Introduction to CIM

Acknowledgment: These slides were downloaded from CIM user group website at http://cimug.ueatug.org. They are authored by Xtensible Solutions, with modifications for being used in class.

Presentation Contents

• Background
• What is the CIM
• How the CIM is used in the Utility Enterprise
  – As a semantic model for information exchange
• Three Layer Architecture for Using the CIM Standards
• CIM UML model
• Profiles for business context
• Implementation syntax
  – XML Schema – for messaging
  – RDF Schema - for model exchange
• Where to get CIM information
CIM History

- 1992 – Unified Information turned over a data model based on the EPRI OTS to the CCAPI Task Force with the understanding it would be turned into an industry standard model
- 1993 to 1996 - The CCAPI task force expanded the data model with a primary goal of enabling use of plug compatible applications to help protect utility investment in applications
  - Entity Relationship Visio Diagram with MS Access database
- 1996 – The CIM was turned over to IEC Technical Committee 57, Working Group 13&14, where it is advancing through the standards process. It covers both electric utility transmission and distribution business operations
  - Converted to UML and initially maintained in Rational Rose
- 2000 – NERC mandates CIM and first IOP test
- 2003 – ISO/RTO Council and EPRI sponsored an initiative to expand CIM into Market Operations, a.k.a. CME, followed by extensions for Planning and Dynamics
- 2005 – First edition of IEC 61970-301 CIM Base
- 2005 – CIM Users Group established under UCA Users Group
- 2008 – CIM adopted by UCTE
- 2009 – NIST identifies CIM as key standard for Smart Grid interoperability
- 2010 – ENTSO-E migrates to CIM and holds first IOP test

The IEC Common Information Model (CIM) - What Is It?

- A set of standards in enable system integration and information exchange based on a common information model
  - Provides a general information model and message/file schemas for messages/files exchanged between systems
- A key differentiator: The CIM standards are based on a Unified Modeling Language (UML) based information model representing real-world objects and information entities exchanged within the value chain of the electric power industry
  - Provides common semantics for all information exchanges
    - referred to as Model-Driven Integration (MDI)
  - Not tied to a particular application’s view of the world
    - But permits same model to be used by all applications to facilitate information sharing between applications
- Maintained by IEC in Sparx Enterprise Architect modeling tools
- Many tools available generating design artifacts and documentation
- Enable data access to enterprise data warehouse in a standard way
GridWise Interoperability Framework

Role of CIM

Organizational (Pragmatics)

Informational (Semantics)

Technical (Syntax)

1. Basic Connectivity
2. Network Interoperability
3. Syntactic Interoperability
4. Semantic Understanding
5. Business Context
6. Business Procedures
7. Business Objectives
8. Strategic and Tactical Objectives Shared Between Businesses
9. Alignment Between Operational Business Processes and Procedures
10. Economic/Regulatory Policy

GridWise Interoperability Framework

Sample Power System Model

Company

Generator

AC Line

Substation

Load Area

Member Of

Belongs To

Operates

Connects To

Owns

Operates

Connects To

Xtensible Solutions
Application of Information Model

Common model creates understanding

Information is Needed From Many Individual Systems
The **Common Language** Should Provide Relevant Information To A User Regardless of Source

---

**Engineering Concerns**
- The logical view of how the type of equipment fits (will fit) in the electrical network. Nominal configuration of “as-built” and “future” states:
  - Field Name
  - Spatial Location
  - Version
  - Physical Connectivity
  - Load Projections
  - Capacity Requirements
  - Compatible Unit
  - Equipment Ratings

**Materials Management Concerns**
- Planning and tracking material requirements for construction and maintenance. Information about physical pieces of equipment:
  - Asset Identifier
  - Compatible Unit
  - Equipment Component Type
  - Equipment Manufacturer/Model
  - Serial Number
  - Location
  - Equipment Location History
  - Manufacturer Specifications

**Construction Concerns**
- Lifecycle information regarding when and how to install equipment:
  - Field Name
  - Location
  - Equipment Manufacturer/Model
  - Compatible Unit
  - Equipment Ratings
  - Work Order
  - Work Design
  - Installation Schedule & Budget
  - Permits
  - Manufacturer Specifications
  - Safety Requirements

---

**The Needs of Various Users – Some Same, Some Different**

---

**Operations Concerns**

**Protection Concerns**

**Maintenance Concerns**

---

**Xtensible Solutions**
The Needs of Various Users – Some Same, Some Different (continued)

Operations Concerns
Real-time condition of equipment and electrical network necessary to maintain reliable network operation:
- Field Name
- Schematics & Spatial Location
- Electrical Connectivity
- Operational Limits (dynamic)
- Equipment Status
- Clearances
- Network Measurements (voltage, current, frequency)
- Equipment Faults
- Weather Measurements
- Operational Restrictions

Protection Concerns
Setting and configuring relays based on equipment and network protection requirements:
- Field Name
- Schematics
- Electrical Connectivity
- Maximum Capacity
- Zones Of Protection
- Equipment Status
- Clearances
- Network Measurements (voltage, current, frequency, transients)
- Equipment Faults

Maintenance Concerns
Lifestyle information regarding when and how equipment is maintained:
- Field Name
- Location
- Equipment Manufacturer/Model
- Equipment Ratings
- Routine Maintenance
- Testing & Diagnostics Procedures
- Equipment Condition
- Inspection Schedule
- Equipment Repair Records
- Site Service Records
- Maintenance Budget
- Safety Requirements

Exchanging Common Language Messages Among Systems Should Provide Relevant Information To Each System That Is Harmonious With All Other Systems’ Information

Service Connection Request
Blah, Blah, Blah, Organization, Blah, Blah, Blah

Work
Blah, Blah, Blah, Organization, Blah, Blah, Blah

Asset Catalog
Blah, Blah, Blah, Organization, Blah, Blah, Blah

Planned Outage
Blah, Blah, Blah, Organization, Blah, Blah, Blah

Crew
Blah, Blah, Blah, Organization, Blah, Blah, Blah

Maintenance
Blah, Blah, Blah, Organization, Blah, Blah, Blah

Switching Schedule
Blah, Blah, Blah, Organization, Blah, Blah, Blah

Meter Reading
Blah, Blah, Blah, Organization, Blah, Blah, Blah

Load Data Set
Blah, Blah, Blah, Organization, Blah, Blah, Blah

Load Control
Blah, Blah, Blah, Organization, Blah, Blah, Blah

For example, in each of the message exchanges depicted above, the same Organization is referenced for different reasons. There should be NO inconsistencies about this Organization in them!
For example, a common language-based logical infrastructure facilitates collaboration among the many applications involved in Asset Management.

Application To Common Language Mapping – The Typical Field to Field Process Is Cumbersome

- Individual fields of data models from data sources are mapped to each other.
- Approach does not scale well as the number of maps grows exponentially with each new data source.
- Mapping is a challenge as ‘mappers’ must have an in depth understanding of all relevant data sources – a tall order!
Using A Semantic Model To Simplify & Scale Up The Mapping Process

• What is a Semantic Model?
  – The key ingredients that make up a semantic model are a vocabulary of basic terms, a precise specification of what those terms mean and how they relate to each other.

• How is it used?
  – Before making mappings, a model (or an ontology) of a given business domain is defined.
  – The model is expressed in a knowledge representation language and it contains business concepts, relationships between them and a set of rules.
  – By organizing knowledge in a discrete layer for use by information systems, semantic models enable communication between computer systems in a way that is independent of the individual system technologies, information architectures and applications.
  – Compared to one-to-one mappings, mapping data sources to a common semantic model offer a much more scaleable and maintainable way to manage and integrate enterprise data.

The CIM Provides a Semantic Layer in an Enterprise Architecture

[Source: TopQuadrant Technology Briefing, July 2003]
The CIM and Related Standards

- But the CIM standards are more than just an abstract information model expressed in UML
- Profiles for specifying a subset of the CIM classes and attributes for a specific business context at a specific system interface or system interaction
- Implementation models
  - Use of XML to create serialized files and messages
    - RDF Schema-based standards for power system model exchange
    - XML Schema-based standards for information message payloads
  - ETL based on CIM for data base access
    - DDLs for data tables
TC57 Layered Architecture

Information and Semantic Models

- **CIM UML**
  - Information Model
    - Generalized model of all utility objects and their relationships
    - Application independent

Context

- **Profile**
  - Contextual layer restricts information model
    - Constrain or modify data types
    - Cardinality (may make mandatory)
    - Cannot add to information model

Message Syntax

- **Message XML Schema**
  - Message syntax describes format for instance data
    - Can re-label elements
    - Change associations to define single structure for message payloads
    - Mappings to various technologies can be defined

Semantic Models and Profiles

Information and Semantic Models

- **CIM UML**

Context

- **Profile**
  - 61968 Rules
  - CIM/XML Rules
  - Project Rules

Message Syntax

- **Message XML Schema**
- **CIM/XML RDF Schema**
- **Relational Database**
To Summarize

- The CIM is an abstract **information model** standard expressed in UML.
- **Profiles** specifying a subset of the CIM classes and attributes for specific business context
- **Implementation technologies**, such as use of XML to create serialized files and messages
  - Standards for power system models
  - Standards for information message payloads
- Also, the CIM UML can be extended
  - Standard extensions for new functional areas
  - Private extensions for specific utility requirements

Let’s Look at each Layer of the CIM

- **Context**
  - **Profiles**
    - Contextual layer restricts information model
      - Specifies which part of CIM is used for given profile
      - Mandatory and optional
      - Restrictions
      - But cannot add to information model
- **Message Syntax**
  - XML/RDF Schema
    - File syntax
      - Can re-label elements
      - Change associations to define single structure for message payloads
      - Mappings to various technologies can be defined
Foundational Relationships Of The CIM

PowerSystemResource
Electrical Network Role Used For Planning, Operations, etc.

Asset
Physical Plant Filling A Role Such As A Transformer, Pole, etc.

Location
Where To Find Something By GPS, Address, Electronically, etc.

Organisation
Entities Performing Roles Such As Operations, Tax Authority

Contact
People Performing Roles Such Dispatcher, Field Operator, etc.

Customer
Industrial, Commercial, & Residential Which Can Have Multiple Accounts

Document
Information Containers Such As Trouble Ticket, Work Orders, etc.

The CIM Is Expressed In Unified Modeling Language (UML) Notation*

Class Name usually describes things in the real world

Class Attributes describe significant aspects about the thing

This Specialization indicates that a "Pole" is a type of "Structure." Since a "Structure" is a type of "Asset," the Pole inherits all of the attributes from both Structure and Asset

Associations connect classes and are assigned a role that describes the relationship

* For more information on UML notation (a standard), refer to Martin Fowler’s book “UML Distilled,” Addison-Wesley
**Concepts: Generalization/Inheritance**

- **Breaker**: Specialization of ProtectedSwitch
- **ProtectedSwitch**: Specialization of Switch
- **Switch**: Specialization of Conducting Equipment
- **ConductingEquipment**: Specialization of Equipment
- **Equipment**: Specialization of PowerSystem Resource

**Equipment Inheritance Hierarchy**
Naming Hierarchy 1

```
class NamingHierarchyPart1

  Core::
    Substation
    VoltageLevel
    SubGeographicalRegion
    Line
    GeographicalRegion
    IdentifiedObject
      + aliasName: String [0..1]
      + description: String [0..1]
      + localName: String [0..1]
      + mRID: String [0..1]
      + name: String [0..1]
      + pathName: String [0..1]

  Core::
    Equipment
    EquipmentContainer
    PowerSystemResource
    Plant
    ConnectivityNodeContainer
      + EquipmentContainer 0..1
      + Equipments 0..*
      + Region 0..1
      + Regions 0..*
      + Substations 0..*
      + Lines 0..1
      + VoltageLevels 0..1
      + Bays 0..*

  Core::
    Circuit
      + Region 0..1
      + Regions 0..*
      + Substations 0..1
      + Substation 0..1
      + VoltageLevels 0..*

  Core::
    Equipment
      + name: String [0..1]
      + pathName: String [0..1]

```

Naming Hierarchy 2

```
class NamingHierarchyPart2

  Core::
    Fus
t
    EnergyConsumer
    Chokes
    Connector
    BusbarSection
    Breaker
    ACLineSegment
    Disconnect
    Jumper
    FrequencyConverter
    StaticVarCompensator
    RectifierInverter
    Conductor
    Core::
      ConductingEquipment
      + name: String [0..1]
      + pathName: String [0..1]

  Core::
    PowerSystemResource
      + name: String [0..1]
      + pathName: String [0..1]

  Core::
    Transformer
      + Windings 1..*
      + PowerTransformer 1
      + GeneratingUnit 0..1
      + SynchronousMachines 1..*
      + HeatExchanger 0..1
      + PowerTransformer 1
      + CompositeSwitch 0..1
      + Switches 0.. *

  Core::
    RegulatingCondEq
      + GroundDisconnector 0..1
      + Ground 0..1
      + NonGrounded 0..1
      + Grounded 0..1

  Core::
    Production::GeneratingUnit

```

Xtensible Solutions
Converting a Circuit to CIM Objects

- Example to show how voltage levels, current transformers, power transformers and generators are modelled
- Circuit contains a single generating source, load, line and busbar. The circuit also contains two power transformers resulting in three voltage levels of 17kV, 33kV and 132kV

Taken from McMorran, “An Introduction to IEC 61970-301 & 61968-11: The Common Information Model”, University of Strathclyde, Glasgow, UK
Example Circuit as a Single Line Diagram

Representing a Power Transformer as CIM Objects

- A power transformer is not mapped to a single CIM class
  - Represented by a number of components with a single PowerTransformer container class
  - Two-winding power transformer becomes two TransformerWinding objects within a PowerTransformer container
- If a tap changer is present to control one of the windings
  - An instance of the TapChanger class is associated with that particular winding
  - Also contained within the PowerTransformer instance
Transformer Class Diagram

- Transformer 17-33 is represented as four CIM objects

CIM Mapping for Transformer 17-33

- Transformer 17-33 is represented as four CIM objects
Transformer Model Diagram from 61970-301 CIM Base

Transformer Winding Attributes

Transformer Winding
- b: Susceptance
- insulationKV: Voltage
- connectionType: WindingConnection
- emergencyMVA: ApparentPower
- g: Conductance
- grounded: Boolean
- r: Resistance
- r0: Resistance
- ratedKV: Voltage
- rated MVA: ApparentPower
- rground: Resistance
- shortTermMVA: ApparentPower
- windingType: WindingType
- x: Reactance
- xo: Reactance
- xground: Reactance
Example Circuit with Full CIM Mappings

- Maps to
  - 17 CIM classes
  - 45 CIM objects
- Could be extended further with addition of objects for
  - control areas
  - equipment owners
  - measurement units
  - generation and load curves
  - asset data

How The CIM Handles Location For Logical Devices And/OR The Physical Asset Performing The Device’s Role
Types Of Document Relationship Inherited By All Assets

Activity Records
Let’s Look at each Layer of the CIM

Information and Semantic Models

- **CIM UML**
  - Information Model
    - Defines all concepts needed for any application

Message Syntax

- **XML/RDF Schema**
  - File syntax
    - Can re-label elements
    - Change associations to define single structure for message payloads
    - Mappings to various technologies can be defined

Common Power System Model (CPSM) Profile

- IEC 61970-452 specifies the specific profile (or subset) of the CIM for exchange of static power system data between utilities, security coordinators and other entities participating in a interconnected power system
- All parties have access to the modeling of their neighbor’s systems that is necessary to execute state estimation or power flow applications
- A companion standard, IEC 61970-552, defines the CIM XML Model Exchange Format based on the Resource Description Framework (RDF) Schema specification language which can be used to transfer power system model data for a particular profile
- Interoperability tests have validated several vendor’s products for exchanging complete power system models, partial models, and incremental updates
Let's Look at each Layer of the CIM

Information and Semantic Models

CIM UML

- Defines all concepts needed for any application

Context

Profiles

Contextual layer restricts information model
- Specifies which part of CIM is used for given profile
- Mandatory and optional
- Restrictions
- But cannot add to information model
XML Implementation Technologies

- **XML Schema**
  - Used for generation of message payloads for system interfaces in system integration use cases

- **RDF Schema**
  - Used for exchange of power system models

---

What is XML?

- **eXtensible Markup Language**
  - A text-based tag language, similar in style to HTML but with user-definable tags
    - Similar in use of ASCII text and tags
  - Based on Standard Generalized Markup Language (SGML), which is ISO 8879.

- **Self-describing**

- **Open industry standard - W3C Recommendation (spec)**
  - Broad usage across industries (many XML tools available)

- **Cross-platform and vendor-neutral standard**

- **Easy to use, easy to implement**
Basic Syntax

• Starts with XML declaration
  ```xml
  <?xml version="1.0"?>
  ```
• Rest of document inside the "root element"
  ```xml
  <TEI.2>…</TEI.2>
  ```
• Tags are used to provide information about the document content (metadata)
• Start and end tags must match exactly

What is an XML Element?

• An XML element is everything from (including) the element's start tag to (including) the element's end tag.
• An element can contain other elements, simple text or a mixture of both. Elements can also have attributes.
• `<bookstore>`
  ```xml
  <book category="CHILDREN">
  <title>Harry Potter</title>
  <author>J.K. Rowling</author>
  <year>2005</year>
  <price>29.99</price>
  </book>
  </bookstore>
  ```
• In the example above, `<bookstore>` and `<book>` have element contents, because they contain other elements. `<author>` has text content because it contains text.
• In the example above only `<book>` has an attribute (category="CHILDREN").
Implementation Syntax – XML Schema

• Example of use of XML Schema
• Mapping Proprietary EMS Interfaces to the CIM
  – Provide enterprise system access to transformer data

Mapping EMS Interfaces to the CIM – User access to transformer data

• EMS Native Interface attributes:
  – TRANS_NAME – The Transformer’s name
  – WINDINGA_R – The Transformer’s primary winding resistance
  – WINDINGA_X – The Transformer’s primary winding reactance
  – WINDINGB_R – The Transformer’s secondary winding resistance
  – WINDINGB_X – The Transformer’s secondary winding reactance
  – WINDINGA_V – The Transformer’s primary winding voltage
  – WINDINGB_V – The Transformer’s secondary winding voltage
Transformer Class Diagram in CIM

CIM Interface Mapping
- Beginnings of Profile/Message Payload Definition
Message Payload in UML

- PowerTransformer
- TransformerWinding
- Voltage level
- BaseVoltage

Note:
- Associations changed to aggregations
- Parent classes removed
  - Not required in actual message content
  - Parent classes already known by both sender and receiver
    - Corollary: Only those parts of the CIM used in message exchange need to be supported by interface applications
- End result – modified class structure
  - Example of application of business context to information model

Schemas – Meta Data

- A Schema is a description or definition of the structure of a database or other data source. It provides:
  - Allowable content or structure of data of a variety of types
  - Abstract definition of the relationships and characteristics of a class of objects or pieces of data

- Database Schema
  - Defines the table names and columns, describes the relationships between tables (via keys), and acts as a repository for triggers and stored procedures.

- XML Schema
  - Describes the ordering and inter-relationship of
    - XML elements (i.e., sequence and nesting of tags) and
    - Attributes (i.e., values, types, defaults) in the class of XML documents to which the schema applies.

XML Schema of CIM

- An XML Schema of the CIM can be generated with XML tools
- The CIM classes and attributes are used to define tags
- Then the CIM can be shown in XML as well as UML
- Example is PowerTransformer

Transformer Model Diagram from 61970-301 CIM Base
XML Schema for Transformer Message

Sample Transformer Interface Message Payload in XML
**XML Implementation Technologies**

- **XML Schema**
  - Used for generation of message payloads for system interfaces in system integration use cases

- **RDF Schema**
  - Used for exchange of power system models

**Big Issue**

- “Although we can swap our documents with each other through XML, we still haven’t a clue what they mean.”

- Resource Description Framework (RDF) Is W3C’s Means To Resolve This.
RDF Schema

- RDF Schema mechanism is a set of RDF resources (including properties) and constraints on their relationships
- Defines application-specific RDF vocabularies, for example CIM vocabulary
- RDF Schema URI unambiguously identifies a single version of a schema

[Courtesy Of Leila Schneburger]

Technical Approach

- RDF (Resource Description Framework)
  - Defines mechanism for describing resources that makes no assumptions about a particular application domain, nor defines the semantics of any application domain. The definition of the mechanism is domain neutral, yet the mechanism is suitable for describing information about any domain:
    - For more information: http://www.w3.org/RDF
    - Status: W3C Recommendation 22 February 1999
      - http://www.w3.org/TR/REC-rdf-syntax/
  - RDF Schema
    - Defines a schema specification language. Provides a basic type system for use in RDF models. It defines resources and properties such as Class and subClassOf that are used in specifying application-specific schemas:
      - Status: W3C Proposed Recommendation 03 March 1999
        - http://www.w3.org/TR/PR-rdf-schema/
Technical Approach (Cont.)

• Namespaces
  - provide a simple method for qualifying element and attribute names used in XML documents by associating them with namespaces identified by URI references:
      • http://www.w3.org/TR/REC-xml-names/

• URI (Uniform Resource Identifiers)
  - provide a simple and extensible means for identifying a resource:
    – Status: Internet RFC August 1998
      • ftp://ftp.isi.edu/in-notes/rfc2396.txt

CIM UML=>RDF Schema=>RDBMS

<table>
<thead>
<tr>
<th>UML.</th>
<th>RDF</th>
<th>Relational Model</th>
</tr>
</thead>
<tbody>
<tr>
<td>Object</td>
<td>Resource</td>
<td>Tuple (i.e. row)</td>
</tr>
<tr>
<td>Attribute or association</td>
<td>Property</td>
<td>Attribute (i.e. column) or foreign key</td>
</tr>
<tr>
<td>Class</td>
<td>Class</td>
<td>Relation (i.e. table)</td>
</tr>
<tr>
<td>Resource Description</td>
<td></td>
<td>Tuple value</td>
</tr>
<tr>
<td>URI</td>
<td></td>
<td>Key value</td>
</tr>
<tr>
<td>Value</td>
<td></td>
<td>Field value</td>
</tr>
</tbody>
</table>

[Courtesy Of Leila Schneburger]
Siemens 100 Bus Network Model in RDF

Top of RDF Schema version of Siemens 100 bus model

<?xml version="1.0" encoding="UTF-8"?>
<rdf:RDF xml:base="siemens" xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#"
xmlns:cim="http://iec.ch/TC57/2001/CIM-schema-cim10#">
  <cim:Unit rdf:ID="_5EAAD38A446E429E9905FAC32070D6FC"><cim:Naming.name>Amperes</cim:Naming.name></cim:Unit>
</rdf:RDF>

CIM Usage

- Many EMS vendors support power system model exchange using CIM/RDF/XML, some with CIM-based databases behind the scenes
- EPRI has sponsored 12 interoperability tests for transmission model exchange and service validation and more recently for planning and distribution
- Utilities have implemented CIM-based integration using EAI technologies
- Utilities have used the CIM as the basis for developing common messages for integration
- Asset and work management vendors as well as GIS application vendors are supporting CIM/XSD standards
- AMI (Smart Meter) projects use IEC 61968 Part 9 for meter related information exchange
- CIM has been extended into the power market, planning, and dynamic model exchange
- CIM provides a foundation for Service-Oriented Architecture (SOA) and Web service implementations
- Vendors have developed tools to build CIM-based information exchange messaging, ESB and OPC interfaces, and repository applications that can process CIM-aware data
- MultiSpeak is converting to CIM-based UML models and XML
- ENTSO_E is converting power model exchanges and day-ahead forecasts for planning/operational applications to CIM based format
  - Second IOP conducted in July 2010 (first was UCTE IOP in March 2009)
- Many Smart Grid-related activities based on CIM
  - Separate presentations during week
Concluding Remarks

- Bottom line: CIM standards are different and much more powerful
  - Can be applied in many ways
  - Support many types of functions/applications through combination of reuse and extension
  - Architecture supports future, unknown applications