

An Architectural Framework for using GIS as the Smart Grid Platform

- Maximizing Data Value with GIS and CIM in a Smart Grid World

Esri UC, San Diego, July 10th 2013



Presenters from DONG Energy



Signe Bramming Andersen, sigba@dongenergy.dk
MSc in Economics & Business Administration,
Manager, Energy Management, DONG Energy

Since 1999 working with IT in DONG Energy. IT responsible for the projects ADMS, Wind Farm Management Data Platform, Power Hub (VPP), Bio Hub



Jesper Vinther Christensen, jesper@similix.dk
Ph.D. in GeoScience & Computing Science. Owner, Similix

Since 2011 Lead Architect, DONG Energy Smart Grid programme. 20 years of experience with IT and especially GIS, architecture and project management.



Rushi Amin, rusam@dongenergy.dk
MSc Computer Science, Research in Software reuse

Since 2012 Senior System Consultant, DONG Energy. System Architect for CIM Integration tool. 9 years of experience with software architecture and development in GIS

DONG Energy Sales & Distribution DK

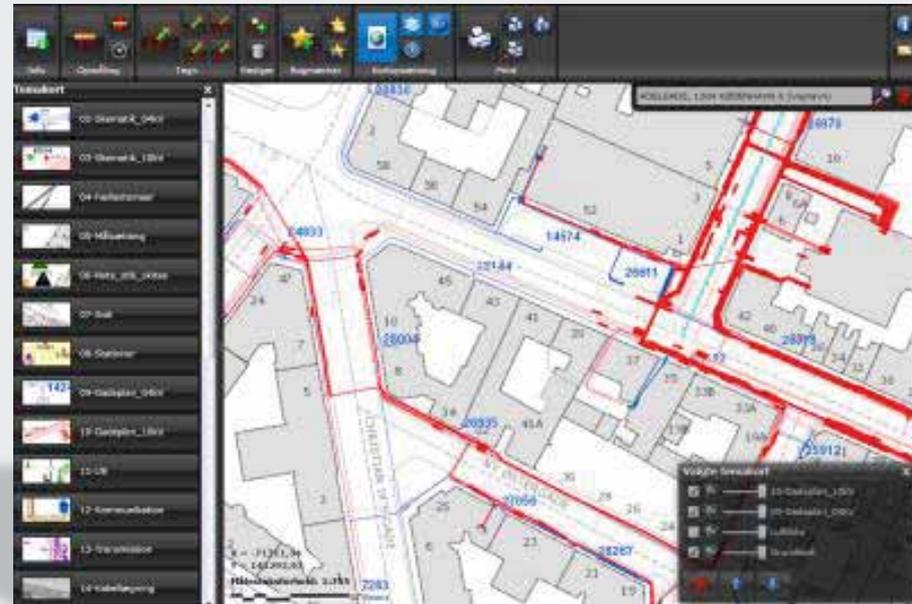
We supply more than 1,000,000 private, public and trade customers in Denmark with electricity and/or natural gas.

The electricity distribution is concentrated around Copenhagen and the north eastern part of Zealand.

The grid comprises 19,000 kilometres of cables and overhead lines and approximately 10,000 transformer stations.

In 2010 approximately 970,000 power take-off points were supplied with electricity, corresponding to 30% of all power take-off points in Denmark.

The total amount of distributed electricity in 2010 was approximately 9,100 GWh.



DONG Energy is one of the leading energy groups in Northern Europe

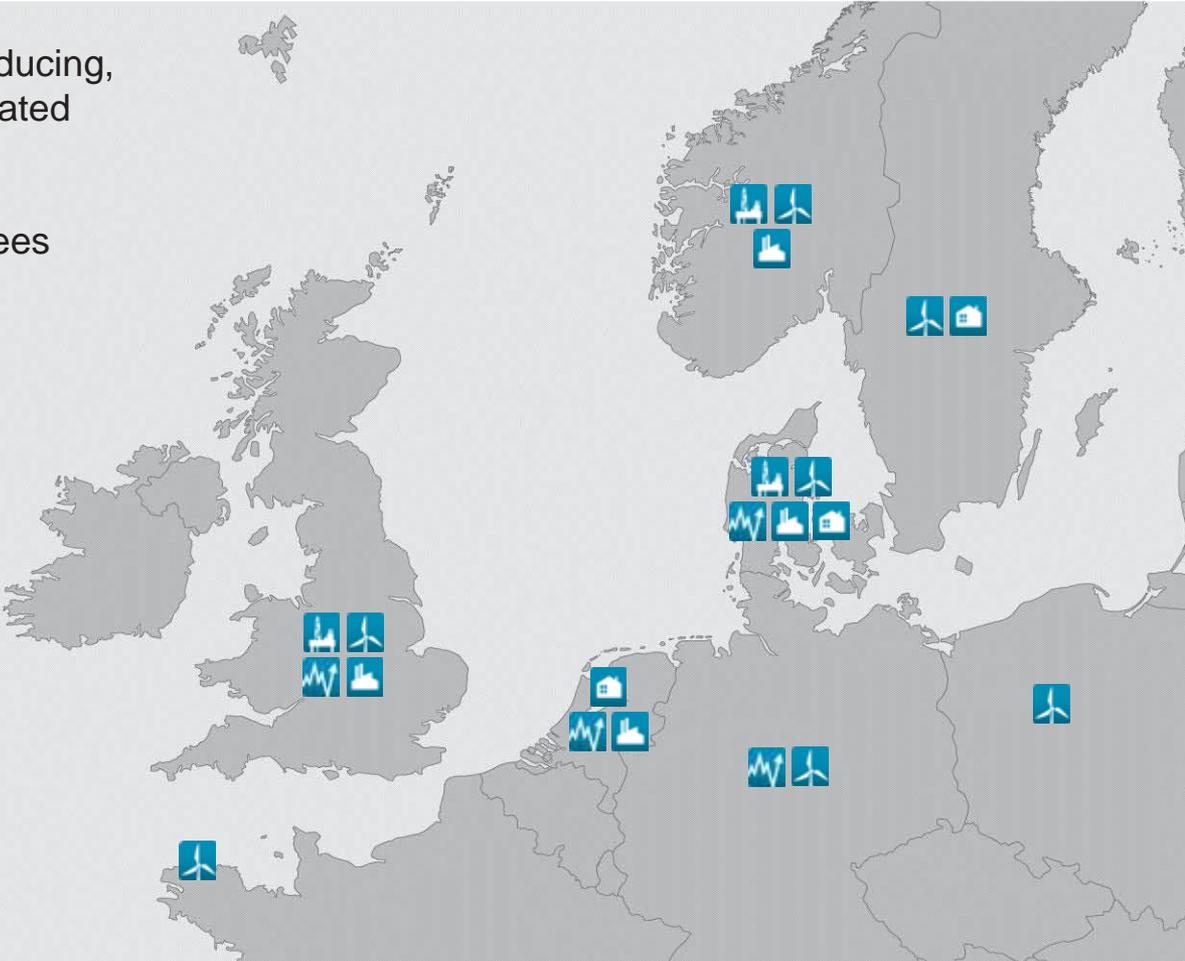
Our business is based on procuring, producing, distributing and trading in energy and related products in Northern Europe.

DONG Energy has nearly 7,000 employees and is headquartered in Denmark.

Owners at 31.12.2012

| | |
|------------------|--------|
| The Danish State | 79.96% |
| SEAS-NVE Holding | 10.88% |
| Others | 9.16% |

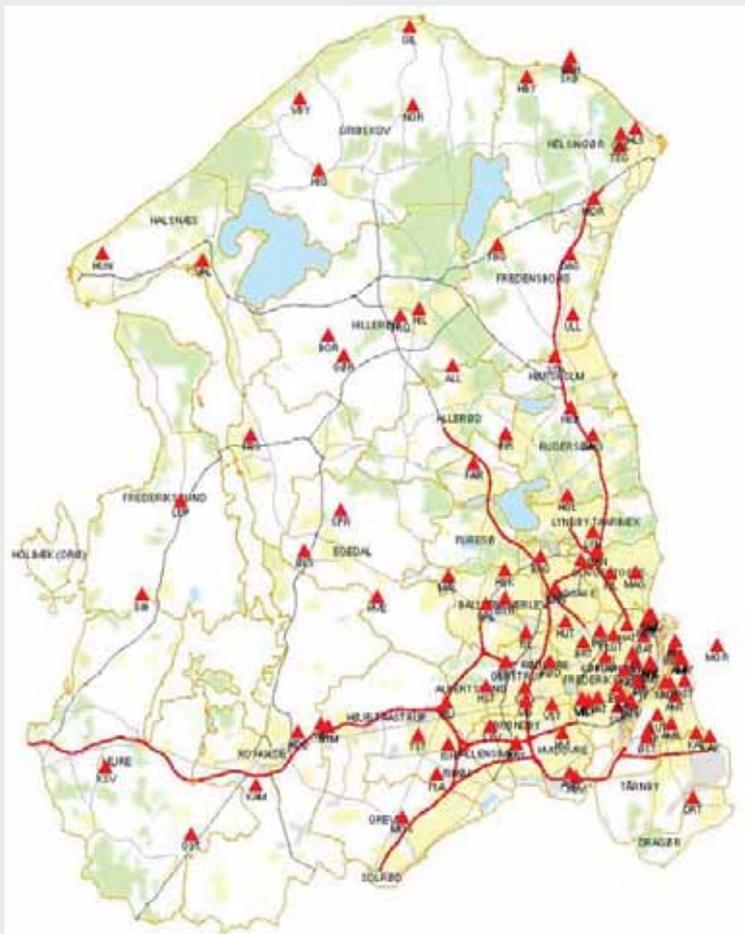
-  Exploration & Production
-  Wind Power
-  Thermal Power
-  Energy Markets*
-  Sales & Distribution*



* Customers & Markets from 1 May 2013

The power distribution grid

DONG Energy Sales & Distribution DK



| Object type | Numbers |
|-----------------------------------|---------|
| Primary substations | 100 |
| 10 KV Feeders | 2,000 |
| Feeder Measurements | 2,500 |
| Primary substation breakers | 2,500 |
| Primary substation disconnectors | 3,000 |
| 10 KV lines | 13,000 |
| 10 KV cables | 61,000 |
| 0.4 KV lines | 40,000 |
| 0.4 KV cables | 220,000 |
| Substations | 10,000 |
| Substation breakers | 25,000 |
| Substation transformers | 12,000 |
| Substation transformer breakers | 12,000 |
| | |
| Remotely operated/measured points | 2,000 |
| | |
| No. of RTU's | 350 |
| No. of AMR | 30,000 |

Smart Grid ambitions

The energy system of yesterday

Characteristics:

- Unidirectional grid
- Production followed demand
- Predictability and stability
- Little customer awareness around energy
- Over capacity in the grid



The energy system of tomorrow

The Challenge

- Integration of volatile wind power
- New customer demands: electric vehicles, solar power, heat pumps

The solution = Smart Energy

- An intelligent (Smart) Grid
- Customer flexibility and energy awareness



IT-Vision

Supporting the business strategy & processes

by state of the art standard products

integrated by CIM (Common Information Model)

Figure 1. MarketScope for Energy and Utility Geographic Information Systems

| | RATING | | | | |
|-------------------------------|-----------------|---------|-----------|----------|-----------------|
| | Strong Negative | Caution | Promising | Positive | Strong Positive |
| Autodesk | | | | x | |
| Bentley | | | x | | |
| Esri | | | | | x |
| GE Energy | | | | x | |
| Intergraph | | | | x | |
| Pitney Bowes Business Insight | | x | | | |

As of 17 March 2011

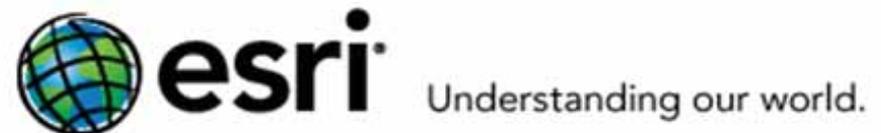
Source: Gartner (March 2011)

Figure 1. MarketScope for Advanced Distribution Management Systems

| | RATING | | | | |
|----------------------------------|-----------------|---------|-----------|----------|-----------------|
| | Strong Negative | Caution | Promising | Positive | Strong Positive |
| Alstom Grid | | | | x | |
| Efacec ACS | | | x | | |
| GE Energy | | | | x | |
| Intergraph | | | x | | |
| Open Systems International (OSI) | | | x | | |
| Oracle | | | | x | |
| Siemens | | | x | | |
| Telvent | | | | | x |
| Ventyx | | | | x | |

As of 21 March 2012

Source: Gartner (March 2012)



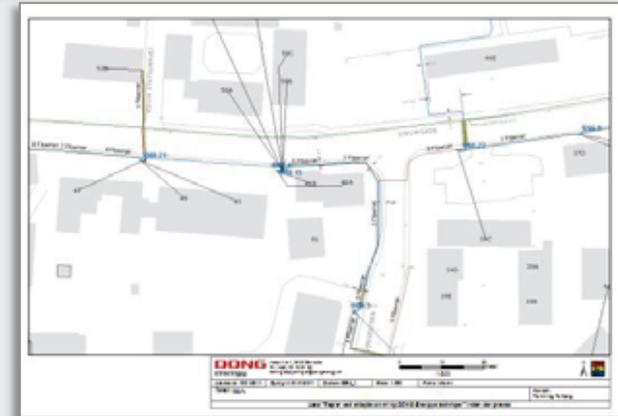
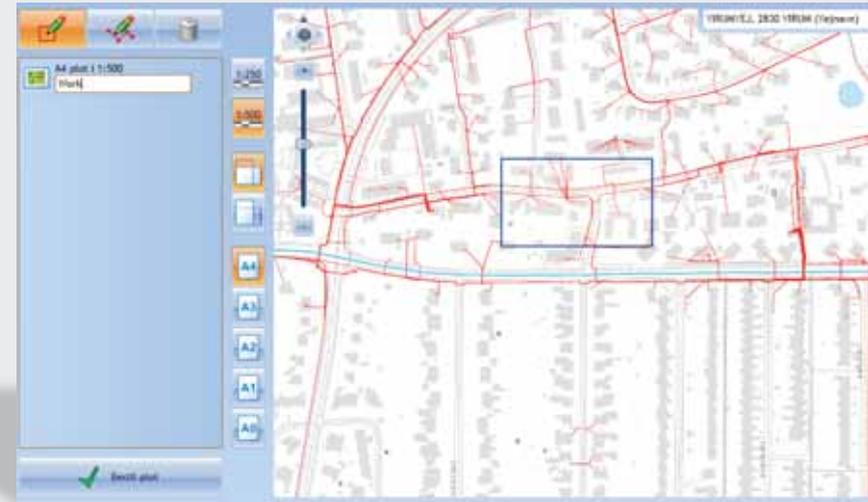
ESRI GIS in DONG Energy Sales & Distribution

ESRI contract signed in 1995

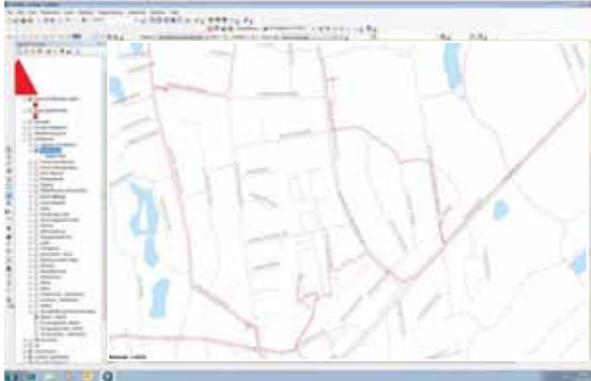
Current version of ArcGIS
is 10.0.3

Telvent utility extension ArcFM
& Designer Express on top

Web apps are built with Silverlight
and ArcGIS server technology



Geographic Information for Smart Grids



Esri ArcGIS

- Supports Design and Maintenance processes
- Leading system for the Static Network and owns the Normal Network State
- Visualization & Cartographic representation



Schneider ADMS

- Operational perspective
- Leading System for the Dynamic State of the Network and owns the Current Network State
- Fault & Alarm handling
- Study & Playback scenarios



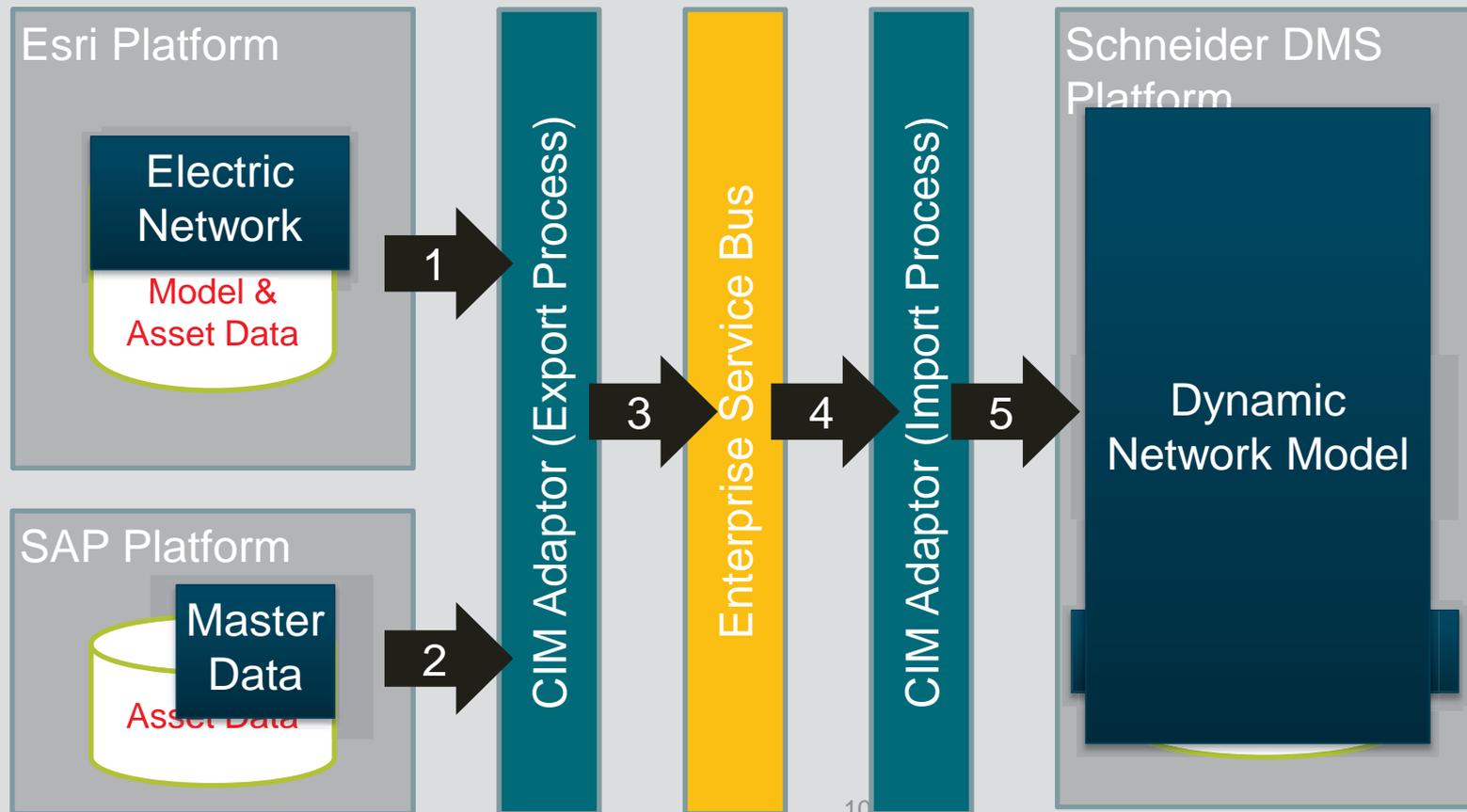
DONG Energy/Schneider GridHub

- Risk, Contingency and Investment planning
- Time Series Analysis
- Snapshot of dynamic model
- 4 Billions Records added per year

Model-based Integration based on CIM IEC 61970 + 61968

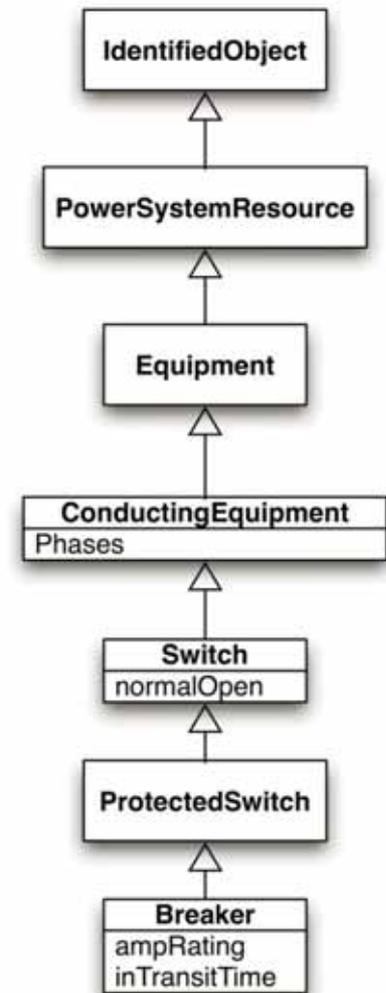
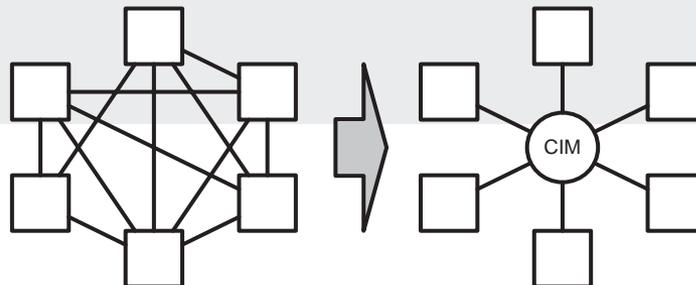
ETL Engine record snapshots of the dynamic network state

Maintaining the Network Model in DMS

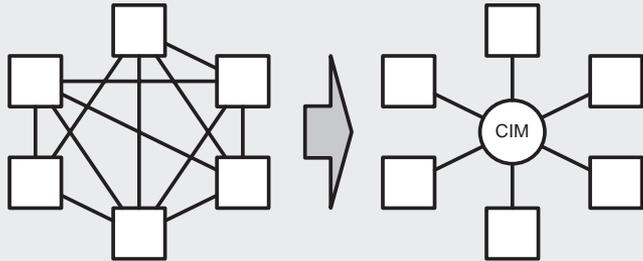


Common Information Model (CIM) – The most brief story

- CIM is a semantic model that describes the components and structure of electric power system
- It enables the exchange of information between applications
- It is specified in the IEC 61970 (Transmission) and 61968 (Distribution) standards. Using UML as the specification language
- Uses XML and RDF (Resource Description Framework) to encapsulate descriptions of e.g. electric networks
- CIM profiles are used to define a subset of the CIM-model relevant to specific usages of the standards
- Profiles can also be used to extend the CIM model to fit specific needs



CIM mapping



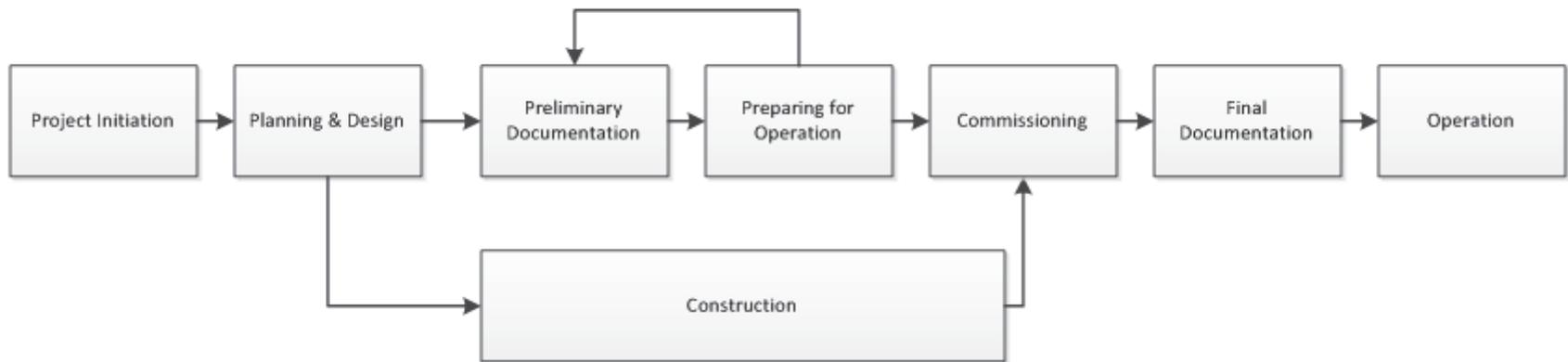
The vision is to use CIM for enabling the exchange of information between all systems...

There is a significant effort needed to define the master and slave system sometimes on field level – and doing the data clean up.

| Entity | ID | Status | Master field | Master value | Slave field | Slave value | Level |
|---------|-------------------|---------------|----------------------|--------------------------|-------------|-------------------|--------|
| Breaker | 51254_T1 | not in Slave | | | | | none |
| Breaker | 6242_T2 | not in Slave | | | | | none |
| Breaker | 53264_T2 | not in Slave | | | | | none |
| Breaker | 51879_T1 | not in Slave | | | | | none |
| Breaker | 53338_T2 | not in Slave | | | | | none |
| Breaker | 31304_T2 | not in Master | | | | | none |
| Breaker | 60242-60411-60411 | not in Master | | | | | none |
| Breaker | 51613-55140-51613 | not in Master | | | | | none |
| Breaker | 52462_T1 | not in Master | | | | | none |
| Breaker | 820-1517-820 | not equal | HIGHVOLTLINESEGNAME | GRANHØJEN | FELTNAVN | GRANDHJEN | high |
| Breaker | 5479-5480-5479 | not equal | HIGHVOLTLINESEGNAME | AMTSSYGEHUS FREDERIKSSUN | FELTNAVN | AMTSSYGEHUS FR. A | high |
| Breaker | 41-2094-41 | not equal | HIGHVOLTLINESEGID | 41-2094 | HOVSTR | 2094-41 | high |
| Breaker | DYR12-829-829 | not equal | HIGHVOLTLINESEGNAME | DYR12 | FELTNAVN | DYREGÅRD | medium |
| Breaker | 1848-3957-1848 | not equal | MAXCONTINUOUSCURRENT | 200 | AFBRSTR | 400 | medium |
| Breaker | 1401-4703-1401 | not equal | MAXCONTINUOUSCURRENT | 400 | AFBRSTR | 200 | medium |
| Breaker | 51651-52075-52075 | not equal | HIGHVOLTLINESEGNAME | BRYDES ALLE 2 | FELTNAVN | | low |
| Breaker | 51651-52075-52075 | not equal | MAXCONTINUOUSCURRENT | 400 | AFBRSTR | | low |
| Breaker | GHO03-1545-1545 | not equal | HIGHVOLTLINESEGNAME | GHO03 | FELTNAVN | | low |
| Breaker | 6251-6252-6252 | not equal | MAXCONTINUOUSCURRENT | 400 | AFBRSTR | 0 | low |
| Breaker | 1231-4462-1231 | not equal | HIGHVOLTLINESEGNAME | KETTEVEJ VEST | FELTNAVN | | low |
| Breaker | 6405_T1 | not equal | MAXCONTINUOUSCURRENT | 100 | AFBRSTR | | low |
| Breaker | 1710_T1 | not equal | MAXCONTINUOUSCURRENT | 25 | AFBRSTR | | low |
| Breaker | 4132_T1 | not equal | MAXCONTINUOUSCURRENT | 25 | AFBRSTR | | low |
| Breaker | 638-5131-5131 | not equal | HIGHVOLTLINESEGNAME | LILLE SVERIGE | FELTNAVN | | low |

Integrating GIS and DMS – two scenarios

- Patch or incremental exports
 - To support the life-cycle of projects, incremental changes or patches are used to describe added or removed components, that will be energized in one operation.

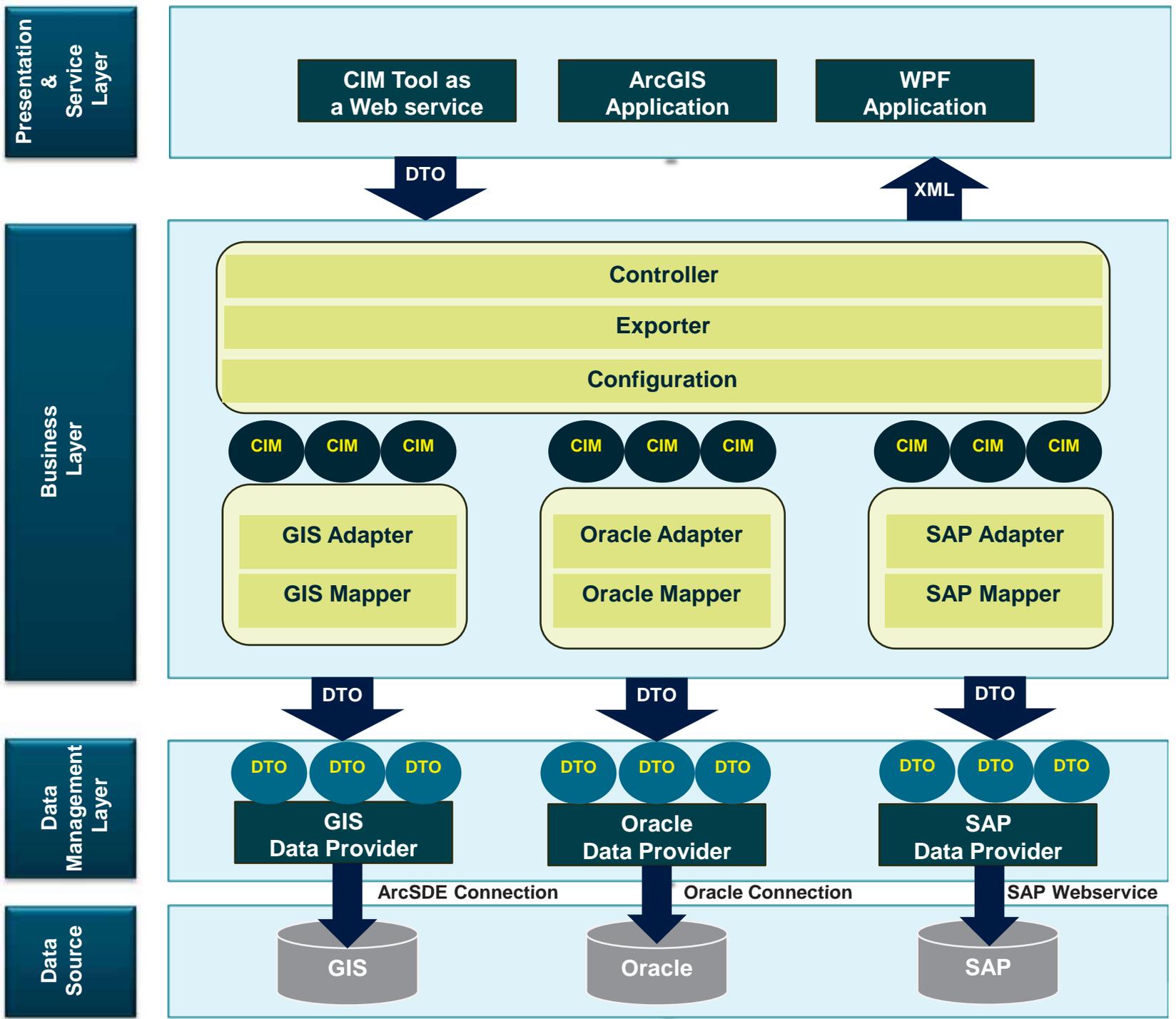


- Full Feeder Export
 - Full feeder export from GIS and SAP supports migration of data to DMS and will also be used for initial export of new feeders and to validate GIS and DMS model against each other.

CIM Tool Architecture

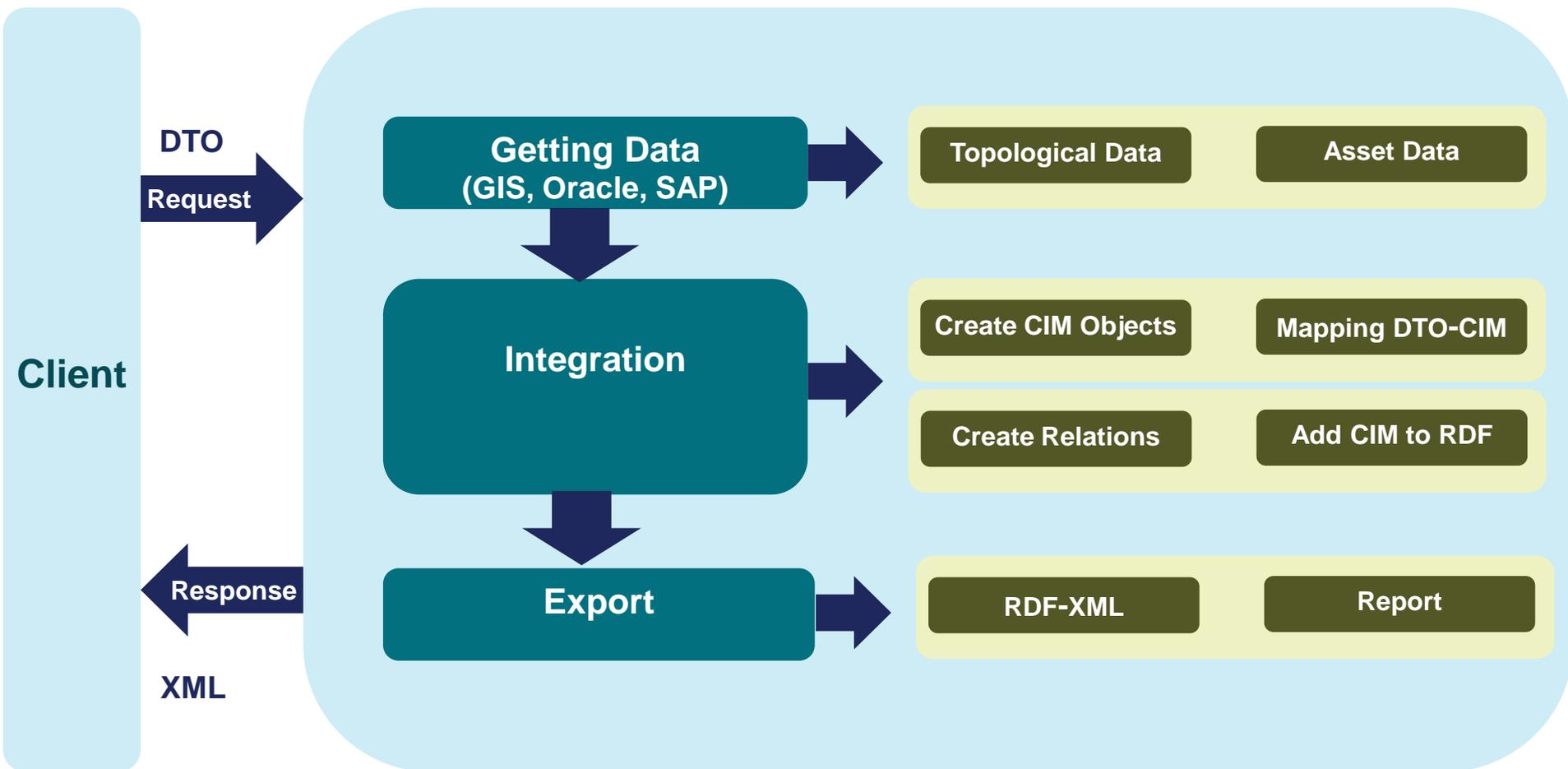
Architectural Approach

- Controller – Adapter – Data provider structure.
 - **Data Provider:** The Data provider will be able to get data from a datasource and deliver it in a local format that the adapter understands.
 - **Adapter:** The Adapter calls the data provider when necessary and is responsible for adapting the data from the data provider to the structure of the CIM profile.
 - **Controller:** The controller is responsible to for calling the configured adapters and generating the required output. This is done by calling an output module.



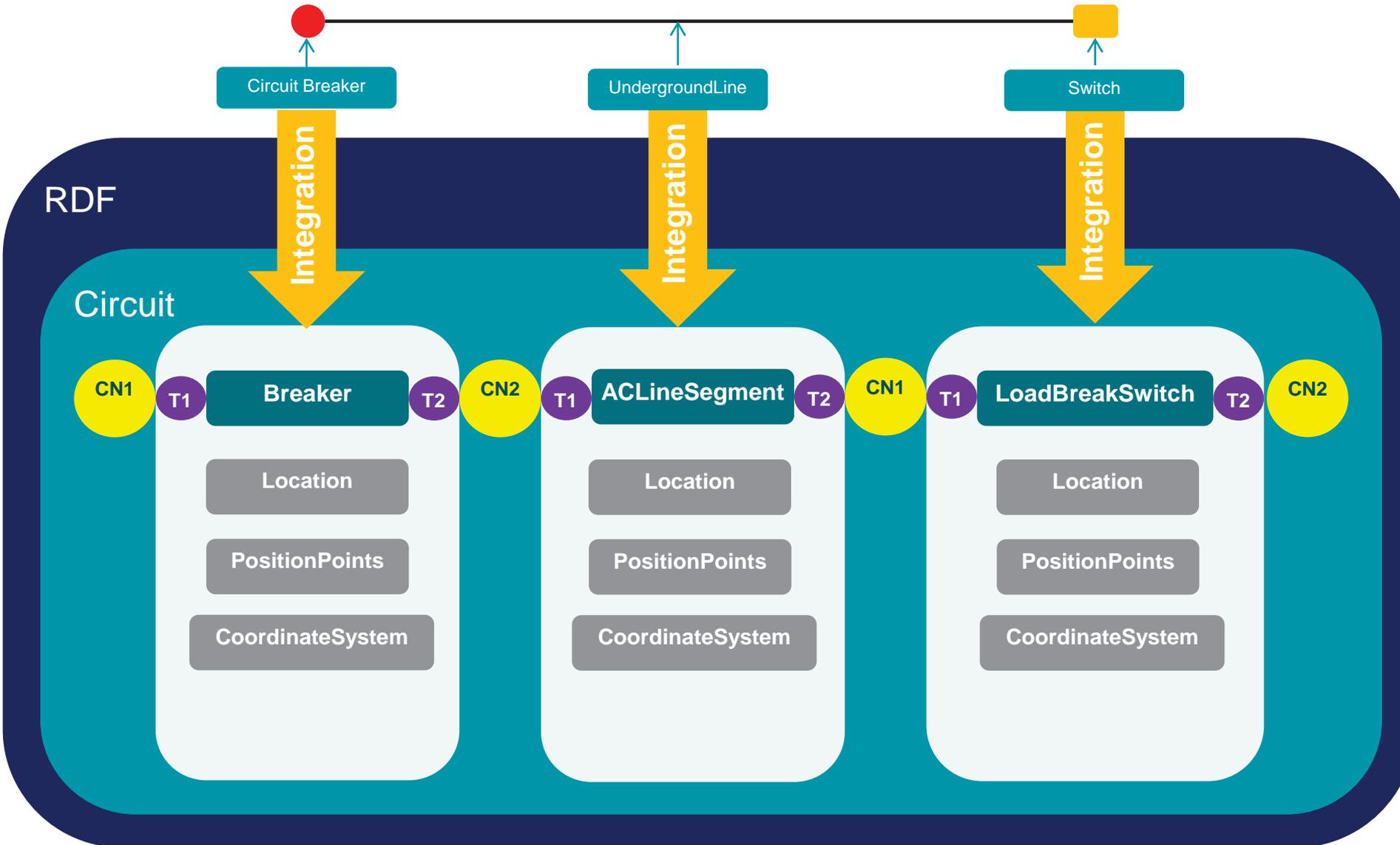
Data Extract Process

System Flow



Cont.

GIS to DMS Migration



Sample XML – Switch to LoadBreakSwitch

```
<cim:LoadBreakSwitch rdf:ID="_HighVoltageSwitch.2719">
  <cim:IdentifiedObject.description>2062-2637</cim:IdentifiedObject.description>
  <cim:IdentifiedObject.mRID>HighVoltageSwitch.2719</cim:IdentifiedObject.mRID>
  <dong:IdentifiedObject.name>TÅSTRUP ELME ALLE</dong:IdentifiedObject.name>
  <dong:PowerSystemResource.doc3>2637-2062</dong:PowerSystemResource.doc3>
  <cim:PowerSystemResource.Location rdf:resource="#_HighVoltageSwitch.2719.L" />
  <dong:Equipment.manufacturer>LK</dong:Equipment.manufacturer>
  <dong:Equipment.operationsManager>DE</dong:Equipment.operationsManager>
  <tdms:Equipment.private>true</tdms:Equipment.private>
  <dong:Equipment.standardTypeLibrary>HIGHVOLTAGESWITCH_CATALOG</dong:Equipment.standardTypeLibrary>
  <cim:Equipment.EquipmentContainer rdf:resource="#_Station.2637" />
  <tdms:ConductingEquipment.numberOfPhases>3</tdms:ConductingEquipment.numberOfPhases>
  <cim:ConductingEquipment.phases>ABC</cim:ConductingEquipment.phases>
  <tdms:ConductingEquipment.ratedVoltage>10000</tdms:ConductingEquipment.ratedVoltage>
  <cim:ConductingEquipment.BaseVoltage rdf:resource="#_BV.12000" />
  <tdms:Switch.breakingCurrent>3500</tdms:Switch.breakingCurrent>
  <tdms:Switch.feederID1>VEJ_10_06_S0001</tdms:Switch.feederID1>
  <cim:Switch.normalOpen>false</cim:Switch.normalOpen>
  <tdms:Switch.ratedCurrent>200</tdms:Switch.ratedCurrent>
  <dong:Switch.shortCircuitIndicator>true</dong:Switch.shortCircuitIndicator>
  <dong:Switch.switchType>OAF</dong:Switch.switchType>
  <dong:LoadBreakSwitch.peakCurrent>32000</dong:LoadBreakSwitch.peakCurrent>
  <dong:LoadBreakSwitch.thermalCurrent>13000</dong:LoadBreakSwitch.thermalCurrent>
</cim:LoadBreakSwitch>
<cim:Location rdf:ID="_HighVoltageSwitch.2719.L">
  <cim:IdentifiedObject.mRID>HighVoltageSwitch.2719.L</cim:IdentifiedObject.mRID>
</cim:Location>
  <cim:CoordinateSystem rdf:ID="_HighVoltageSwitch.2719.L.CS">
    <cim:PowerSystemResource.Location rdf:resource="#_HighVoltageSwitch.2719.L" />
    <cim:IdentifiedObject.name>EPSG:29900</cim:IdentifiedObject.name>
  </cim:CoordinateSystem>
    <cim:PositionPoint rdf:ID="_HighVoltageSwitch.2719.L.CS.PP.1">
      <cim:PositionPoint.sequenceNumber>0</cim:PositionPoint.sequenceNumber>
      <cim:PositionPoint.rotationAngle>177.8</cim:PositionPoint.rotationAngle>
      <cim:PositionPoint.xPosition>707600.218985607</cim:PositionPoint.xPosition>
      <cim:PositionPoint.yPosition>6172136.06051004</cim:PositionPoint.yPosition>
      <cim:PositionPoint.CoordinateSystem rdf:resource="#_HighVoltageSwitch.2719.L.CS" />
    </cim:PositionPoint>
  </cim:PositionPoint>
```

LoadBreakSwitch

Location

Coordinate System

Position Point

Sample XML - Connectivity

```
<rdf:RDF xmlns:tdms="http://web.telventdms.com/CIM15/2010/extension#"
xmlns:dong="http://web.telventdms.com/CIM15/DONG/extension#"
xmlns:cim="http://iec.ch/TC57/2010/CIM-schema-cim15#" xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#">
  <cim:ConnectivityNode rdf:ID="_Node.HighVoltageSwitch.2719_UndergroundElectricLineSegment.4797">
    <cim:IdentifiedObject.mRID>Node.HighVoltageSwitch.2719_UndergroundElectricLineSegment.4797</cim:IdentifiedObject.mRID>
    <cim:ConnectivityNode.ConnectivityNodeContainer rdf:resource="#_Station.2637" />
  </cim:ConnectivityNode>
  <cim:ConnectivityNode rdf:ID="_Node._HighVoltageSwitch.2719_noconnection.1">
    <cim:IdentifiedObject.mRID>Node._HighVoltageSwitch.2719_noconnection.1</cim:IdentifiedObject.mRID>
    <cim:ConnectivityNode.ConnectivityNodeContainer rdf:resource="#_Station.2637" />
  </cim:ConnectivityNode>
  <cim:Terminal rdf:ID="_HighVoltageSwitch.2719.T.1">
    <cim:IdentifiedObject.mRID>HighVoltageSwitch.2719.T.1</cim:IdentifiedObject.mRID>
    <cim:Terminal.ConductingEquipment rdf:resource="#_HighVoltageSwitch.2719" />
    <cim:Terminal.ConnectivityNode rdf:resource="#_Node.HighVoltageSwitch.2719_UndergroundElectricLineSegment.4797" />
    <cim:Terminal.sequenceNumber>1</cim:Terminal.sequenceNumber>
  </cim:Terminal>
  <cim:Terminal rdf:ID="_HighVoltageSwitch.2719.T.2">
    <cim:IdentifiedObject.mRID>HighVoltageSwitch.2719.T.1</cim:IdentifiedObject.mRID>
    <cim:Terminal.ConductingEquipment rdf:resource="#_HighVoltageSwitch.2719" />
    <cim:Terminal.ConnectivityNode rdf:resource="#_Node._HighVoltageSwitch.2719_noconnection.1" />
    <cim:Terminal.sequenceNumber>2</cim:Terminal.sequenceNumber>
  </cim:Terminal>
</rdf:RDF>
```

Connectivity Nodes

Terminals