Grid-Interop

Using SPARQL/OWL for Validation of Smart Grid Standards
Semantic Harmonization of Smart Grid Concepts

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- How to reconcile vocabularies, concepts and relations among all the smart grid standards?

- Overlapping, different and sometimes contradictory vocabularies and definitions among standards

Approach: STEP#1

Using the
ASHRAE/NEMA Facilities Smart Grid Model (FSGIM)

1 Convert standard specification into RDF, OWL

2 Demonstrate a web app for easy interrogation of the model by the standardization community

3 Expose inconsistencies among concepts in different standards to harmonize terms

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AUTOMATED PROCESS

1 Export XMI from Enterprise Architect

2 Interpretation into OWL using SPARQLMotion scripts

IMPORT DATA

- ✓ 4 core FSGIM components: Energy Manager | Generator | Load | Meter
- ✓ Common Primitive Types, Classes and Enumerations
- ✓ Use Case Information
- ✓ All <u>referenced</u> external classes (from other standards - Energy Interoperation, EMIX, WS-Calendar, WXXM, IEC 61850, NAESB EUI)

Approach: STEP#2

Using the
ASHRAE/NEMA Facilities Smart Grid Model (FSGIM)

1 Convert standard specification into RDF, OWL

2 Demonstrate a web app for easy interrogation of the model by the standardization community

3 Expose inconsistencies among concepts in different standards to harmonize terms

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ARCHITECTURE

SPARQL Query Editor

http://fsgim.sv.cmu.edu

TopBraid Live on AWS

Tomcat

Amazon Web Server (AWS)

SPARQL QUERY EDITOR

http://fsgim.sv.cmu.edu

Sample Query: Datatypes not inheriting from standards

Revision 1666: 30 non-conforming datatype declarations

cls	role	range	rootDatatypeOfRange
energy_manager_component---model_components:Interval	energy_manager_component---model_components:hasDtEnd	ea_java_types_package---ea_primitivetypes_package:dateTime	ea_java_types_package---ea_primitivetypes_package:dateTime
energy_manager_component---model_components:Interval	energy_manager_component---model_components:hasDtStart	ea_java_types_package---ea_primitivetypes_package:dateTime	ea_java_types_package---ea_primitivetypes_package:dateTime
energy_manager_component---model_components:Interval	energy_manager_component---model_components:hasDuration	ea_java_types_package---ea_primitivetypes_package:duration	ea_java_types_package---ea_primitivetypes_package:duration
esi_energy_manager---energy_manager_component:DemandThreshold	esi_energy_manager---energy_manager_component:hasPeakTimestamp	ea_java_types_package---ea_primitivetypes_package:wscalTimeStampType	ea_java_types_package---ea_primitivetypes_package:wscalTimeStampType
esi_energy_manager---energy_manager_component:ESI_EMInterval	esi_energy_manager---energy_manager_component:hasEmissionsTotal	ea_java_types_package---ea_primitivetypes_package:EmissionsProfile	ea_java_types_package---ea_primitivetypes_package:EmissionsProfile
load_component---model_components:CurtailableLoad	load_component---model_components:hasActualCurtailmentsInPeriod	ea_java_types_package---ea_primitivetypes_package:Integer	ea_java_types_package---ea_primitivetypes_package:Integer
load_component---model_components:CurtailableLoad	load_component---model_components:hasCurtailmentCost	ea_java_types_package---ea_primitivetypes_package:Real	ea_java_types_package---ea_primitivetypes_package:Real
load_component---model_components:CurtailableLoad	load_component---model_components:hasCurtailmentStateTimeRemaining	ea_java_types_package---ea_primitivetypes_package:Integer	ea_java_types_package---ea_primitivetypes_package:Integer
load_component---model_components:CurtailableLoad	load_component---model_components:hasLoadPriority	ea_java_types_package---ea_primitivetypes_package:Integer	ea_java_types_package---ea_primitivetypes_package:Integer
load_component---model_components:CurtailableLoad	load_component---model_components:hasMaxCurtailmentsInPeriod	ea_java_types_package---ea_primitivetypes_package:Integer	ea_java_types_package---ea_primitivetypes_package:Integer
load_component---model_components:CurtailableLoad	load_component---model_components:hasMaximumCurtailTime	ea_java_types_package---ea_primitivetypes_package:Duration	ea_java_types_package---ea_primitivetypes_package:Duration
load_component---model_components:CurtailableLoad	load_component---model_components:hasMinimumCurtailTime	ea_java_types_package---ea_primitivetypes_package:Duration	ea_java_types_package---ea_primitivetypes_package:Duration
load_component---model_components:CurtailableLoad	load_component---model_components:hasMinimumReleaseTime	ea_java_types_package---ea_primitivetypes_package:Duration	ea_java_types_package---ea_primitivetypes_package:Duration
load_component---model_components:CurtailableLoad	load_component---model_components:hasPriceThreshold	ea_java_types_package---ea_primitivetypes_package:Real	ea_java_types_package---ea_primitivetypes_package:Real
load_component---model_components:DAbsoluteAmount	load_component---model_components:hasCurtailAmount	ea_java_types_package---ea_primitivetypes_package:Real	ea_java_types_package---ea_primitivetypes_package:Real
load_component---model_components:DAnalogOutputLevel	load_component---model_components:hasPercentage	ea_java_types_package---ea_primitivetypes_package:Real	ea_java_types_package---ea_primitivetypes_package:Real
load_component---model_components:DPieceWiseLinear	load_component---model_components:hasDuration	ea_java_types_package---ea_primitivetypes_package:Duration	ea_java_types_package---ea_primitivetypes_package:Duration
load_component---model_components:DPowerSource	load_component---model_components:hasPowerSourceID	ea_java_types_package---ea_primitivetypes_package:LocalID	ea_java_types_package---ea_primitivetypes_package:LocalID
load_component---model_components:DemandAndEnergyPriceInfo	load_component---model_components:hasDemandPrice	ea_java_types_package---ea_primitivetypes_package:Real	ea_java_types_package---ea_primitivetypes_package:Real
load_component---model_components:DemandAndEnergyPriceInfo	load_component---model_components:hasEnergyPrice	ea_java_types_package---ea_primitivetypes_package:Real	ea_java_types_package---ea_primitivetypes_package:Real
load_component---model_components:ForecastedDemand	load_component---model_components:hasConfidenceLevel	ea_java_types_package---ea_primitivetypes_package:Integer	ea_java_types_package---ea_primitivetypes_package:Integer
load_component---model_components:ForecastedDemand	load_component---model_components:hasTimePeriod	ea_java_types_package---ea_primitivetypes_package:ETimeUnits	ea_java_types_package---ea_primitivetypes_package:ETimeUnits
load_component---model_components:Load	load_component---model_components:hasActivePowerSource	ea_java_types_package---ea_primitivetypes_package:Integer	ea_java_types_package---ea_primitivetypes_package:Integer
load_component---model_components:Load	load_component---model_components:hasLoadID	ea_java_types_package---ea_primitivetypes_package:LocalID	ea_java_types_package---ea_primitivetypes_package:LocalID
load_component---model_components:Load	load_component---model_components:hasLoadType	ea_java_types_package---ea_primitivetypes_package:String	ea_java_types_package---ea_primitivetypes_package:String

Revision 1698*: 0 datatype errors

Query Result

cls role range rootDatatypeOfRange

*Revision 1698: Advisory Public Review Revision of FSGIM

Sample Query: All datatypes inheriting from standard definitions or the Common Primitive Types (Revision 1666)

cls	role	range	rootDatatypeOfRange
esi_energy_manager···energy_manager_component:ESI_EM	esi_energy_manager···energy_manager_component:hasAvailableOnsiteGeneration	esi_java_types_package···esi_primitivetypes_package:Float	uml.xml:UnlimitedNatural
esi_energy_manager···energy_manager_component:ESI_EM	esi_energy_manager···energy_manager_component:hasAvailableStorage	esi_java_types_package···esi_primitivetypes_package:Float	uml.xml:UnlimitedNatural
esi_energy_manager···energy_manager_component:ESI_EM	esi_energy_manager···energy_manager_component:hasAvailableThermalStorage	esi_java_types_package···esi_primitivetypes_package:Float	uml.xml:UnlimitedNatural
esi_energy_manager···energy_manager_component:ESI_EM	esi_energy_manager···energy_manager_component:hasEMID	primitive_data_types···common_primitive_types_classes_and_enumerations:String	primitive_data_types···common_primitive_types_classes_and_enumerations:String
esi_energy_manager···energy_manager_component:ESI_EM	esi_energy_manager···energy_manager_component:hasFacilityID	primitive_data_types···common_primitive_types_classes_and_enumerations:String	primitive_data_types···common_primitive_types_classes_and_enumerations:String
esi_energy_manager···energy_manager_component:ESI_EMInterval	esi_energy_manager···energy_manager_component:hasAvoidedUsageAggregated	esi_java_types_package···esi_primitivetypes_package:Float	uml.xml:UnlimitedNatural
esi_energy_manager···energy_manager_component:ESI_EMInterval	esi_energy_manager···energy_manager_component:hasEnergyPriceTotal	esi_java_types_package···esi_primitivetypes_package:Float	uml.xml:UnlimitedNatural
esi_energy_manager···energy_manager_component:ESI_EMInterval	esi_energy_manager···energy_manager_component:hasGeneratedEnergyAggregated	esi_java_types_package···esi_primitivetypes_package:Float	uml.xml:UnlimitedNatural
esi_energy_manager···energy_manager_component:ESI_EMInterval	esi_energy_manager···energy_manager_component:hasGrossUsageAggregated	esi_java_types_package···esi_primitivetypes_package:Float	uml.xml:UnlimitedNatural
esi_energy_manager···energy_manager_component:ESI_EMInterval	esi_energy_manager···energy_manager_component:hasNetUsageAggregated	esi_java_types_package···esi_primitivetypes_package:Float	uml.xml:UnlimitedNatural
esi_energy_manager···energy_manager_component:ThermalType	esi_energy_manager···energy_manager_component:hasCapacity	esi_java_types_package···esi_primitivetypes_package:Float	uml.xml:UnlimitedNatural
internal_energy_manager···energy_manager_component:AggregateQuantity	internal_energy_manager···energy_manager_component:hasName	primitive_data_types···common_primitive_types_classes_and_enumerations:String	primitive_data_types···common_primitive_types_classes_and_enumerations:String
internal_energy_manager···energy_manager_component:Aggregation	internal_energy_manager···energy_manager_component:hasName	primitive_data_types···common_primitive_types_classes_and_enumerations:String	primitive_data_types···common_primitive_types_classes_and_enumerations:String
internal_energy_manager···energy_manager_component:Collection	internal_energy_manager···energy_manager_component:hasName	primitive_data_types···common_primitive_types_classes_and_enumerations:String	primitive_data_types···common_primitive_types_classes_and_enumerations:String
internal_energy_manager···energy_manager_component:ComponentElement	internal_energy_manager···energy_manager_component:hasLocation	primitive_data_types···common_primitive_types_classes_and_enumerations:String	primitive_data_types···common_primitive_types_classes_and_enumerations:String

Revision 1666: 34 properly defined datatypes occurrences of 12 distinct datatypes

Sample Query: All datatypes inheriting from standard definitions or
the Common Primitive Types (Revision 1698)

cls	role	range	rootDatatypeOfRange
energy_manager_component---model_components:Interval	energy_manager_component---model_components:hasDuration	primitive_data_types---common_primitive_types_classes_and_enumerations:Duration	primitive_data_types---common_primitive_types_classes_and_enumerations:Duration
energy_manager_component---model_components:Interval	energy_manager_component---model_components:hasDtStart	primitive_data_types---common_primitive_types_classes_and_enumerations:AbsoluteDateTime	primitive_data_types---common_primitive_types_classes_and_enumerations:AbsoluteDateTime
energy_manager_component---model_components:Interval	energy_manager_component---model_components:hasDtEnd	primitive_data_types---common_primitive_types_classes_and_enumerations:AbsoluteDateTime	primitive_data_types---common_primitive_types_classes_and_enumerations:AbsoluteDateTime
esi_energy_manager---energy_manager_component:DemandThreshold	esi_energy_manager---energy_manager_component:hasPeakTimestamp	primitive_data_types---common_primitive_types_classes_and_enumerations:AbsoluteDateTime	primitive_data_types---common_primitive_types_classes_and_enumerations:AbsoluteDateTime
esi_energy_manager---energy_manager_component:ESI_EM	esi_energy_manager---energy_manager_component:hasFacilityID	primitive_data_types---common_primitive_types_classes_and_enumerations:String	primitive_data_types---common_primitive_types_classes_and_enumerations:String
esi_energy_manager---energy_manager_component:ESI_EM	esi_energy_manager---energy_manager_component:hasEMID	primitive_data_types---common_primitive_types_classes_and_enumerations:String	primitive_data_types---common_primitive_types_classes_and_enumerations:String
esi_energy_manager---energy_manager_component:ESI_EMInterval	esi_energy_manager---energy_manager_component:hasEnergyPriceTotal	esi_java_types_package---esi_primitivetypes_package:Float	uml.xml:UnlimitedNatural
internal_energy_manager---energy_manager_component:AggregateQuantity	internal_energy_manager---energy_manager_component:hasName	primitive_data_types---common_primitive_types_classes_and_enumerations:String	primitive_data_types---common_primitive_types_classes_and_enumerations:String
internal_energy_manager---energy_manager_component:Aggregation	internal_energy_manager---energy_manager_component:hasName	primitive_data_types---common_primitive_types_classes_and_enumerations:String	primitive_data_types---common_primitive_types_classes_and_enumerations:String
internal_energy_manager---energy_manager_component:Collection	internal_energy_manager---energy_manager_component:hasName	primitive_data_types---common_primitive_types_classes_and_enumerations:String	primitive_data_types---common_primitive_types_classes_and_enumerations:String
internal_energy_manager---energy_manager_component:ComponentElement	internal_energy_manager---energy_manager_component:hasTag	primitive_data_types---common_primitive_types_classes_and_enumerations:String	primitive_data_types---common_primitive_types_classes_and_enumerations:String
internal_energy_manager---energy_manager_component:ComponentElement	internal_energy_manager---energy_manager_component:hasLocation	primitive_data_types---common_primitive_types_classes_and_enumerations:String	primitive_data_types---common_primitive_types_classes_and_enumerations:String
internal_energy_manager---energy_manager_component:EM	internal_energy_manager---energy_manager_component:hasEMID	primitive_data_types---common_primitive_types_classes_and_enumerations:String	primitive_data_types---common_primitive_types_classes_and_enumerations:String
internal_energy_manager---energy_manager_component:Ruleset	internal_energy_manager---energy_manager_component:hasRules	primitive_data_types---common_primitive_types_classes_and_enumerations:String	primitive_data_types---common_primitive_types_classes_and_enumerations:String

Revision 1698: 53 properly defined datatypes occurrences of 8 distinct datatypes

What is possible now:

Simple way of Quality Checking a model

Other Possibilities:

✓ Refactoring the model

✓ Pruning the model

✓ Reconciling vocabularies, concepts and relations among all Smart Grid Information Standards

- ➢ Build an interactive UI using SPARQL web pages

- ➢ Enhance the sophistication of queries

- ➢ Check for compliance with dos-and-don'ts in the model