Welcome to the CIM University

EPRI
Charlotte, North Carolina
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Introduction to CIM
And Its Role in the Utility Enterprise
Data Preparation, Exchange, Integration, and Enterprise Information Management
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
- 2003 – ISO/RTO Council and EPRI sponsored an initiative to expand CIM into Market Operations, a.k.a. CME
- 2005 – First edition of IEC 61970-301 CIM Base
- 2005 – CIM Users Group established under UCA Users Group
- 2008 – CIM adopted by UCTE
The IEC Common Information Model (CIM) - What Is It?

- 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
  - Maintained by IEC in Sparx Enterprise Architect modeling tools
- Enable integration of applications/systems
  - Provides a common semantic model behind all messages exchanged between systems
    - Enterprise semantic model
  - Basis for defining information exchange models
- Enable data access in a standard way
  - Common language to navigate and access complex data structures in any database
    - Provides a hierarchical view of data for browsing and access with no knowledge of actual logical schema
  - Inspiration for logical data schemas (e.g., for an operational data store)
- 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
- Cited as key for Smart Grid semantic model for SG interoperability framework
Sample Power System Model
Application of Information Model

Common model creates understanding
Information is Needed From Many “Islands of Automation”

- AM/FM/GIS
- Mobile
- SCADA
- Work Mgmt
- Protection
- Asset Planning
- Risk Analysis
- Network Planning
- Maintenance & Inspection
- Customer Information
- Financial
- Contract Management
- HR
- Network Management
- Compliance
- Property Mgmt
- Outage Management
- Historian
- VENDOR HELP!
The *Common Language* Should Provide Relevant Information To A User Regardless of Source
### The Needs of Various Users – Some Same, Some Different

#### 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

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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
Lifecycle 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

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.

[source: DistribuTECH 2003 paper by Zhou & Robinson]
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.

[source: TopQuadrant Technology Briefing, July 2003]
The CIM Provides a Semantic Layer in an Enterprise Architecture

Composite Applications  |  Business Intelligence

Web Services  |  Integration Bus  |  ETL

Common Language

Generic Services

Apps.

Semantic Model Metadata

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Decoupled Information Exchange

Publisher

Subscribers:
Several Application Adapters Receive The Same Message
Each Adapter:
• Parses Message, Pulling Out Data Needed By Application
• Transforms Data (if necessary) to Local Application Format
• Passes Data To Local Application And/Or Database Through Most Appropriate Means

Message Type Instance: ChangedNetworkDataSet (Expressed In Common Language)

Event History

AM/FM/GIS

Human Resources

Work Management

Substation Automation

Data Warehouse

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The CIM and Related Standards

• But the CIM standards are more than just an abstract **information model** expressed in UML

• **Profiles** specifying a subset of the CIM classes and attributes for specific business context at a specific system interface

• **Implementation models**, such as 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
We Need An Organizing Framework

• Layered Reference Architecture for TC57
• Based on UN/CEFACT
  – Information Model
  – Contextual Model
  – Message Syntax
    • Rules for Message Assembly
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

Context

Profile

Message Assembly

Message Syntax

CIM UML

Profile

61968 Rules

CIM/XML Rules

Project Rules

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 models**, 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
Example: Power Flow Network Model Exchange

Information and Semantic Models

- Information Model
  - Defines all concepts needed for exchange of operational load flow models
  - Reused parts
  - New extensions

Context

- Contextual layer restricts information model
- Specifies which part of CIM is used for static model exchange
- Mandatory and optional
- Restrictions
- But cannot add to information model

Message Syntax

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

Conforms to IEC 61970-301 CIM

Conforms to IEC 61970-452 Model Exchange Profile

Conforms to IEC 61970-501 and -552-4 CIM XML Model Exchange Format

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Ex: Power Flow Network Model Exchange

Information Model
- Defines all concepts needed for exchange of operational load flow models
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The IEC Standards for Power System Model Exchange

- The CIM translated into the industry standard eXtensible Markup Language (XML):
  - Uses a standard XML format that any EMS can understand using standard Internet and/or Microsoft technologies

- IEC 61970 series of standards
  - Part 301 CIM Base
    - Specifies UML model
  - Part 452 CIM Model Exchange Specification
    - Specifies guidelines for the definition of specific profiles (or subsets) of the CIM for particular power system model exchange requirements
  - Part 501 CIM RDF Schema
    - Specifies mapping between UML model and XML model using RDF Schema
    - This was mandated by NERC for exchange of models between Reliability Coordinators
  - Part 552-4 CIM XML Model Exchange Format
    - Specifies simplified RDF Schema and extensions to transfer incremental updates via difference file
Let’s Look at each Layer of the CIM

**Information and Semantic Models**
- **Information Model**
  - Defines all concepts needed for planning
  - Reused parts
  - New extensions

**Context**
- **Contextual layer restricts information model**
  - Specifies which part of CIM is used for static model exchange
  - Mandatory and optional
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**Message Syntax**
- **File syntax**
  - Can re-label elements
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- Conforms to IEC 61970-301 CIM
- Conforms to IEC 61970-452 Model Exchange Profile
- Conforms to IEC 61970-552-4 CIM XML Model Exchange Format
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.
CIM Packages

CombinedVersion

+ date: AbsoluteDateTime [0..1] = 2008-12-17-see... {readOnly}
+ version: String [0..1] = iec61970CIM13v1... {readOnly}

class Main

IEC61970

IEC61968

MarketOperations

Reservation

Financial

EnergyScheduling

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class Main

LoadModel

Outage

Protection

ControlArea

Equivalents

Wires

Generation

Production

(from Generation)

GenerationDynamics

(from Generation)

Contingency

«WorkInProgress»

StateVariables

Meas

OperationalLimits

Topology

«Global» Domain

Production

(from Generation)

«WorkInProgress»

Contingency

«WorkInProgress»

StateVariables

Meas

Core

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WG16 CIM Market Extensions

WG16

- Bid
- FTR
- RTO
- Security Constraints
- Resource
- Clearing Results
CIM IEC Standards

- 61970 CIM UML has annual release cycle
  - Current official annual release is IEC61970CIM13v19
  - Basis for IEC 61970-301 CIM Base Third Edition
    - Word document auto-generated from the UML electronic model
    - Information system and Profile documents are synchronized with UML model release
- 61968 CIM UML different update cycles
  - Basis for IEC 61968-11 CIM Distribution Information Exchange Model
- Complete CIM UML available as a combined model on CIMug Sharepoint site
  - Iec61970cim13v19_iec61968cim10v18_combined_EAP
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

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

- Breaker: Specialization of Switch
- Switch: Specialization of Conducting Equipment
- ConductingEquipment: Specialization of PowerSystem Resource
Equipment Inheritance Hierarchy
Equipment Containers
Connectivity Model
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

- PowerSystemResource
  - Equipment
    - ConductingEquipment
    - PowerTransformer
      - TransformerWinding
        - Physically connected to network and conducts electricity, so inherits from ConductingEquipment
      - TapChanger
        - Part of TransformerWinding, not separate piece of equipment
      - Shell of transformer, containing windings, insulation, magnetic core, etc.
        - Inherits from Equipment, since does not conduct electricity
CIM Mapping for Transformer 17-33

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

<table>
<thead>
<tr>
<th>Transformer Winding</th>
</tr>
</thead>
<tbody>
<tr>
<td>b: Susceptance</td>
</tr>
<tr>
<td>insulationKV: Voltage</td>
</tr>
<tr>
<td>connectionType: WindingConnection</td>
</tr>
<tr>
<td>emergencyMVA: ApparentPower</td>
</tr>
<tr>
<td>g: Conductance</td>
</tr>
<tr>
<td>grounded: Boolean</td>
</tr>
<tr>
<td>r: Resistance</td>
</tr>
<tr>
<td>r0: Resistance</td>
</tr>
<tr>
<td>ratedKV: Voltage</td>
</tr>
<tr>
<td>rated MVA: ApparentPower</td>
</tr>
<tr>
<td>rground: Resistance</td>
</tr>
<tr>
<td>shortTermMVA: ApparentPower</td>
</tr>
<tr>
<td>windingType: WindingType</td>
</tr>
<tr>
<td>x: Reactance</td>
</tr>
<tr>
<td>x0: Reactance</td>
</tr>
<tr>
<td>xground: Reactance</td>
</tr>
</tbody>
</table>
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

- **Asset** (from AssetBasics)
  - 0..n +Assets
  - 1 +Asset
  - +Location 1..n

- **Location**
  - coordinate : CoordinatePair
  - coordinateList : PointSequence
  - polygonFlag : Boolean
  - type : String
  - code : String

- **PowerSystemResource** (from Core)
  - 0..1 +PowerSystemResource
  - 0..n +PowerSystemResources
  - 0..n +Location

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Types Of Document Relationship Inherited By All Assets

- **AssetModel**
  - number : String
  - version : String
  - 0..n

- **QualificationRequirement**
  - qualificationID : String

- **AssetProperty**
  - propertyType : String
  - propertyValue : String
  - units : String

- **AssetRating**
  - ratingType : String
  - property : String
  - ratingValue : Float
  - units : String

- **Document**
  - (from DocumentationProperty)
  - 0..n

- **MaintenanceProcedure**
  - type : String

- **InspectionRoutine**
  - (from AssetsInspection)
  - type : String

- **PowerSystem Resource**
  - (from Core)
  - 0..n

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Activity Records

ActivityRecord
- createdOn : AbsoluteDateTime
- status : String
- statusReason : String
- remarks : String

History
- 0..n

ErpContact
- (from ERP_Support)
- 0..n

Customer
- (from ConsumerPackage)
- 0..n

Organisation
- (from TopLevelPackage)
- 0..n

Asset
- (from AssetBasics)
- 0..n

PowerSystem Resource
- (from Core)
- 0..n

Work
- (from WorkInitiationPackage)
- 0..n

WorkTask
- (from WorkDesignPackage)
- 0..1

Location
- (from LocationPackage)
- 0..n
CIM UML in Enterprise Architect

- The CIM UML model is maintained in Sparx Enterprise Architect (EA)
- Current UCTE CIM UML Model for IOP
  - iec61970cim14v01_ipec61968cim10v16_combined.eap
- Go to UML model in EA
Questions?
Let’s Look at each Layer of the CIM

**Information and Semantic Models**
- Conforms to IEC 61970-301 CIM
- Information Model
  - Defines all concepts needed for planning
    - Reused parts
    - New extensions

**Context**
- Conforms to IEC 61970-452 Model Exchange Profile
- Contextual layer restricts information model
  - Specifies which part of CIM is used for static model exchange
  - Mandatory and optional
  - Restrictions
  - But cannot add to information model

**Message Syntax**
- Conforms to IEC 61970-552-4 CIM XML Model Exchange Format
- File syntax
  - Can re-label elements
  - Change associations to define single structure for message payloads
  - Mappings to various technologies can be defined
Profile Documents

- IEC 61970-4xx series of Component Interface Standards (CIS)
  - Specifies the functional requirements for interfaces that a component (or application) implements to exchange information with other components (or applications) and/or to access publicly available data in a standard way
  - Component interfaces describe the specific message contents and services that can be used by applications for this purpose
  - Implementation of these messages in a particular technology is described in Part 5 of the standard
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 61970-552-4, 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

- Information Model
  - Defines all concepts needed for planning
    - Reused parts
    - New extensions

- CIM UML

Context

- Conforms to IEC 61970-452 Model Exchange Profile

- Contextual layer restricts information model
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Message Syntax

- Conforms to IEC 61970-552-4 CIM XML Model Exchange Format

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- CIM/RDF Schema
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.
- In the example:
  - `<zone>` and `<link>` have **element contents**, because they contain other elements.
  - `<zone>` and `<link>` also have **attributes** (name="Zone A")

XML Example

```xml
<?xml version="1.0" encoding="utf-8"?>
<Network>
  <zone name="Zone A">
    <Load>10000MW</Load>
    <Prod>9000MW</Prod>
  </zone>
  <zone name="Zone B">
    <Load>20000MW</Load>
    <Prod>21000MW</Prod>
  </zone>
  <Link name="Interconnect">
    <Ptransit>1000MW</Ptransit>
  </Link>
</Network>
```
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

- PowerSystemResource
  - Equipment
    - ConductingEquipment
    - PowerTransformer
      - TransformerWinding
        - TapChanger
          - 1
          - 0..n
CIM Interface Mapping
- Beginnings of Profile/Message Payload Definition

Two different interface attributes (WINDINGA_R and WINDINGB_R) map to same CIM attribute.

Aggregation changed from 0..n to 2.

Multiplicity changed from 0..1 to 1.
Message Payload in UML

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
Sample Transformer Interface

Message Payload in XML

```xml
<?xml version="1.0" encoding="UTF-8"?>
<电源变压器>
  <命名 name>SGT1</命名>
  <包含变压器绕组>
    <变压器绕组 r>0.23</变压器绕组.r>
    <变压器绕组 x>0.78</变压器绕组.x>
    <绕组类型>WindingType.primary</绕组类型>
    <包含电压等级>
      <电压等级 基数电压>400</电压等级.基数电压>
    </包含电压等级>
  </包含变压器绕组>
  <包含变压器绕组>
    <变压器绕组 r>0.46</变压器绕组.r>
    <变压器绕组 x>0.87</变压器绕组.x>
    <绕组类型>WindingType.secondary</绕组类型>
    <包含电压等级>
      <电压等级 基数电压>275</电压等级.基数电压>
    </包含电压等级>
  </包含变压器绕组>
</电源变压器>
```
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
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:
    - Status: WC3 Recommendation 14-January-1999
      - 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
XML Namespaces

- Distinguish between duplicate element type and attribute names
- Collection of element type and attribute names. The namespace is identified by a URI.
- Declared with an xmlns attribute, which can associate a prefix with the namespace.
- If XML namespace declaration contains a prefix, refer to element type and attribute names in that namespace with the prefix. E.g. cim:Substation, UCTE:Substation
- If XML namespace declaration does not contain a prefix, the namespace is the default XML namespace, refer to element type names in that namespace without a prefix.
### 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>Tuple value</td>
<td></td>
</tr>
<tr>
<td>URI</td>
<td>Key value</td>
<td></td>
</tr>
<tr>
<td>Value</td>
<td>Field value</td>
<td></td>
</tr>
</tbody>
</table>

[Courtesy Of Leila Schneberger]
Simple Network Example

SS1

SS2

400KV

12345 MW

12345 KV

BB1

12345 MW

T1

110KV

Cable1

Cable2

Cable3

SS1-SS2

SS1

SS4
Simple Network Connectivity Modeled with CIM Topology
Siemens 100 Bus Network Model in RDF

Top of RDF Schema version of Siemens 100 bus model

<?xml version="1.0" encoding="UTF-8"?>
ACLineSegment in RDF

Siemens 100 bus model - RDF schema

<?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:ACLineSegment rdf:ID="_6B1DD5C2CB934E86AC53FFD886E2D1B3">
    <cim:Naming.name>BBD-RSK2</cim:Naming.name>
    <cim:Conductor.bch>2.79</cim:Conductor.bch>
    <cim:Conductor.x>4.3378</cim:Conductor.x>
    <cim:Conductor.r>0.4761</cim:Conductor.r>
  </cim:ACLineSegment>
  <cim:Terminal rdf:ID="_EB6085D9DF364DA78A884D4D0A571371">
    <cim:Naming.name>T2</cim:Naming.name>
    <cim:Terminal.ConnectivityNode rdf:resource="#_CC312D30C85C4236948A4129AE3B5F7"/>
    <cim:Terminal.ConductingEquipment rdf:resource="#_6B1DD5C2CB934E86AC53FFD886E2D1B3"/>
  </cim:Terminal>
  <cim:Terminal rdf:ID="_7C8354E0DA247DBB3611E2E8BF8A86D">
    <cim:Naming.name>T1</cim:Naming.name>
    <cim:Terminal.ConnectivityNode rdf:resource="#_D16F09501444AECBF8157D1E4764E38"/>
    <cim:Terminal.ConductingEquipment rdf:resource="#_6B1DD5C2CB934E86AC53FFD886E2D1B3"/>
  </cim:Terminal>
</rdf:RDF>
ACLineSegment in RDF

Siemens 100 bus model - RDF schema

```xml
<?xml version="1.0" encoding="UTF-8"?>
<rdf:RDF xml:base="siemens" xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#"
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  </cim:Terminal>

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    <cim:Naming.name>T1</cim:Naming.name>
    <cim:Terminal.ConductingEquipment rdf:resource="#_6B1DD5C2CB934E86AC53FFD886E2D1B3"/>
  </cim:Terminal>
</rdf:RDF>
```
Containment in RDF

Substation VOL with 230 KV voltage level and Bay 240W79 with Breaker CB

Further down in document

Xtensible Solutions
Measurement in RDF

```xml
<cim:Measurement rdf:ID="_5B22599688AC4DE6B99FD8B13C1BA36F">
  <cim:Naming.name>LN    1 MVAr</cim:Naming.name>
  <cim:Measurement.MeasurementType rdf:resource="#_83D7B035901D4D2E80C040609D5ED7EC"/>
  <cim:Measurement.Unit rdf:resource="#_61784D3DA1954750A4E09444BE5206CB"/>
</cim:Measurement>

<cim:MeasurementValue rdf:ID="_FF332A9A82FF43719AAF4E5DAFCFB9CD">
  <cim:Naming.aliasName>ICCP ID     24</cim:Naming.aliasName>
  <cim:Naming.name>MVAr</cim:Naming.name>
  <cim:MeasurementValue.MeasurementValueSource rdf:resource="#_F0F5BA1CDE23483A8C80D20A4907A272"/>
  <cim:MeasurementValue.MemberOf_Measurement rdf:resource="_5B22599688AC4DE6B99FD8B13C1BA36F"/>
</cim:MeasurementValue>
```
Implementation Syntax – WG13 61970

• Part 501 specifies the translation of the CIM in UML form into a machine readable format as expressed in the Extensible Markup Language (XML) representation of that schema using the Resource Description Framework (RDF) Schema specification language
  – The resulting CIM RDF schema supports CIM Model Exchange specifications, as presented in IEC 61970-452 and others

• Part 552-4 describes the CIM XML format at a level for implementation to support the model exchange requirements in IEC 61970-452
  – This standard relies upon the CIM RDF Schema of IEC 61970-501
Basics: Schema from CIM

CIM (in UML)  
Enterprise Architect

CIM as XML/RDF Schema

Power System Data Exporter

Power System Data as XML/RDF

UML to RDF Transformers

specifies
references
Key Standards and Related Organizations

- MultiSpeak (NRECA)
- Open Application Group
- EPRI CCAPI Project
- OLE Process Control (OPC)
- TC57
  - WG14 DMS
  - WG13 EMS
  - WG16
  - WG17
  - WG18
  - WG9 Distribution Feeders
- Coordination WG19
- EPRI UCA2 Project
- EPRI
  - WG10 Substations
- UCA : User groups
- W3C
- EBXML Object Mgmt. Group
- OASIS
- ebXML
- UN/CEFACT
- Xtensible Solutions
Where to Get More Information About the CIM and Related Standards

- Visit CIM User Group (CIMug) Web Site
  - [http://cimug.ucaiug.org](http://cimug.ucaiug.org)

- Single site for gaining access to information about the CIM and related standards
  - Includes all standards being developed by IEC TC57 Working Groups 13, 14, 16, and 19

- Now provide access to:
  - Announcements of CIM-related activities and events
  - Calendar of activities
  - CIM electronic model in various formats
  - Lists of CIM-related tools and access to open source tools
  - Documents that are publicly available
    - Draft IEC TC57 CIM standards for CIMug members
  - Lists of the CIMug working groups and works in progress as well as minutes of meetings and conference calls
  - CIM issues lists and status of resolution
  - Help desk
  - Discussion forums
  - Links to other CIM-related sites
Questions?

• Contact tsaxton@xtensible.net
• Thank you
How Are CIM Standards Used?

• Unlike most standards we use
  – Ex: ICCP/TASE.2 Communication Protocol standard
  – Fixed functionality, very **stable**, easy to test **compliance**, but **inflexible**
• CIM standards can be strictly applied and tested for compliance
  – Ex: CIM/XML Power system model exchange
  – Product interfaces can be developed and tested for compliance
  – Subject of several EPRI-sponsored interoperability tests for specific interface definition
Example: Power Flow Network Model Exchange

Information and Semantic Models

- Conforms to IEC 61970-301 CIM

CIM UML

- Information Model
  - Defines all concepts needed for exchange of operational load flow models
    - Reused parts
    - New extensions

Context

- Conforms to IEC 61970-452 Model Exchange Profile

Common Power System Model Profile

- Contextual layer restricts information model
  - Specifies which part of CIM is used for static model exchange
  - Mandatory and optional
  - Restrictions
  - But cannot add to information model

Message Syntax

- Conforms to IEC 61970-501 and -552-4 CIM XML Model Exchange Format

CIM/RDF Schema

- File syntax
  - Can re-label elements
  - Change associations to define single structure for message payloads
  - Mappings to various technologies can be defined
Ex: Power Flow Network Model Exchange

Information Model
- Defines all concepts needed for exchange of operational load flow models
  - Reused parts
  - New extensions

Contextual layer restricts information model
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  - Mandatory and optional
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  - But cannot add to information model

File syntax
- Can re-label elements
- Change associations to define single structure for message payloads
- Mappings to various technologies can be defined
How Are CIM Standards Used?

• Unlike most standards that we are used to
  – Ex: IDDP/TASE.2 Communication Protocol standard
  – Fixed functionality, very **stable**, easy to test **compliance**, but **inflexible**

• CIM standards can be strictly applied and tested for compliance
  – Ex: CIM/XML Power system model exchange
  – Product interfaces can be developed and tested for compliance
  – Subject of several EPRI-sponsored interoperability tests for specific interface definition

• CIM can also be used as a starter kit
  – Basis for an Enterprise Semantic Model (ESM) which includes other models/semantics from other sources
  – Ex: Sempra Information Model (SIM)
  – Interfaces are usually project-defined, so no standard tests
  – System interfaces are managed and tested for each project
GridWise Interoperability Framework

Role of CIM

1: Basic Connectivity
2: Network Interoperability
3: Syntactic Interoperability
4: Semantic Understanding
5: Business Context
6: Business Procedures
7: Business Objectives
8: Economic/Regulatory Policy

Organizational (Pragmatics)

Political and Economic Objectives as Embodied in Policy and Regulation
Strategic and Tactical Objectives Shared between Businesses
Alignment between Operational Business Processes and Procedures

Informational (Semantics)

Relevant Business Knowledge that Applies Semantics with Process Workflow
Understanding of Concepts Contained in the Message Data Structures
Understanding of Data Structure in Messages Exchanged between Systems
Exchange Messages between Systems across a Variety of Networks
Mechanism to Establish Physical and Logical Connectivity of Systems

Technical (Syntax)

Xtensible Solutions
Role of Enterprise Semantic Model

Open Standards

Application Information

Process Integration

BPM/Workflow

Business Intelligence

Enterprise Semantic Model

Business Definitions

Applications Metadata

Enterprise Integration Platforms

Xtensible Solutions
Building and Using an ESM – Xtensible MD3i

1) Establish Vocabulary
   • Control Content
   • Collaborate
   • Identify and refine semantics

2) Develop ESM
   • Model using vocabulary terms
   • Refine context

3) Generate Canonicals
   • Syntactically and semantically consistent canonical models

Semantic Formalization  Semantic Consistency

Context Refinement

Existing Terminology and Metadata
Semantic Models and Profiles

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

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
Let’s Apply to a Utility Project
- Interface Architecture
Ex: Project Interaction Test

Enterprise Semantic Model
- Defines all concepts needed for Enterprise
  - Reused parts
  - New extensions for project

Contextual layer restricts ESM
- Specifies which part of ESM is used for specific system interaction
- Mandatory and optional
- Restrictions
- But cannot add to information model

File syntax
- Can re-label elements
- Change associations to define single structure for message payloads
- Mappings to various technologies can be defined
Project Integration Architecture
Data Architecture – Model

- CIM
- CIS
- OTHER

Semantics Model

Business Entity

DB Schema

XML Schema

REFEFENCE MODELS

SEMPRA MODEL

MESSAGES

SCHEMAS
Use of ESM to Implement a Service Oriented Architecture (SOA)

- CAISO designed a new power market system
  - Multi-year program that involved many vendors, new systems, as well as numerous legacy systems
    - Includes EMS, Full Network Model, Outage Management, PI Historian, Market Systems, many others
    - External interfaces to Market Participants included
- Integration Competency Center decided on a Service Oriented Architecture (SOA) for the integration framework
  - Require all new applications and systems to be “Integration Ready” with service-enabled interfaces
  - Use only standard CAISO-defined services
  - Payloads based on the CIM
  - Based on Web services
  - CIM and Model Driven Integration (MDI) methodology used to define information exchange
## Interface Examples:

<table>
<thead>
<tr>
<th>Interface Type</th>
<th>Example</th>
<th>Implemented by</th>
<th>Utilized by</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Information Creation</td>
<td>submitBid(XML)</td>
<td>Vendor</td>
<td>Enterprise</td>
<td>These interfaces are for creating or modifying information within a system of record.</td>
</tr>
<tr>
<td>Information Transfer</td>
<td>publishCleanBidSet(XML)</td>
<td>CAISO</td>
<td>Vendor</td>
<td>These interfaces are for transferring information and releasing custody.</td>
</tr>
<tr>
<td>Information Interest</td>
<td>receiveCleanBidSet(XML)</td>
<td>Vendor</td>
<td>EAI</td>
<td>These interfaces are implemented by vendors to allow systems to receive information as it becomes available. This indicates a subscription type interest in data.</td>
</tr>
<tr>
<td>Information Sharing</td>
<td>getResourceInfo(XML)</td>
<td>Vendor</td>
<td>Enterprise</td>
<td>These interfaces are implemented by the vendors to surface information currently within custody to the enterprise.</td>
</tr>
</tbody>
</table>
System A Integration Layer

- PI
- BITS
- MC

WS broadcastMarketMeterData
WS retrieveMarketMeterData
WS broadcastMarketMeterData
WS retrieveMarketInterchange
WS broadcastInvoiceData
WS broadcastGeneralLedgerData
WS receiveInvoiceData
WS broadcastStatusInvoiceData
WS receiveGeneralLedgerData

(Slide from Stipe Fustar, KEMA)
CAISO Project Statistics

22 Systems
- Dispatch System
- MP Report Interface
- Load Forecast
- Transmission Capacity Calculator
- Real Time Nodal System
- Settlement and Market Clearing
- Bid Interface and Validation

7 Vendors
- Siemens - Market Systems
- ABB - EMS system
- Areva - Settlement System
- Legacy - CAISO system
- Nexant - Congestion Revenue Rights System
- MCG - Interchange Scheduling System
- Potomac - Default Energy Bids
- Default Energy Bids
- Real Time Metering
- Adjusted Metering
- Market Participants
  - Bidding
  - Market Results
  - Settlement
  - Outage Scheduling
  - Dispatch Signals
- Forward Market Nodal System
- EMS
- OASIS
- Interchange Scheduling System
- Congestion Revenue Rights
- Intermittent Resources
- Compliance
- RMR Validation
- Generation Outage Scheduling
- Transmission Outage Scheduling
- Market Quality System (ATF updates)

Appr 130 integrations between the 22 systems
Appr 75 message schemas
Appr 175 service definitions
Appr 450 publisher/consumer testable data transfers between systems
Pacificorp Use of CIM

- PacifiCorp is successfully using CIM to design both interfaces and databases
  - CIM was adopted in 1999 as PacifiCorp’s application integration standard
  - Used for both messaging and database design for new projects
  - Existing interfaces are reworked when the need arises
- Model Driven Integration based on the CIM viewed internally as “Best Practice”
  - Having a common vocabulary reduces semantic misinterpretation
  - Reusing messages minimizes integration costs
  - Minimal knowledge of internal application designs required
  - Xtensible MDI Workbench used for message creation, management, and maintenance
- CIM is here to stay
  - CIM is standard design practice
  - PacifiCorp vendors are getting used to the idea
  - PacifiCorp’s data warehouse is based on the CIM
  - EMS/SCADA system (Ranger) uses a CIM-based data maintenance tool
## CIM Scorecard – Examples of CIM use

<table>
<thead>
<tr>
<th>Business Units</th>
<th>Application/Project</th>
<th>Message(s)</th>
<th>CIM</th>
<th>Pct of message that is CIM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power Delivery</td>
<td>Substation Measurements</td>
<td>IntervalRead, SubstationEquipment.Measurement</td>
<td>MeasurementList</td>
<td>90%</td>
</tr>
<tr>
<td>Retail Access Project</td>
<td>RegisterReadRequest, BillDeterminant, CustDrop, Enroll.DACust, EnrollmentChange, NonDACust, Reg.ESSRegister, Register.ESS, ESSStatusChange, SESSESSRelationshipChange, RegisterReadResponse, CnlConsumption, DAEnrollConsumption, EnrollmentChange, NonDAEnrollConsumption, ESSStatusChange</td>
<td>CustomerMeterDataSet, CustomerServiceAgreement, MeasurementList, Document, ActivityRecord, CustomerBilling, BillingDeterminant</td>
<td>80%</td>
<td></td>
</tr>
<tr>
<td>Pole Attachment System</td>
<td>FacilityPoint, JointUse.Agreement, JointUse.Attachment, JointUse.Notice, JointNoticeRequest, FacilityPoint</td>
<td>AssetList</td>
<td>70%</td>
<td></td>
</tr>
<tr>
<td>Transmission</td>
<td>Transmission Planned Outages</td>
<td>PlannedOutage.Change</td>
<td>PlannedOutageNotification</td>
<td>50%</td>
</tr>
<tr>
<td>Transmission Wholesale Billing System</td>
<td>TransmissionData, STLossData, LTLossData, Scheduling.LoadData, ConsumptionData, InvoiceData</td>
<td>Settlement and MarketClearing</td>
<td>70%</td>
<td></td>
</tr>
<tr>
<td>EMS SCADA</td>
<td>WeatherData</td>
<td></td>
<td>MeasurementList</td>
<td>100%</td>
</tr>
</tbody>
</table>
## CIM Scorecard Cont’d

<table>
<thead>
<tr>
<th>Business Units</th>
<th>Application/Project</th>
<th>Message(s)</th>
<th>CIM</th>
<th>Pct of message that is CIM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power Supply/Generation</td>
<td>Availability Information System</td>
<td>GeoThermalPlantGeneration</td>
<td>MeasurementList</td>
<td>60%</td>
</tr>
<tr>
<td></td>
<td>Hydro Information Website</td>
<td>FlowDisplay</td>
<td>MeasurementList</td>
<td>100%</td>
</tr>
<tr>
<td>Commercial &amp; Trading</td>
<td>CRS</td>
<td>MarkToMarketData</td>
<td>MarkToMarket (Not in CIM)</td>
<td>80%</td>
</tr>
<tr>
<td></td>
<td>California ISO interface</td>
<td>EDI810</td>
<td>Settlement</td>
<td>50%</td>
</tr>
<tr>
<td>Corporate</td>
<td>Giving Campaign</td>
<td>EmployeeDetails, ContributionPayrollDetails</td>
<td>Employee (erpPerson)</td>
<td>70%</td>
</tr>
<tr>
<td></td>
<td>Sarbanes Oxley Audit</td>
<td>ChangeAuditReport</td>
<td>ChangeAudit (Not in CIM)</td>
<td>90%</td>
</tr>
</tbody>
</table>
Addressing Objections to the Use of the CIM Standards

- **Claim: CIM is not stable**
  - Fact: The CIM UML model *is* evolving as new applications are identified
  - Fact: Only small part of CIM information model is used for a given interface, so change of information model unlikely to affect specific interface.
  - Solution: Version control - tie interface designs to project specifications, not directly to standard

- **CIM is too complex to learn and contains many parts I do not need**
  - Fact: The overall CIM UML model is large and complex
  - Reality: A typical interface requires only very small subset of information model

- **CIM creates too much overhead in message content**
  - Fact: Only instantiated concrete class/attributes are actually sent in a message instance
  - Reality: Message payload is no larger than any XML formatted message

- **I don’t want to add in an extra step of converting to CIM for system integration**
  - Fact: There is an extra step of mapping to CIM for one connection
  - Reality: Consequence of not mapping to a common language is solution that does not scale:
    - \( n(n-1) \) instead of \( 2n \) connection mappings

- **I can’t expect my vendors to adopt the CIM model for their interface**
  - Fact: Only a few parts of the CIM need to be “Known” by the vendor
  - Reality: Approach is to specify the mappings to a common language (CIM) as part of the interface contract

- **I don’t want to convert all my metadata to the CIM**
  - Fact: CIM is a starter kit
  - Reality: Use CIM as appropriate for building your own ESM – far better than starting from scratch

- **CIM does not contain everything I need or in the form I need for my interfaces**
  - Fact: CIM UML is extensible
  - Reality: Many utilities still use the CIM as a starting point, using namespaces to maintain traceability
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 11 interoperability tests for transmission model exchange and GID validation and more recently for planning (plans for distribution and UCTE).
- 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, GID interfaces, and repository applications that can process CIM-aware data.
- MultiSpeak is converting to CIM-based UML models and XML.
- UCTE is converting power model exchanges for planning applications to CIM based format.
CIM Acceptance

- In use at dozens of utilities throughout world
  - In North America, used at TSOs, RTO/ISOs and NERC as well
  - In Europe now being adopted by UCTE and TOs
- 50+ applications based on CIM
- 40+ suppliers sell application/products based on CIM
  - See CIM Reference List for Details
- Endorsed by other standards organizations
  - Multispeak, Zigbee, HAN, UCTE, etc.
- Foundation for information exchange between utilities and/or other external organizations
- Foundation for Model-Driven Integration (MDI) architecture based on Enterprise Information Model (EIM) within an enterprise
- Key building block in Smart Grid to achieve interoperability
- CIM User Group to deal with questions and issues arising from increased use
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
Questions?

• Contact tsaxton@xtensible.net
• Thank you