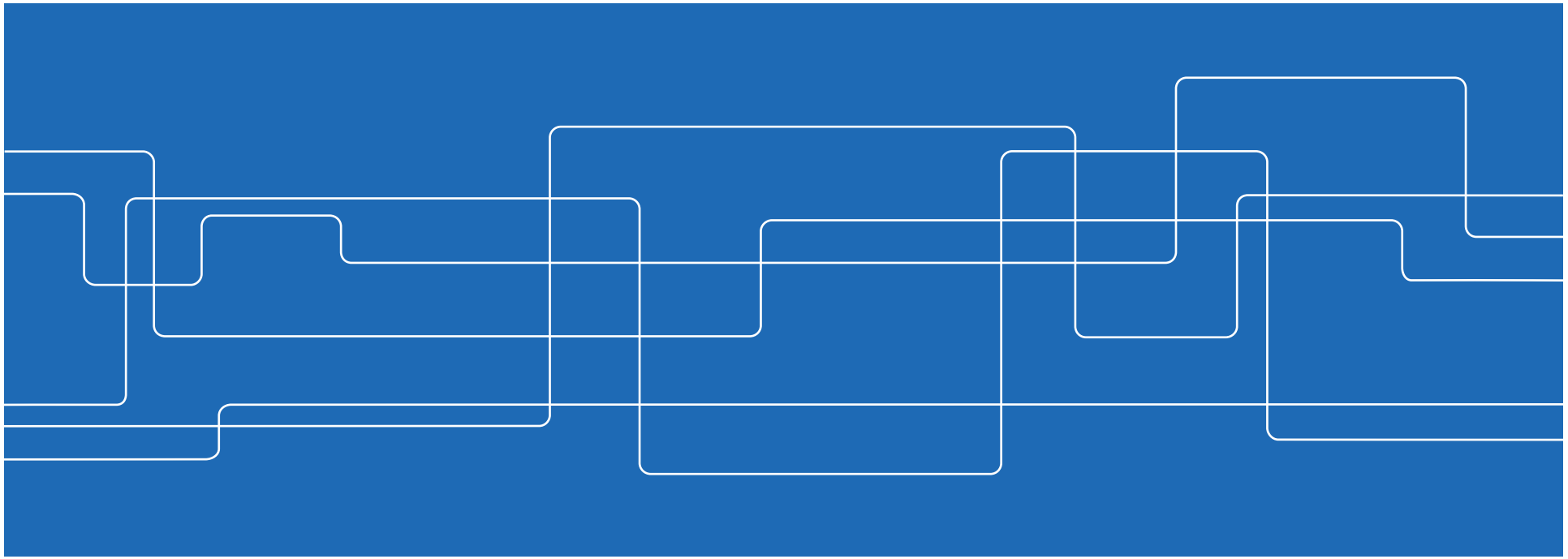
KTH ROYAL INSTITUTE
OF TECHNOLOGY

Lecture #9
Power System Information Modeling



Contents

XML Review

Information Modeling in Power Industry

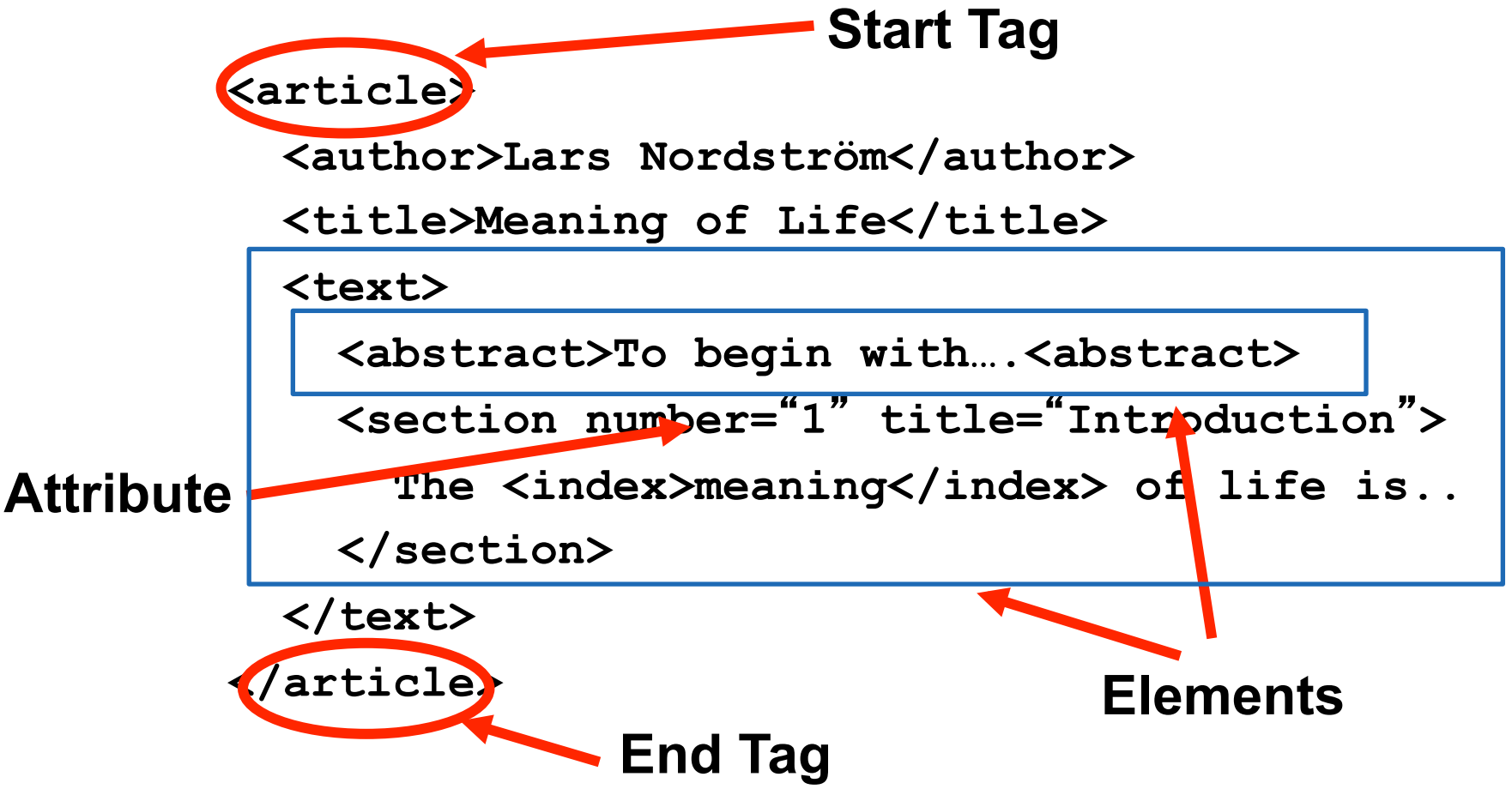
- Information Exchange Need

RDF – Resource Description Framework

Information modeling

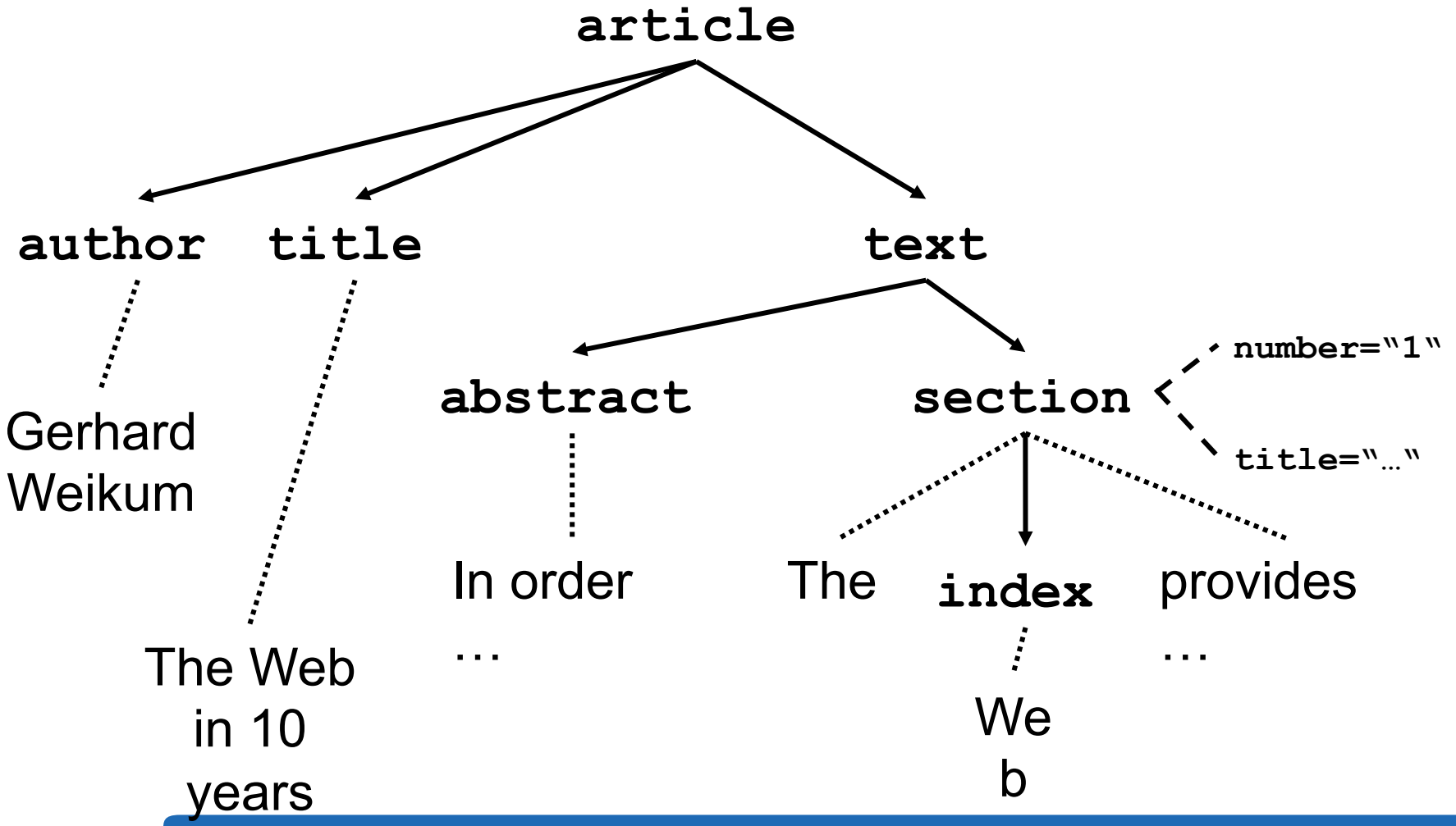
CIM based Modeling of Power Systems

A Simple XML Document



Source: XML for Beginners, Ralf Schenkel April 2003.

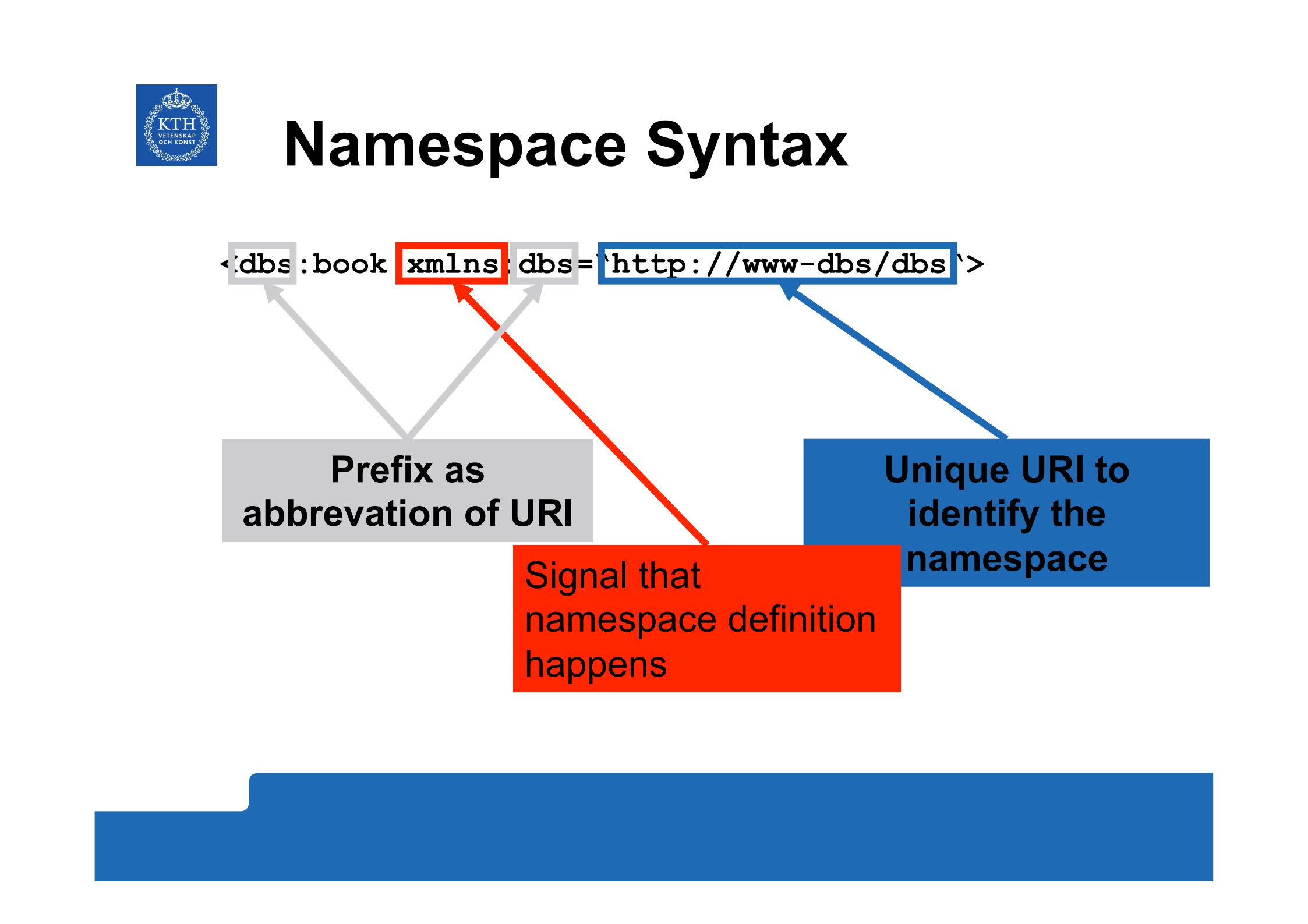
XML Documents as Ordered Trees



Namespaces

```
<library>
  <description>Library of the CS
    Department</description>
  <book bid="HandMS2000">
    <title>Principles of Data Mining</title>
    <description>
      Short introduction to <em>data
    mining</em>, useful
      for the IRDM course
```

Semantics of the `description` element is ambigous
Content may be defined differently
Renaming may be impossible (standards!)


Namespace Syntax
<dbs:book xmlns:dbs="http://www-dbs/dbs">
Prefix as abbrevation of URI
Signal that namespace definition happens
Unique URI to identify the namespace

Namespace Example

```
<dbs:book xmlns:dbs="http://www-dbs/dbs">
  <dbs:description> ... </dbs:description>
  <dbs:text>
    <dbs:formula>
      <mathml:math xmlns:mathml="http://
www.w3.org/1998/Math/MathML">
        ...
      </mathml:math>
    </dbs:formula>
  </dbs:text>
</dbs:book>
```

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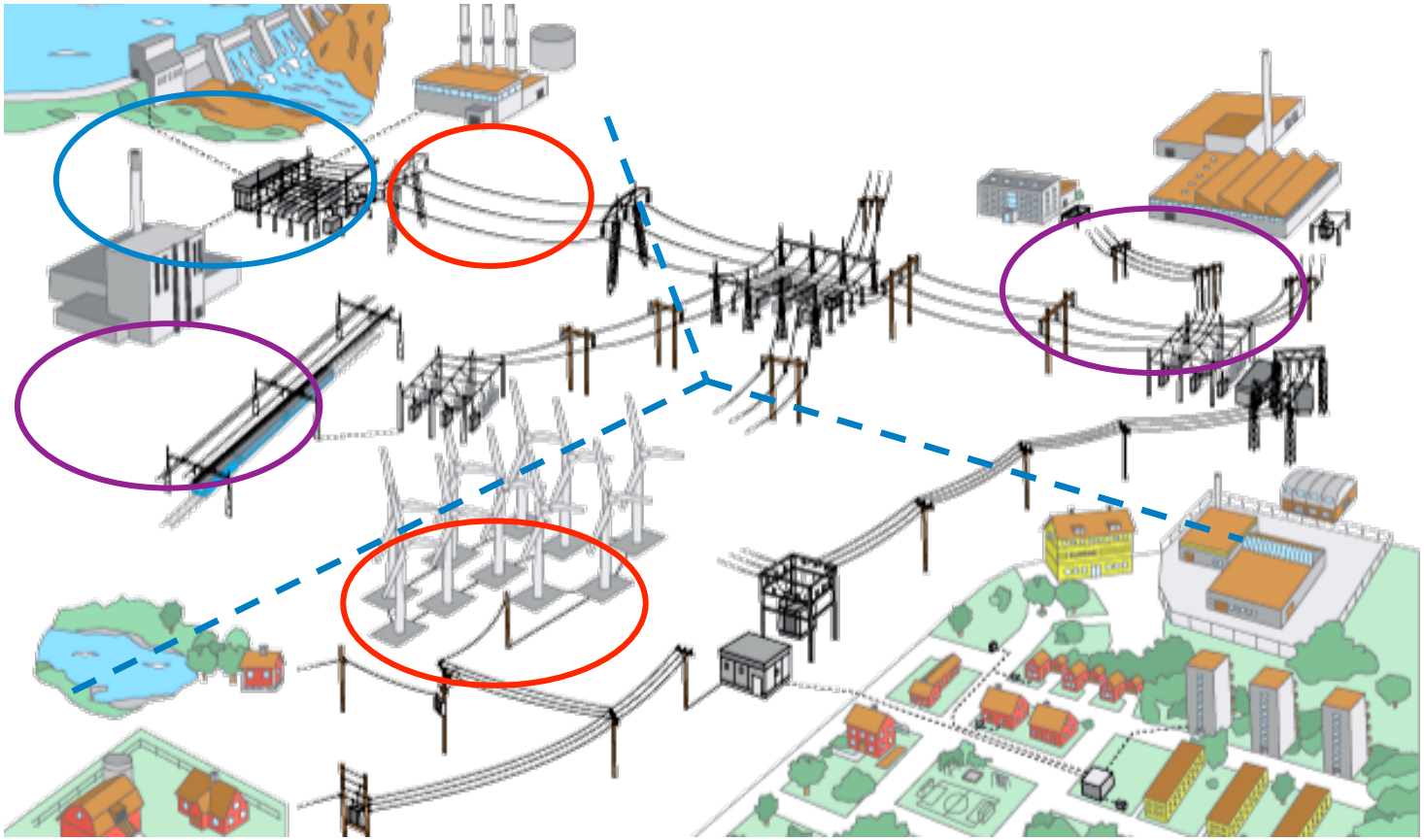
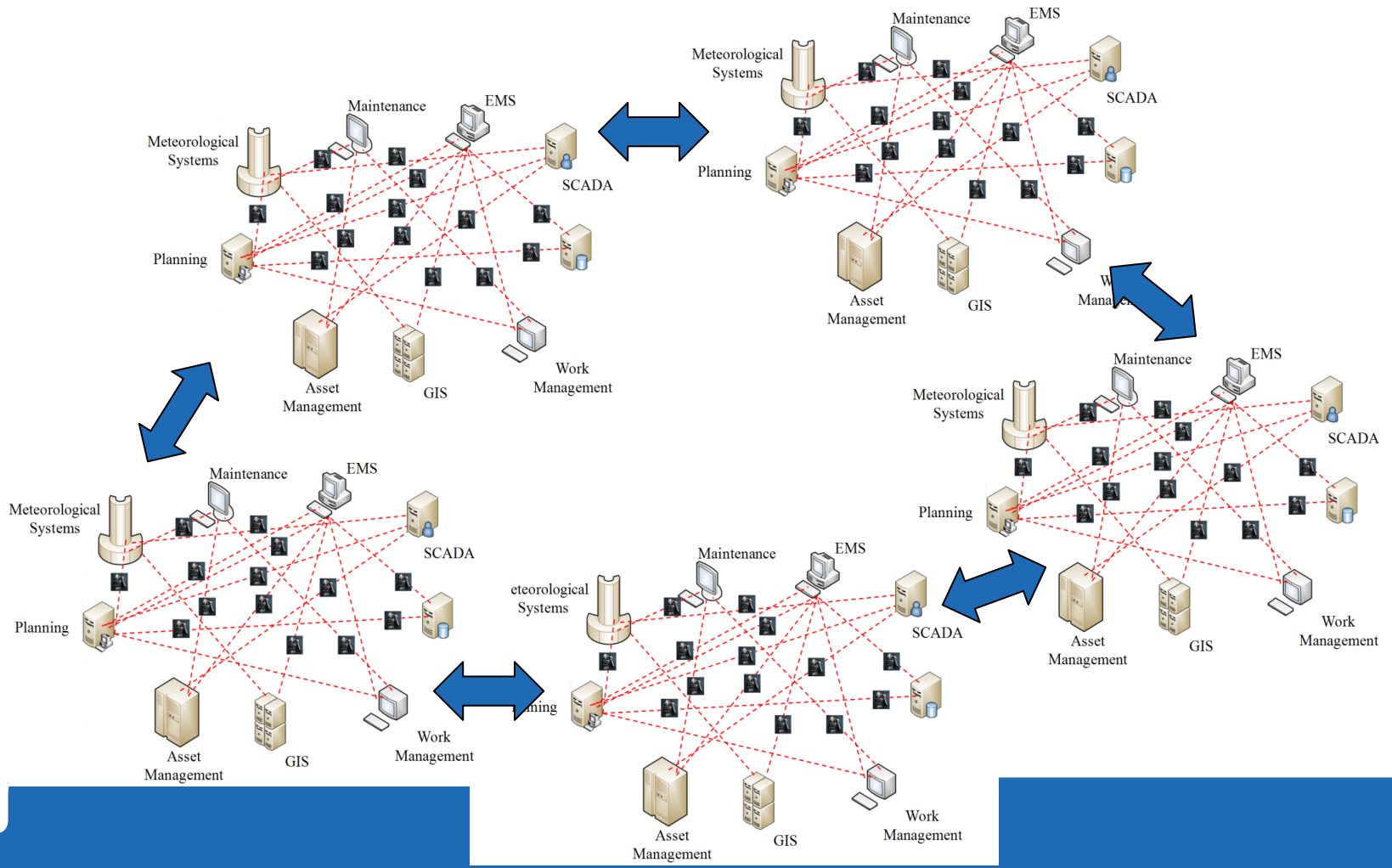
Deregulated Power Industry



Cross-utilities Information Exchange for planning and operation



Data Exchange needs

Exchanging measurements for enabling observability of neighbouring grids

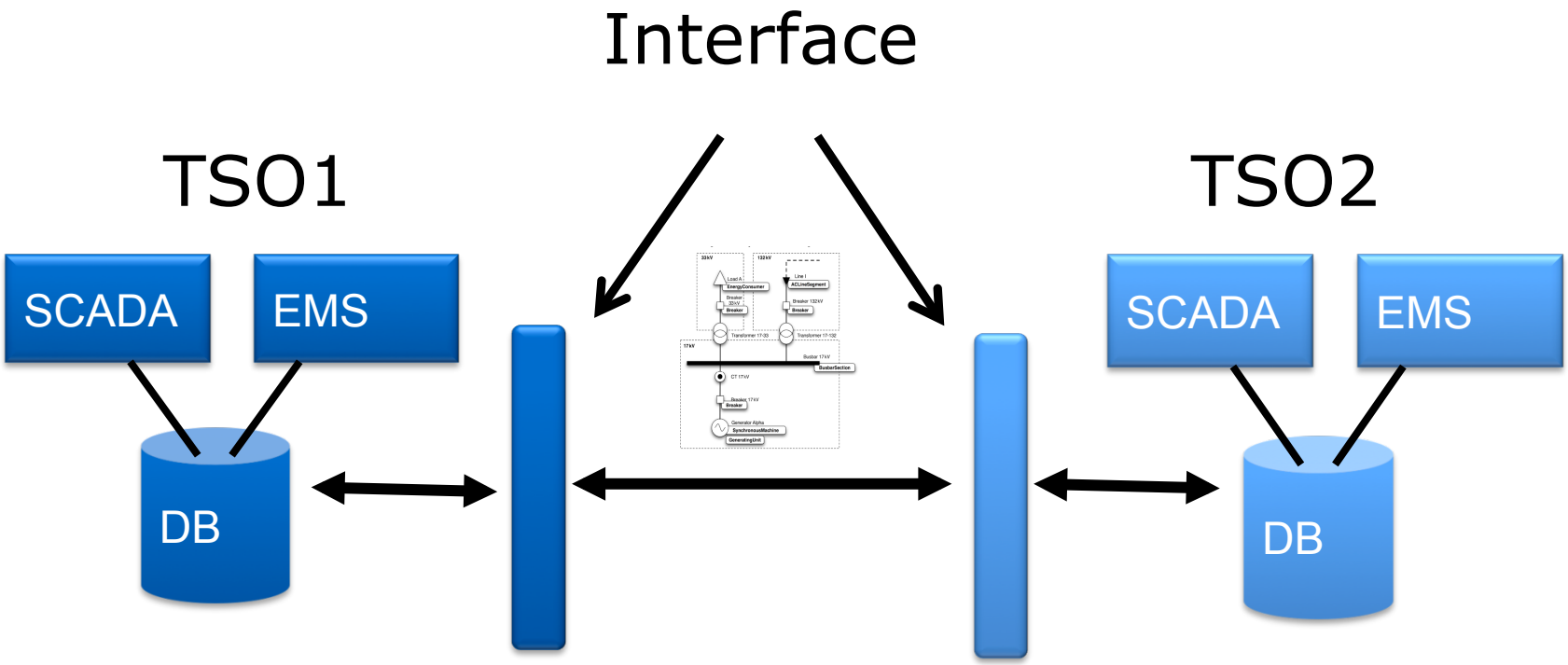
Congestion forecasting, depedning on planned production, will there be congestion?

Market settlement – how much was transfered through a line or grid section.

Exchanging information about planned interruptions.

….

Data exchange architecture



Power system model transfer between TSOs

Serialisation of the Data model

To transfer information between two systems, the data needs to be converted into some type of file/stream.

XML (just as is used in 61850) is a suitable type of file

XML file structure recap

<tag>…contained data…</tag>

But is XML expressive enough?

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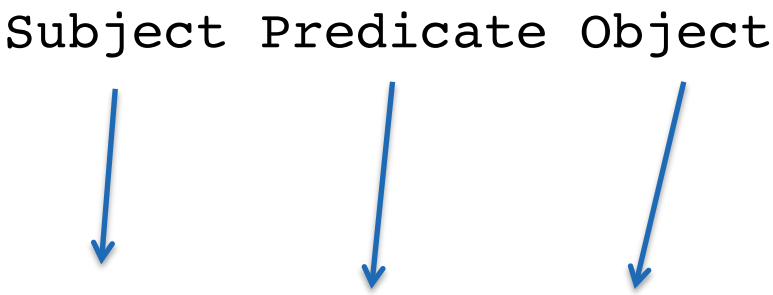
RDF

RDF is ”language” to describe relation between things.

It is based on the format:

For example



RDF continued

Consider the following Example:

Library data encoded in XML

```
<library name="Glasgow Library">
  <book title="History of Glasgow, 1900-1950" author="Walter Hannah">
    <position section="A" shelf="2"/>
  </book>
  <book title="A Brief History of Time" author="Stephen Hawking">
    <position section="E" shelf="4"/>
  </book>
  <book title="History of Glasgow, 1950-2000" author="Walter Hannah">
    <position section="A" shelf="2"/>
  </book>
</library>
```

How to specify that Hannah's books are related?

RDF continued

By allowing relation between XML nodes (elements) relations can be described

A key requirements is of course that nodes (elements) are uniqly identifiable – this can be achieved by Name spaces and URIs

URIs are pointers to unique identifers of tags. In a way the URI is the uniquness, it may point to nothing.

RDF continued

```
<rdf:RDF xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#"
xmlns:lib="http://www.strath.ac.uk/libraries/2006/library-schema#">
<lib:library lib:name="Glasgow Library">
  <lib:book lib:title="History of Glasgow, 1900-1950" lib:author="Walter
Hannah" rdf:ID="_entry0001">
    <lib:position lib:section="A" lib:shelf="2"/>
    <lib:sequel rdf:resource="#_entry0003"/>
  </lib:book>
  <lib:book lib:title="A Brief History of Time" lib:author="Stephen Hawking"
rdf:ID="_entry0002">
  <lib:position lib:section="E" lib:shelf="4"/>
</book>
  <lib:book lib:title="History of Glasgow, 1950-2000" lib:author="Walter
Hannah" rdf:ID="_entry0003">
    <lib:position lib:section="A" lib:shelf="2"/>
    <lib:sequelTo rdf:resource="#_entry0001"/>
  </lib:book>
</lib:library>
</rdf:RDF>
```

RDF Schema – defining the RDF format

- Again, we need to define what we can write in the RDF file about books.
- Just like with XML Schema, we defined what we can write in an XML document.
- Enter the RDF Schema
  - This is essentially Object oriented modeling using text/ XML

RDF Schema for our library system

```
<rdfs:Class rdf:ID="book>
   <rdfs:label xml:lang="en">Book</rdfs:label>
   <rdfs:comment>A book contained within a library</rdfs:comment>
</rdfs:Class>

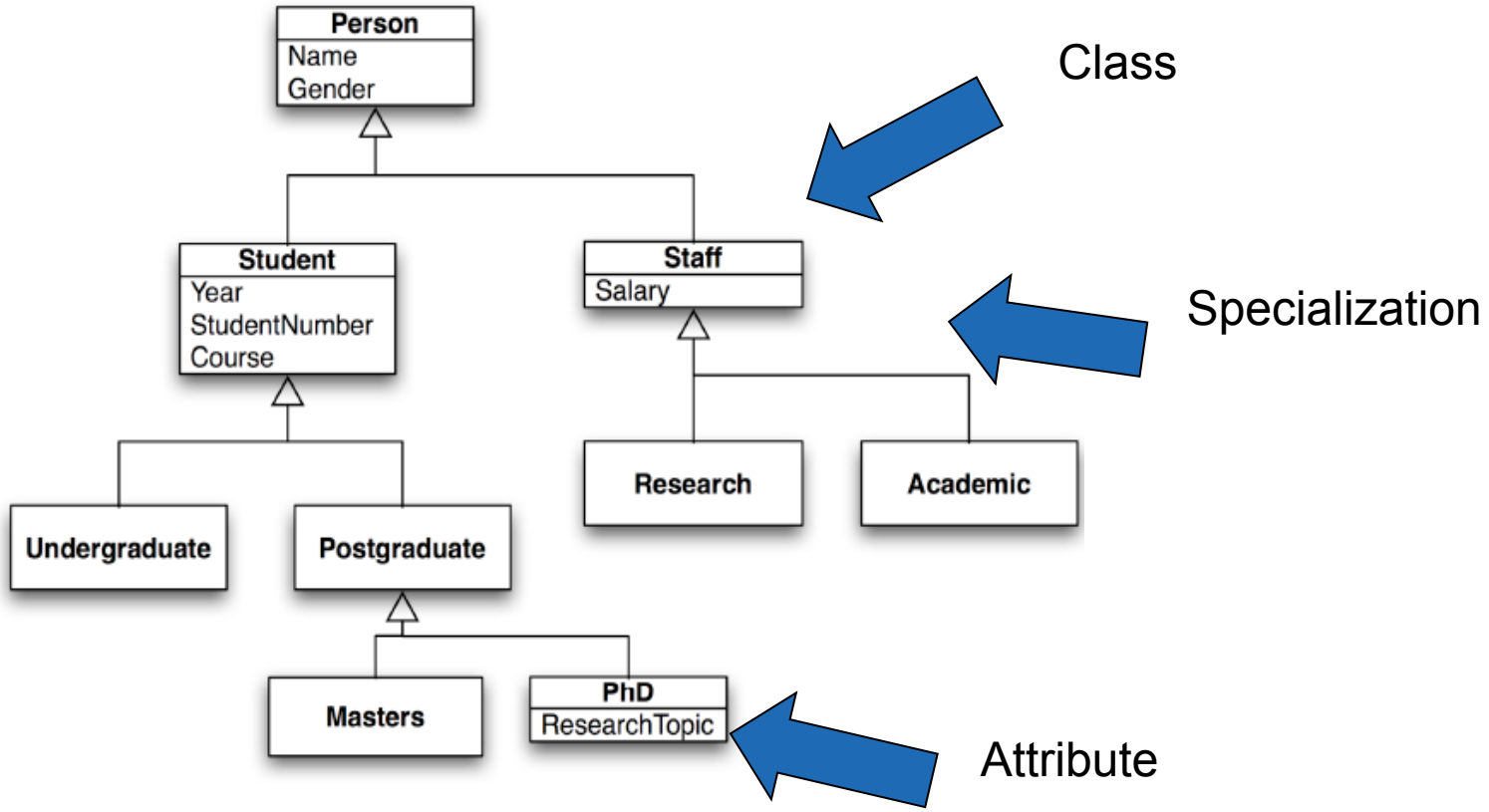
<rdf:Property rdf:ID="sequel">
   <rdfs:label xml:lang="en">Sequel</rdfs:label>
   <rdfs:comment>Indicates that the book has a sequel that is also within the
library</rdfs:comment>
   <rdfs:domain rdf:resource="#book"/>
   <rdfs:range rdf:resource="#book"/>
</rdf:Property>

<rdf:Property rdf:ID="sequelTo">
   <rdfs:label xml:lang="en">SequelTo</rdfs:label>
   <rdfs:comment>Indicates that the book is the sequel to another book also
within the library</rdfs:comment>
   <rdfs:domain rdf:resource="#book"/>
   <rdfs:range rdf:resource="#book"/>
</rdf:Property>
```

But where does the RDF Schema file come from?

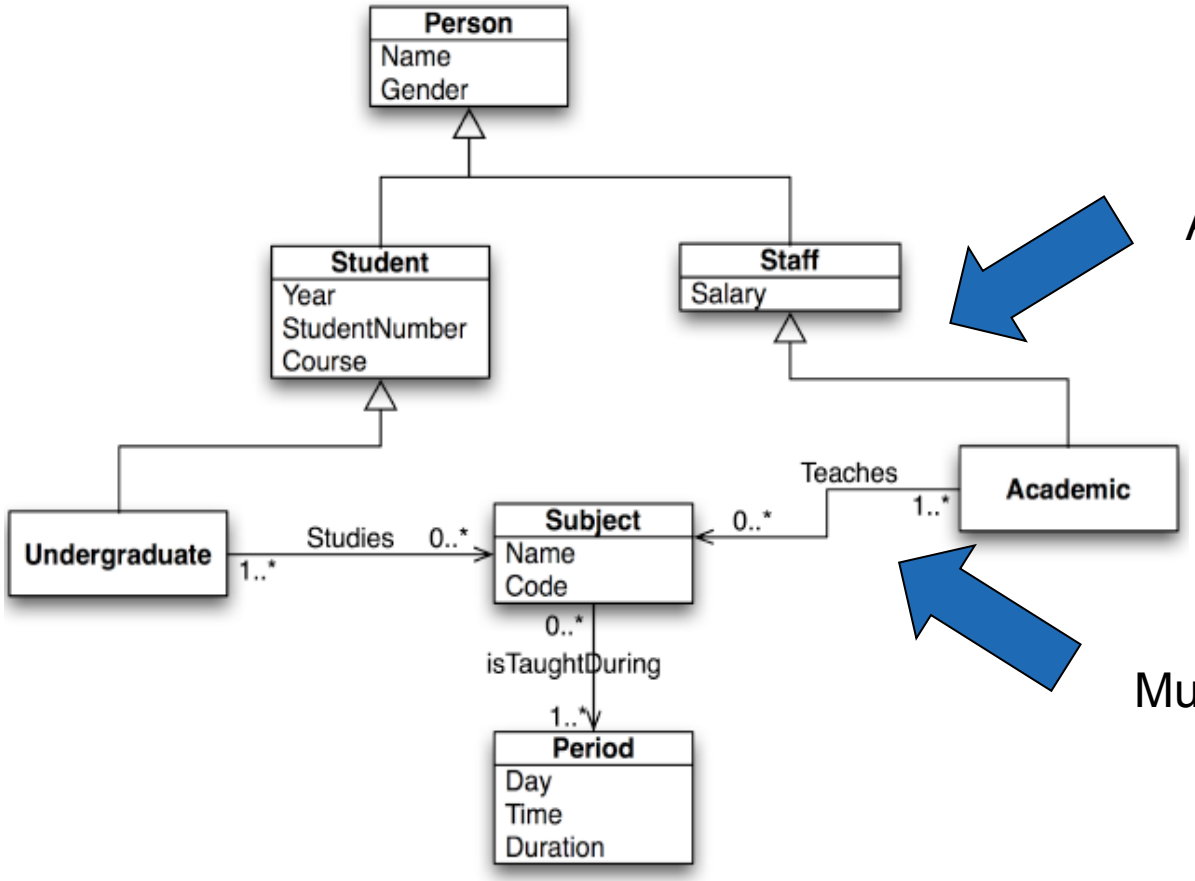
From an Information model!

Fundamentals for UML
- Class Diagram



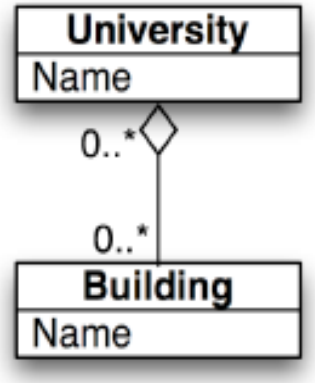
Class Hierarchy of people at a University

Object Associations

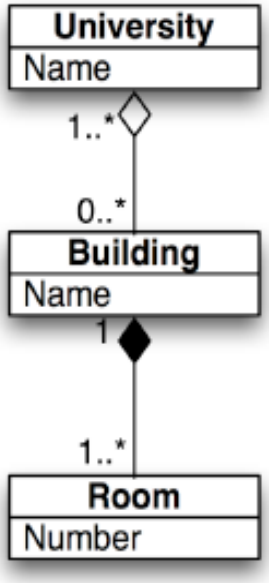


Class hierarchy of students, staff and subjects

Aggregation and Composition (Association)

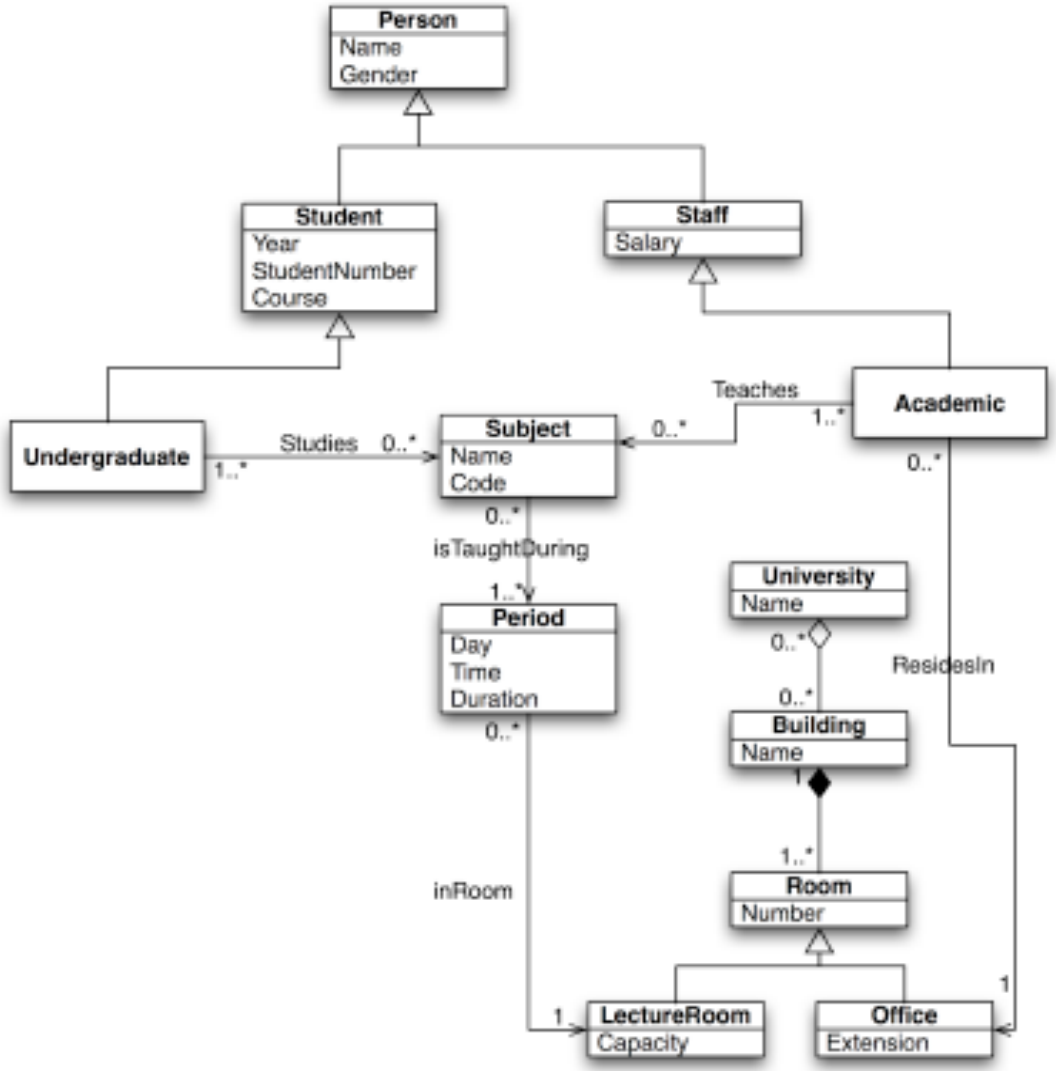


Aggregation



Composition

Classes, Associations, Aggregations and Compositions



What is the CIM?

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

A tool to enable integration and information exchange to enable data access in a standard way

A common language to navigate and access complex data structures in any database

It is not tied to a particular vendor's view of the world

It also provides consistent view of the world by operators regardless of which application user interface they are using

Courtesy of T.Saxton TC57 WG13 chairman

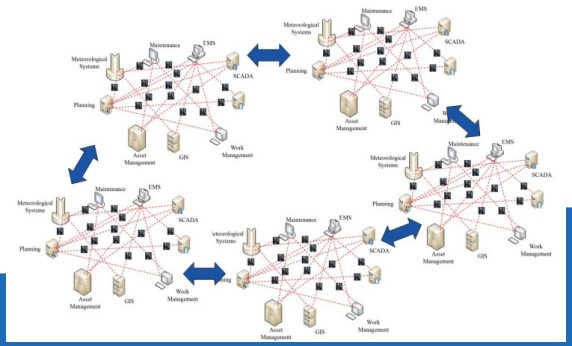
IEC 61970-301

Semantic model that describes the components of a power system and the relationships between each component

Exchange of data between transmission system operators

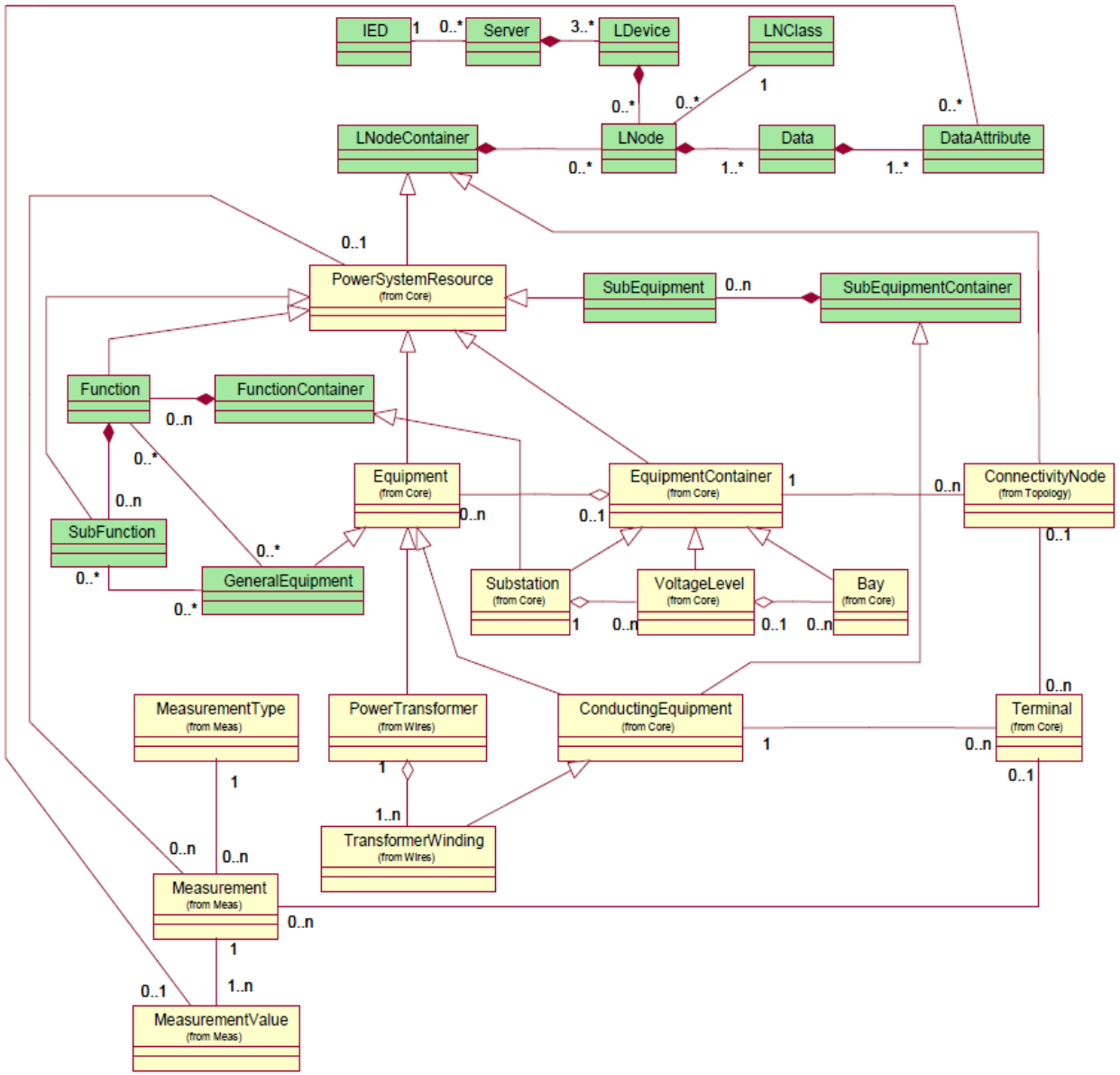
Enabling power flow calculation/state estimation on neighbouring transmission systems

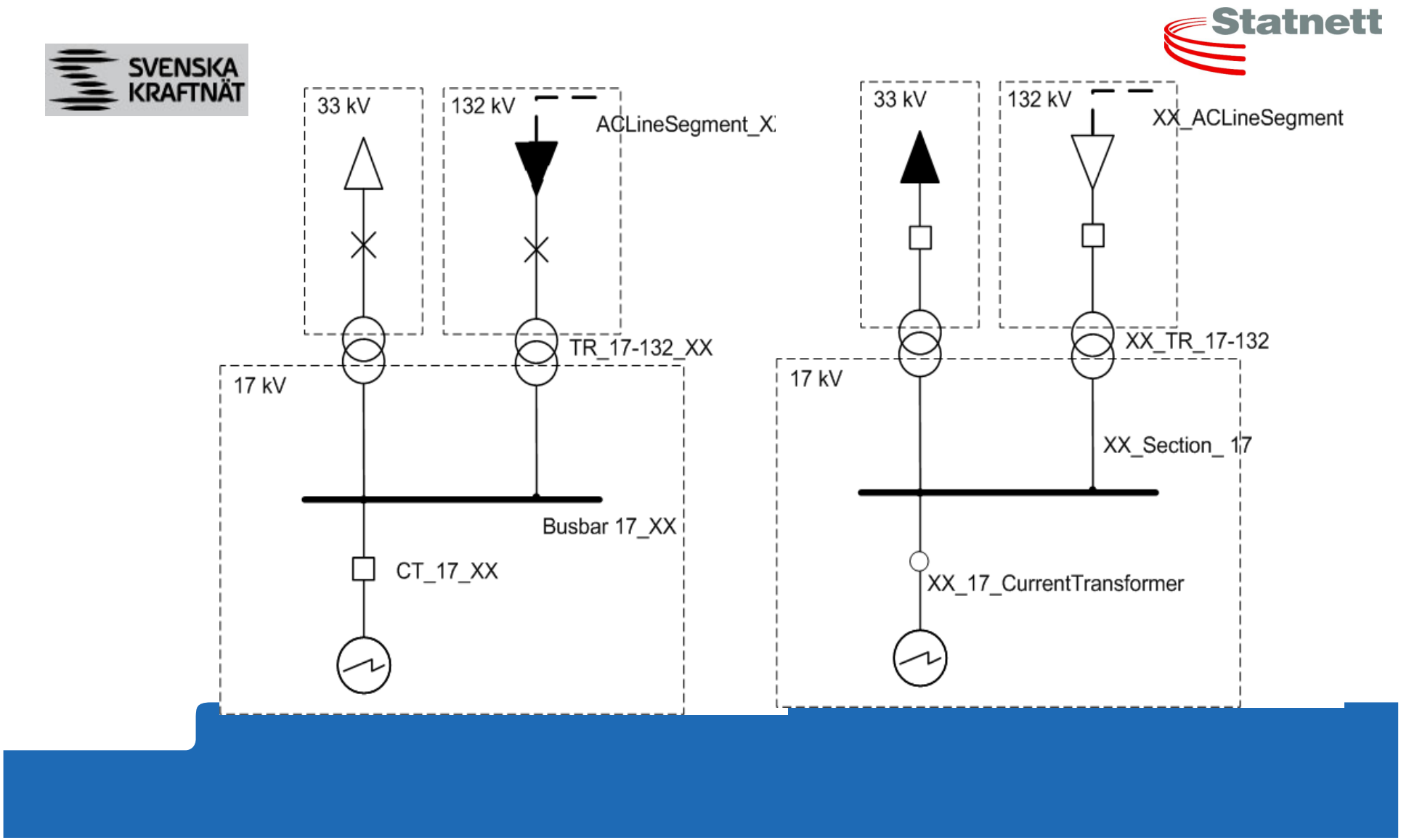
No



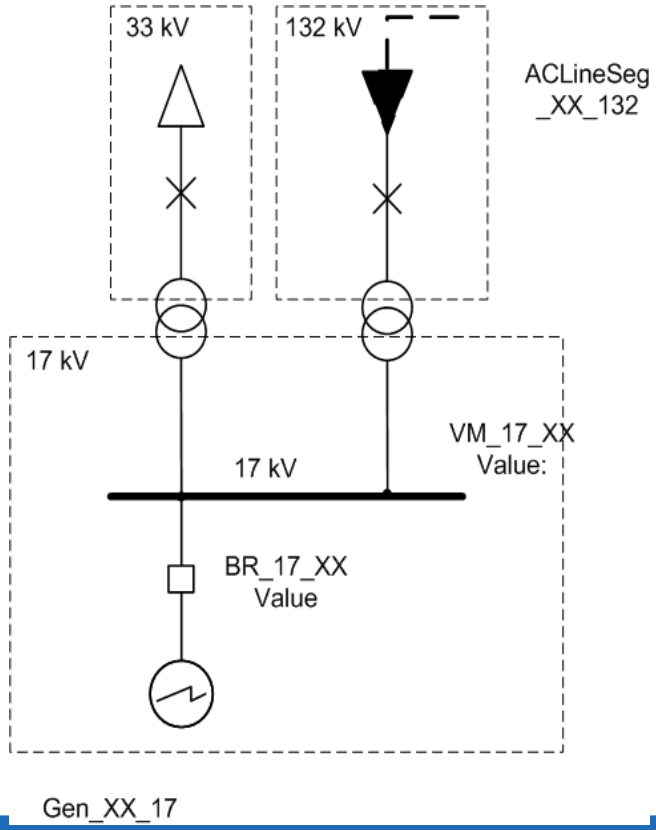
Not yet for dynamic calculations

stems

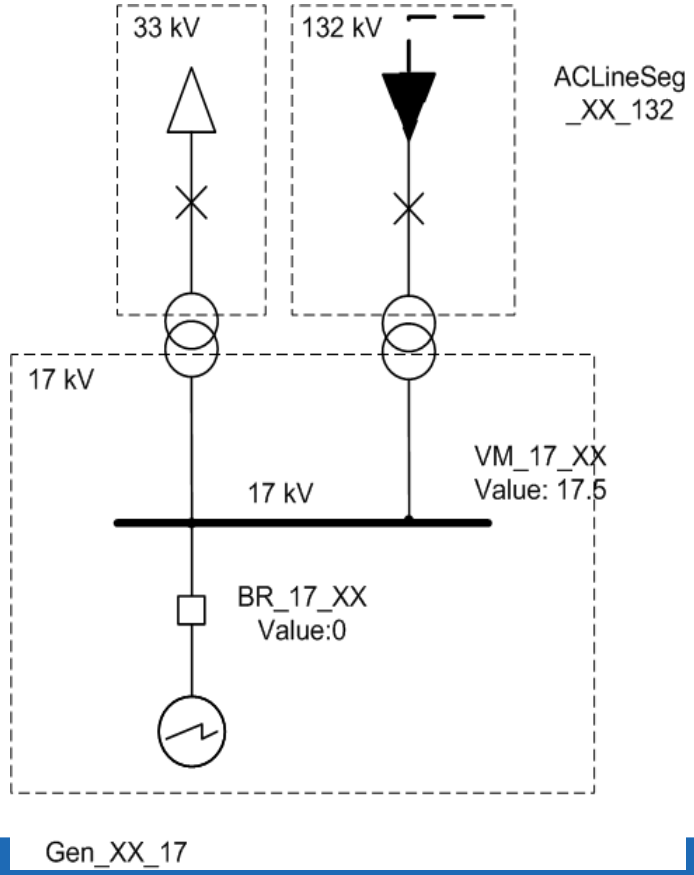

IED
Server
LDevice
LNClass
LNodeContainer
LNode
Data
DataAttribute
PowerSystemResource
(from Core)
SubEquipment
SubEquipmentContainer
Function
FunctionContainer
SubFunction
GeneralEquipment
Equipment
(from Core)
EquipmentContainer
(from Core)
ConnectivityNode
(from Topology)
Substation
(from Core)
VoltageLevel
(from Core)
Bay
(from Core)
MeasurementType
(from Meas)
PowerTransformer
(from Wires)
ConductingEquipment
(from Core)
Terminal
(from Core)
TransformerWinding
(from Wires)
Measurement
(from Meas)
MeasurementValue
(from Meas)


33 kV
132 kV
ACLineSegment_X
TR_17-132_XX
17 kV
Busbar 17_XX
CT_17_XX
33 kV
132 kV
XX_ACLineSegment
XX_TR_17-132
17 kV
XX_Section_ 17
XX_17_CurrentTransformer

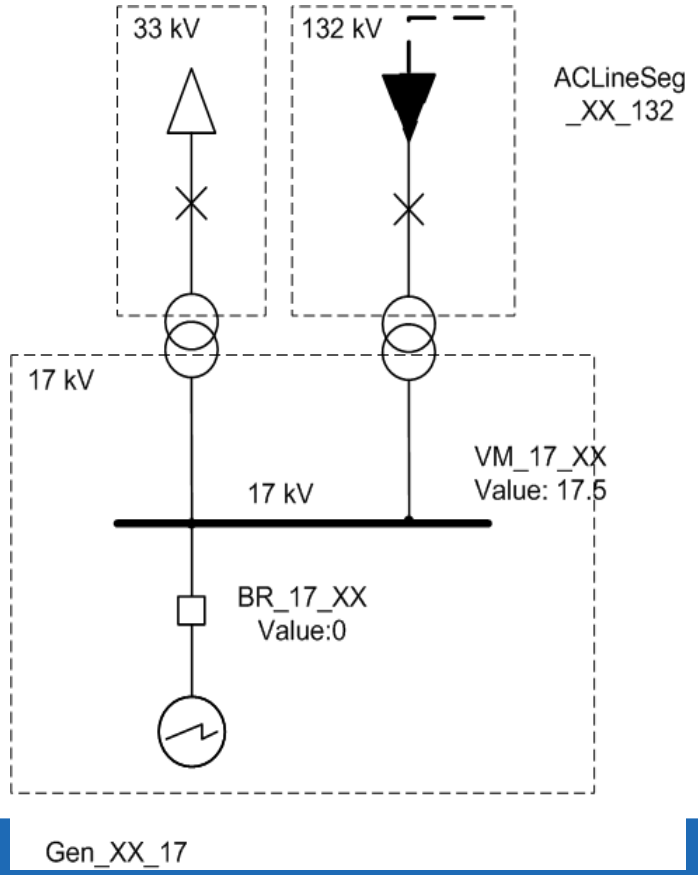
Step 1: (Static Model)



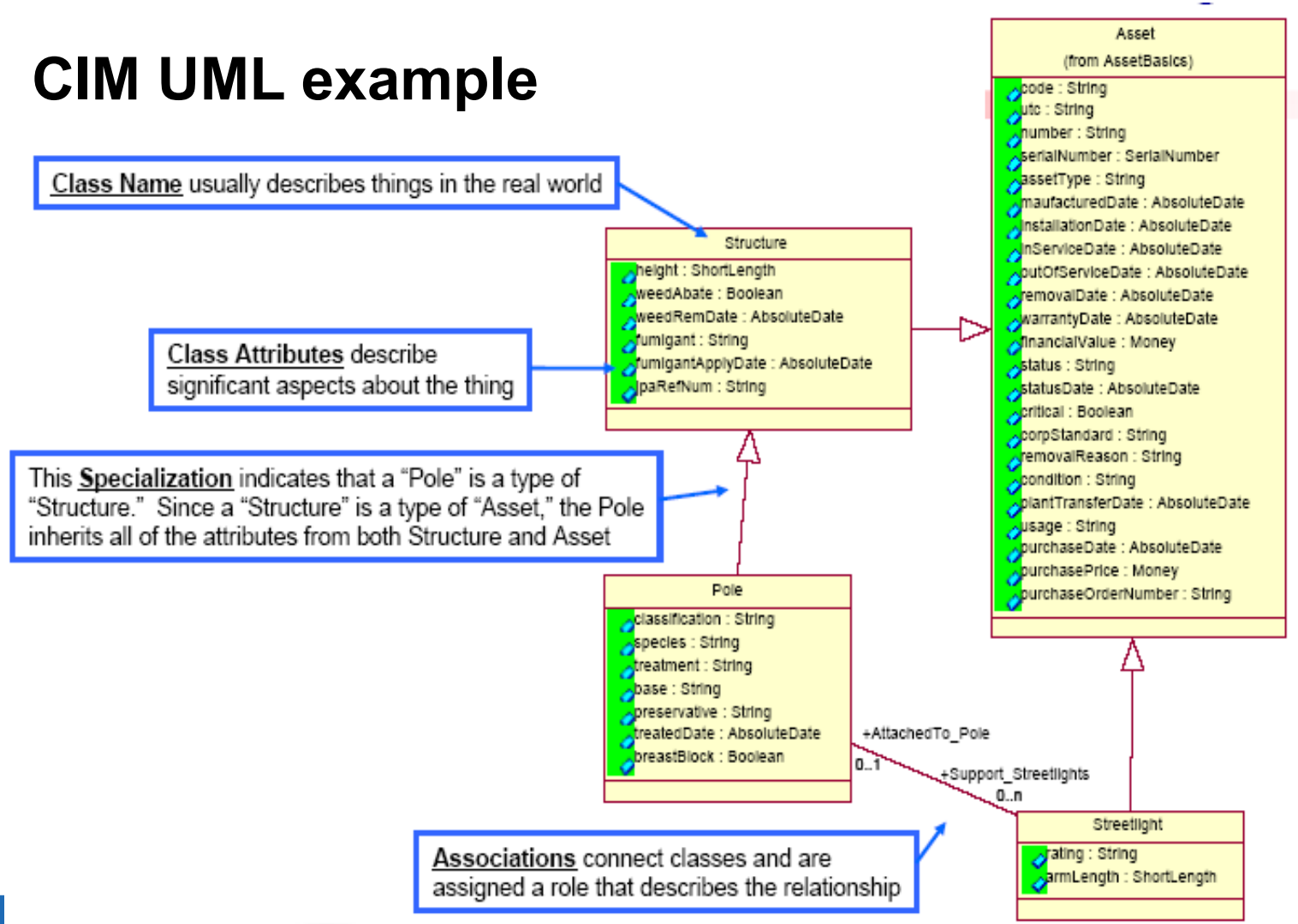
Step 2: Schedules (fixed values)



Step 3 : Real-time information

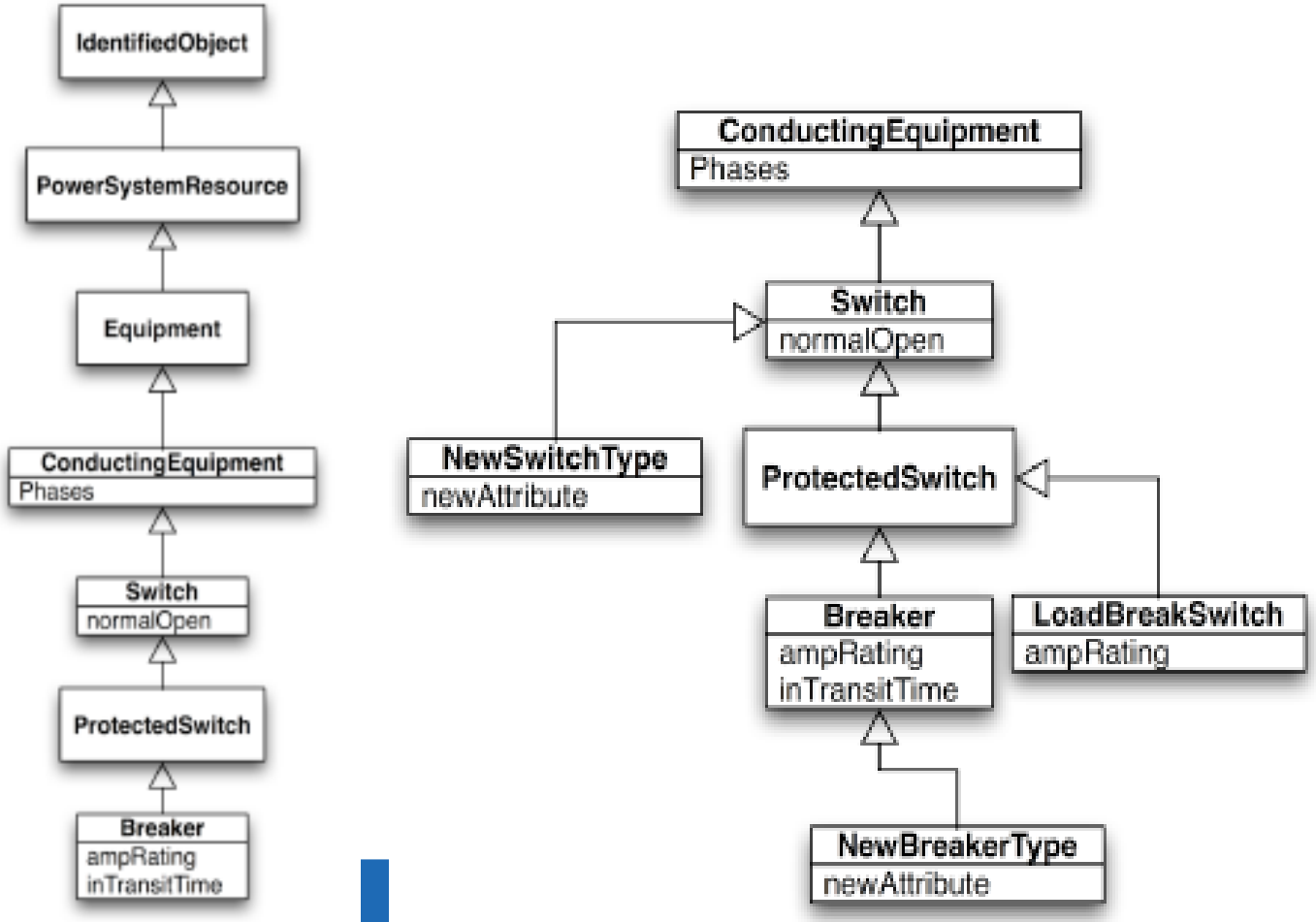


CIM UML example

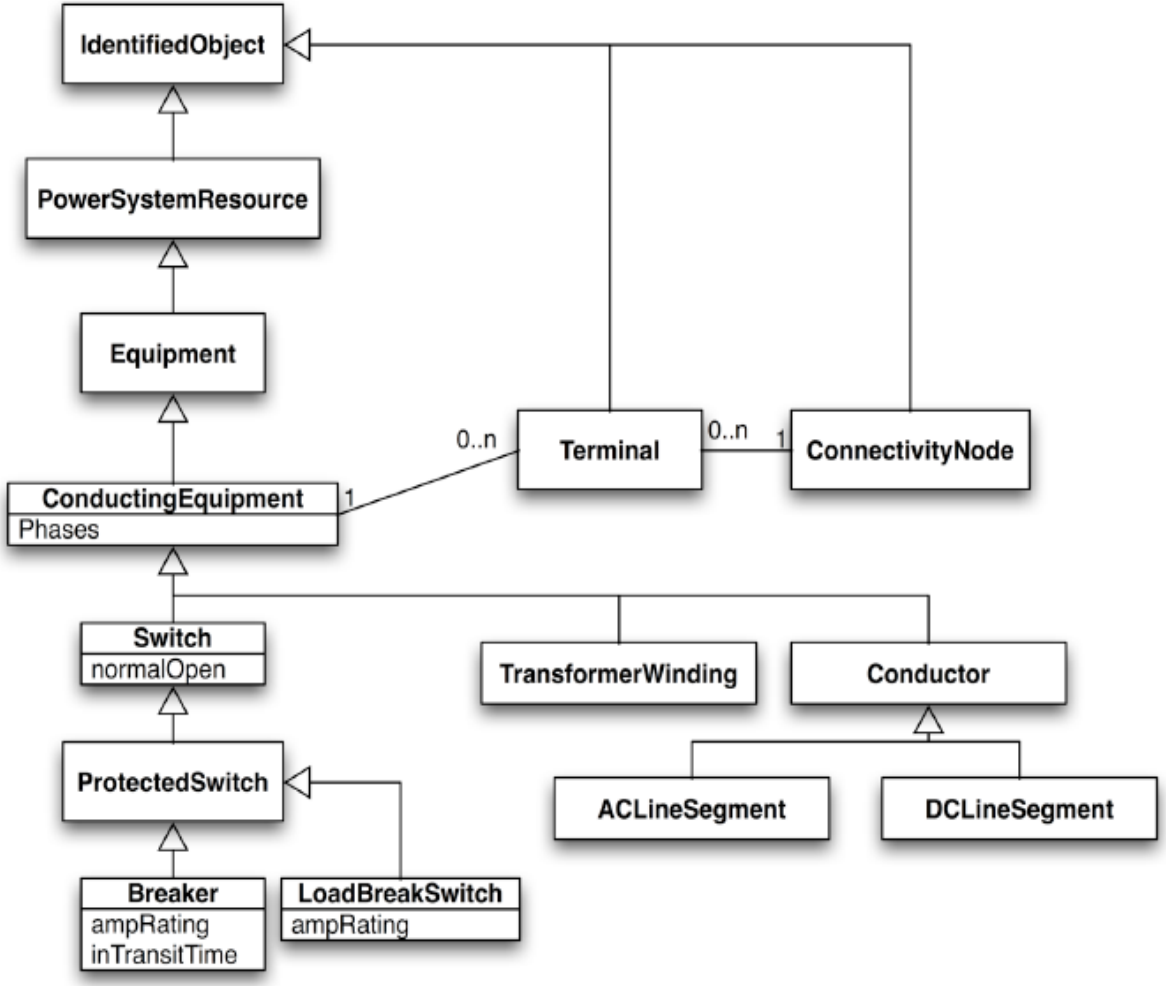


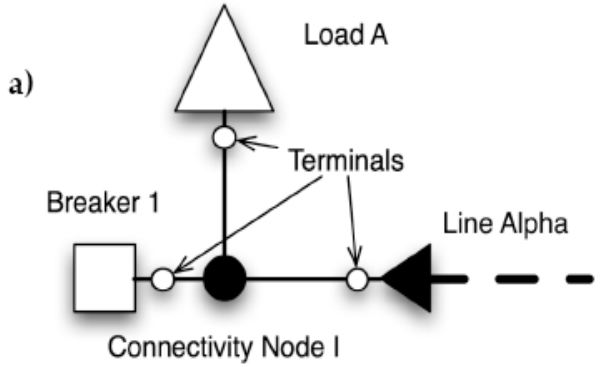
Courtesy of T.Saxton TC57 WG13 chairman

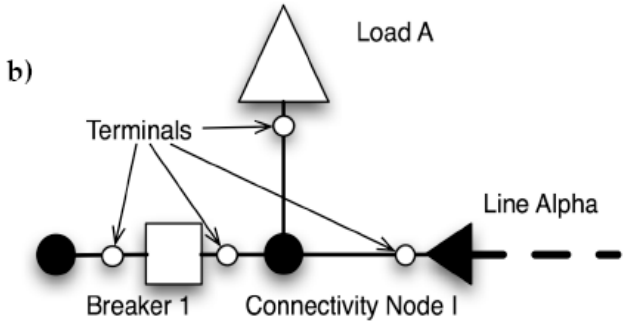
Example Hierarchy in the Breaker Class



Conducting Equipment and Connectivity

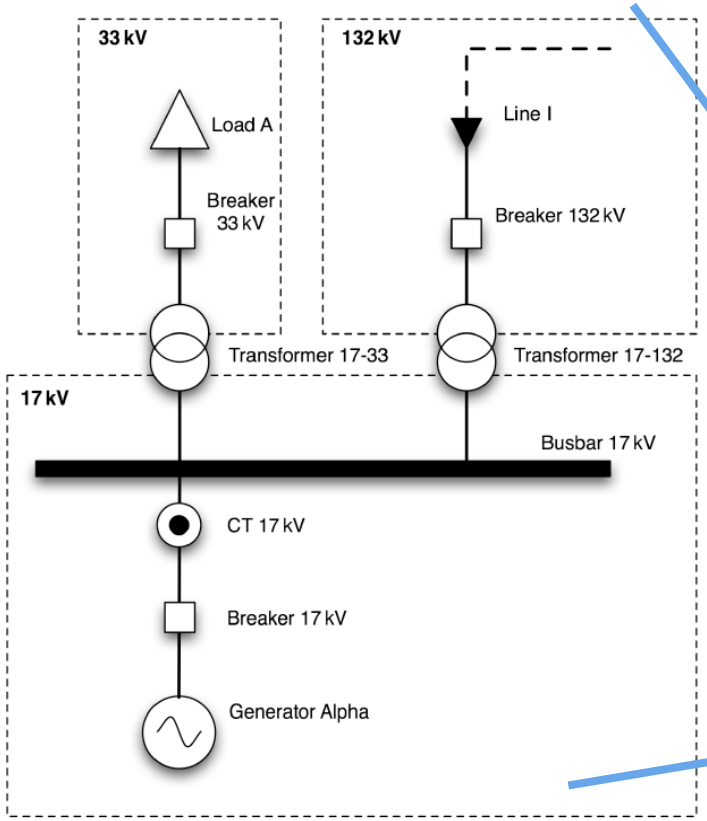


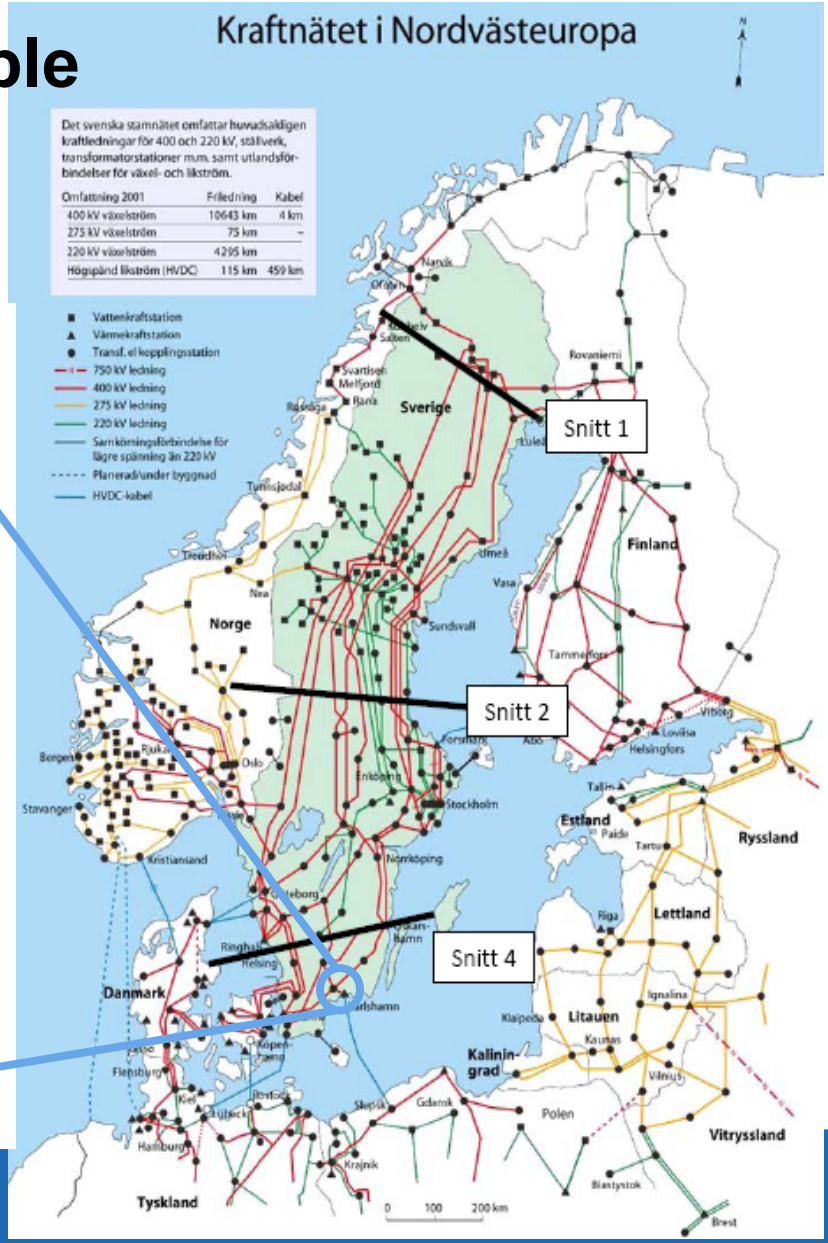




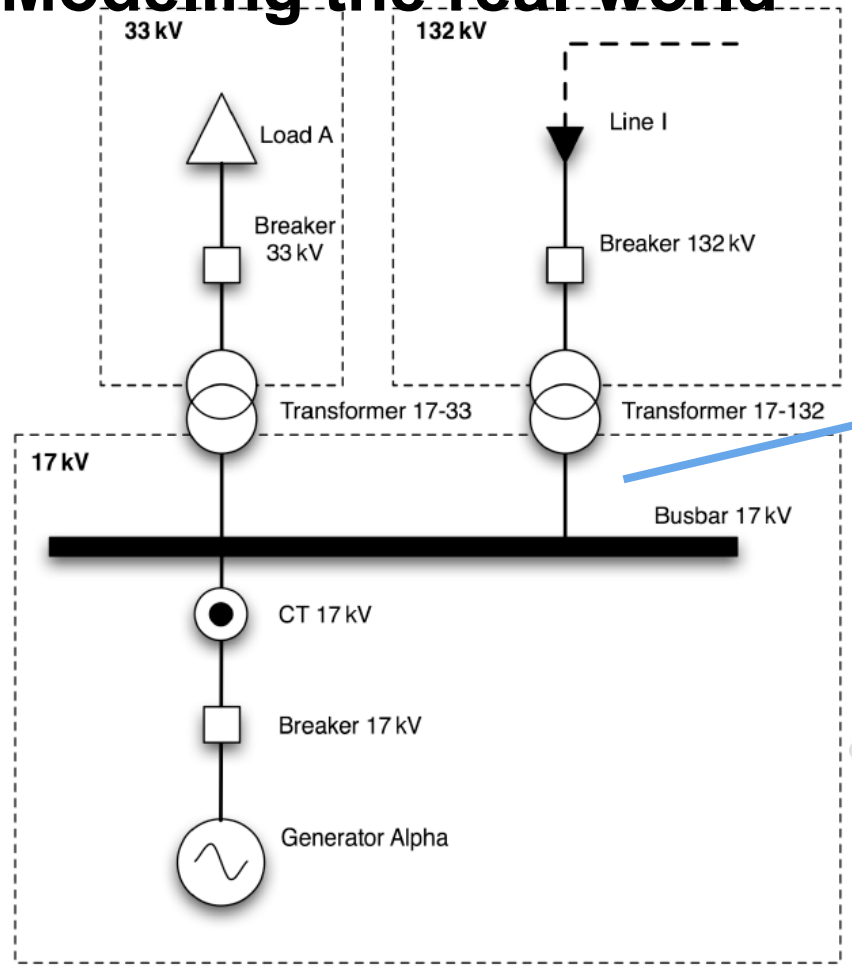
Conducting Equipment and Connectivity class diagram

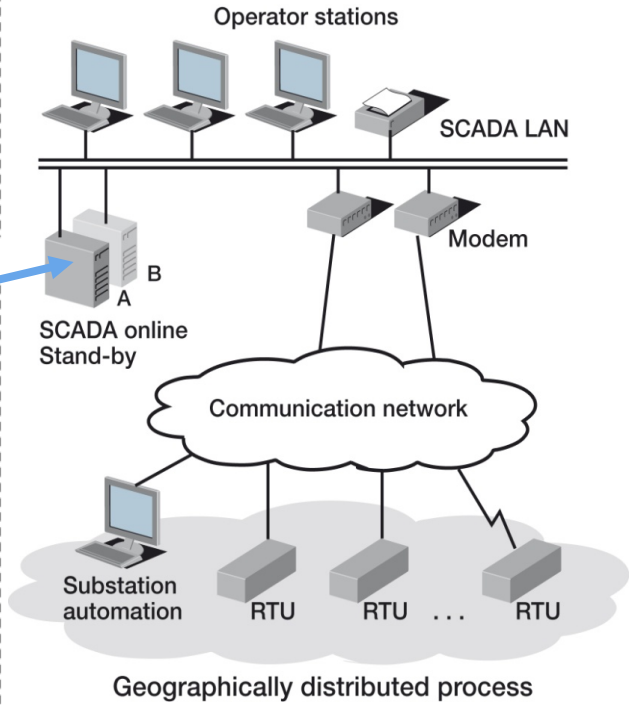
CIM Modeling example



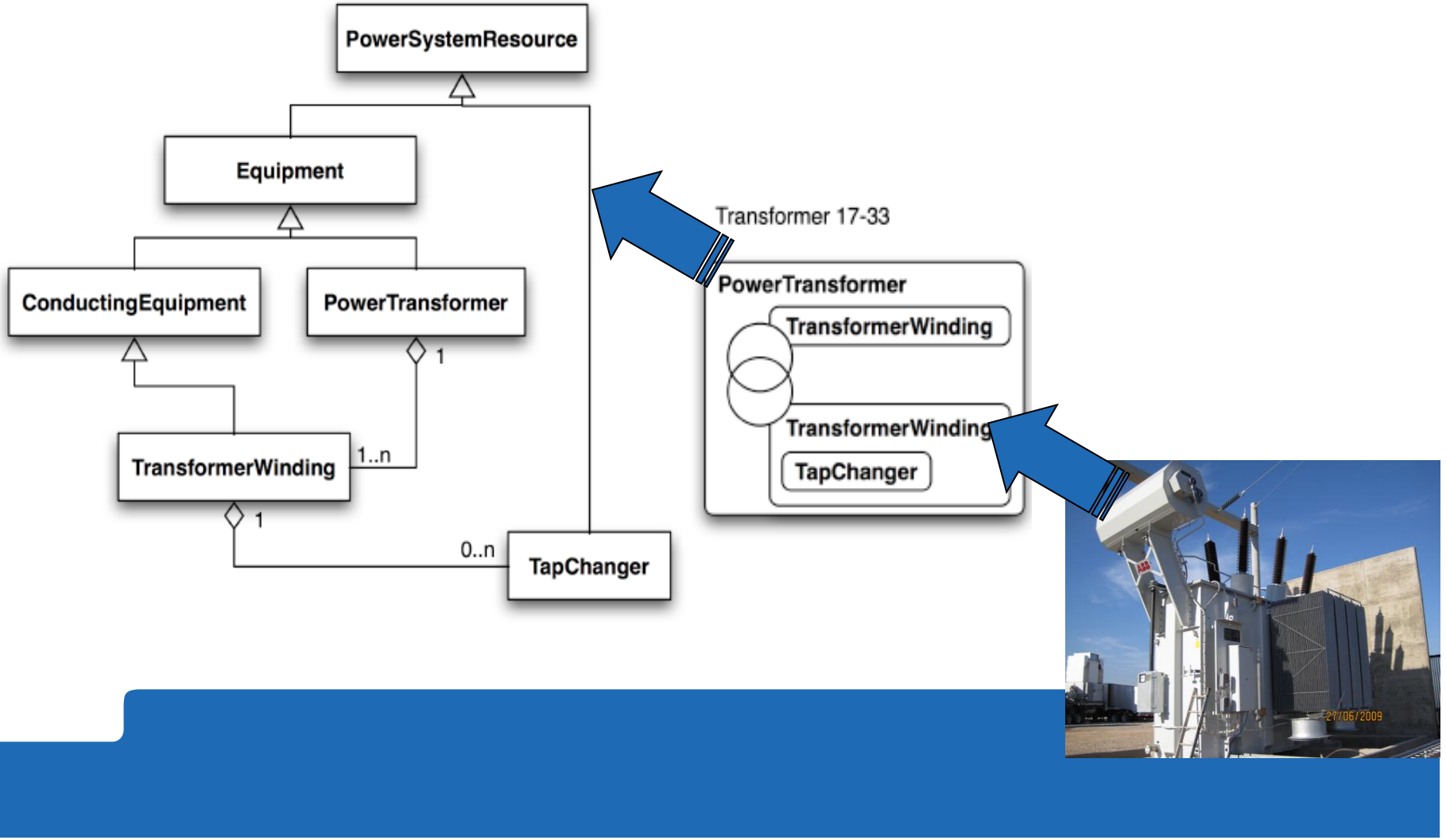


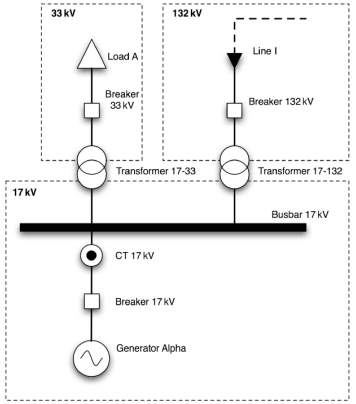
Modeling the real-world

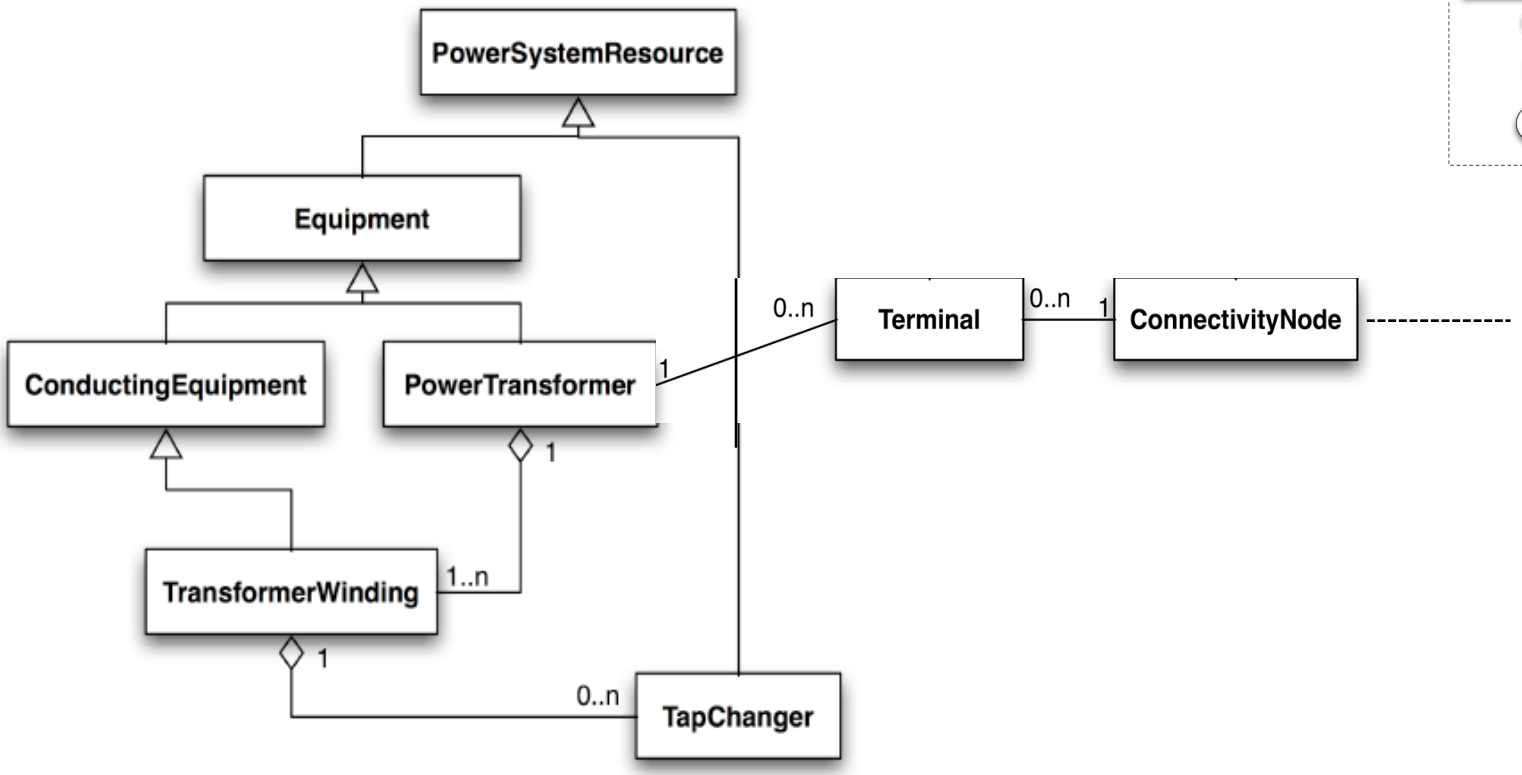


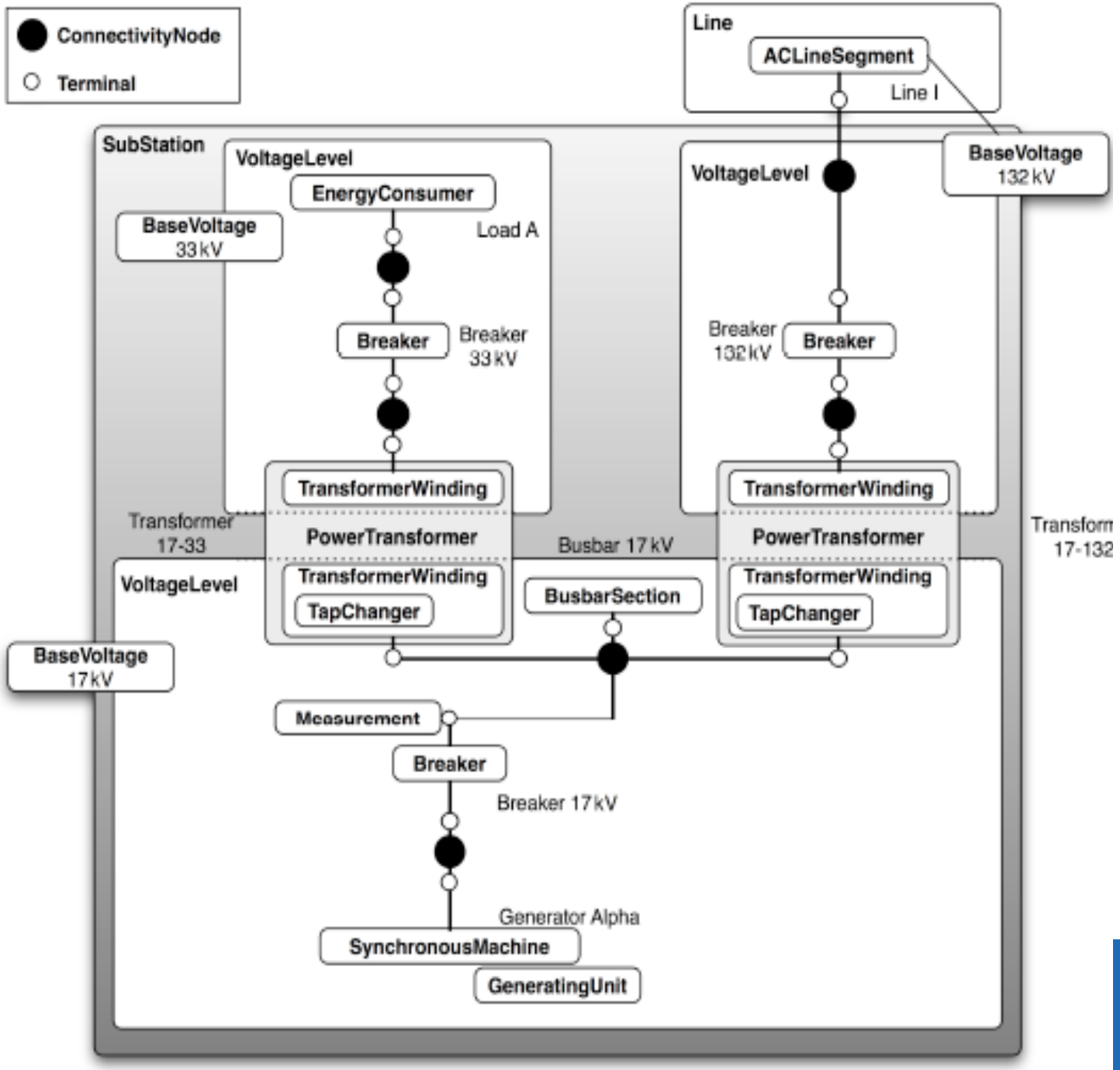


Representing transformers




33 kV
132 kV
Load A
Line I
Breaker 33 kV
Breaker 132 kV
Transformer 17-33
Transformer 17-132
17 kV
Busbar 17 kV
CT 17 kV
Breaker 17 kV
Generator Alpha


PowerSystemResource
Equipment
ConductingEquipment
PowerTransformer
TransformerWinding
TapChanger
Terminal
ConnectivityNode
0..n
1
1..n
0..n
1
0..n
1


ConnectivityNode
Terminal
Line
ACLineSegment
Line I
SubStation
VoltageLevel
EnergyConsumer
Load A
BaseVoltage
33 kV
Breaker
Breaker
33 kV
VoltageLevel
BaseVoltage
132 kV
Breaker
132 kV
Breaker
TransformerWinding
PowerTransformer
TransformerWinding
TapChanger
Transformer
17-33
Busbar 17 kV
TransformerWinding
PowerTransformer
TransformerWinding
TapChanger
Transform
17-132
VoltageLevel
BusbarSection
BaseVoltage
17 kV
Measurement
Breaker
Breaker 17 kV
Generator Alpha
SynchronousMachine
GeneratingUnit

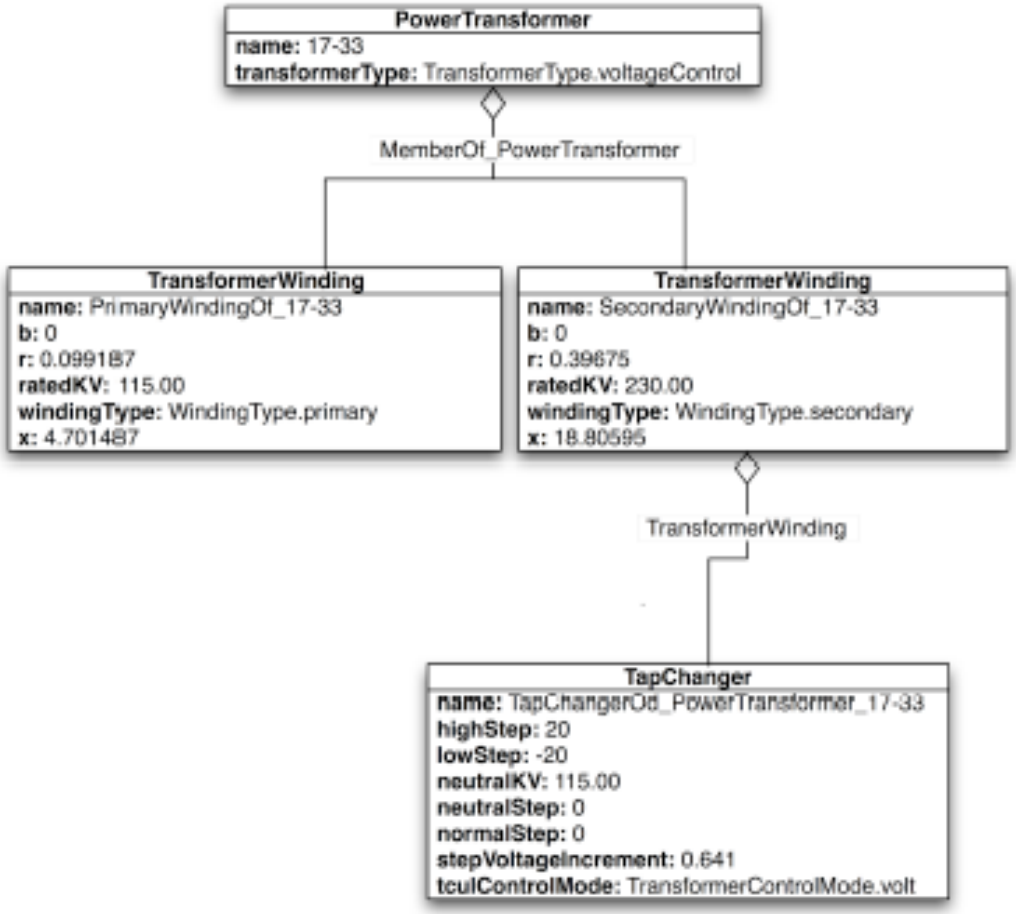
Now we can “define” the CIM RDFSchema

```
<rdfs:Class rdf:ID="PowerSystemResource">
   <rdfs:label xml:lang="en">PowerSystemResource</rdfs:label>
   <rdfs:subClassOf rdf:resource="#Naming"/>
</rdfs:Class>

<rdfs:Class rdf:ID="Equipment">
   <rdfs:label xml:lang="en">Equipment</rdfs:label>
   <rdfs:subClassOf rdf:resource="#PowerSystemResource"/>
</rdfs:Class>

<rdfs:Class rdf:ID="ConductingEquipment">
   <rdfs:label xml:lang="en">ConductingEquipment</rdfs:label>
   <rdfs:subClassOf rdf:resource="#Equipment"/>
</rdfs:Class>
```

CIM RDF example



CIM RDF example continued

```
<rdf:RDF xmlns:cim="http://iec.ch/TC57/2003/CIM-schema-cim10#"
xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#">

<cim:PowerTransformer rdf:ID="PowerTransformer_1733">
  <cim:PowerTransformer.transformerType
rdf:resource="http://iec.ch/TC57/2003/CIM-schema-
cim10#TransformerType.voltageControl"/>
  <cim:Naming.name>17-33</cim:Naming.name>
</cim:PowerTransformer>

<cim:TransformerWinding rdf:ID="PrimaryWindingOf_PowerTransformer_1733">
  <cim:TransformerWinding.b>0</cim:TransformerWinding.b>
  <cim:TransformerWinding.r>0.099187</cim:TransformerWinding.r>
  <cim:TransformerWinding.ratedKV>115.00</cim:TransformerWinding.ratedKV>
  <cim:TransformerWinding.windingType
rdf:resource="http://iec.ch/TC57/2003/CIM-schema-cim10#WindingType.primary"/>
  <cim:TransformerWinding.x>4.701487</cim:TransformerWinding.x>
  <cim:TransformerWinding.MemberOf_PowerTransformer
rdf:resource="#PowerTransformer_302"/>
  <cim:Naming.name>PrimaryWindingOf_17-33</cim:Naming.name>
</cim:TransformerWinding>
```

```
<cim:TransformerWinding rdf:ID="SecondaryWindingOf_PowerTransformer_1733">
  <cim:TransformerWinding.b>0</cim:TransformerWinding.b>
  <cim:TransformerWinding.r>0.39675</cim:TransformerWinding.r>
  <cim:TransformerWinding.ratedKV>230.00</cim:TransformerWinding.ratedKV>
  <cim:TransformerWinding.windingType
rdf:resource="http://iec.ch/TC57/2003/CIM-schema-
cim10#WindingType.secondary"/>
  <cim:TransformerWinding.x>18.80595</cim:TransformerWinding.x>
  <cim:TransformerWinding.MemberOf_PowerTransformer
rdf:resource="#PowerTransformer_302"/>
  <cim:Naming.name>SecondaryWindingOf_17-33</cim:Naming.name>
</cim:TransformerWinding>

<cim:TapChanger rdf:ID="TapChangerOf_PowerTransformer_1733">
  <cim:TapChanger.highStep>20</cim:TapChanger.highStep>
  <cim:TapChanger.lowStep>-20</cim:TapChanger.lowStep>
  <cim:TapChanger.neutralKV>115.00</cim:TapChanger.neutralKV>
  <cim:TapChanger.neutralStep>0</cim:TapChanger.neutralStep>
  <cim:TapChanger.normalStep>0</cim:TapChanger.normalStep>
  <cim:TapChanger.stepVoltageIncrement>0.641</cim:TapChanger.stepVoltageIncre
ment>
  <cim:TapChanger.tculControlMode  rdf:resource="http://iec.ch/TC57/2003/CIM-
schema-cim10#TransformerControlMode.volt"/>
  <cim:TapChanger.TransformerWinding
rdf:resource="#PrimaryWindingOf_PowerTransformer_302"/>
  <cim:Naming.name>TapChangerOf_PowerTransformer_17-33</cim:Naming.name>
</cim:TapChanger>

</rdf:RDF>
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