A Semantic Testbed for Smart Grid
Information Standards

Steve Ray
Testbeds for Smart Grids and Smart Cities
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Models of electricity
Smart Electrical Grid

Models of electricity

Models of information

Electricity

Information
How is Smart Grid Information Modeled?
Part of a UML Model

Energy Manager Component:: EM
- hasLoads: Boolean
- hasElectricalGenerators: Boolean
  + eMs 0..*

ForecastSequence
- timeOfForecast: UTCDateTime [0..1]
  + forecasts 0..*

ComponentElement
- Energy Manager Component:: EM

IntervalDataType
- instanceUid: GlobalId
- timeReference: UCTimeInterval [0..1]
- tolerance: ToleranceValue [0..1]
  + localTimeParameters
    + dstEndRule: DstTransitionRule
    + dstOffset: Integer
    + dstStartRule: DstTransitionRule
    + tzOffset: Integer
  + intervals 1..*
  + attach 0..1
    {redefines attach}

FullInterval

SimpleInterval

Sequence
- /intervalDuration: Duration [0..1]
- name: String
- timeOfLastSync: UTCDateTime [0..1]
  + billingCycle 0..*
  + userSequence 0..*
  + forecasts 0..*

PeakPowerData
- demandPrice: MonetaryQuantity [0..1]
- supplyPrice: MonetaryQuantity [0..1]
  + peakPower 0..1
  + peakNetDemand 0..1
  + peakNetSupply 0..1
Some Smart Grid Information Standards

- CIM 61968
- CIM 61970
- CIM 61850
- ISO 16484
- BACnet
- 61850-410 hydro
- OASIS energy interop
- 61850-420 DER (solar...)
- CIM 62325
- Multispeak
- ISA88
- ISA95
- ISA88
- ISA95
- 61850-420 DER (solar...)
- NASB
- energy usage info
- 62351-7 comm net and system mgnt
- C12.19
- CEA 709 LonTalk
- Zigbee smart energy profile
- ASHRAE SPC201 FSGIM
- ISO 16484 BACnet
- Carnegie Mellon University
- Silicon Valley
Challenge

- How to test whether an information standard (i.e. information model)
  1. is self consistent? (verification testing)
  2. is compatible with other standards? (to support interoperability)
     - How to reconcile vocabularies, concepts and relations among all the smart grid information standards?

- Information models are engineered artifacts designed within a stated or unstated context
“Meter”
Do they all really mean the same thing?
What’s the risk?

- You might have **connectivity** but not **interoperability**
- Misunderstanding of information flowing between systems

By Robin Lloyd
CNN Interactive Senior Writer

(CNN) -- NASA lost a $125 million Mars orbiter because a Lockheed Martin engineering team used English units of measurement while the agency's team used the more conventional metric system for a key spacecraft operation, according to a review finding released Thursday.

- “Set Thruster to 324.59”
Need context (a.k.a. metadata)

“Set Thruster to 324.59”

(...without even getting into uncertainty)
ASHTAE SPC201 Standard (excerpt)
Semantic Testbed

Testing the integrity of a standard

Standards

Text

UML

XSD

Model Transformation

Semantic representation
Web Ontology Language (OWL)

Model Verification Testing
Multiple Smart Grid Standards
Pick-lists of queries

Custom Query Manager Editor

- Model Name: FSGIM
- Model Version: 3745
- Query Classification: Class
- Query Name: --- Please select an option ---
  - Classes defined but never referred to in a relation
  - Classes that share substantially the same properties
  - Display the UML package hierarchy for the class containing "string"
  - Identify all external classes pointing to FSGIM classes
  - Navigate up superclasses to find the ultimate parent class, for all classes containing a given string
  - Superclasses that have no properties
Sample Query

Model Name: OpenADR
Model Version: 201307
Query Classification: xsd
Query Name: Finding in-line complex type definitions
Query Prefix:

```
PREFIX composite: <http://www.topbraid.org/2007/05/composite.owl#>
PREFIX smf: <http://topbraid.org/sparqlmotionfunctions#>
PREFIX xsd:

SELECT ?subject ?parentName
WHERE {
  ?subject a xsd:ComplexType .
  OPTIONAL {
    ?subject xsd:name ?name .
  }.
  FILTER (lsmf:isBound(?name)).
  OPTIONAL {
    ?parent xsd:name ?parentName .
  }.
}
```

Result Display: Truncated

<table>
<thead>
<tr>
<th>subject</th>
<th>parentName</th>
</tr>
</thead>
<tbody>
<tr>
<td>file:///OpenADR/input/oadr_ei_20b.xsd#-61-1</td>
<td>eventResponses</td>
</tr>
<tr>
<td>file:///OpenADR/input/oadr_ei_20b.xsd#-100-1</td>
<td>oadrTransports</td>
</tr>
<tr>
<td>file:///OpenADR/input/oadr_ei_20b.xsd#-110-1</td>
<td>oadInfo</td>
</tr>
</tbody>
</table>
# Viewing and Navigation between classes

## AbstractMeasure

### Annotations
- **comment**: Abstract measurement class. Each measurement has a unit of measure, uom. WXXM allows more than one uom -- eg F/C/K for temperature. FSGIM only allows one choice of uom for a physical quantity.
- **label**: AbstractMeasure

### Class Axioms
- **subClassOf**: Thing
  - powerOfTenMultiplier max 1
  - powerOfTenMultiplier min 0
  - powerOfTenMultiplier only SiScaleCodeType
  - uom exactly 1
  - uom only UnitSymbolKind
  - has Value exactly 1
  - has Value only Real

### Properties
- **http://uml.topquadrant.com/owl/uml/smg/uml2owl#belongsToGeneratedPackage**: Documentr-1-0-3-2-1-0
- **type**: Class
Benefits

- Exhaustively searches a standard to find errors that might escape human detection
  - Orphan definitions (defined but never used)
  - Opportunities for model refactoring (similar classes)
  - Disallowed changes to imported standards
  - Redundant classes and properties
  - Non-standard data type definitions
After Verification Testing

- **Model Healing**
  - Recommendations to correct errors
  - Automatic error correction for native OWL specifications

- **Conformance Testing**
  - Does a particular implementation properly represent the information according to the standard?
  - Generation of reference data sets

- **Standards Harmonization**
  - Checking for missing information
    - Information present in one standard but not in another
  - Mapping among different ways of modeling the same information
Thank you

More information: steve.ray@sv.cmu.edu