumpAndGenerator" the associated SynchronousMachine shall have SynchronousMachine.type set to "motor", "generatorOrMotor" or "generatorOrCondenserOrMotor".
- C:452:EQ:LinearShuntCompensator.gPerSection:valueRange
LinearShuntCompensator.gPerSection shall be a positive value or zero.
- C:452:EQ:NonlinearShuntCompensatorPoint.g:valueRange
NonlinearShuntCompensatorPoint.g shall be a positive value or zero.
- C:452:EQ:OperationalLimitSet:limits
OperationalLimitSet has associations with ACDCTerminal and Equipment. In case the OperationalLimitSet is the operational limit of the AuxiliaryEquipment, then the association end OperationalLimitSet.Equipment is also required. In the case where OperationalLimitSet.Equipment is associated with an instance of ConductingEquipment, OperationalLimitSet.Terminal shall be one of the ConductingEquipment's Terminal-s.
- C:452:EQ:PhaseTapChanger:controlModeP
The association TapChanger.TapChangerControl for PhaseTapChanger-s shall only point to a TapChangerControl that has the following control modes for RegulatingControl.mode: activePower or voltage.
- C:452:EQ:PowerTransformerEnd:pu
The parameters r, x, g and b are specified for each end and are not related to the overall base voltage. These values are specified in engineering units. Any PU calculations are internal to particular tools and are not part of the data exchange.
- C:452:EQ:PowerTransformerEnd.b:valueRange
PowerTransformerEnd.b shall be negative value or zero. Negative magnetising branch susceptance (PowerTransformerEnd.b) means inductive reactive power losses in no load.
- C:452:EQ:PowerTransformerEnd.g:valueRange
PowerTransformerEnd.g shall be positive value or zero. Positive magnetising branch conductance (PowerTransformerEnd.g) means positive active power losses in no load.
- C:452:EQ:PowerTransformerEnd.x:value
Transformers with zero series reactance do not exist. PowerTransformerEnd.x of high voltage end in case of a two winding transformer shall be a positive value. In case of a three winding transformer the PowerTransformerEnd.x shall not be zero, but it can be a negative value.
- C:452:EQ:RatioTapChanger:controlMode
The association TapChanger.TapChangerControl for RatioTapChanger-s shall only point to a TapChangerControl which has the following control modes for RegulatingControl.mode: voltage, reactivePower and powerFactor.
- C:452:EQ:ReactiveCapabilityCurve.CurveData:xvalue
All CurveData.xvalue for a given ReactiveCapabilityCurve shall be unique, e.g. it is not allowed for two or more .xvalue to have the same float value for a given ReactiveCapabilityCurve.
R:452:EQ:ReactiveCapabilityCurve:styles
Two different styles of ReactiveCapabilityCurve-s can be defined for a SynchronousMachine. The style is defined by Curve.curveStyle attribute as shown in the Annex E.

- C:452:EQ:ReactiveCapabilityCurve:units
For a ReactiveCapabilityCurve associated with SynchronousMachine, the Curve.xUnit shall be set to UnitSymbol.W and both Curve.y1Unit and Curve.y2Unit shall be set to UnitSymbol.VAr. As the multiplier is not included in the profile it is defined the same as the multiplier used for datatype ActivePower and ReactivePower, i.e. UnitMultiplier.M.
- C:452:EQ:RegulatingControl:RegulatingEquipment
A RegulatingControl that is not a TapChangerControl must have at least one regulating equipment associated through the RegulatingCondEq.RegulatingControl. That is, a RegulatingControl cannot exist without some equipment using it for regulating.
- C:452:EQ:RegulatingControl:point
In cases where the controlling point is a ConnectivityNode multiple instances of RegulatingControl maybe be needed for proper modelling and connectivity of the grid.
- C:452:EQ:RegulatingControl:samePoint
A RegulatingControl will have associations to one or more instances of RegulatingCondEq and an association to a Terminal. The ConnectivityNode associated with the Terminal is the regulated point. It is common to have cases where multiple pieces of equipment regulate ConnectivityNodes that under normal network topology are associated with the same TopologicalNode. In this case, the same instance of RegulatingControl should be used by all of those regulating equipment if possible. If it is not possible, such as the case where a SynchronousMachine and a RatioTapChanger are regulating the same point using associations to instances of RegulatingControl and TapChangerControl, the number of instances of RegulatingControl and TapChangerControl should be minimized. Additionally, the target and deadband values for the same regulated point should not be contradictory.
Profile restriction: If multiple instances of RegulatingControl control the same regulation point, the targetValues must not be contradictory.
- C:452:EQ:RegulatingControl.targetValue:tapChanger
In cases where RegulatingControl.mode is "voltage" and both TapChanger.controlEnabled and RegulatingControl.enabled are "true",
 - The RegulatingControl.targetValue in per unit value is calculated by $\text{RegulatingControl.targetValue} / \text{BaseVoltage.nominalVoltage}$.
 shall be within the regulating capability limits:
 - The tap changer upper capability limit in per unit value is calculated by $1 + \text{RatioTapChanger.stepVoltageIncrement} / 100 * (\text{TapChanger.highStep} - \text{TapChanger.neutralStep})$.
 - The tap changer lower capability limit in per unit value is calculated by $1 - \text{RatioTapChanger.stepVoltageIncrement} / 100 * (\text{TapChanger.neutralStep} - \text{TapChanger.lowStep})$.
- C:452:EQ:ShuntCompensator:controlMode
For ShuntCompensator, the association RegulatingCondEq.RegulatingControl shall only point to a RegulatingControl that has the following control modes for RegulatingControl.mode: voltage, reactivePower and powerFactor.
- C:452:EQ:ShuntCompensator.voltageSensitivity:valueRange
The ShuntCompensator.voltageSensitivity attribute shall be greater than zero.
- C:452:EQ:StaticVarCompensator:controlMode
For StaticVarCompensator, the association RegulatingCondEq.RegulatingControl is required and shall only point to a RegulatingControl that has the following control modes for RegulatingControl.mode: voltage and reactivePower.
- C:452:EQ:Switch:containment
For Switch, the association Equipment.EquipmentContainer is required and shall point to EquipmentContainer of type Bay, VoltageLevel or DCConverterUnit.

- C:452:EQ:SynchronousMachine:aggregate
If only one SynchronousMachine is associated with the GeneratingUnit then the Equipment.aggregate flag shall be consistent between the SynchronousMachine and GeneratingUnit if it exists in both.
- C:452:EQ:SynchronousMachine:controlMode
For SynchronousMachine, the association RegulatingCondEq.RegulatingControl shall only point to a RegulatingControl that has the following control modes for RegulatingControl.mode: voltage, reactivePower and powerFactor.
- C:452:EQ:SynchronousMachine:reactiveLimits
ReactiveCapabilityCurve-s are not required if the reactive power limits of the SynchronousMachine do not vary with real power output. SynchronousMachine.minQ and SynchronousMachine.maxQ are required if SynchronousMachine.InitialReactiveCapabilityCurve is not provided. If the association SynchronousMachine.InitialReactiveCapabilityCurve is provided it takes precedence to the information provided by the attributes SynchronousMachine.minQ and SynchronousMachine.maxQ. However, if both SynchronousMachine.minQ, SynchronousMachine.maxQ and ReactiveCapabilityCurve are present, the SynchronousMachine.minQ shall be equal to min of CurveData.y1value-s and SynchronousMachine.maxQ shall be equal to max CurveData.y2value-s.
C:452:EQ:SynchronousMachine:ratedS
For SynchronousMachine, the attribute RotatingMachine.ratedS is required in case of data exchange to support dynamic simulations.
- C:452:EQ:SynchronousMachine.maxQ:valueRangePair
SynchronousMachine.maxQ shall be greater than or equal to SynchronousMachine.minQ.
- C:452:EQ:SynchronousMachine.type:condenser
The SynchronousMachine is not required to be associated with a GeneratingUnit via the association RotatingMachine.GeneratingUnit in cases where a synchronous condenser is being modelled as there is no capability for real power output. In this case, the SynchronousMachine.type shall be set to "condenser". If there is no capability for real power output, the SynchronousMachine.type-s: "motorOrCondenser", "generatorOrCondenser", and "generatorOrCondenserOrMotor" are not allowed to be used.
- C:452:EQ:Switch:connection
Switch and its subclasses shall only connect to ConnectivityNode-s that are contained in either the same VoltageLevel or in different VoltageLevel-s which have the same BaseVoltage.
- C:452:EQ:TapChangerControl:remoteQcontrol
A power transformer cannot efficiently control reactive power flow on remote Terminal-s. Therefore, a TapChangerControl with RegulatingControl.mode which equals to reactivePower shall only control the reactive flow at one of the Terminal-s (via the association RegulatingControl.Terminal), which is also associated with PowerTransformerEnd-s of the PowerTransformer where the TapChanger is located.
- C:452:EQ:Terminal:connection
Terminal-s of the two sides of a two-terminal ConductingEquipment (or any of its subclasses) shall not be connected to the same ConnectivityNode.
- C:452:EQ:SynchronousMachine.qPercent:usage
The attribute SynchronousMachine.qPercent in the EQ profile specifies a default value. The participation of the devices regulating a particular node can be set in other profiles such as SSH. Therefore, the implementations shall consider this in the load flow calculation and normalize the participation based on what devices are participating in the regulation of a particular node.
- C:452:EQ:Switch:usage
Busbar couplers shall be modelled explicitly if they are to be retained. The substitution of busbar couplers with zero impedance branches shall not be permitted for exchanges.

- C:452:EQ:NA:zeroImpedance
Zero impedance lines are permitted if they represent real elements in the model.
- C:452:EQ:NA:negativeImpedance
Except for series capacitors, negative branch reactance shall not represent real devices. Negative impedance is allowed for EquivalentBranch. Negative value limits the selection of load flow solution techniques and shall be avoided, if possible.
- C:452:EQ:EnergyConsumer:constantP
If the association EnergyConsumer.LoadResponse to LoadResponseCharacteristic is missing, this load is assumed to be constant power.
- C:452:OP:NA:measurement
In the context of this profile the following classes: AccumulatorValue, AnalogValue, DiscreteValue, StringMeasurementValue are only used to define measurements that are available via ICCP (inter-control center communications protocol) and to define the location of SCADA (supervisory control and data acquisition) measurements for use by state estimator. It is not used to supply values for those measurements. Consequently, the value attribute is not included in this profile.
- C:452:OP:Measurement.Terminal:requiredCases
The association Measurement.Terminal shall reference a Terminal of the Equipment referenced by Measurement.PowerSystemResource except in cases where Measurement.measurementType is either "TapPosition" or "SwitchPosition" in which the association is not exchanged.
- C:452:ALL:IdentifiedObject.description:stringLength
The string IdentifiedObject.description is maximum 256 characters.
- C:452:OP:Measurement.measurementType:analogValues
For Analog, Measurement.measurementType is restricted to the following valid values: ThreePhasePower, ThreePhaseActivePower, ThreePhaseReactivePower, LineCurrent, PhaseVoltage, Voltage, Angle, Frequency and TapPosition.
- C:452:OP:Measurement.measurementType:accumulatorValues
For Accumulator, Measurement.measurementType is restricted to the following valid values: ApparentEnergy, ReactiveEnergy, ActiveEnergy.
- C:452:OP:Measurement.measurementType:discreteValues
For Discrete, Measurement.measurementType is restricted to the following valid values: SwitchPosition.
- C:452:OP:Measurement.unitSymbol:analogValues
For Analog, Measurement.unitSymbol is restricted to the following valid values: W, deg, VA, A, VAr, V, Hz.
- C:452:OP:Measurement.unitSymbol:accumulatorValues
For Accumulator, Measurement.unitSymbol is restricted to the following valid values: VAh, VArh, Wh.
- C:452:OP:Measurement.unitSymbol:discreteValues
For Discrete, Measurement.unitSymbol is restricted to the following valid values: none.
- C:452:OP:MeasurementValueSource:name
For MeasurementValueSource, attribute IdentifiedObject.name is restricted to the following strings for MeasurementValueSource: ICCP, SCADA.

- C:452:EQ:RegularTimePoint:values
RegularTimePoint is associated with types of schedules (ConformLoadSchedule, NonConformLoadSchedule) where value1 will always be specified in MW and value2 will always be specified in MVar. In these cases, the value1Multiplier and value2Multiplier attributes of BasicIntervalSchedule do not need to be specified thus not included in the profile.
- C:452:EQ:RegulationSchedule:values
By convention, for RegulationSchedule the attribute "value1" represents the target voltage or real power. "value2" is the deviation. For instance, a value1 of 100 and value2 of 1 means regulating to 100 kV plus or minus 1 kV, if the units are set to kV. In this case the range would be from 99 kV to 101 kV.
- C:452:SC:BusbarSection.ipMax:optional
The attribute BusbarSection.ipMax is an optional attribute even if short circuit data is exchanged, as not always entered by the user (e.g. the IEC TR 60909-4 example test model described in Subclause 6.2 of IEC TR 60909-4:2021 does not include these values).
- C:452:SC:PowerTransformerEnd.grounded:grounding
If TransformerEnd.grounded is true, then TransformerEnd.rground and TransformerEnd.xground are required.
- C:452:SC:SeriesCompensator.varistorRatedCurrent:required
The SeriesCompensator.varistorRatedCurrent is required if SeriesCompensator.varistorPresent is true.
- C:452:SC:SeriesCompensator.varistorVoltageThreshold:required
The SeriesCompensator.varistorVoltageThreshold is required if SeriesCompensator.varistorPresent is true.
- C:452:SC:SynchronousMachine.earthing:attributes
If SynchronousMachine.earthing is true, then SynchronousMachine.earthingStarPointR and SynchronousMachine.earthingStarPointX are required.

4.4 Transformer modelling

A two winding PowerTransformer has two PowerTransformerEnds. This gives the option to specify the impedance values for the equivalent pi-model completely at one end or split them between the two ends. The impedances shall be specified at the primary voltage side as shown in Figure 1 where the left side is the "primary" (high voltage) voltage side.

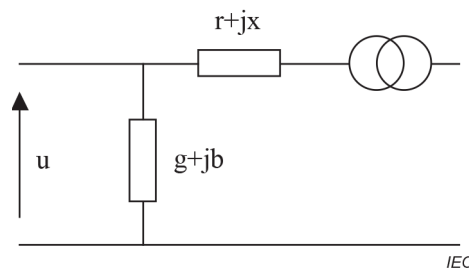


Figure 1 – Two winding transformer impedance

A three winding PowerTransformer has three PowerTransformerEnds. The equivalent pi-model corresponds to three ends connected in wye configuration as shown below. The impedance values for a three winding transformer are specified on each of the three TransformerWindings. Each of the ends has series impedances $r_n + jx_n$ and shunt $g_n + jb_n$ where n is: p for primary, s for secondary and t for tertiary as shown in Figure 2.

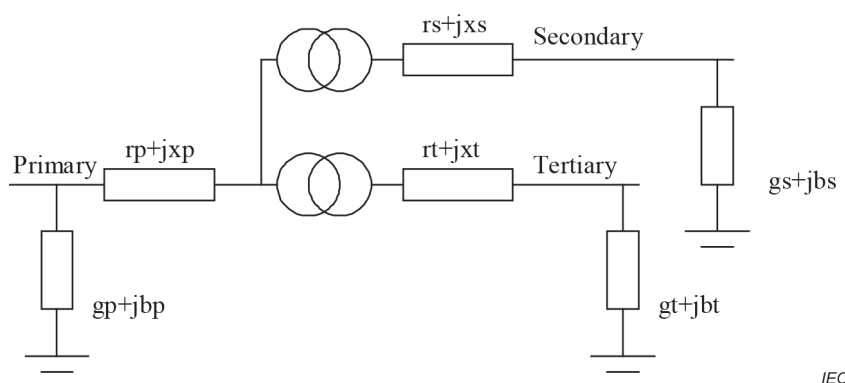


Figure 2 – Three winding transformer impedance

Additional requirements related to transformer modelling are listed below.

- Each PowerTransformer shall have at least two and no more than three PowerTransformerEnds.
- Each PowerTransformerEnd can have at most one tap changer (RatioTapChanger, PhaseTapChangerLinear, PhaseTapChangerSymmetrical, or PhaseTapChangerAsymmetrical). If a PowerTransformerEnd does not have an associated tap changer, the end should be considered to have a fixed tap.

Multiple types of regulating transformers are supported by the CIM model. Depending on the regulation capabilities, the effects of tap movement will be defined using the RatioTapChanger class, PhaseTapChangerLinear class, PhaseTapChangerSymmetrical class, or PhaseTapChangerAsymmetrical class. Each of these classes are subtypes of the TapChanger class. The use of the various subtypes is explained in IEC 61970-301.

4.5 Modelling authorities

From the use cases for model exchange detailed in Annex A, it is clear that most situations involve multiple entities that shall cooperate. In these situations, it is very important to establish which entity has the authority for modelling each region or set of data objects. For this purpose we use the concepts of ModelingAuthority and ModelingAuthoritySet. ModelingAuthority and ModelingAuthoritySet are not defined as classes in the normative portion of the CIM. When multiple modelling entities are involved, each modelled object is assigned to a ModelingAuthoritySet. A ModelingAuthority can be responsible for one or more ModelingAuthoritySets. A more detailed description of the use ModelingAuthorities and ModelingAuthoritySets can be found in Annex B. When using the concept of ModelingAuthoritySets, a single file shall contain only data objects associated with a single ModelingAuthoritySet.

4.6 Use of measurement classes

4.6.1 General

Use of the CIM Measurement classes (Analog, Accumulator, and Discrete) is frequently misunderstood and has changed over time. Previously in addition to the use representing points in the system where telemetry is available, the classes had been used to associate Limits with a piece of Equipment and to define regulated points. Measurements are now only used to define where telemetry is available and to facilitate exchange of ICCP data.

A Measurement shall be associated with a PowerSystemResource to convey containment information for the Measurement. Transmission line measurements should be associated with an ACLineSegment, not with a Line. Transformer measurements should be associated with a PowerTransformer, not with a Transformer Winding. Voltage measurements should be associated with a piece of equipment, not with a VoltageLevel. A TapPosition measurement shall be associated with a tap changer (RatioTapChanger, PhaseTapChangerLinear, PhaseTapChangerSymmetrical or PhaseTapChangerAsymmetrical). A SwitchPosition measurement shall be associated with a Switch or a subtype of Switch.

The Measurement may also be associated with one of the Terminals associated with the piece of equipment. For measurements representing actual telemetered points, it is especially important that the association to a Terminal defines the specific topological point in the network that is measured. A Measurement can be associated with at most one Terminal. Each flow measurement (active power, reactive power, or current) shall be associated with a terminal. This association is particularly important for State Estimation. The measurement shall be associated with the correct terminal of the piece of conducting equipment that is being measured (SynchronousMachine, EnergyConsumer, ACLineSegment, PowerTransformer, etc.). Associating the measurement with a terminal of the wrong equipment or the terminal on the wrong end of the correct piece of equipment will cause problems for State Estimation. Only two types of measurement, TapPosition and SwitchPosition, do not require an association to a Terminal.

Three subtypes of Measurement are included in this profile, Analog, Accumulator, and Discrete. To describe what is being measured, the attribute Measurement.measurementType is used, but only particular measurementTypes are valid for each of the subtypes of Measurement. The valid associations are defined in Table 436.

4.6.2 ICCP data exchange

Refer to IEC 61970-301 for rules regarding ICCP data.

4.7 Voltage or active power regulation

To use CIM to define how a piece of equipment regulates a point in the system, an association is defined between the regulating conducting equipment (SynchronousMachine, LinearShuntCompensator, NonLinearShuntCompensator, StaticVarCompensator, RatioTapChanger, PhaseTapChangerLinear, PhaseTapChangerSymmetrical, PhaseTapChangerAsymmetrical, PhaseTapChangerTabular or ExternalNetworkInjection) and an instance of RegulatingControl or TapChangerControl. The RegulatingControl or TapChangerControl shall be associated with a Terminal. The control for a piece of regulating equipment can refer to a Terminal associated with another PowerSystemResource. For instance, for voltage regulation purposes the control for a SynchronousMachine could refer to a Terminal associated with a BusbarSection. The specified Terminal shall be associated with the connectivity node that is the controlled point.. The association between RegulatingControl or TapChangerControl and Terminal is required to define regulation of voltage or active power.

For a piece of equipment that is not regulating, the association to RegulatingControl or TapChangerControl is not required.

4.8 Use of curves

4.8.1 General

The use of the Curve and CurveData attributes will differ for the different types of curves derived from Curve (GrossToNetActivePowerCurve, ReactiveCapabilityCurve and VsCapabilityCurve). Annex E summarizes the use of ReactiveCapabilityCurve styles. Data requirements are described below for the case of a generating unit where the reactive power limits of the generating unit do not vary with the real power output.

4.8.2 Generating unit reactive power limits

Generating unit reactive power limits shall be included in data exchange, but may be specified differently depending on the characteristics of the generating unit being represented. In most cases, a SynchronousMachine should be associated with a default ReactiveCapabilityCurve using the SynchronousMachine.InitialReactiveCapabilityCurve association.

If the reactive power limits of the generating unit do not vary with the real power output, the reactive power limit attributes on the SynchronousMachine class, minQ and maxQ, can be used. If the reactive power output of the generating unit is fixed, the reactive power limits should both be set to the fixed reactive output value.

4.9 Definition of schedules

The use of the `RegularIntervalSchedule` and `RegularTimePoint` attributes will differ for the different types of schedules derived from `RegularIntervalSchedule`. To specify a relative time for a schedule, the date portion of the `dateTime` format can be eliminated, which leaves the ISO 8601 time of day format "hh:mm:ss". In this format, hh is the number of complete hours that have passed since midnight, mm is the number of complete minutes since the start of the hour, and ss is the number of complete seconds since the start of the minute.

The earliest allowed time used in a schedule (`BasicIntervalSchedule.startTime`) is "00:00:00". The latest allowed time used in a schedule (`RegularIntervalSchedule.endTime`) is "24:00:00". The point in time specified by the `endTime` is not included in the period of the schedule.

A schedule defining a day shall be defined with multiple `RegularTimePoints` associated with the same `RegularIntervalSchedule`. It shall not be defined with multiple schedules.

For schedules that are associated with `Season` and `DayType`, the associations to `Season` and `DayType` are not required. If a schedule does not have an associated `Season`, the schedule will be considered valid for all `Seasons`. Similarly, if a schedule does not have an association to a `DayType`, the schedule will be considered to apply to all days of the week.

When `SeasonDayTypeSchedules` are defined for a given entity, such as `ConformLoadSchedules` for a given `ConformLoadGroup`, only one schedule can be defined for a given combination of `Season` and `DayType`.

5 Detailed profile specification

5.1 General

This clause lists the profiles that will be used for data exchange and the classes, attributes, and associations that are a part of each profile. Included are all the classes that a data consumer would be expected to recognize in the data being consumed. Additional classes are referenced in this chapter, when the classes to be exchanged inherit attributes or associations. For instance, many classes inherit attributes from the class `IdentifiedObject`. However, no instances of the class `IdentifiedObject` would exist in the data exchanged, so `IdentifiedObject` has not been included in the set of CIM classes for exchange.

The `CoreEquipment` profile primarily defines the existence of equipment in the network model and specifies the physical characteristics of the network model equipment such as impedance and connectivity. The `Operation` profile specifies data pertaining to how the system is operated such as limits and voltage regulation. The `ShortCircuit` profile specifies additional electrical characteristics necessary to execute Short Circuit studies. The `Operation` and `Short Circuit` profiles reference data defined in the `CoreEquipment` profile. A particular data exchange may or may not include all of these profiles. Data validation, such as cardinality of attributes and associations, only applies to the profiles specified for the exchange.

5.2 Core Equipment Profile

5.2.1 General

This is the IEC 61970-452 core equipment profile.

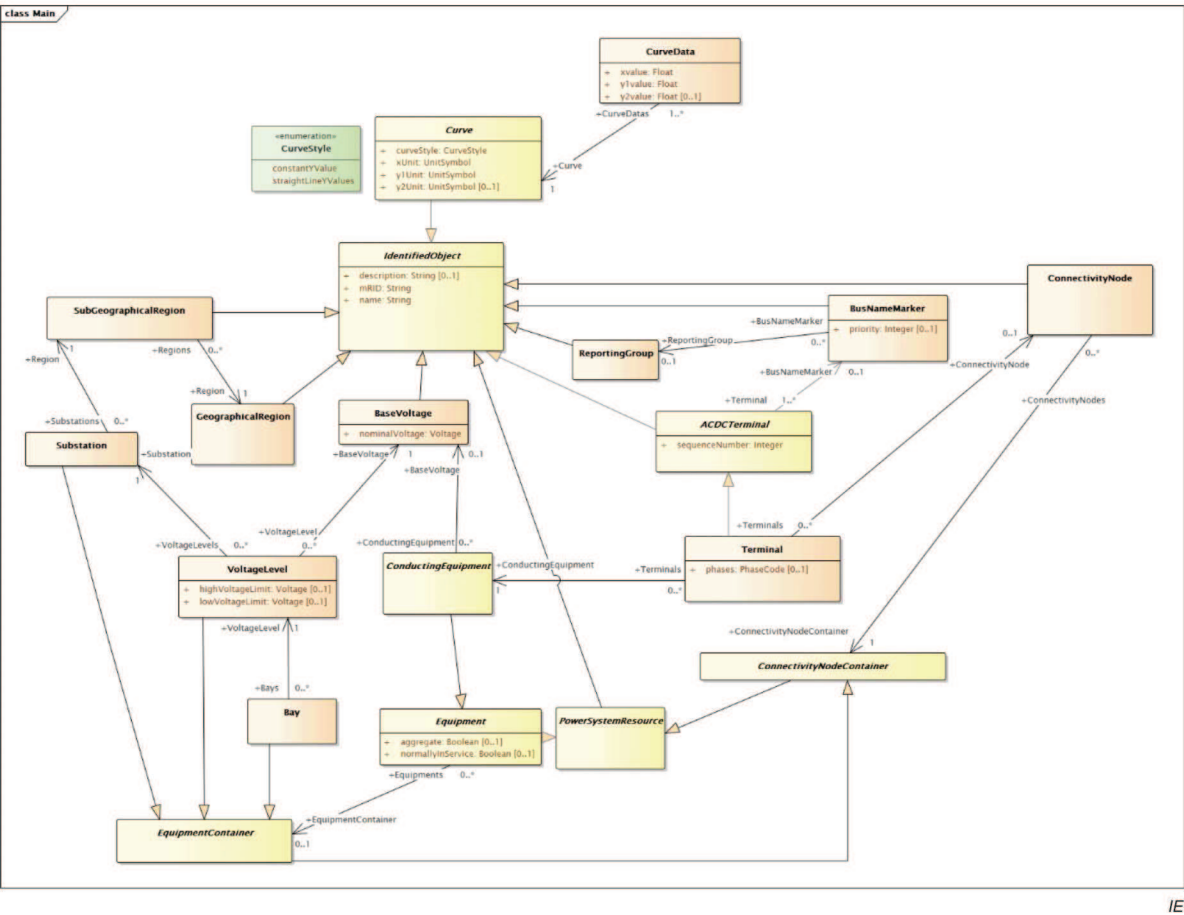


Figure 3 – Class diagram CoreEquipmentProfile::Main

Figure 3: The main diagram of the equipment core profile.