Adapting the CIM model to describe electrified railway systems

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Abstract

The Common Information Model (CIM) is a standard based on UML that is used to precisely describe electric networks. It has been developed by the electric power industry to allow an easy exchange of information between different IT platforms and different companies. Practical implementation of the CIM model uses XML for data exchanging and thus benefits of the XML advantages (portability, extendibility, human readable…) as its syntax checking mechanisms (well formedness check and validation against schemas).

This paper presents an adaptation of the CIM that has been developed to describe the railway systems facilities and components which are not included in the CIM model, such as: DC Traction Substation and Neutral Zone.

This model is intended to be used as a standard exchange format between control centres (normally developed by different companies) of the Spanish railway infrastructure manager (ADIF). This development will significantly enhance the interoperability of different control centres and thus improve the robustness of the railway network.
Keywords: railway systems, power supply, interoperability, control centres, CIM.

1 Introduction

An Energy Management System (EMS) consists of different applications intended to remotely manage an electric power system [1]. To optimize the correct operation of the EMS, these applications need to exchange information about the electric system in the simplest way possible. This implies the creation

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of a semantic information model that describes the components of an electric power system and the relationships between them. This model has to be common for all the applications, so that there is no need to use converters to exchange data between different-vendor systems. A concrete format to exchange the information between the applications is also needed to guarantee their interoperability and therefore the proper operation of the EMS.

The main purpose of the Common Information Model (CIM), defined in the standards IEC 61970 [2, 3] and IEC 61968 [4], is to achieve the interoperability between applications in an EMS, or between applications in different EMS's, by describing the semantic model quoted above. The CIM also provides the CIM/XML, which is a concrete XML-based format allowing the exchange of information between the applications.

Railway systems have their own remote management systems including different applications that need to exchange information about the components they are intended to manage. Therefore, there is an obvious interest in applying the CIM general model in this particular type of electric systems in order to improve their operation.

This paper presents the adaptation of the CIM to the railway systems by creating an extension model to describe typical railway systems components. Following sections will describe:

- The CIM semantic model information [2]
- The CIM/XML [3] format for information exchange between applications
- The typical railway system components which are not included in the CIM [9]
- The extension model created for the CIM adaptation to electrified railway systems
- A practical example in which a real railway system facility is represented in CIM/XML by using this extension CIM model

This extension model is intended to help solving the problem of interoperability between control centres (management systems) which manage the Spanish railway infrastructure manager (ADIF) facilities.

2 CIM semantic model

The CIM semantic model is described in the standard IEC 61970-301 [2] and is based on UML. UML is a general-purpose language with graphical notation used to describe an object-oriented abstract model. By using UML diagrams, the CIM is able to describe all the necessary relationships to represent any electric system topology. Thus, the CIM organize the information of electric power systems in class hierarchies, in which each class describes a type of component in the electric power system and the associations between classes, called rolenames, describe the relationships between the different types of components. For example, Figure 1 represents the UML diagram which describes the relationships between the following classes: Power Transformer, Transformer Winding, Conducting Equipment and Terminal.

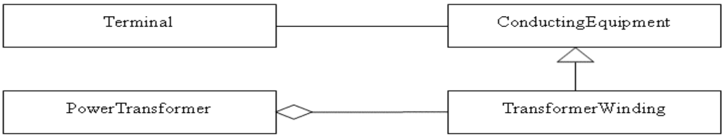

Figure 1: CIM UML diagram.

The CIM considers three different types of relationships between classes:

- Aggregation is a relationship between classes which means that one of them, Power Transformer, contains the other, Transformer Winding.
- Inheritance is a relationship in which there is a parent class, Conducting Equipment, and a sub-class derived from it, Transformer Winding. This means that all Conducting Equipment attributes and rolenames are inherited by Transformer Winding class.
- Association is a relationship between classes which can not be described as aggregation or inheritance: for example, the relationship which describes that any instance of the Conducting Equipment class may have Terminals for defining its interconnections with other Conducting Equipment instances.

3 CIM/XML

The Extensible Markup Language (XML) [7] is a universal format that allows users to design their own markup languages. These markup languages organize the information in a simple way by using tags, providing the advantages of: portability, extensibility, syntax checking mechanisms and being human and machine-readable.

The CIM/XML [3] is a XML-based format used for the exchange of CIM information between applications. It uses the Resource Description Framework (RDF) [5], because of its usefulness in representing object-oriented models, such as the CIM model, in XML.

Thus, RDF/XML provides tags (rdf:Description, rdf:ID, rdf:resource, etc.) to make it simple the description of resources by using statements which consist of: a resource, a property and a property value.

In CIM/XML users can easily describe instances belonging to a CIM class by assigning specific values to the CIM properties related to that class. However, this is not enough. Users have to be able to describe these classes, properties and the relationships between them. In fact, RDF Schema [5] was created for that purpose, as it provides tags (rdfs:Class, rdfs:subClassOf, etc.) to ease the description of new classes and properties. These new classes and properties will define a new vocabulary which includes all the model concepts and their relationships.

That way, the CIM RDF Schema [3] describes all the CIM classes, properties and their relationships, and as a result of that, defines the cim:vocabulary. To achieve its objective, the CIM RDF Schema uses the mechanisms provided by the RDF Schema vocabulary (rdfs tags), but it also needs to use other terms to represent concepts that are not included in the rdfs:vocabulary, such as:

- Multiplicity, which describes how many instances of a given rolename are allowed for a given class.
- Inverse rolename, which provides the name of the rolename at the opposite class for the association.

4 Need of extensions in the CIM for Railway Adaptation

As it was explained in sections above, the CIM model provides classes, properties and relationships between them to describe power electric systems. This section explains the need of creating extensions to this model to describe railway electrified systems. Thus, there are typical railway systems components [9] which are not included in the CIM and which need to be modelled to properly describe railway electrified systems. These components can be organized in different groups as follows:

4.1 New facilities

The CIM model includes the cim:Substation class, derived from the cim:EquipmentContainner class and associated with the cim:VoltageLevel and cim:Bay classes. This means that any cim:Substation instance can contain different Voltage Levels, Bays and Equipment. In electrified railway systems there are two types of electric facilities which also can contain Voltage Levels, Bays and Equipment. These two types of electric facilities need to be modelled separately because of their own configurations and components:

- DC Traction Substation, which is a substation that feeds track segments in DC. In addition to typical substation equipment (disconnectors, breakers or power transformers), these facilities include components such as rectifiers and other power converters.
- Neutral Zone, which is a facility without tension between two traction substations. It includes components such as asymmetrical section insulators or air section insulators.

4.2 New conducting equipment

Typical conducting equipment from railway electrified systems which are not included in the CIM model are described bellow organized in three different subgroups:

- Switching Elements. The CIM model includes the parent class cim:Switch from which derive the cim:Disconnector and cim:ProtectedSwitch classes. However, there is a need of creating extension classes to clearly distinguish different types of switching elements in railway electrified systems. Thus, disconnectors that can not be remotely operated, Manual Disconnectors, must be differentiated from those that can be remotely operated, Motorized Disconnectors. In addition, switching elements have to be clearly differentiated according to their ability to open loads: Disconector, which can not open loads, Nominal Load Breaker, which can open nominal loads and Abnormal Load Breaker, which can open abnormal loads. Finally, it is necessary to distinguish between switching elements located in the catenary and those which are not.

- Power Converters. There is not a cim:class which represents these type of railway electrified systems components. Four different groups of converters need to be modelled: DC to AC Converter, DC to DC Converter, AC to AC Converter and AC to DC Converter.
- Other Conducting Equipment. Other typical railway systems conducting equipment, such as: rectifier group transformer, batteries, track segments and overhead contact line segments, are not included in the CIM model and need to be described.

4.3 New no conducting equipment

There are also no conducting components which have to be modelled to describe railway systems, but which do not appear in the CIM, such as: asymmetrical section insulators, air section insulators or train ground cabinets.

4.4 Blocks

A block is a group of elements (disconnectors, breakers, rectifiers, etc.) belonging to a facility. The CIM includes the cim:Bay class, which represents groups of elements in an facility. However, elements organization in bays may not fit with the organization of these elements in blocks, as it may occur that a bay is composed of several blocks. Therefore, it is necessary to extend the CIM model to represent the block type components.

4.5 Regions/SubRegions

In railway systems, it is necessary to divide the network in different regions and subregions according to the element assignment to different control centres. In this case, there is no need to define new adifcim:classes, because there are two cim:classes (cim:GeographicalRegion and cim:SubGeographicalRegion) that can be used for this particular purpose.

5 ADIFCIM Extension model

Section 4 explained the reasons which make necessary the creation of a CIM model extension to include different railway systems components which are not represented in the original cim:vocabulary. In section 5, the solution adopted for this extension model, adifCIM extension model, is shown. Thus, this section will explain the creation of the cim:vocabulary extension, the adifcim:vocabulary, in order to provide the necessary classes and properties to describe the typical electrified railway systems components.

The CIM is an object-oriented model in which the inheritance is an important issue, as it is the main type of relationship between CIM classes. This fact provides a huge advantage when going through a model extension. This way, all the new classes described in adifcim:vocabulary were derived from existing CIM class in the cim:vocabulary, inheriting existing CIM rolenames and attributes that do not have to be redefined again in the extension model.

The new classes and properties described in the extension model were organized in different groups depending on the component type that it was going to be modelled.

5.1 New facilities

The solution adopted to model the new facilities explained in section 4.1 was to create two new classes derived by inheritance from the cim:Substation class: adifcim:DCTractionSubstation and adifcim:NeutralZone.

Figure 2 shows the ADIFCIM RDF Schema fragment which describes of the adifcim:DCTractionSubstation class.

```xml
<rdfs:Class rdf:ID="DCTractionSubstation">
        <rdfs:label xml:lang="en">DCTractionSubstation </rdfs:label>
        <rdfs:comment>A DC traction substation, derived form Substation.</rdfs:comment>
        <cims:profile>adifCIM</cims:profile>
        <cims:belongsToCategory rdf:resource="http://iec.ch/TC57/2001/CIM-schema-cim10#Core"/>
        <rdfs:subClassOf rdf:resource="http://iec.ch/TC57/2001/CIM-schema-cim10#Substation"/>
</rdfs:Class>
```

Figure 2: ADIFCIM RDF Schema fragment for DC Traction Substation definition.

All the ADIFCIM Schema classes are described in the same way, i.e., by using the following terms: rdfs:label, rdfs:comment, rdfs:subClassOf (used to refer to the parent class from which the new one is derived), cims:profile (provides the possibility of specifying the standard profile in which this new class is being described) and cims:belongsToCategoy, which is used to refer to the CIM package to which the new class belongs.

5.2 New conducting equipment

Extensions regarding the new conducting components which have to be included in CIM model for its railway systems adaptation were created as follows:

- Switching Elements. Figure 3 shows the UML diagram describing the ADIFCIM classes created to represent the switching elements explained in section 4.2. As it is shown, these new classes derive from: cim:Disconnector class, cim:LoadBreakSwitch and cim:Breaker class.
- Power Converters. Four new classes (like adifcim:DCtoACConverter) were created corresponding with the four different types of power converters. All of them were derived from cim:ConductingEquipment.
- Other Conducting Equipment. The ADIFCIM RDF Schema also defines classes which represent other conducting equipment not included in the CIM, such as: adifcim:RectifierGroupTransformer, derived from

cim:PowerTransformer, adifcim:OverheadLineSegment and adifcim:TrackSegment both derived from cim:DCLineSegment and adifcim:Battery, derived from cim:EquivalentSource.

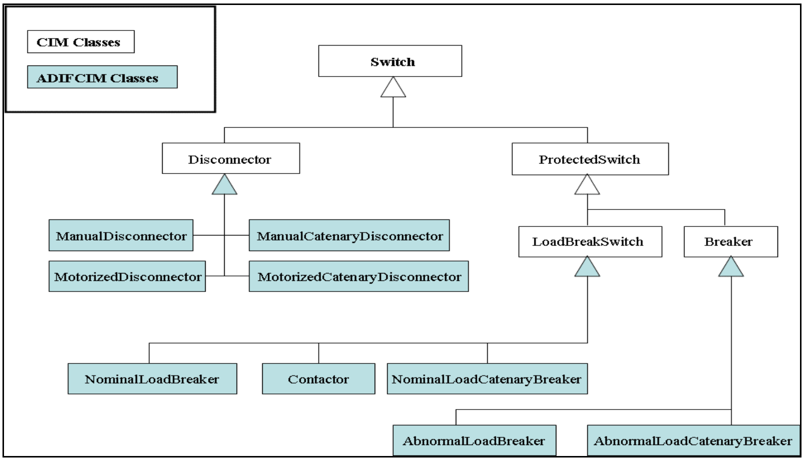

Figure 3: UML diagram for switching elements.

5.3 New no conducting equipment

The ADIFCIM Schema describes those no conducting components quoted in section 4.2 with different classes derived from cim:Equipment class, such as: adifcim:TrainGroundCabinet or adifcim:AirSectionInsulator.

5.4 Blocks

The description of the block type components is given by the adifcim:Block class, which derives from the cim:Bay class.

5.5 ADIFCIM Extensions Summary

Table 1 shows all the ADIFCIM classes with their CIM parent classes.

Table 1: ADIFCIM classes.

ADIFCIM class	CIM parent class	ADIFCIM class	CIM parent class
New Installations		adifcim:DCtoACConverter	cim:ConductingEquipment
adficim:DCTractionSubstation	cim:Substation	adifcim:DCtoDCConverter	cim:ConductingEquipment
adifcim:NeutralZone	cim:Substation	adifcim:ACtoDCConverter	cim:ConductingEquipment
New Conducting Equipment		adifcim:ACtoACConverter	cim:ConductingEquipment
adifcim:ManualDisconnector	cim:Disconnector	adifcim:RectifierGroupTransformer	cim:PowerTransformer
adifcim:MotorizedDisconnector	cim:Disconnector	adifcim:OverheadLineSegment	cim:DCLineSegment
adifcim:ManualCatenaryDisconnector	cim:Disconnector	adifcim:Battery	cim:EquivalentSource
adifcim:MotorizedCatenaryDisconnector	cim:Disconnector	**New No Conducting Equipment**	
adifcim:NominalLoadBreaker	cim:LoadBreakSwitch	adifcim:AsymetricalSectionInsulator	cim:Equipment
adifcim:Contactor	cim:LoadBreakSwitch	adifcim:AirSectionInsulator	cim:Equipment
adifcim:NominalLoadCatenaryBreaker	cim:LoadBreakSwitch	adicim:TrainGroundCabinet	cim:Equipment
adifcim:AbnormalLoadBreaker	cim:Breaker	**Blocks**	
adifcim:AbnormalLoadCatenaryBreaker	cim:Breaker	adifcim:Block	cim:Bay

6 A practical example

Finally, this section shows the CIM/XML description of some components from a real Spanish railway system DC Traction Substation by using the cim:vocabulary and the adifcim:vocabulary extension. Figure 4 shows a part of the real DC Traction Substation single line diagram.

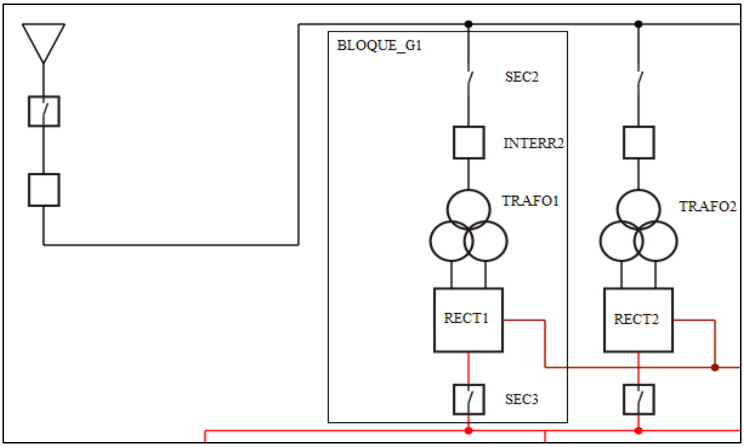

Figure 4: Real facility single line diagram.

Figure 5 shows the facility CIM/XML description. An extension class is used for this purpose: the adifcim:DCTractionSubstation. This particular facility is named SE_EXAMPLE and belongs to the SubGeographicalRegion ES_CENTRE, meaning that is located in the centre region of Spain. As it is shown, these properties, name and region, are inherited from existing CIM classes. Therefore, there was no need to redefine them in the extension ADIFCIM RDF Schema.

```
<adifcim:DCTractionSubstation rdf:ID="_SE_EXAMPLE" >
  <cim:IdentifiedObject.name>SE_EXAMPLE</cim:IdentifiedObject.name>
  <cim:Substation.Region rdf:resource="#_ES_CENTRE"/>
</adifcim:DCTractionSubstation>
```

Figure 5: Real facility CIM/XML description.

In SE_EXAMPLE there are several components which are not included in the CIM model. The description of those elements requires the use of the adifcim:vocabulary classes, which were explained in section 5. Thus, the definition of one of the Rectifier Group Transformers is shown in Figure 6. This particular Rectifier Group Transformer: is named EXAMPLE_TRAFO1, has three windings, it is a fix transformer (do not control voltage or phase) and belongs to block BLOQUE_G1. Again all these properties are inherited from existing CIM classes.

```
<adifcim:RectifierGroupTransformer rdf:ID="_EXAMPLE_TRAFO1">
  <cim:PowerTransformer.transformerType rdf:resource="http://iec.ch/TC57/2006/CIM-schema-cim10#TransformerType.fix"/>
  <cim:PowerTransformer.Contains_TransformerWindings rdf:resource="#_EXAMPLE_TRAFO1_ARROLL1"/>
  <cim:PowerTransformer.Contains_TransformerWindings rdf:resource="#_EXAMPLE_TRAFO1_ARROLL2"/>
  <cim:PowerTransformer.Contains_TransformerWindings rdf:resource="#_EXAMPLE_TRAFO1_ARROLL3"/>
  <cim:Equipment.MemberOf_EquipmentContainer rdf:resource="#_BLOQUE_G1"/>
  <cim:IdentifiedObject.name>EXAMPLE_TRAFO1</cim:IdentifiedObject.name>
</adifcim:RectifierGroupTransformer>
```

Figure 6: TRAFO1 CIM/XML description.

In addition to the Rectifier Group Transformer, BLOQUE_G1 also has these components:

- SEC2, which is a Manual Disconnector
- INTERR2, which is a Breaker
- RECT1, which is an AC to DC Converter
- SEC3, which is a Motorized Disconnector

Figure 7 shows the SEC2 CIM/XML description. This CIM/XML description shows that SEC2 is manual disconnector, which is normally closed (the cim:Switch.normalOpen property is set to false) and whose associated Terminals are: _TERM_EX_SEC2_1 and _TERM_EX_SEC2_2.

```
<adifcim:ManualDisconnector rdf:ID="_SEC2">
  <cim:ConductingEquipment.Terminals rdf:resource="#_TERM_TARD_SEC2_1"/>
  <cim:ConductingEquipment.Terminals rdf:resource="#_TERM_TARD_SEC2_2"/>
  <cim:Switch.normalOpen>false</cim:Switch.normalOpen>
  <cim:Equipment.MemberOf_EquipmentContainer rdf:resource="#_BLOQUE_G1"/>
  <cim:IdentifiedObject.name>SEC2</cim:IdentifiedObject.name>
</adifcim:ManualDisconnector>
```

Figure 7: SEC2 CIM/XML description.

Finally, the connections between conducting components are described by defining their Terminals and the Connectivity Nodes. Thus, a conducting component has one or more Terminals associated with it, and these Terminals are associated with a single Connectivity Node. For example, Figure 8 shows the Connectivity Node CN_EX_4 definition, which describes the connection between SEC2 and INTERR2.

```
<cim:ConnectivityNode rdf:ID="_CN_EX_4">
  <cim:ConnectivityNode.Terminals rdf:resource="#_TERM_EX_SEC2_2"/>
  <cim:ConnectivityNode.Terminals rdf:resource="#_TERM_EX_INTERR2_1"/>
  <cim:ConnectivityNode.MemberOf_EquipmentContainer rdf:resource="#_ZONA_V_AT_AC"/>
  <cim:IdentifiedObject.name>CN_EX_4</cim:IdentifiedObject.name>
</cim:ConnectivityNode>
```

Figure 8: CN_EX_4 CIM/XML description.

7 Conclusions

There is an obvious interest in adapting the CIM model to the railway electrified systems as it will ease the interoperability between different control centres applications, even if they are not from the same vendor.

The main problem when working in this adaptation is the existence of several railway systems components which need to be modelled for the description of the system and which are not included in the CIM. Throughout this paper these railway components are identified and the ADIFCIM extension model is explained.

Finally, this paper describes a practical example in which a real DC Traction Substation from the Spanish railway electrified system is modelled in CIM/XML format by using the ADIFCIM extension.

References

[1] IEC (2003) "IEC 6970-1 Energy management system application program interface Part 1: Guidelines and general requirements"
[2] IEC (2006) "IEC 6970-301 Energy management system application program interface Part 301: Common Information Model (CIM) Base"
[3] IEC (2006) International Electrotechnical Commission, "IEC 6970-501 Energy management system application program interface Part 501: Common Information Description Framework (CIM RDF) schema"
[4] IEC (2006) "IEC 61968-13 Ed.1: System interfaces for distribution management- Interface Reference Model"
[5] RDF Primer. W3C Recommendation, 10 February 2004. Frank Manola, Eric Miller. www.w3.org/TR/REC-rdf-syntax/
[6] RDF Vocabulary Description Language 1.0: RDF Schema, W3C Recommendation, 10 February 2004. Dan Brickley, R.V. Guha. www.w3.org/TR/rdf-schema/
[7] Extensible Markup Language (XML) 1.0 (Fourth Edition), W3C Recommendation, 19 August 2006, Tim Bray, Jean Paoli, C. M. Sperberg-McQueen, Eve Maler, François Yergeau. www.w3.org/XML/
[8] Namespaces in XML (Second Edition), W3C Recommendation, 16 August 2006, Tim Bray, Dave Hollander, Andrew Layman, Richard Tobin. www.w3.org/TR/REC-xml-names/
[9] Technical and functional requirements for the supply and facility of Control Centres in Railway Systems, ADIF, October 2006