CIM in the Middle
Integrating Transmission and Distribution Systems using CIM

Alan McMorran
Susan Rudd
Open Grid Systems

Dora Nakafuji
Lauren Gouveia
Hawaiian Electric Company
Introduction
Consultancy and software company based in Glasgow, UK

Provide services and software to the power industry working with vendors and utilities

Work focussed on Model Driven Architectures, Open Standards and cutting-edge technologies

Member IEC TC57 Working Groups 13,14 & 19
Hawaiian Electric Company

- Hawaiian Electric Company (HECO) is the largest supplier of electricity in the state of Hawaii.
- It operates the electrical network on the island of Oahu including transmission and distribution networks.
- HECO generates and provides power to residential, industrial and commercial customers.
Distributed Generation

- HECO has a high penetration of distributed generation (DG), including domestic roof-top solar systems and wind generation.

- Utility staff recognised that there will be a need to account for the aggregated impact of this DG on the integrated system.

- As part of a High Penetration Photo Voltaic (PV) Initiative funded by the California Public Utilities Commission (PUC) HECO collaborated with Sacramento Municipal Utility District to enhance the distribution models for distributed PV.

- This was part of a Proactive Modelling methodology.
Integration Challenge
Distributed Generation

- HECO has increasing amounts of Distributed Generation including photovoltaic solar and wind turbines being added at the distribution level.

- This provides new challenges for operators and planners trying to control the grid and plan future network expansion.
Integration of Distribution Networks

- Viewing a distribution network as a series of predictable, equivalent loads is no longer true.
- An operator may find that a distribution network is producing more power than it is consuming.
- Without accurate, detailed, up-to-date network models, the operator will find it hard to predict the behaviour of the whole network.
- Being able to conduct accurate studies and simulations requires a fully interconnected model.
Planners using the high voltage planning model have no visibility of the small scale generation on the distribution network.

For system operators and planners the distribution grids are becoming more dynamic and the sudden, simultaneous loss of multiple small scale generation facilities has the potential to affect the stability of the transmission network.
Abstract to Detailed

- As more distributed generation is added to the network the system operator needs to know **where** and **how** the generation is connected.
- This is as much for **contingency analysis** and **planning** as it is for **real-time control**.
Network Models

- In HECO there were three network models being used for analysis, which are maintained in two different software packages:

  - The **high-voltage planning** network was stored in the planning analysis application’s **proprietary bus-branch power flow format**

  - The balanced **medium voltage sub-transmission** network was extracted from the GIS and stored in **SynerGEE**’s internal data format

  - The **unbalanced low voltage distribution** network was also stored in SynerGEE
HECO required a solution that would:

- **Integrate** the transmission, sub-transmission and distribution networks
- **Aggregate** the loads and generation on the low-voltage unbalanced network into **balanced equivalents**
- **Export** the resulting **integrated model** into the **power-flow format** for use in the transmission planning application
Challenges

- Integrating **three models in two different formats** from different software packages posed **significant challenges**:  
  - Node-breaker vs branch-branch  
  - Unbalanced vs balanced  
  - Equipment catalogues vs per-component values for electrical properties  
  - Engineering units vs per-unit values  
  - Incompatible naming/identifiers  
  - The transmission and sub-transmission networks contained **equivalents of each other**
CIM Based Solution
Why CIM?

- The problem itself did not require CIM to be used
- The inputs were:
  - SynerGEE MDB files (Access)
  - The proprietary power-flow format
  - A list of equivalent nodes (in CSV as key/value pairs of identifiers)
- The output was then in the proprietary power-flow format
- Introducing CIM into this process may seem like an additional, unnecessary step
Why CIM?

- Open Grid Systems has done a number of projects involving data transformation to and from other formats.

- Translating from one proprietary format to another is nearly always more complex than simple one to one mappings between data elements.

- We want to eliminate or reduce the amount of time spent implementing duplicate functionality for different formats and structures.

- As with many systems integration projects, doing point to point translations quickly becomes unmanageable.
A Common Language
A Common Language
Standards Approach

- The benefit of converting to a standard form first is that supporting \textbf{N formats} requires at most \(2N\) \textbf{transformations} (and often the conversion is omni-directional)

- It also allows any software for \textbf{analysis} and \textbf{validation} to be focussed on the standard format

- This means that \textbf{topology processors, network load aggregation, schematic generation} etc. is written for one network representation not duplicated for each format
Model Driven Transformation

- With a Model Driven Architecture, applications are written to deal with **data** irrespective of where it is stored and in what format.

- **Model-Driven Transformation** defines the data mappings at the **meta-model level**, independent of the source and target formats.
Transform Definitions

- Transformations are written against the model and there are a number of model-driven transformation languages including QVT and ATL.

- The same transformation can be used with data coming from web services, databases, files or any other data source as they run against the data objects.

- Interfaces can be model-agnostic (e.g. RDF XML) or model dependent (e.g. power-flow formats).

- Multiple interfaces can be used to save/load data in the same structure to/from different formats.
Transformation Process

SynerGEE File

SynerGEE File Parser (XML or MDB)

SynerGee Data Model

Model Driven Transformation

CIM

CIM Data Objects

Powerflow File

Powerflow File Parser

Powerflow Meta-Model

CIM

CIM Data Objects

CSV File

CSV Key/Value Pair Parser
CIM Processing

• There is now a **common definition** of the network at a high level of detail **compatible** with the **transmission**, **sub-transmission** and **distribution** models.

• All the **processing**, **integration** and **analysis** of the data itself is done in its **CIM** format.

• Time can be spent processing the **standard** representation of the data instead of duplicating functionality across multiple formats.
Workflow

- The resulting **workflow** has **multiple inputs** and **processing stages**

- The **processing** and **integration** of the data takes place on the **CIM representation** of the data

- This allows us to focus **time and effort** on **software** that works with the **CIM representation**

- **Different input and output formats** can then be **substituted** without impacting the processing and integration
Workflow

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- This allows us to focus **time** and **effort** on **software** that works with the **CIM representation**
- **Different input** and **output formats** can then be **substituted** without impacting the processing and integration
- The **CIM outputs** can be used with other **modules** or sent to other **systems**
CIM as an Output
Data Quality

- The conversion algorithms can be perfect but still produce unusable output
- Distribution data quality can be extremely variable
  - Disconnected sections and Dummy Equipment left in the model
  - Incomplete data with branches finishing at nodes with no load or generation attached
Data Quality

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One Output, Multiple Uses

- CIM is supported by other applications including multiple CIM based validation tools that can be used to check that the resulting data is compliant with CIM profiles.

- Topological processors can check for topological integrity and identify any islands (then produce a file-per-island if required).

- During the course of the project another group in HECO expressed an interest in the CIM model as there was a requirement for a detailed model to populate a new Distribution Management System (DMS).

- The intermediary CIM model thus became an additional output of the process.
DMS Challenges

- The addition of the DMS to the project required some additional work on the CIM transformations.

- When the CIM was only intermediary there was no requirement to pass through all data if it was not required in the power-flow format output.

  - e.g. Geographical data was now included and feeder containment maintained and/or calculated.

- The DMS also identified issues with missing loads and disconnected sections that were not an issue for the planning export.

- Common, persistent names and identifiers (i.e. UUIDs) were required but not present in the source data.
Conclusions
Data Integration

- As networks become smarter and more distributed generation is integrated, distribution networks cannot be treated as simple dumb loads.

- Integrating transmission and distribution networks will be critical in analysing the impact of new technology on both transmission and distribution systems.

- Data quality and a variety of incompatible formats is a challenge when dealing with distribution networks.

- Focussing on a standard, common format reduces the need to duplicate effort when dealing with data from multiple applications and systems.
Benefits of CIM

- The use of CIM was initially as an intermediary format for data transformation but provided many benefits to the project.
- This approach allowed the conversion to be modularised and existing CIM-compatible components could be re-used.
- It provides a more robust architecture moving forward by decoupling the integration and processing of the data from the initial source or final target format.
- The production of a standard model for the network was then of benefit to other projects by providing an unambiguous, standard network model the DMS vendor already supported.
Questions?

www.opengrid.com

alan@opengrid.com