ASHRAE Standard 201: Facility Smart Grid Information Model (FSGIM)

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Learning Objectives

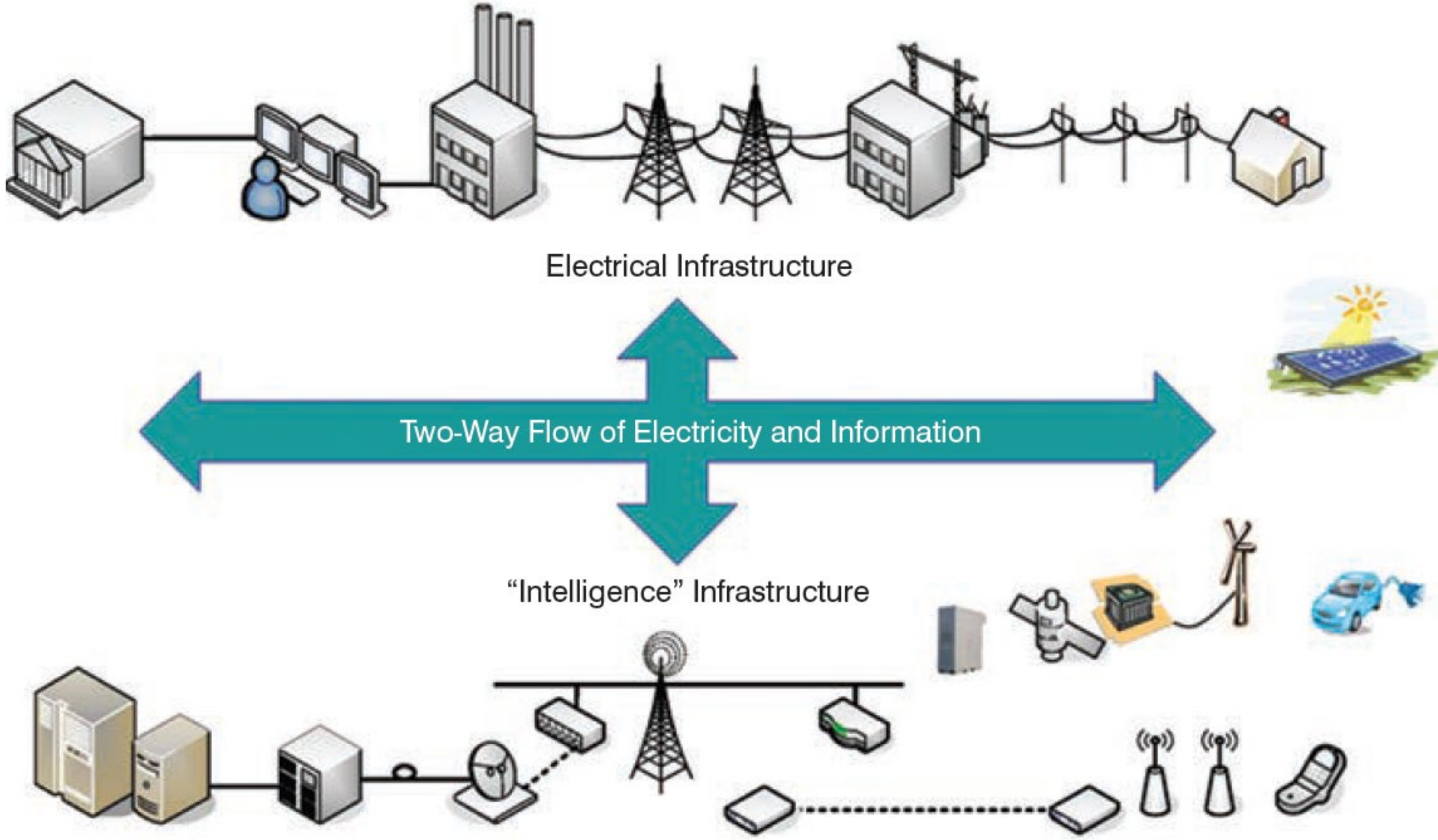
- Understand the purpose and scope of ASHRAE Standard 201 in the context of smart grid integration
- Interpret the structure of FSGIM using Unified Modeling Language (UML) diagrams, classes, and attributes
- Understand the role of standard data models and interoperability in enabling demand response and energy management
- Recognize the connection between ASHRAE 201 and other related standards

Outline

- Overview
- Device and Model Components
- Common Primitive Types, Classes, and Enumerations
- Model Elements from External Sources
- Summary

Traditional Grid vs. Smart Grid

- Traditional grid is characterized by centralized power generation, one-way power flow, and limited communication capabilities.
- Smart grid features decentralized energy sources (e.g., PV, storage, and flexible loads), bidirectional power flow and information, advanced metering infrastructure, and integrated communication systems.



Source: Bushby (2011)

Facility

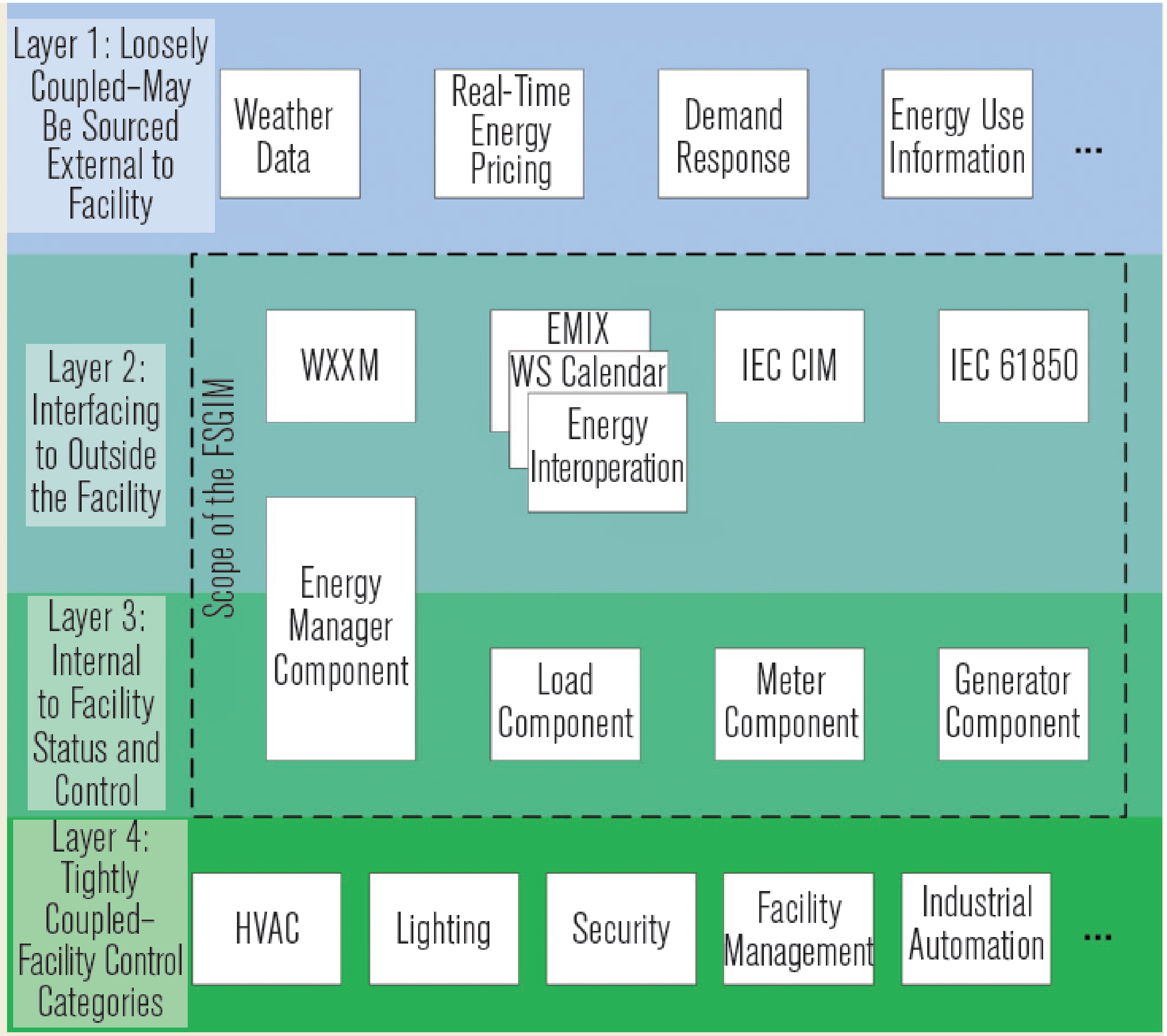
- Facility Types
  - Residential buildings (e.g., a single-family house)
  - Commercial buildings (e.g., a 3-storey office building)
  - Industrial buildings (e.g., a bakery manufacturing plant)
  - A collection of buildings of the same owner (e.g., a university campus)
- Different facility types have common characteristics and needs with respect to interactions with the grid.

FSGIM

- Was developed by ASHRAE in collaboration with The National Electrical Manufacturers Association.
- Defines the information in a standard way to enable the management of onsite distributed energy sources and their interactions with relevant external entities, mostly electrical service providers.
- Uses the Unified Modeling Language (UML) to define its structure and semantics.
- Intends to support a wide range of applications, such as:
    - Manage onsite generation and storage to minimize cost
    - Measure energy cost, emissions, and consumption for different purposes, such as human-machine-interface display, benchmarking, and validation
    - Determine the current electricity demand at different levels (e.g., a piece of equipment, a subsystem, a single building)
    - Forecast electricity demands
    - Others

FSGIM Architecture

- Layer 1: data sources that are externally available but need to accessed by the facility.
- Layer 2: how to represent the information exchanged between the facility and the external entities by leveraging other standards.
- Layer 3: how to abstract the analysis, monitoring, and control of physical devices in the facility.
- Layer 4: actual physical devices and associated controls used in the facility.



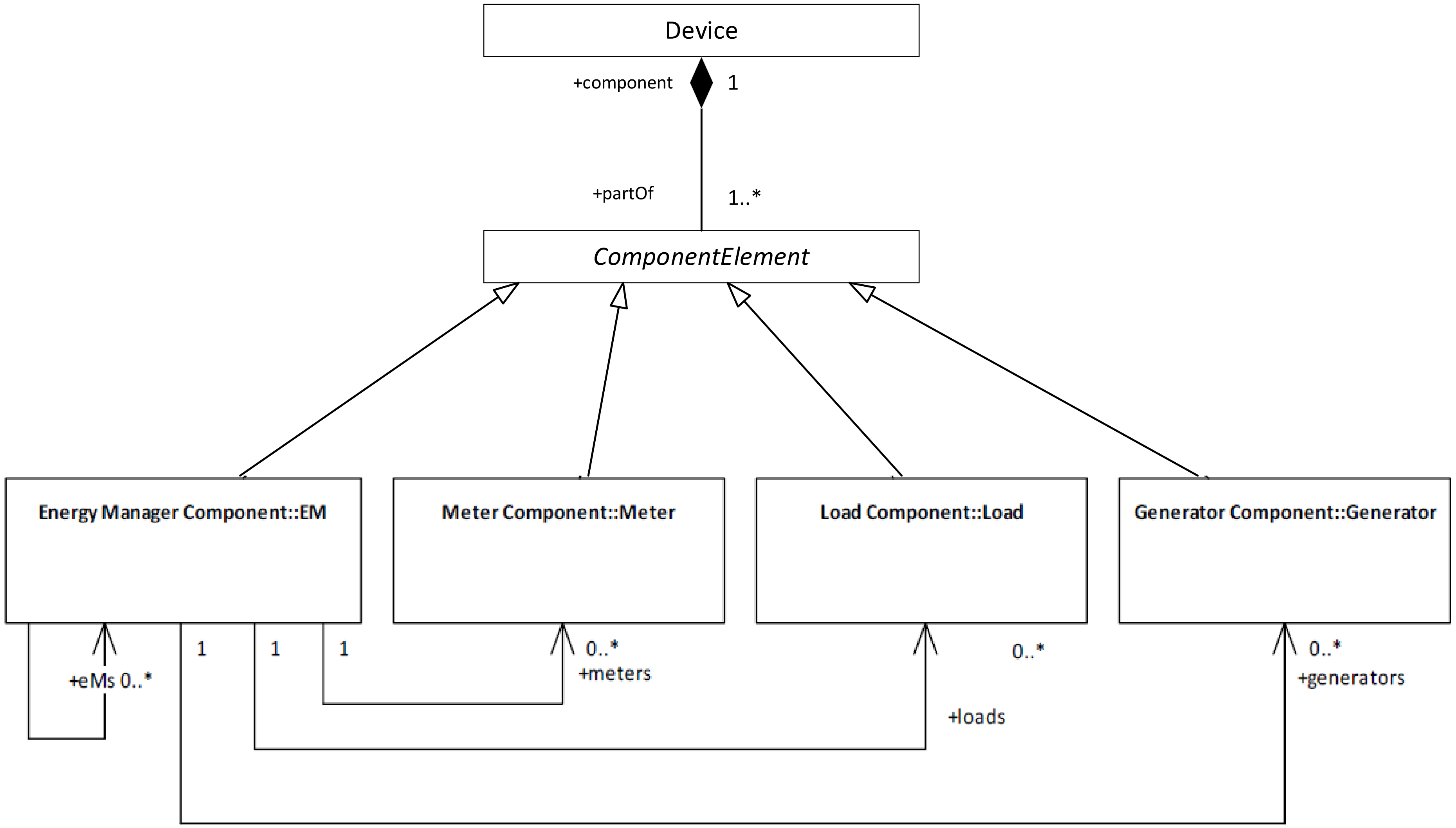
Source: Bushby and Jones (2016)

List of Major Packages

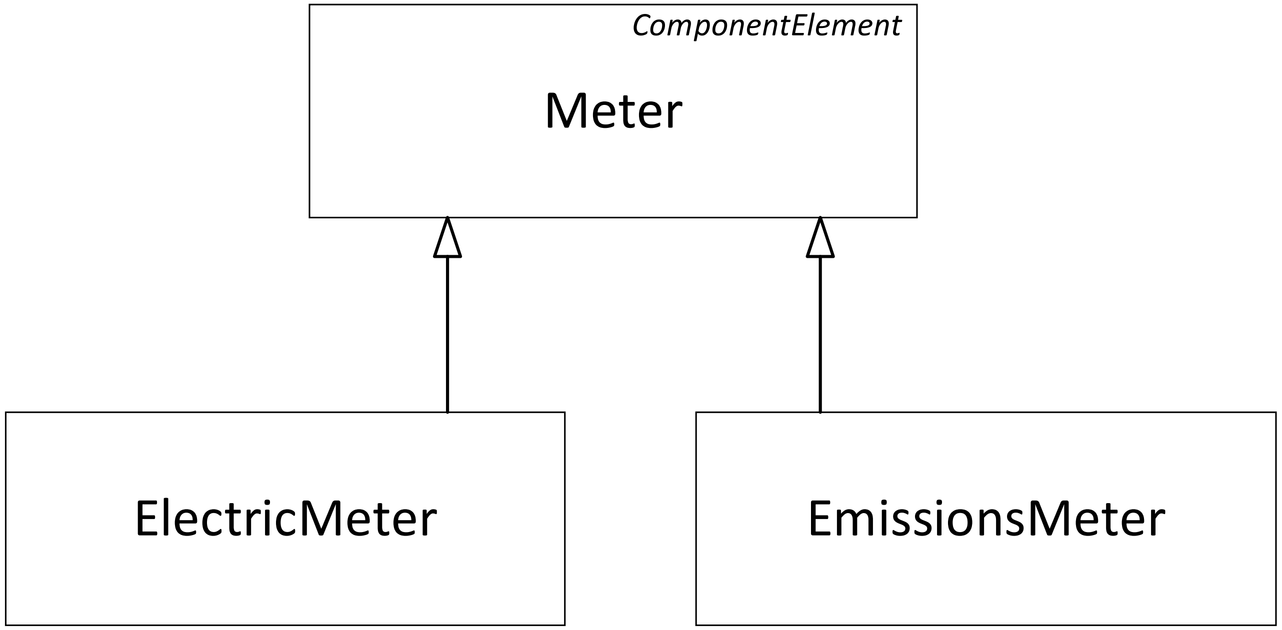
- Device and Model Components
  - Represent physical devices and systems in a facility (e.g., a chiller, all lights on the 3rd floor, roof-top PVs, an electric meter, and a controller for building automation)
- Common Primitive Types, Classes, and Enumerations
  - The primitive data types (e.g., Boolean, Integer, Real, and String), classes, and enumerations that are used throughout the FSGIM
- Model Elements from External Sources
  - Other standards used to create the FSGIM model

Package of Device and Model Components

Device and Model Components



Meter Component

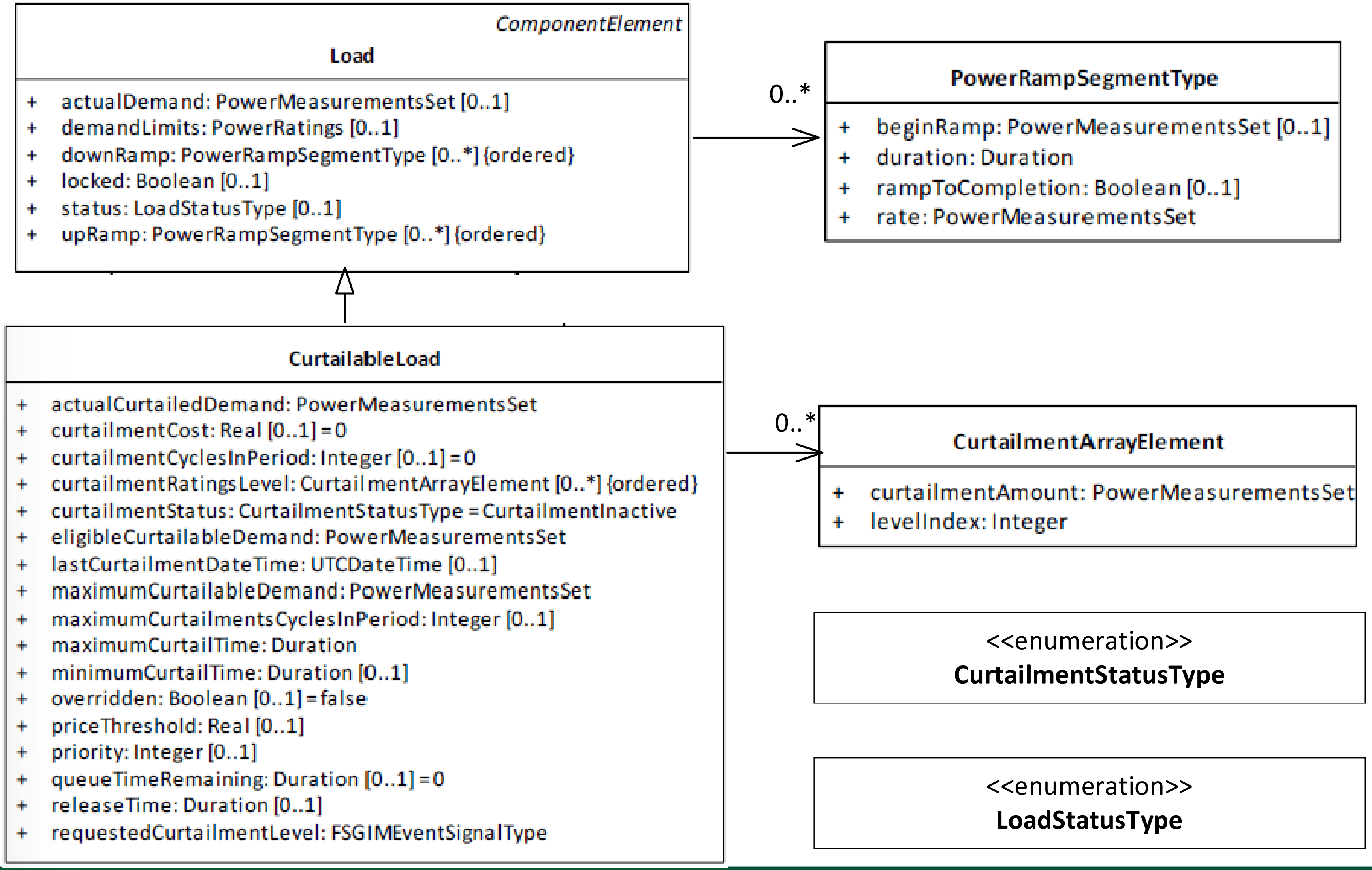


- The Meter Class is used to model devices that measure electricity or pollution emissions.
- The Meter Class has two subclasses: the ElectricMeter Class and the EmissionsMeter Class.

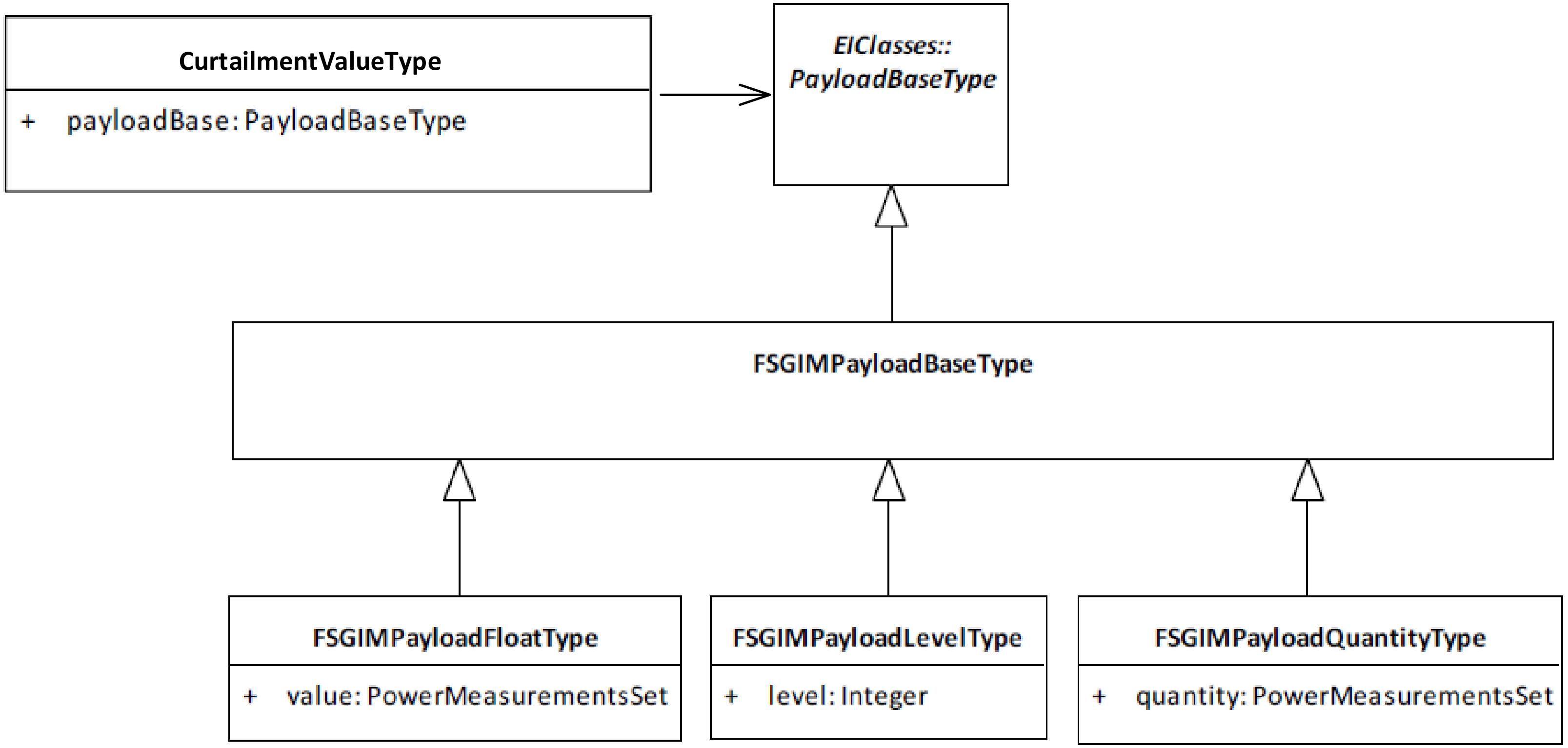
Load Component

- The Load Component consists of load classes and all their associated classes.
- The Load Class is used to model devices that consume electricity.
- The Load Class has one subclass – the CurtailableLoad Class, used to model devices whose electrical consumption can be modified in response to grid signals.
- The attributes define the information elements that support the functionality of a load. For a curtailable load, the attributes represent curtailment characteristics with respect to load priorities, cost constraints, equipment protection and restoration of curtailed loads.

Load Component Class Diagram (1)

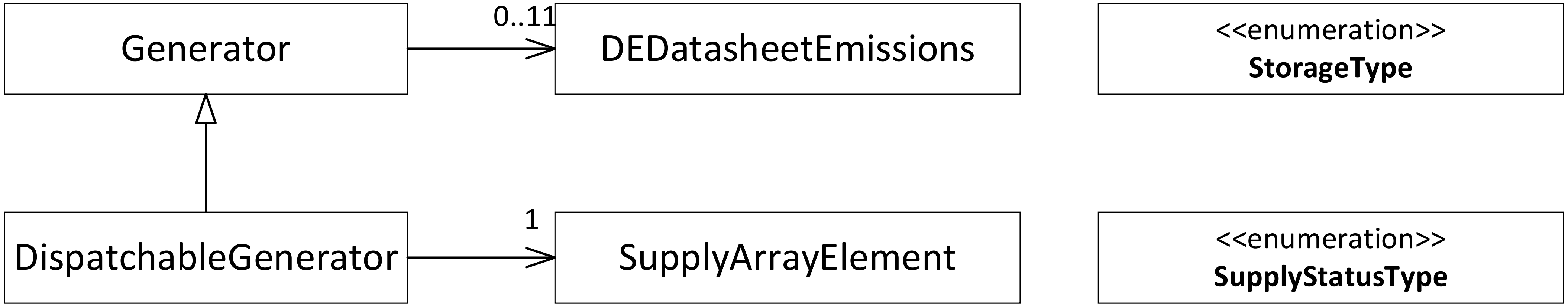


Load Component Class Diagram (2)



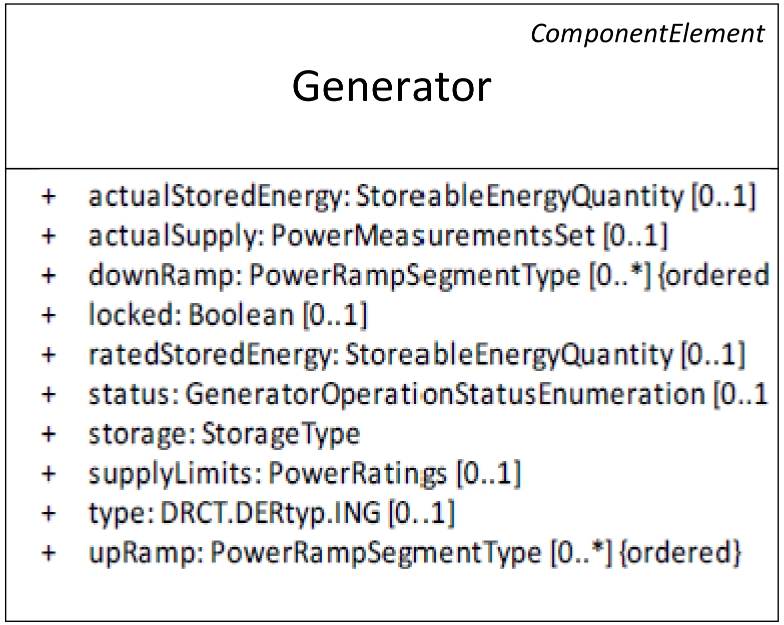
- FSGIMPayloadFloatType: an absolute or relative demand curtailment value from the baseline
- FSGIMPayloadQuantityType: a percentage of the baseline
- FSGIMPayloadLevelType: a predefined level of curtailment

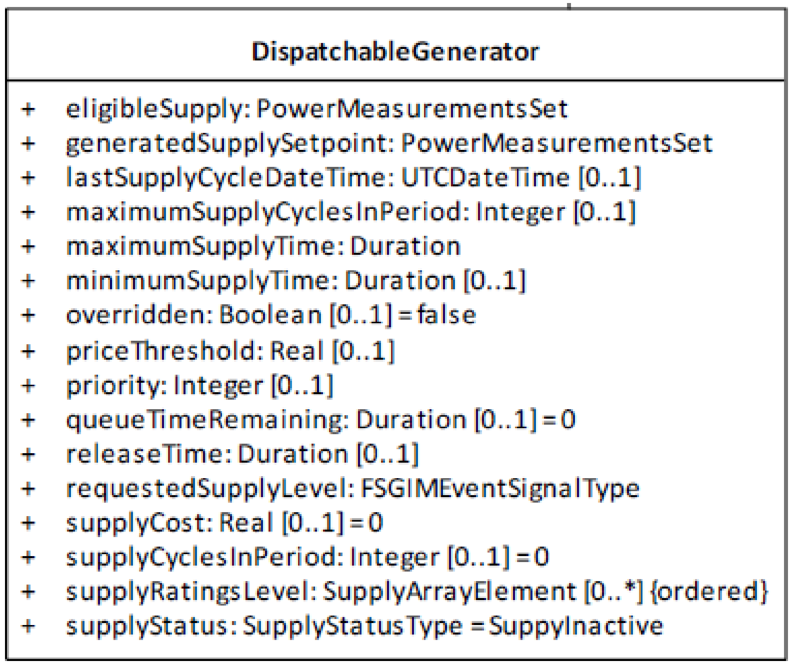
Generator Component



- The Generator Component consists of generator classes and all their associated classes.
- The Generator Class is used to model devices that produce electricity.
- The Generator Class has one subclass – the DispatchableGenerator Class, used to model devices whose electrical production can be modified in response to grid signals.

Generator Class Attributes





- The attributes define the information elements that support the functionality of a generator.
- For a dispatchable generator, the attributes represent supply characteristics such as priorities, cost constraints, equipment protection and safety constraints.
- Table 5.23 and Table 5.25 in the FSGIM Standard have details.

Exercise 1

- Imagine you are designing the smart grid interface for a new, small-sized commercial office building. The building has the following key energy-consuming and generating components:
  - A packaged rooftop unit equipped with a variable-speed supply fan
  - LED lighting throughout the building
  - A rooftop solar PV array
  - An electrical domestic water heater
  - A main building electrical meter from the utility

Question: What ASHRAE 201 device classes would best represent the above equipment?

Energy Manager (EM) Component

- The EM Component provides the abstract representation of an energy management system that performs the following functionalities:
  - Tracking historical energy data
  - Projecting future electricity demand
  - Interfacing external entities to obtain energy-related information
  - Making analysis and energy-related decisions
- An energy management system may consist of many EMs:
  - Energy service interface EM: an EM that interfaces external entities
  - Local EM: an EM that does not interface external entities

Structure of the Energy Manager (EM) Component

- 9 Classes directly under the Energy Manager Component
- 5 subpackages under the Energy Manager Component
    - Sequences and Intervals
    - Collections, Rule Sets, and Aggregations
    - EnergyRouter
    - FSGIMWeather
    - Key Energy Manager Concepts

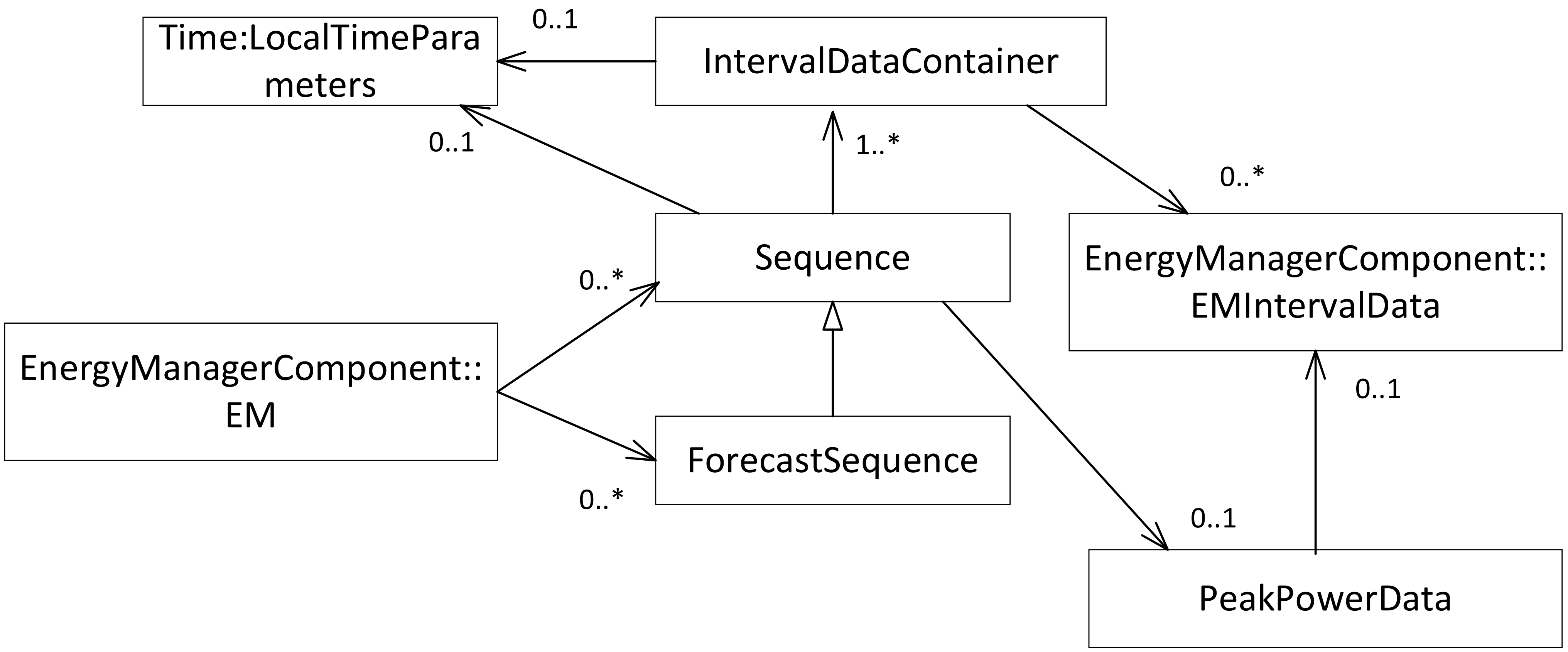
Sequences and Intervals

- A sequence is a set of data elements (e.g., price, power, and event signals) associated with specific time intervals. The sequence concept is needed to model changing values over time.

- An interval defines the time duration and position of a value in a sequence. The IntervalDataContainer Class represents an interval of time that attaches to a collection of data pertinent to that interval.

    - An interval of time is defined with any two of the following three attributes: start time, end time, and duration.

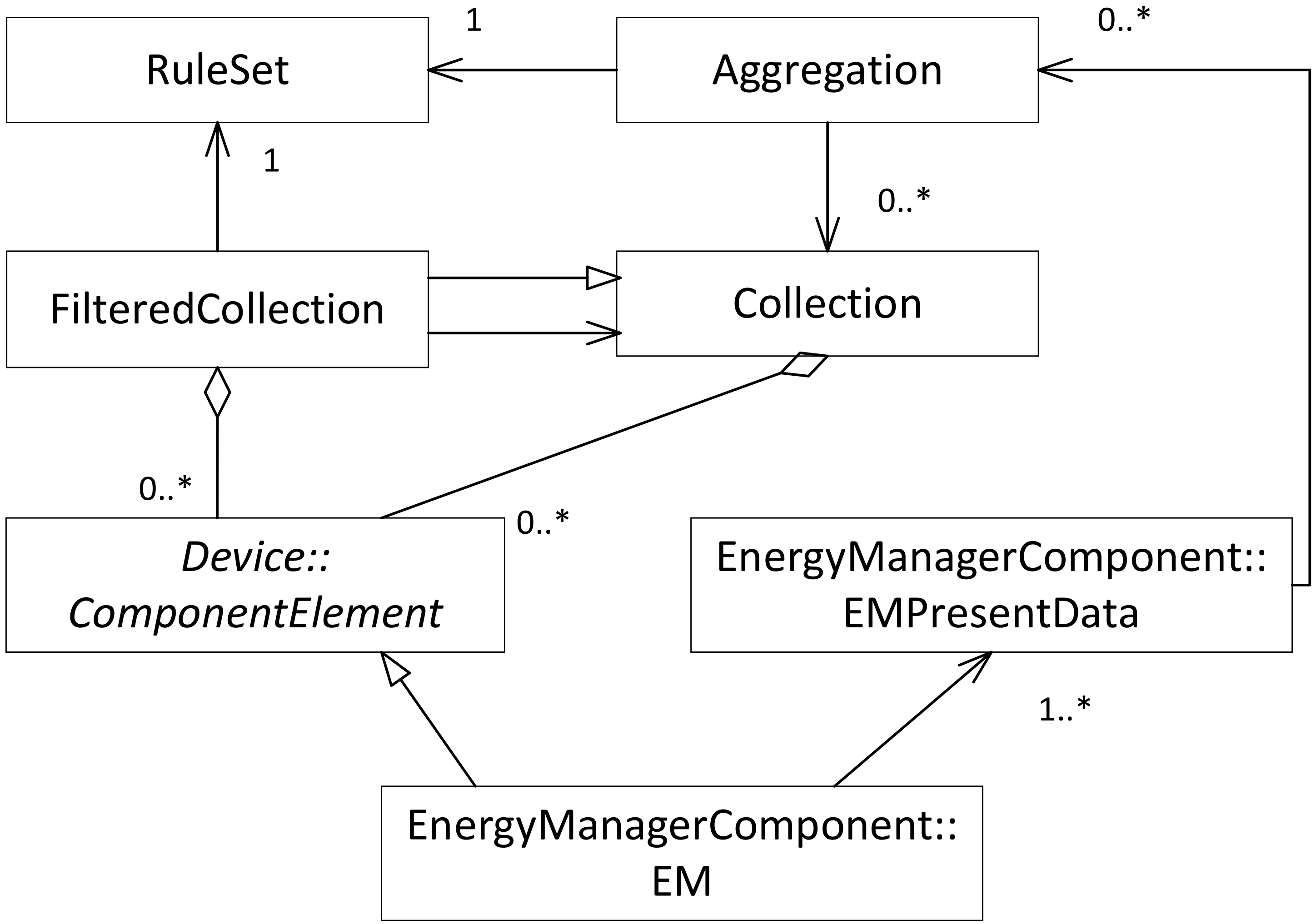
Sequence and Intervals Class Diagram



Collections, Rule Sets, and Aggregations

- The EM needs to identify collections of its managed entities and record and report the aggregated quantities (e.g., energy, demand, and emissions) of the collected entities.
- Key concepts:
  - Collection: a set of entities identified as a group sharing certain traits (e.g., all equipment in the facility, lighting loads on the 3rd floor).
  - Rule set: a set of rules used to determine how the value of an aggregated quantity is derived or how the members of a collection are filtered.
  - Aggregation: the quantity computed by applying aggregation rules against a collection of entities.

Collection, RuleSet and Aggregation Class Diagram



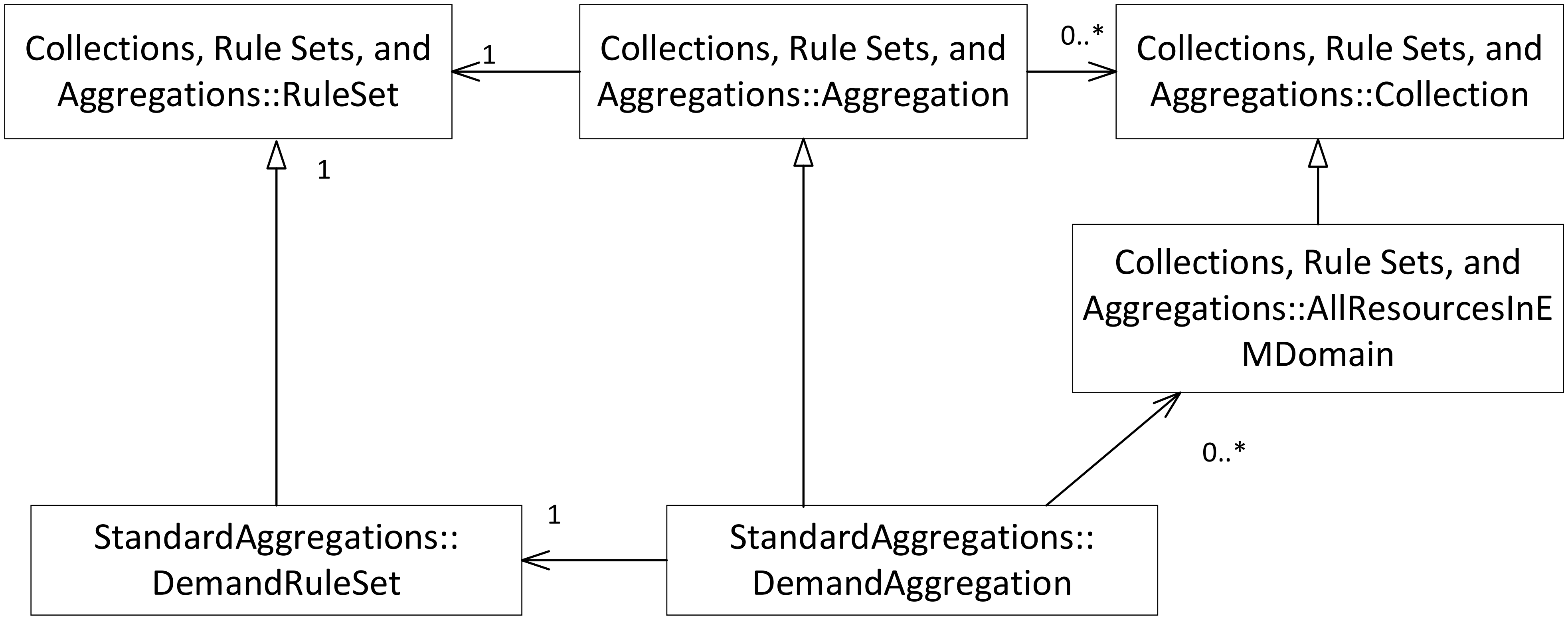
Standard Aggregations and RuleSets

Aggregation Class	RuleSet Class	Aggregated Item
DemandAggregation	DemandRuleSet	Power demand of loads
SupplyAggregation	SupplyRuleSet	Power supply of generators and storage devices
AdjustedFullDRDemandAggregation	AdjustedFullDRDemandRuleSet	Power demand of loads assuming the largest acceptable response to DR
AdjustedFullDRSupplyAggregation	AdjustedFullDRSupplyRuleSet	Power supply of generators and storage devices assuming the largest acceptable response to DR
AdjustedNoDRDemandAggregation	AdjustedNoDRDemandRuleSet	Power demand of loads assuming no DR events occurred
AdjustedNoDRSupplyAggregation	AdjustedNoDRSupplyRuleSet	Power supply of generators and storage devices assuming no DR events occurred
NetDemandAggregation	NetDemandRuleSet	Net power demand of loads, generators, and storage devices

Standard Aggregations and RuleSets (Cont'd)

Aggregation Class	RuleSet Class	Aggregated Item
EnergyConsumedAggregation	EnergyConsumedRuleSet	Energy consumed by loads
EnergySuppliedAggregation	EnergySuppliedRuleSet	Energy supplied by generators and storage devices
ElectricalEnergyStoredAggregation	ElectricalEnergyStoredRuleSet	Stored electrical energy
NetEnergyConsumedAggregation	NetEnergyConsumedRuleSet	Net energy consumed by loads, generators, and storage devices
EmissionsGeneratedAggregation	EmissionsGeneratedRuleSet	Emissions from generators and storage devices
EmissionsGenerationRateAggregation	EmissionsGenerationRateRuleSet	The rate of emissions from generators and storage devices
ThermalEnergyStoredAggregation	ThermalEnergyStoredRuleSet	Thermal energy stored by thermal storage devices

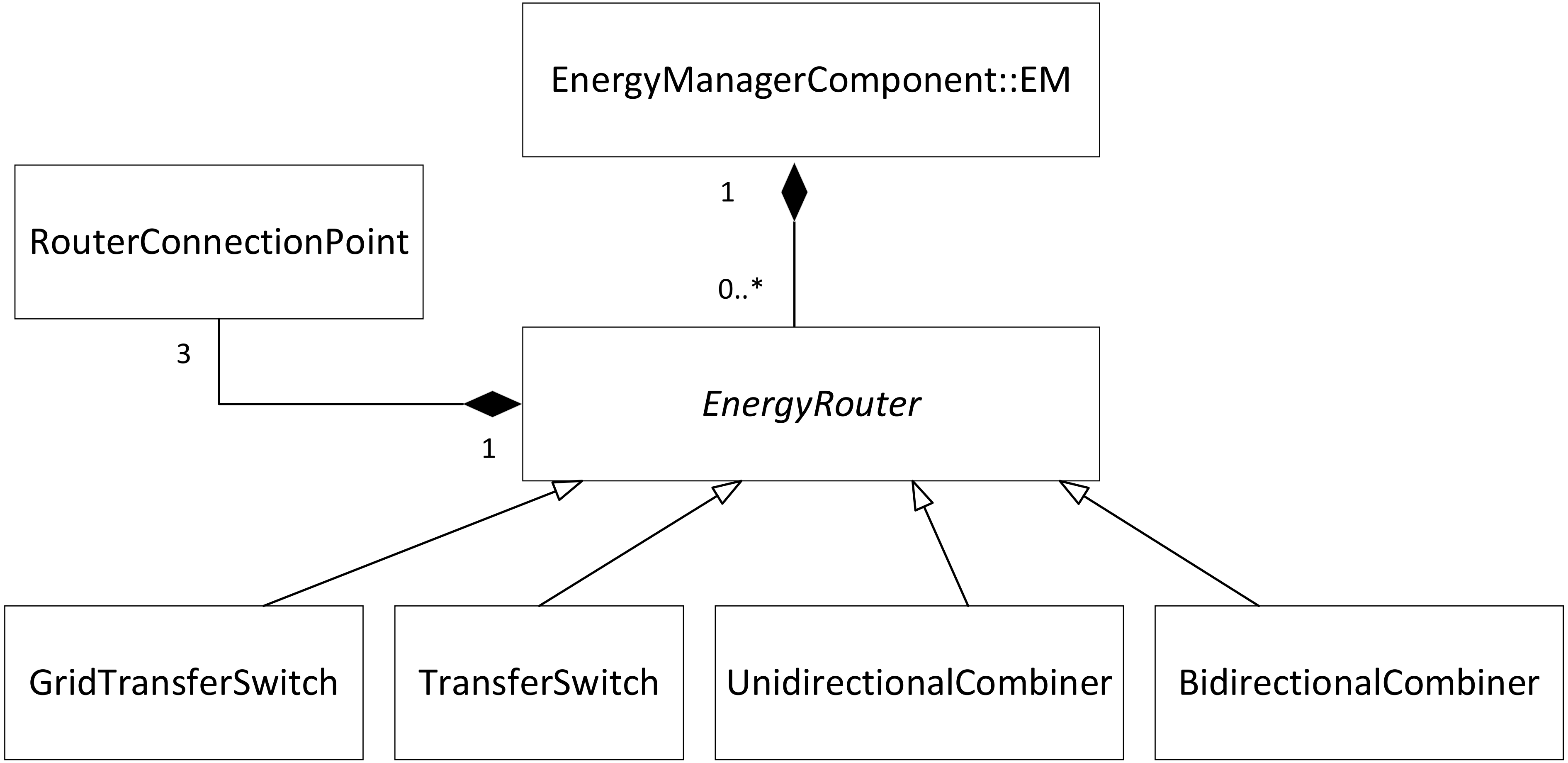
Example: The Inheritance Relationship between Standard Aggregations & RuleSets and the General Ones



EnergyRouter

- The EnergyRouter Class is used to model devices that enable a load to receive power from more than one source.
- The FSGIM provides four specialized EnergyRouters:
  - GridTransferSwitch: a switchgear used to allow a load to be switched between two utility feeds
  - TransferSwitch: a transfer switch used to allow a load to be switched between two power sources (e.g., grid and backup generators)
  - BidirectionalCombiner: a bidirectional combiner box used in renewable energy and energy storage systems to manage power flows in both directions – from the grid to the facility load and from the facility generator to the grid.
  - UnidirectionalCombiner: a unidirectional combiner box used in renewable energy and energy storage systems to manage power flows in one direction – from the grid to the facility load.
- EnergyRouter usually has three inputs and outputs, represented by the RouterConnectionPoint.

EnergyRouter Class Diagram



Exercise 2

- Imagine you are designing the smart grid interface for a new, small-sized commercial office building. The building has the following key energy-consuming and generating components:
  - A packaged rooftop unit equipped with a variable-speed supply fan
  - LED lighting throughout the building
  - A rooftop solar PV array
  - An electrical domestic water heater
  - A main building electrical meter from the utility

Questions:

1) Which of the above devices likely need to use EnergyRouter to manage energy flow?

2) Where can the EnergyManager be located if the facility owner wants to participate in a utility's demand response program?

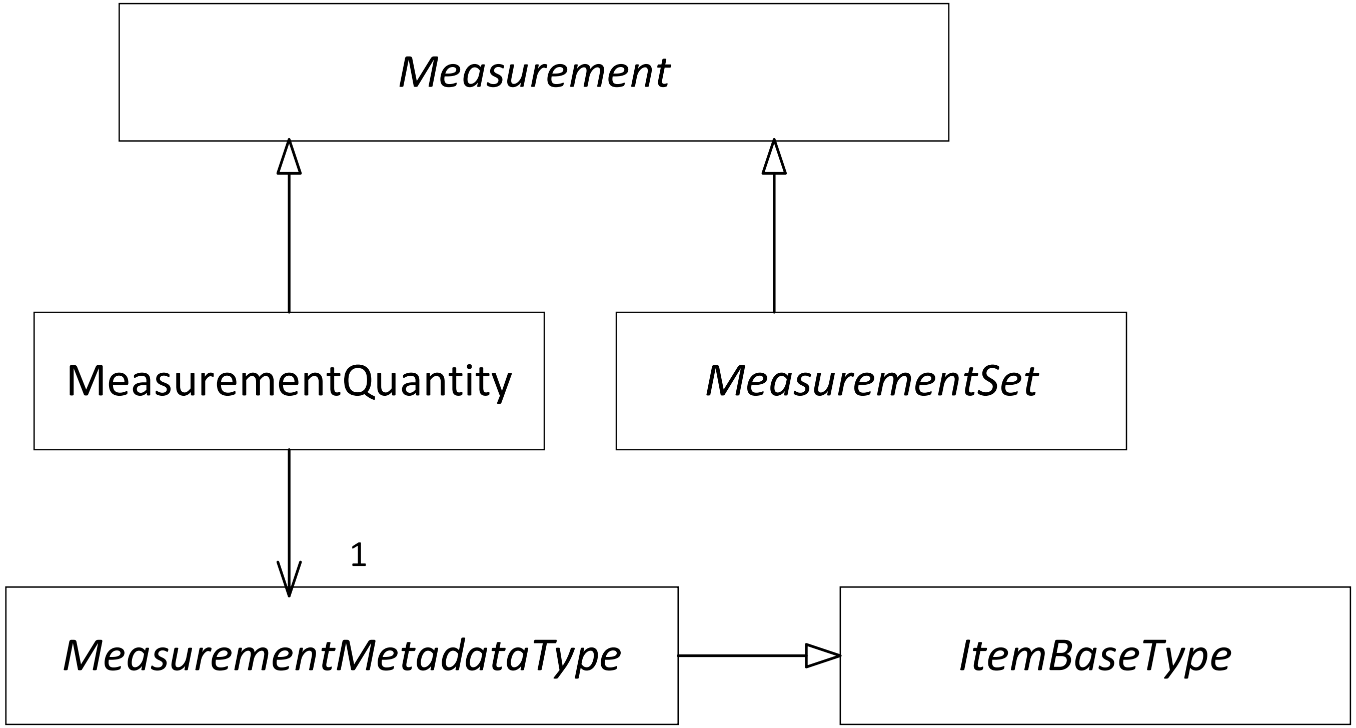
Package of Common Primitive Types, Classes, and Enumerations

Common Primitive Types, Classes, and Enumerations

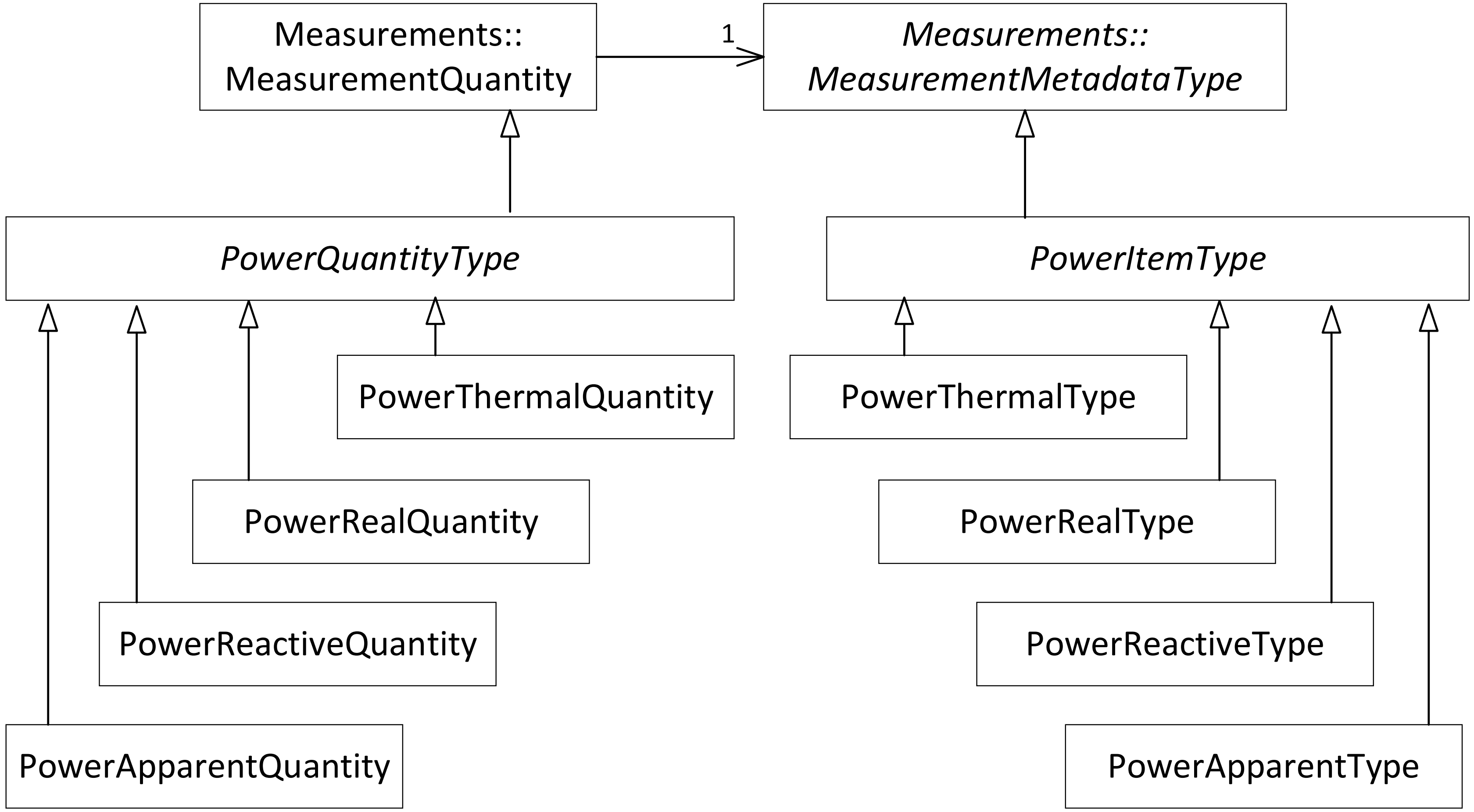
- Time (e.g., LocalTimeParameters and Date)
- Enumerations (e.g., MonthType and UnitSymbolKind)
- Primitive Data Types (e.g., Boolean, Real, and String)
- Measurements
- Other Common Classes (e.g., Circuit and ConnectionPoint)

Measurements Overview

- Used to describe power, energy and emissions which are physically measured by meters.
  - A quantity of the measurement
  - A set of metadata (e.g., unit and accuracy) related to the measurement



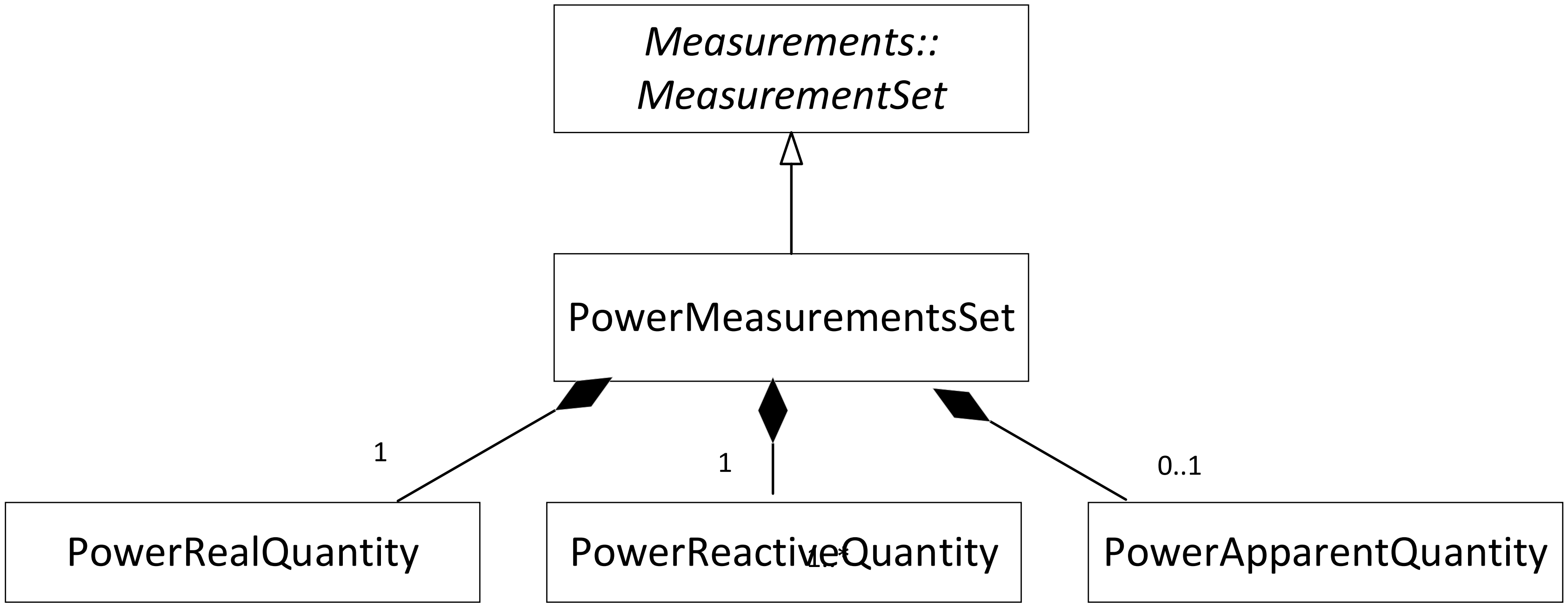
Power Measurements Class Diagram



- Energy measurements and emissions measurements have similar diagrams.

Sets of Power Measurements Class Diagram

- More than one type of power measurement may be needed for a given location and time. For example, both real power and reactive power are needed at a given point in an electric circuit.
- Energy measurements sets and emissions measurements sets have similar diagrams.



Package of Model Elements from External Sources

Other Standards Used to Create the FSGIM

Standards from OASIS (Organization for the Advancement of Structured Information Standards):

- OASIS Energy Interoperation Standard (https://www.oasis-open.org/standard/energyinterop-v1-0/) defines information used to coordinate energy supply and use, including power and ancillary services, between energy suppliers and facilities.
- OASIS Energy Market Information Exchange (EMIX) Standard (https://docs.oasis-open.org/emix/emix/v1.0/emix-v1.0.html) defines the information needed to exchange price and product definitions for power and energy markets. Product definition includes quantity and quality of supply as well as attributes of interest to consumers distinguishing between power and energy sources.
- OASIS WS-Calendar Standard (https://docs.oasis-open.org/ws-calendar/ws-calendar/v1.0/ws-calendar-1.0-spec.html) is used to represent schedules, intervals, and time series of data related to calendar.

Other Standards Used to Create the FSGIM (Cont'd)

Standards from IEC (International Electrotechnical Commission):

- IEC 61850 series of stands, IEC 61850-7-2,3,4 and 420, (https://iec61850.dvl.iec.ch/) are used as the foundation for the FSGIM generator model.
- The NAESB Energy Usage Information Model (https://www.naesb.org/pdf4/naesb_energy_usage_information_model.pdf), which is derived from IEC Common Information Model (CIM), is used to create the FSGIM meter model.

Standards from EUROCONTROL:

- The Weather Information Exchange Model (https://interoperable-europe.ec.europa.eu/collection/eu-semantic-interoperability-catalogue/solution/weather-information-exchange-models) is used to model weather observations and forecasts.

Summary

- FSGIM provides a comprehensive, technology-neutral information model that bridges building automation with the smart grid.
- FSGIM defines key object types – Meter, Load, Generator, Energy Manager, Weather – and uses them to enable applications such as demand response and peak management.
- FSGIM builds on other standards to maintain consistency and harmony among different standards.
- FSGIM is intended to be used to develop or enhance other standards that define technology and communication protocol specific implementations for certain facility types.

References

- ASHRAE Standard 201-2016: Facility Smart Grid Information Model. American Society of Heating, Refrigerating and Air-Conditioning Engineers.
- ASHRAE Standard 201-2016 User's Manual. American Society of Heating, Refrigerating and Air-Conditioning Engineers.
- Bushby, S.T., 2011. Information model standard for integrating facilities with smart grid. *ASHRAE Journal*, *53*(11), pp.B18-B22.
- Bushby, S.T. and Jones, A., 2016. Facility information model standard. *ASHRAE Journal*, *58*(8), pp.24-31.

Further Reading Assignment

- Lawrence, T.M., Boudreau, M.C., Helsen, L., Henze, G., Mohammadpour, J., Noonan, D., Patteeuw, D., Pless, S. and Watson, R.T., 2016. Ten questions concerning integrating smart buildings into the smart grid. *Building and Environment*, *108*, pp.273-283.
- Narang, D., Schwartz, P., Widergren, S., Gonzalez, S., Alam, S.M.S., Bohn, T., Xue, Y., Brown, R., Page, J., Piette, M.A. and Murthy, S., 2021. *GMLC survey of distributed energy resource interconnection and interoperability standards* (No. NREL/TP-5D00-77497). National Renewable Energy Laboratory, Golden, CO.
- US Department of Energy. 2021. A national roadmap for grid-interactive efficient buildings. https://gebroadmap.lbl.gov/A%20National%20Roadmap%20for%20GEBs%20-%20Final.pdf

Acknowledgement

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