INL/RPT-23-70946-Revision-0

DLR Calculation Engine Interoperability Profile

February 2023

Changing the World's Energy Future

Sean Morash, Chuck DuBose, Margaret Goodrich , Jeremy Laundergan, Stephen Arthur Bukowski, Jake P Gentle, Megan Jordan Culler

Idaho National Laboratory

INL is a U.S. Department of Energy National Laboratory operated by Battelle Energy Alliance, LLC

INL/RPT-23-70946-Revision-0

DLR Calculation Engine Interoperability Profile

Sean Morash, Chuck DuBose, Margaret Goodrich , Jeremy Laundergan,
Stephen Arthur Bukowski, Jake P Gentle, Megan Jordan Culler

February 2023

Idaho National Laboratory
Idaho Falls, Idaho 83415

http://www.inl.gov

Prepared for the
U.S. Department of Energy
Under DOE Idaho Operations Office
Contract DE-AC07-05ID14517

DLR Calculation Engine
Interoperability Profile

A Project for the TOGETs Task Force

February 2023 | INL/RPT-23-70946

Idaho National Laboratory

CONTENTS

Sean Morash | Telos Energy
Chuck DuBose, Margaret Goodrich | PCItek
Jeremy Laundergan | EnerNex
Stephen Bukowski, Jake Gentle, Megan Culler | INL

December 2022

Idaho National Laboratory | Idaho Falls, Idaho 83415
http://www.inl.gov

Prepared for the U.S. Department of Energy
Office of Electricity | DOE Idaho Operations Office

Contract DE-AC07-05ID14517

Introduction

Idaho National Laboratory's Transmission Optimization with Grid Enhancing Technologies (TOGETs) project, funded by the U.S. Department of Energy's (DOE's) Office of Electricity (OE) and Wind Energy Technologies Office (WETO), has convened to facilitate the deployment of dynamic line rating (DLR) and power flow control (PFC) technologies across the United States. Because this work is intended in part to help implement systems compliant with the Federal Energy Regulatory Commission (FERC) Order 881[1] across the country, the TOGETs industry task force identified a need for additional public information on the information exchanges required for operationalizing grid-enhancing technologies (GETs) (i.e., integrating GETs within actual utility system operations). As such, the following documents have been developed with input from the TOGETS task force and vendor community:

- **Use Cases** – Provides the step-by-step process for achieving scenarios where technology may be useful. This use case document covers two distinct use cases showing how GETs could be used in (1) contingency situations and (2) the utility day ahead scheduling processes.
- **Systems Architecture Considerations** – Provides guidance on operational technology architectural considerations that accompany GETs deployment into operational practices. This includes identification of existing systems and cybersecurity network validation upfront.
- **This Interoperability Profile** – Shows one example of how the use cases can be implemented leveraging the Common Information Model (CIM) to facilitate data exchanges across software systems potentially developed by different vendors and organizations.
- **This document** – Contains a detailed interoperability profile outlining how the components of the CIM can be used to implement DLR in support of the two use cases identified in the Use Case Document. An interoperability profile is defined by the Smart Electric Power Alliance (SEPA) as a document that "specifies standards-based requirements for interfaces or applications that are accepted by the user-community, testing authorities, and other stakeholders. It specifies configuration options within a standard's requirements sufficient to deliver the desired level of interoperability and functionality."[2] To that end, this document is not in itself a standard, nor has it been approved by any formal body. Rather, it is an example of how to implement the CIM standard and has been reviewed by industry, including transmission operators and DLR vendors.

This document is intended to provide guidance on how the components of CIM can be used to facilitate data exchanges, ultimately helping practitioners integrate systems developed by multiple vendors using a common language. Note that CIM provides a common vocabulary and basic ontology to allow application software systems to exchange information about an electrical network. This is just one layer of interoperability required for full implementation – physical and communication layer protocols should also be considered to get the data into the utility system. Communication and physical layer interoperability are considered out of scope for this effort. Moreover, other utility systems in the utility back office– including many novel analytic solutions- may need to translate out of CIM for data processing, efficient storage, or rapid querying. This interoperability profile therefore has limited (yet important!) utilization at the intersection of DLR Calculation Engines and Bulk Power System Management Systems, such as Energy Management Systems (EMS).

For brevity, we assume that the reader is generally familiar with the potential of DLR to address transmission congestion and other utility practices. An overview of these applications can be found in both the Use Case document available through the TOGETs task force and covered in detail in the 2022 U.S. Department of Energy (DOE) Report *Grid Enhancing Technologies: A Case Study on Ratepayer Impact*[3]. Similarly, readers should be generally familiar with systems architecture and utility systems; a good reference for such systems is included in the *NIST Framework and Roadmap of Smart Grid Interoperability Standards*[4]. Finally, we assume that the reader is familiar with information technology best practices and how data schemas flow across enterprises.

The bulk of this profile is built on the Common Information Model, which is a collection of standards managed by the International Electrotechnical Commission (IEC), particularly by their technical committee 57 (TC57). This group is tasked "to prepare international standards for power systems control equipment and systems including EMS (Energy Management Systems), SCADA (Supervisory Control And Data Acquisition), distribution automation, tele-protection, and associated information exchange for real-time and non-real-time information, used in the planning, operation and maintenance of power systems."[5] Of particular note for the work in GETs generally, and DLR specifically, is the IEC 61970 series of standards that deal with the application program interfaces for energy management systems.

This profile is built entirely from the components of IEC 61970 relevant to the targeted use case. As will become apparent to the reader, implementing both real-time and forecasted dynamic line ratings is a straightforward application of the Common Information Model to facilitate data exchanges between systems.

Organization of Profile

Profiles can be in any number of formats commonly known as serializations. The most popular serializations for IEC standard profiles are either XMS Schema Definition (XSD) or Resource Description Framework Schema (RDFS). The XSD produces an Extensible Markup Language (XML) file that is used for message profiles. It represents the hierarchical organization of the data and does not include any network connectivity. Because of this, it is used as a payload for messages that are contained within a Simple Object Access Protocol (SOAP) or other transport envelope and will provide short messages for command, control and events that occur between systems. Within the CIM world, the Resource Description Framework (RDF) messages contain the full electric system network model, while XML messages contain information about that model in smaller packages.

The RDFS produces an RDF XML file that is used for large instance model exchanges between systems. These instance models contain power system models that are flat files and contain connectivity information that can be used to generate fully connected power systems models within the information systems that receive these files. RDF uses association attributes to connect data. Essentially, an RDF file is composed of lists of data records with associations to other data records referencing the RDF-ID of the target record. This serialization is used to exchange substation or regional power system information between EMS, Distribution Management Systems (DMS) or Distributed Energy Management Systems (DERMS). It can also be used to exchange portions of these models provided there is a full model that can receive these smaller exchange portions.

The selection of which serialization to use depends on what information is exchanged or transmitted between the source and target system. If it is a command or event message, XSD is normally used. XSDs are designed for small bursts of information. Generally, the information transmitted through XSDs is very specific. Examples are information about an outage, meter controls, work management, and customer information.

If it is a full or partial power system model with connectivity, an XML RDF file is normally used. We selected an XSD serialization for our profile since we are transmitting the operational limits of the Line Segment that will be used by the Calculation Engine to define the Dynamic Line Ratings.

There are three Unified Modeling Language (UML) diagrams shown below which show the classes and relationships of the Common Information Model (CIM) where line limits are defined. The diagrams overlap to show how this portion of the model are linked. Including these classes on one diagram would be too busy and too small to read.

For clarity, a quick overview of the key points in in the UML is captured below:

- A class is a blueprint for an object in object-oriented design; classes define what an object can contain.
- ACLineSegment is the primary class for identifying the line for which the DLRs are developed.
  - For ratings developed for the entire length of the modeled ACLineSegment, the name and master

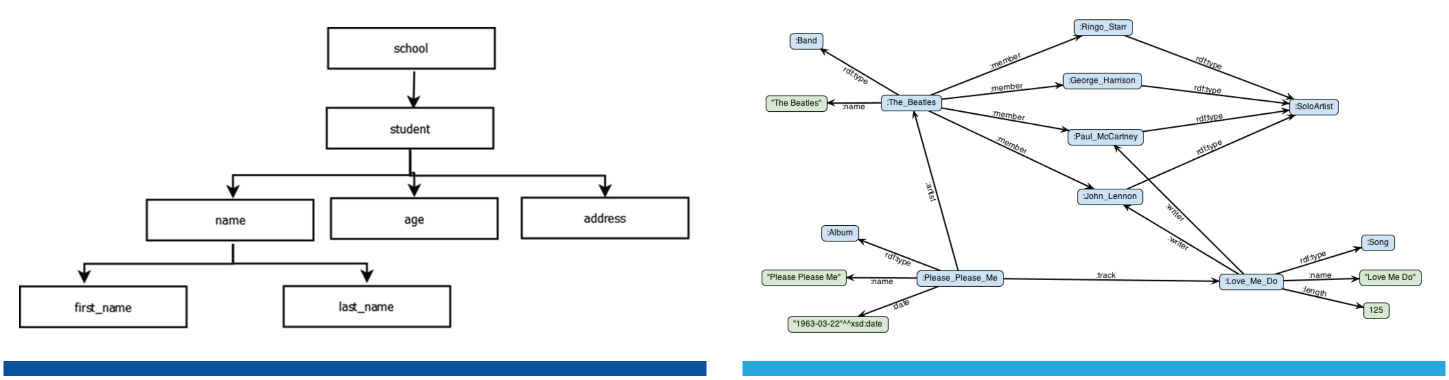

Figure 1 Example of XML (left)[6] and RDF (right)[7] Data Models

resource identifier (mRID) data should be the same as used in the operations control system power flow simulation software.

- OperationalLimit classes, such as CurrentLimit, OperationalLimitSet, and OperationalLimitType are used to store and organize the real-time and forecasted DLR limits.
  - The OperationalLimitSet links the limits to the ACLineSegment.
  - The CurrentLimit class passes the ampacity limit value which the DLR Calculation Engine produces.
- TopologicalNode and BusNameMarker may be needed to map the DLRs to the operational planning models.
- The Names classes are used to link alternate names used by different systems to the dynamic line ratings.

Even though these UML diagrams contain all pieces of information needed to transmit DLRs (in the form of CurrentLimit) from the DLR Calculation Engine to the control system, several mapping issues must be worked out upon implementation. Those are briefly outlined in sections 2.1 and 2.2 below.

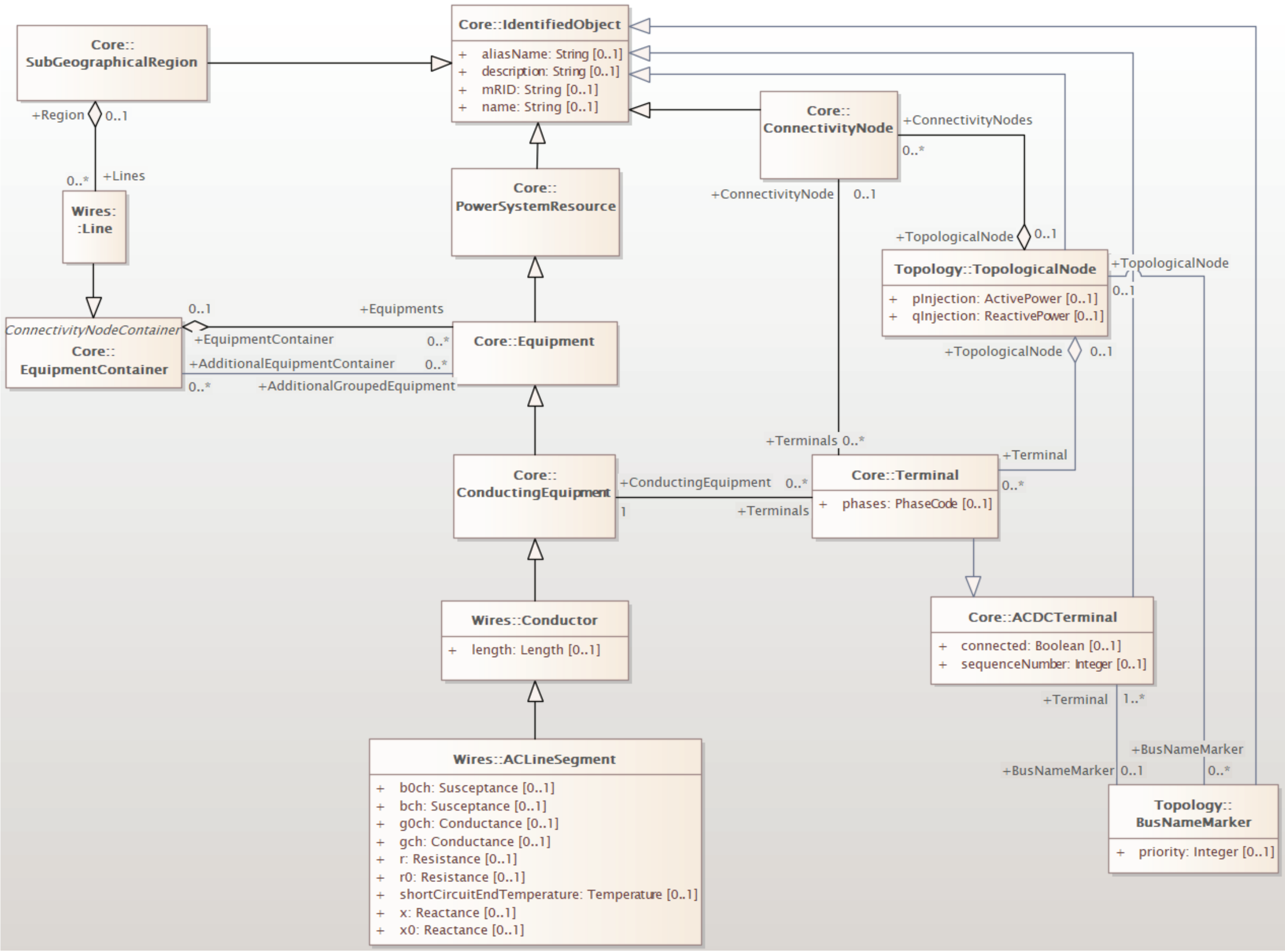

Figure 2 ACLineSegment: CIM Class for Shortest Segment of Line

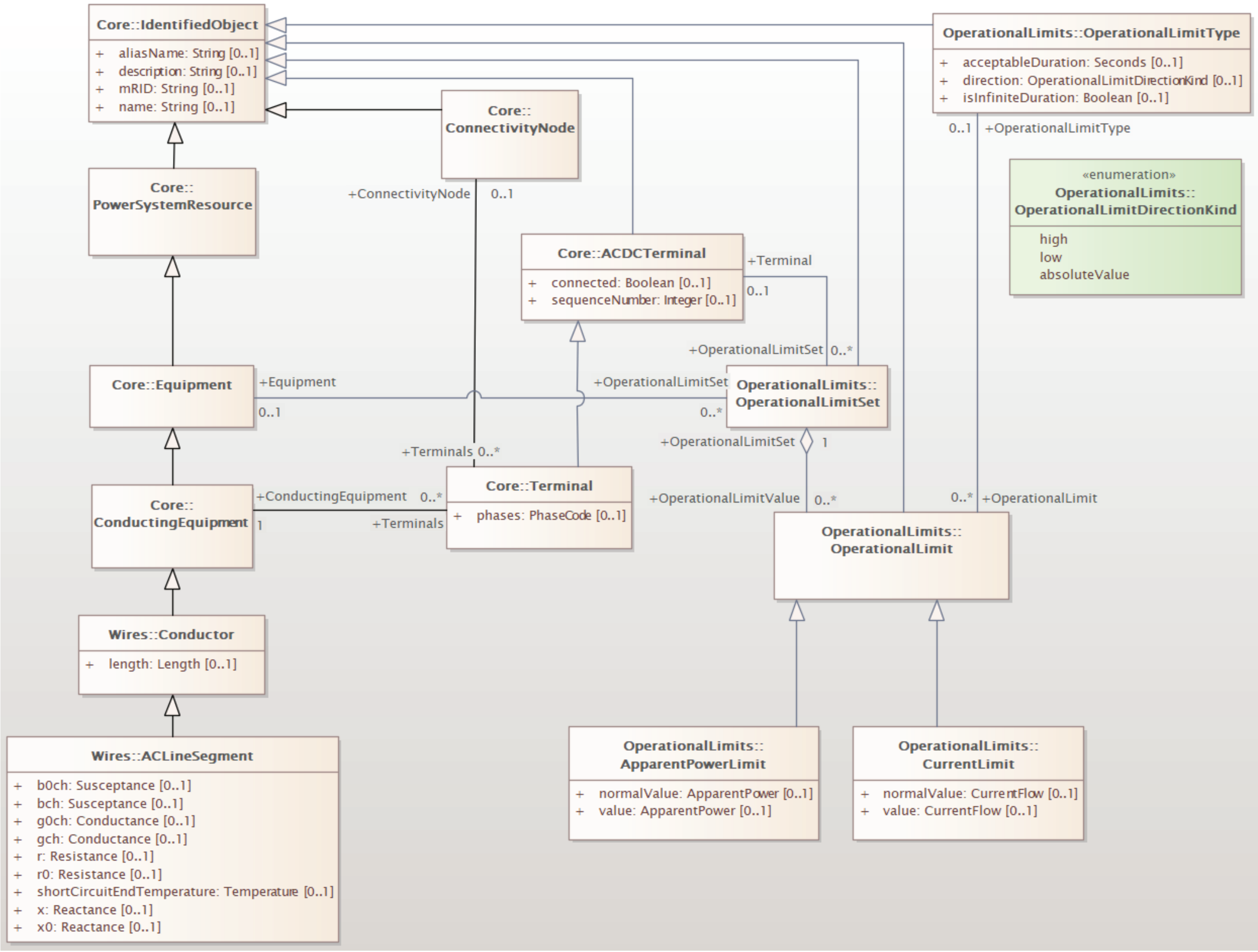

Figure 3 CurrentLimit: Map of Current Limit (Amps) Class to ACLineSegment

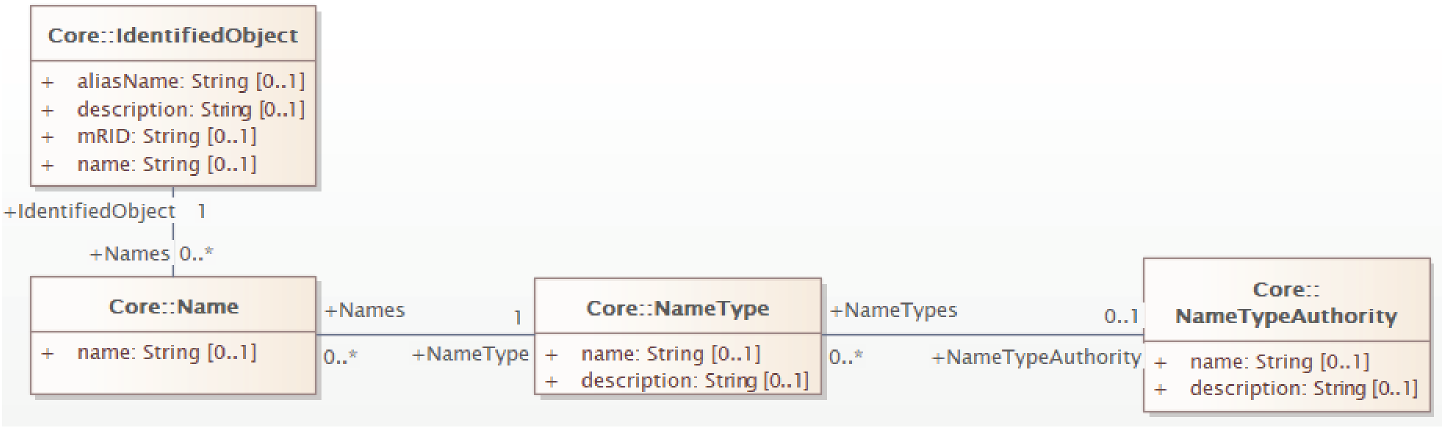

Figure 4 Names: Alternate Names for Everything

Mapping Line Segments

The DLR Calculation Engine can provide ratings for more segments (ACLineSegment) than are modeled in the simulation software.

The temperature-effected sag and ampacity of the conductors are different over the length of most lines even though the conductor and design tension are consistent. The conductor tension is consistent from span to span between dead end structures. Dead end structures are placed in locations where the line turns a significant angle and every so often over the length of the line. Between the dead-end structures, the insulators on structures suspend the wire but do not affect the tension on the adjacent spans. Even though wind flow and sun intensity may vary along the spans, the tension and the sag will be constant between the dead-end structures. Because the ambient conditions change due to wind flow and temperature changes, each subsection of line made up of the spans between two dead end structures may have a different dynamic line rating than other subsections on that line.

Figure 5 shows a few spans of a transmission line. This is not the entire line, only a section in the middle. There are dead-end towers at the structure inside the substation and at periodic points along a transmission path. The structures between the dead-ends are referred to as tangent or suspension structures. These structures only support the conductor vertically. The longitudinal tension of the wire is maintained at the dead-end structures. It should also be noted that the conductor may be different on either side of a dead-end structure. In transmission, the conductor between dead end structures may be assumed to be constant.

The tension of the conductor in one subsection of line between the dead-end towers is not affected by either of the adjacent line subsections. If the DLR Calculation Engine provides limits for more than one of these line sections and each set of results is mapped to a different ACLineSegment, then the multiple ACLineSegments from the DLR Calculation Engine will map to a single set of limits in the control center. Moreover, the graphic shows how transmission lines can cross topographies between substation nodes.

Engineers building models for power flow simulation software generally do not model lines to the granularity described above. Multiple subsections from the DLR Calculation Engine may have to be mapped to a single line in the power flow simulation software. In such a case, the integration software will have to determine which value to pass to the control center. The Names classes may be used to map multiple ACLineSegments that the DLR calculator is using to calculate the DLR on to a single ACLineSegment in the simulation software.

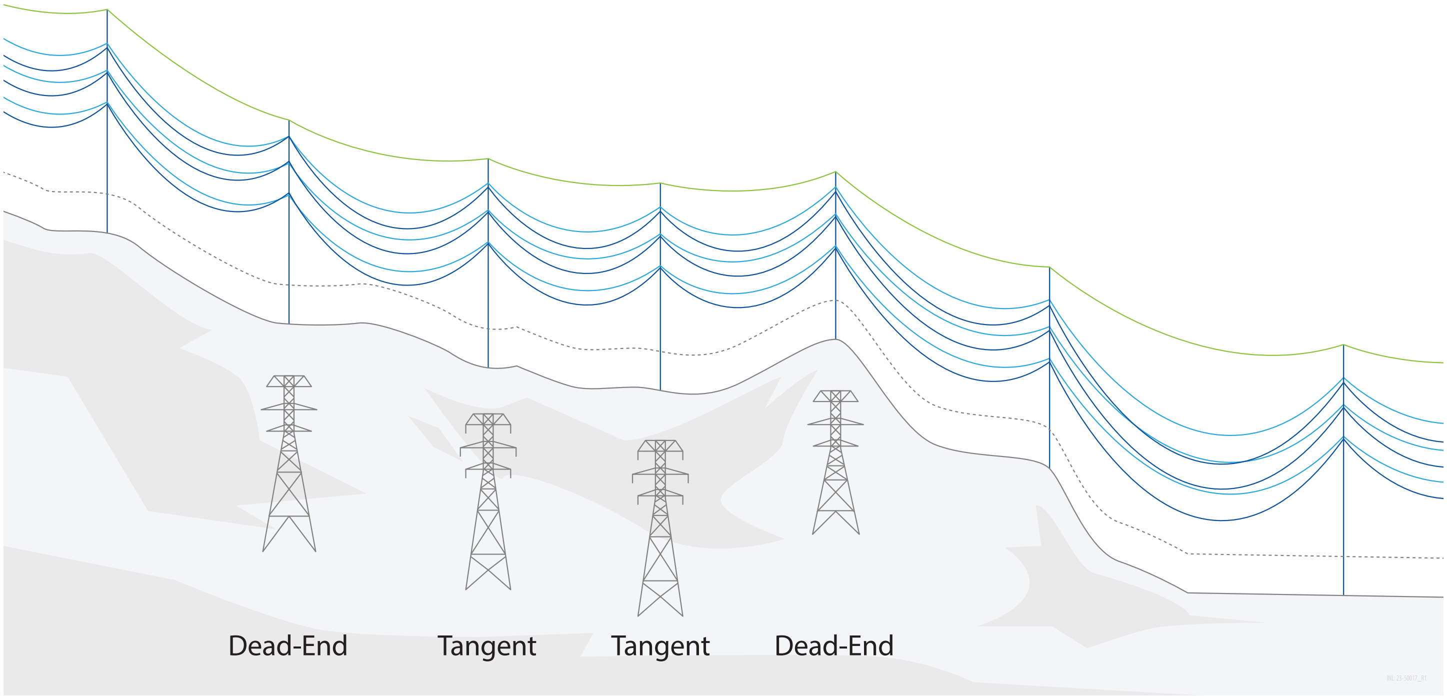

Figure 5: Profile Diagram of a Transmission Line Segment

Mapping Multiple Line Ratings

The use cases accompanying this profile outlines how a real-time line rating (Use Case #1) and a forecasted line rating (Use Case #2) would be used in utility business practices. These two ratings can be achieved through the profile in a few ways. The most straightforward approach would be to specify multiple OperationalLimitSets. This would allow both the real-time and forecasted line ratings to be passed in the same message and map to the same ACLineSegment. Similarly, normal and emergency ratings could be passed as different OperationalLimitSets. The time duration for which the DLR applies is specified in the OperationalLimitType class acceptableDuration attribute.

In each of the use cases, the DLR Calculation Engine is to provide DLRs in time intervals. In Use Case #1, the DLR Calculation Engine regularly publishes updated DLRs for at least the next hour (H +1) in 15-minute intervals, as seen in Figure 6. In Use Case #2, the DLR Calculation Engine publishes forecasted line ratings covering the next 48 hours in hour-long intervals at noon daily, a selection of which is shown in Figure 7. As such, a straightforward application of this profile would involve the OperationalLimitSet pertaining to the real-time DLRs to include multiple OperationalLimitValues associated with each of the 15-minute intervals. The Names attribute within the OperationalLimitSet associates the appropriate 15-minute interval with the integer value provided in OperationalLimitValues. An example of this application of the profile is shown in Figure 6[a].

Note in Figure 6 that the Names attribute is being used to demark the timestep and re-affirm the use case for which the DLRs are useful. In an ideal world, the CIM might include a StartTime and Duration attribute within the OperationalLimitSet. However, because these limits will be exchanged in a system-to-system software environment, manipulating the Names attribute allows us to get the desired functionality while maintaining CIM compliance. The Names can be converted by systems on either end for inclusion in reporting fit for human consumption. Another example of the Names convention is shown in Figure 7, which would support Use Case #2 by providing hourly DLRs in the day-ahead timeframe.

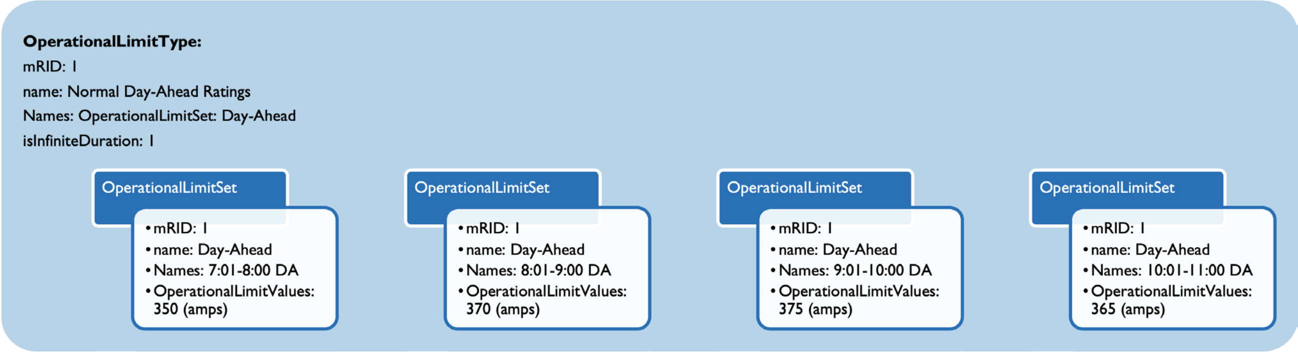

Figure 6 Conceptual Implementation of the Profile for Multiple Time Steps in Real-Time

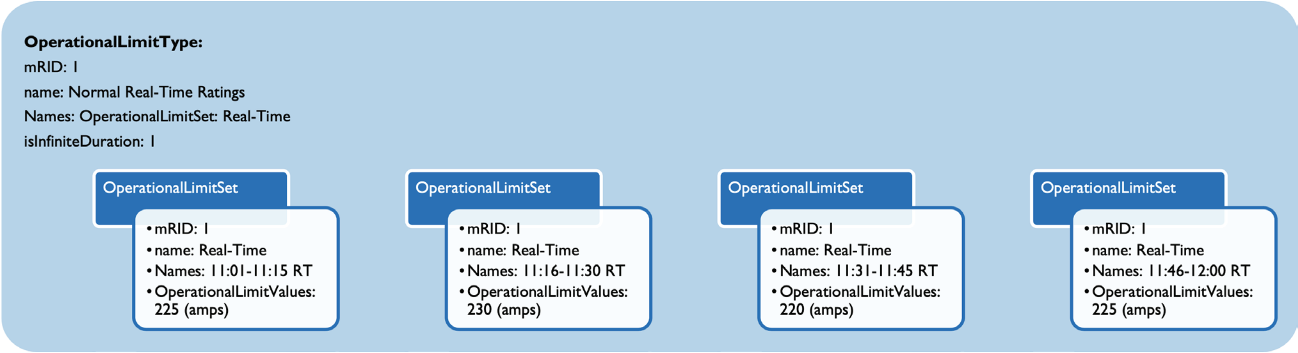

Figure 7 Conceptual Implementation of the Profile for Multiple Hourly Time Steps in Day Ahead

[a] *Note that this graphic has been simplified for new audiences. The other images within this Profile capture the data standard more precisely from a technical perspective.*

Full Profile Definition

The pages below provide a full description of the new DLR Profile. The diagram below provides a picture of the XSD profile, followed by a description of the classes and attributes of the message. Note that the hierarchical definition of the profile begins with the ACLineSegment.

The hierarchy starts with the line, rather than the type of DLR (forecasted, real-time, etc.). There are no known issues with this hierarchy, but it re-emphasizes the need for consistent naming and mapping across the systems with respect to the lines.

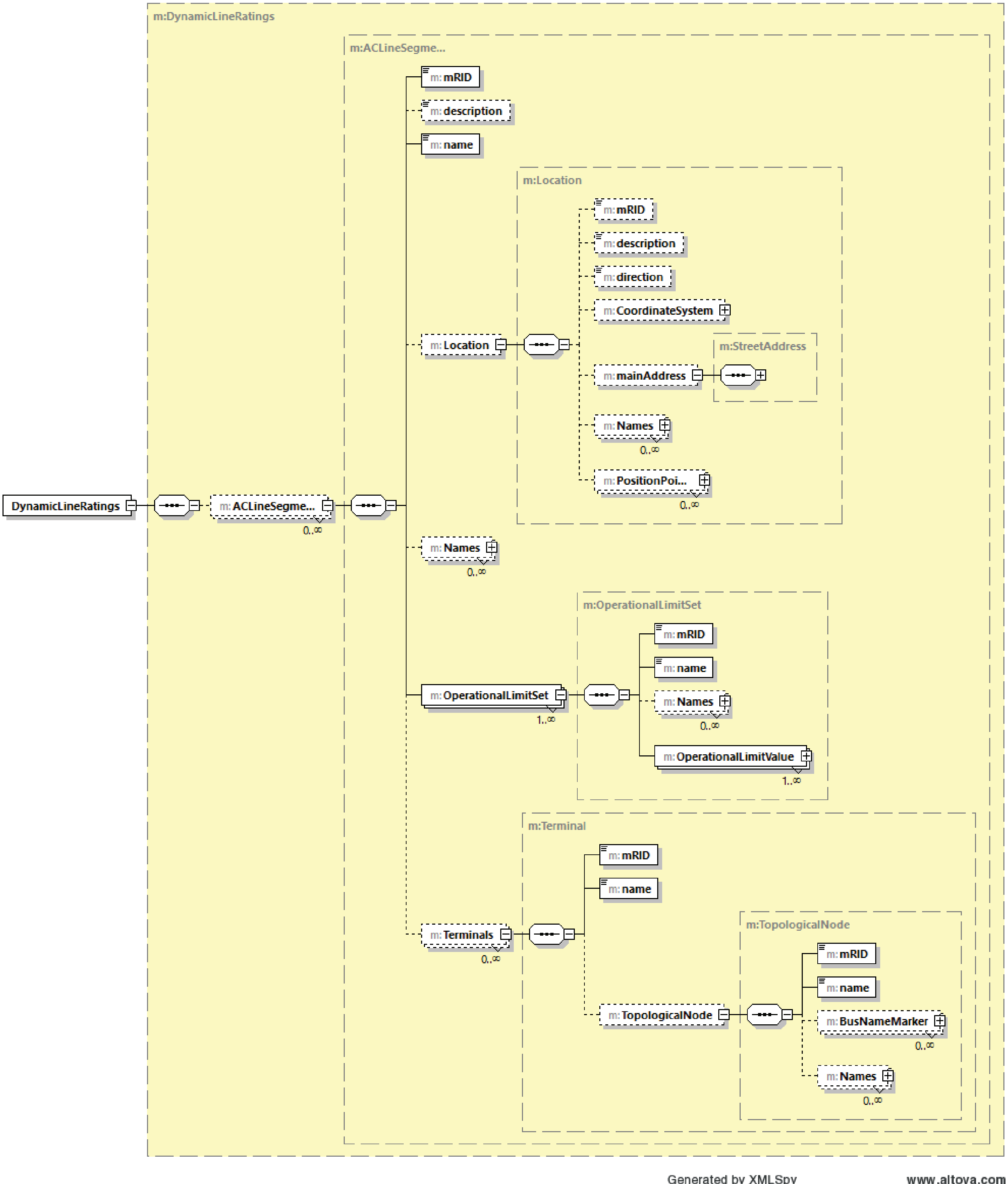

Figure 7 XML Hierarchical Definition of the Data Profile

3.1 Profile Documentation

Profile namespace[b]: http://ucaiug.org/2022/DynamicLineRatings# This Profile is for an XSD message in an XSD/XML serialization.

Concrete Classes – In an XSD, a Concrete Class is the Root Class of the hierarchical message. Therefore, we will start there.

ACLineSegment, Wires Package

A wire or combination of wires, with consistent electrical characteristics, building a single electrical system, used to carry alternating current between points in the power system.

For symmetrical, transposed three phase lines, it is sufficient to use attributes of the line segment, which describe impedances and admittances for the entire length of the segment. Additionally impedances can be computed by using length and associated per length impedances.

Real-Time Use Case Conditions

Object	Quantity	Data Type	Description
mRID	1..1	string	Master resource identifier issued by a model authority. The mRID is unique within an exchange context. Global uniqueness is easily achieved by using a universally unique identifier (UUID), as specified in RFC 4122, for the mRID [8]. The use of UUID is strongly recommended. For CIMXML data files in RDF syntax conforming to IEC 61970-552, the mRID is mapped to rdf:ID or rdf:about attributes that identify CIM object elements [9].
description	0..1	string	A free human readable text describing or naming the object. It may be non-unique and may not correlate to a naming hierarchy.
name	1..1	string	Any free human readable and possibly non unique text naming the object.
Location	0..1	Location	Location of this power system resource.
Names	0..*	Name	All names of this identified object.
OperationalLimitSet	1..*	OperationalLimitSet	The operational limit sets associated with this equipment.
Terminals	0..*	Terminal	Conducting equipment have terminals that may be connected to other conducting equipment terminals via connectivity nodes or topological nodes.

Abstract Classes – In an XSD, these classes are the elements that are linked to the Concrete Class in a hierarchical format.

BusNameMarker, Topology Package

Used to apply user standard names to TopologicalNodes. Associated with one or more terminals that are normally connected with the bus name. The associated terminals are normally connected by non-retained switches. For a ring bus station configuration, all BusbarSection terminals in the ring are typically associated. For a breaker and a half scheme, both BusbarSections would normally be associated. For a ring bus, all BusbarSections would normally be associated. For a "straight" busbar configuration, normally only the main terminal at the BusbarSection would be associated.

[b] *As of publishing, this link does not work, but is provided as common practice for the programmer's use. The profile namespace convention will work in the future once the UCA open source site is working as designed.*

Native Members

Object	Quantity	Data Type	Description
mRID	1..1	string	Master resource identifier issued by a model authority. The mRID is unique within an exchange context. Global uniqueness is easily achieved by using a UUID, as specified in RFC 4122, for the mRID [8]. The use of UUID is strongly recommended. For CIMXML data files in RDF syntax conforming to IEC 61970-552, the mRID is mapped to rdf:ID or rdf:about attributes that identify CIM object elements [9].
name	1..1	string	Any free human readable and possibly non unique text naming the object.
Names	1..*	Name	All names of this identified object.

CoordinateSystem, Common Package

Coordinate reference system.

Native Members

Object	Quantity	Data Type	Description
crsUrn	1..1	string	A uniform resource name (URN) for the coordinate reference system (crs) used to define 'Location.PositionPoints'. An example would be the European Petroleum Survey Group (EPSG) code for a coordinate reference system, defined in URN under the Open Geospatial Consortium (OGC) namespace as: urn:ogc:def:crs:EPSG::XXXX, where XXXX is an EPSG code (a full list of codes can be found at the EPSG Registry web site http://www.epsg-registry.org/). To define the coordinate system as being WGS84 (latitude, longitude) using an EPSG OGC, this attribute would be urn:ogc:def:crs:EPSG::4.3.2.6 A profile should limit this code to a set of allowed URNs agreed to by all sending and receiving parties.

Location, Common Package

The place, scene, or point of something where someone or something has been, is, and/or will be at a given moment in time. It can be defined with one or more position points (coordinates) in a given coordinate system.

Native Members

Object	Quantity	Data Type	Description
mRID	0..1	string	Master resource identifier issued by a model authority. The mRID is unique within an exchange context. Global uniqueness is easily achieved by using a UUID, as specified in RFC 4122, for the mRID [8]. The use of UUID is strongly recommended. For CIMXML data files in RDF syntax conforming to IEC 61970-552, the mRID is mapped to rdf:ID or rdf:about attributes that identify CIM object elements [9].
description	0..1	string	A free human readable text describing or naming the object. It may be non-unique and may not correlate to a naming hierarchy.
direction	0..1	string	(if applicable) A direction allows field crews to quickly find a given asset. For a given location, such as a street address, this is the relative direction in which to find the asset. For example, a streetlight may be located at the 'NW' (northwest) corner of the customer's site, or a usage point may be located on the second floor of an apartment building.
CoordinateSystem	0..1	CoordinateSystem	Coordinate system used to describe position points of this location.
mainAddress	0..1	StreetAddress	Main address of the location.
Names	0..*	Name	All names of this identified object.
PositionPoints	0..*	PositionPoint	Sequence of position points describing this location, expressed in coordinate system 'Location.CoordinateSystem'.

Name, Core Package

The Name class provides the means to define any number of human readable names for an object. A name is not to be used for defining inter-object relationships. For inter-object relationships instead use the object identification 'mRID'.

Native Members

Object	Quantity	Data Type	Description
name	1..1	string	Any free text that name the object.
NameType	0..1	NameType	Type of this name.

NameType, Core Package

Type of name. Possible values for attribute 'name' are implementation dependent but standard profiles may specify types. An enterprise may have multiple IT systems each having its own local name for the same object, e.g. a planning system may have different names from an EMS. An object may also have different names within the same IT system, e.g. localName as defined in CIM version 14. The definition from CIM14 is:

The localName is a human readable name of the object. It is a free text name local to a node in a naming hierarchy similar to a file directory structure. A power system related naming hierarchy may be: Substation, VoltageLevel, Equipment etc. Children of the same parent in such a hierarchy have names that typically are unique among them.

Native Members

Object	Quantity	Data Type	Description
name	1..1	string	Name of the name type.
NameTypeAuthority	0..1	NameTypeAuthority	Authority responsible for managing names of this type.

NameTypeAuthority, Core Package

Authority responsible for creation and management of names of a given type; typically an organization or an enterprise system.

Native Members

Object	Quantity	Data Type	Description
name	1..1	string	Name of the name type authority.

OperationalLimit, OperationalLimits Package

A value and normal value associated with a specific kind of limit.

The sub class value and normalValue attributes vary inversely to the associated OperationalLimitType.acceptableDuration (acceptableDuration for short).

If a particular piece of equipment has multiple operational limits of the same kind (apparent power, current, etc.), the limit with the greatest acceptableDuration shall have the smallest limit value and the limit with the smallest acceptableDuration shall have the largest limit value. Note: A large current can only be allowed to flow through a piece of equipment for a short duration without causing damage, but a lesser current can be allowed to flow for a longer duration.

Native Members

Object	Quantity	Data Type	Description
normalValue	0..1	CurrentFlow	The normal value for limit on current flow. The attribute shall be a positive value or zero.
value	0..1	CurrentFlow	Limit on current flow. The attribute shall be a positive value or zero.
OperationalLimitType	1..1	OperationalLimitType	The limit type associated with this limit.

OperationalLimitSet, OperationalLimits Package

A set of limits associated with equipment. Sets of limits might apply to a specific temperature, or season for example. A set of limits may contain different severities of limit levels that would apply to the same equipment. The set may contain limits of different types such as apparent power and current limits or high and low voltage limits that are logically applied together as a set.

Native Members

Object	Quantity	Data Type	Description
mRID	1..1	string	Master resource identifier issued by a model authority. The mRID is unique within an exchange context. Global uniqueness is easily achieved by using a UUID as specified in RFC 4122, for the mRID [8]. The use of UUID is strongly recommended. For CIMXML data files in RDF syntax conforming to IEC 61970-552, the mRID is mapped to rdf:ID or rdf:about attributes that identify CIM object elements [9].
name	1..1	string	Any free human readable and possibly non unique text naming the object.
Names	0..*	Name	All names of this identified object.
OperationalLimitValue	1..*	OperationalLimit	Values of equipment limits.

OperationalLimitType, OperationalLimits

The operational meaning of a category of limits.

Native Members

Object	Quantity	Data Type	Description
mRID	1..1	string	Master resource identifier issued by a model authority. The mRID is unique within an exchange context. Global uniqueness is easily achieved by using a UUID as specified in RFC 4122, for the mRID [8]. The use of UUID is strongly recommended. For CIMXML data files in RDF syntax conforming to IEC 61970-552, the mRID is mapped to rdf:ID or rdf:about attributes that identify CIM object elements [9].
name	1..1	string	Any free human readable and possibly non unique text naming the object.
Names	1..*	Name	All names of this identified object.

PositionPoint, Common Package

Set of spatial coordinates that determine a point, defined in the coordinate system specified in 'Location.CoordinateSystem'. Use a single position point instance to describe a point-oriented location. Use a sequence of position points to describe a line-oriented object (physical location of non-point oriented objects like cables or lines), or area of an object (like a substation or a geographical zone - in this case, have first and last position point with the same values).

Native Members

Object	Quantity	Data Type	Description
groupNumber	0..1	integer	Zero-relative sequence number of this group within a series of points; used when there is a need to express disjoint groups of points that are considered to be part of a single location.
sequenceNumber	0..1	integer	Zero-relative sequence number of this point within a series of points.
xPosition	0..1	string	X axis position.
yPosition	0..1	string	Y axis position.
zPosition	0..1	string	(if applicable) Z axis position.

Terminal, Core Package

An AC electrical connection point to a piece of conducting equipment. Terminals are connected at physical connection points called connectivity nodes.

Native Members

Object	Quantity	Data Type	Description
mRID	1..1	string	Master resource identifier issued by a model authority. The mRID is unique within an exchange context. Global uniqueness is easily achieved by using a UUID, as specified in RFC 4122, for the mRID [8]. The use of UUID is strongly recommended. For CIMXML data files in RDF syntax conforming to IEC 61970-552, the mRID is mapped to rdf:ID or rdf:about attributes that identify CIM object elements [9].
name	1..1	string	Any free human readable and possibly non unique text naming the object.
TopologicalNode	0..1	TopologicalNode	The topological node associated with the terminal. This can be used as an alternative to the connectivity node path to topological node, thus making it unnecessary to model connectivity nodes in some cases. Note that the if connectivity nodes are in the model, this association would probably not be used as an input specification.

TopologicalNode, Topology Package

For a detailed substation model a topological node is a set of connectivity nodes that, in the current network state, are connected together through any type of closed switches, including jumpers. Topological nodes change as the current network state changes (i.e., switches, breakers, etc. change state).

For a planning model, switch statuses are not used to form topological nodes. Instead they are manually created or deleted in a model builder tool. Topological nodes maintained this way are also called "busses".

Native Members

Object	Quantity	Data Type	Description
mRID	1..1	string	Master resource identifier issued by a model authority. The mRID is unique within an exchange context. Global uniqueness is easily achieved by using a UUID, as specified in RFC 4122, for the mRID[8]. The use of UUID is strongly recommended. For CIMXML data files in RDF syntax conforming to IEC 61970-552, the mRID is mapped to rdf:ID or rdf:about attributes that identify CIM object elements[9].
name	1..1	string	Any free human readable and possibly non unique text naming the object.
BusNameMarker	0..*	BusNameMarker	BusnameMarkers that may refer to a pre defined TopologicalNode.
Names	0..*	Name	All names of this identified object.

Enumerations

Compound Types

StreetAddress, Common Package

General purpose street and postal address information.

Members

Object	Quantity	Data Type	Description
postalCode	0..1	string	Postal code for the address.
streetDetail	0..1	StreetDetail	Street detail.
townDetail	0..1	TownDetail	Town detail.

StreetDetail, Common Package

Street details, in the context of address.

Members

Object	Quantity	Data Type	Description
addressGeneral	0..1	string	First line of a free form address or some additional address information (for example a mail stop).
addressGeneral2	0..1	string	(if applicable) Second line of a free form address.
addressGeneral3	0..1	string	(if applicable) Third line of a free form address.
name	0..1	string	Name of the street.
number	0..1	string	Designator of the specific location on the street.
prefix	0..1	string	Prefix to the street name. For example: North, South, East, West.
suffix	0..1	string	Suffix to the street name. For example: North, South, East, West.
suiteNumber	0..1	string	Number of the apartment or suite.

TownDetail, Common Package

Town details, in the context of address.

Members

Object	Quantity	Data Type	Description
Code	0..1	string	Town code.
country	0..1	string	Name of the country.
name	0..1	string	Town name.
section	0..1	string	Town section. For example, it is common for there to be 36 sections per township.
stateOrProvince	0..1	string	Name of the state or province.

Datatypes

CurrentFlow

Electrical current with sign convention: positive flow is out of the conducting equipment into the connectivity node. Can be both AC and DC.

XSD type: float

Acronyms

CIM	Common Information Model
CRS	Coordinate reference system
DERMS	Distributed Energy Resources Management System
DLR	Dynamic Line Rating
DMS	Distribution Management System
DOE	Department of Energy
EMS	Energy Management Systems
EPSG	European Petroleum Survey Group
FERC	Federal Energy Regulatory Commission
GETs	Grid Enhancing Technologies
IEC	International Electrotechnical Commission
INL	Idaho National Lab
mRID	master Resource Identifier issued by a model authority
NIST	National Institute of Standards and Technology
OE	Office of Electricity
OFC	Open Geospatial Consortium
PFC	Power flow control
RDF	Resource Description Framework
RDFS	Resource Description Framework Schema
SCADA	Supervisory Control And Data Acquisition
SEPA	Smart Electric Power Alliance
SOAP	Simple Object Access Protocol
TOGETS	Transmission Optimization for Grid Enhancing Technologies
UML	Unified Modeling Language
URN	Unform Resource Name
UUID	Universally Unique Identifier
WETO	Wind Energy Technologies Office
XML	Extensible Markup Language
XSD	XMS Schema Definition

References

1 Federal Energy Regulatory Commission / Managing Transmission Line Ratings / Order 881, *2021*.

2 *D. Chung, "Interoperability Profiles – A Better Way to Buy Grid Technology," SEPA, 2 April 2020. [Online]. Available: https://sepapower.org/knowledge/interoperability-profiles-a-better-way-to-buy-grid-technology/. [Accessed 21 November 2022].*

3 *U.S. Department of Energy, "Grid-Enhancing Technologies: A Case Study on Ratepayer Impact," April 2022. [Online]. Available: https://www.energy.gov/sites/default/files/2022-04/Grid%20Enhancing%20Technologies%20-%20A%20Case%20Study%20on%20Ratepayer%20Impact%20-%20February%202022%20CLEAN%20as%20of%20032322.pdf. [Accessed October 2022].*

4 *NIST, "NIST Framework and Roadmap of Smart Grid Interoperability Standards, Release 4.0," October 2022. [Online]. Available: https://www.nist.gov/ctl/smart-connected-systems-division/smart-grid-group/smart-grid-framework.*

5 *IEC TC 57, "IEC - TC 57 Dashboard>Scope," [Online]. Available: https://www.iec.ch/dyn/www/f?p=103:7:517240052971079::::FSP_ORG_ID,FSP_LANG_ID:1273,25. [Accessed 28 October 2022].*

6 *P. Jackson, "XML Tutorial for Beginners," Guru99, 11 November 2022. [Online]. Available: https://www.guru99.com/xml-tutorials.html.*

7 *Stardog, "RDF Graph Data Model," Stardog union, [Online]. Available: https://docs.stardog.com/tutorials/rdf-graph-data-model. [Accessed 21 November 2022].*

8 *Network Working Group, "A Universally Unique IDentifier (UUID) URN Namespace," 2005. [Online]. Available: https://www.rfc-editor.org/rfc/rfc4122.*

9 *International Electrotechnical Commission, "Energy management system application program interface (EMS-API) - Part 552: CIMXML Model exchange format," 2016. [Online]. Available: https://webstore.iec.ch/publication/25939.*


Idaho National Laboratory