Abstract-- Powerlink Queensland is currently in the advanced stage of implementing a CIM-based enterprise-wide network asset model maintenance system. This model allows a single common repository for the planned and operational network model for use by Planning, Operations, EMS and Protection. Planners are able to enter future projects with multiple possible scenarios with the capability to move the projects or phases in the project as required. The CIM model defined in IEC#61970 has been enhanced to incorporate full representation of sequence models, mutual couplings and power system dynamic data. This parallels the effort to develop a CIM for Planning reference being led by EPRI in the US. In addition, the CIM-based database is also being used as a centralized plant register for other corporate applications such as a Switching Sheet Program and Outage Management System. Automatic export of the model is also provided to the EMS so that newly commissioned plant is automatically added to the model as planned projects are placed in operation.

Index Terms—CIM, Power System Control, Power System Planning, IEC 61970

I. NOMENCLATURE

CIM – EPRI Common Information Model
GridDB – The current legacy AM/FM system used by Powerlink for the network model maintenance
eDRMS – Electronic Document and Records Management System
TNDB – Transmission Network Database, the new CIM compliant database being implemented by Powerlink
EMS – Energy Management System
NEMMCO – National Electricity Market Management Company
COTS – Commercial of the Shelf software
NPR – Powerlink developed Network Plant Register

II. INTRODUCTION

Powerlink Queensland is a state government owned Transmission Network Service Provider, which owns, develops, and operates the A$3.9 billion Queensland high voltage transmission network that extends 1700km from Far North Queensland to the New South Wales border - almost half of Australia's eastern seaboard.

Since 1997, Powerlink has been using a legacy AM/FM application known as GridDB to develop and maintain a transmission system network connectivity model for use by Grid Planning, Protection and Operations groups. Each of the three major customers of GridDB share a common model definition to provide the necessary information for planning future network extensions, fault calculations, contingency analysis and operating the transmission network.

The transmission network model is exported from GridDB to the real-time Energy Management System (EMS) and the power systems analysis tool for planning. The transmission network model is also exported from the GridDB to NEMMCO (the Australian National Independent System Operator), including the EMS view of the data, which shows the connectivity down to the switching level.

III. LIMITATIONS OF EXISTING FACILITIES

The GridDB is no longer supported by the original vendor and could not be developed any further to support changed business processes and increased network modeling data requirements. The following list outlines the main limitations of the existing system:

1. The data model in the highly customized GridDB application could not be easily extended to support the increased network modeling requirements such as support for seasonal plant and feeder ratings or the data used for performing dynamics stability and small signal stability analysis.

2. The implementation of the future network models through projects in GridDB lacks the flexibility to support the growth of Powerlink’s network and the required Planning network analysis.

3. Powerlink’s applications such as the Switching Sheet Program and Outage Management System are unable to interface to the existing GridDB which resulted in duplication of data.

4. The existing solution is not accessible to the general Powerlink users. There is only access available to five or six users at any-time.

5. Powerlink is unable to develop new applications or
interface existing applications to GridDB. There is no well defined API for attaching existing or new applications.

IV. GRIDDB REPLACEMENT PROJECT REQUIREMENTS

There was a need for a considerably more powerful and flexible application to meet the following requirements:

- Support for the network model exchange using the industry-standard EPRI Common Information Model (CIM) to support future interfaces with the EMS and external companies;
- Include a full temporal model allowing the management of the future network with the extended capability for analyzing scenarios to support the revised Planning business process;
- Support a more extensive network model to facilitate additional comprehensive network analysis, including:
  - seasonal plant and line ratings,
  - measurements data to support historical network model analysis and network baseline analysis using the historical and near real-time measurement values
  - support for the data used for dynamics stability analysis,
  - enhanced auditing by recording the change history for plant,
  - links to reference documentation about power system resources;
- Ability to extend the data model and add custom attributes;
- Web view interface;
- Replace the existing NPR and implement a central repository of all plant names to reduce the duplication of data across various applications;
- Implement a commercial of the shelf (COTS) product that will continually be developed by the vendor;
- An open and extensible software architecture that can be easily integrated with other Powerlink applications to provide a true central network model repository.

On this basis, Powerlink initiated a new project to implement Transmission Network Database (TNDB), an enterprise-wide CIM compliant central database repository for the existing and planned transmission network model and associated attributes.

TNDB is to become the source of all data required to support Powerlink’s EMS and network analysis applications including Fault Calculations (balanced and unbalanced), Power Flow, State Estimator, Contingency Analysis, Dynamic Stability and Small Signal Stability Analysis. Added to the scope is the intention to link in other applications including Outage Management System and Switching Sheet Program.

V. SOLUTION STRATEGY

After undertaking a specification and tender process, Powerlink selected a solution based on a commercially available CIM compliant product. Although not all of the required features existed in the current version of the product, the vendor agreed to work with Powerlink to extend the core product functionality to include Powerlink’s requirements, such as support for future projects and scenarios, ability to add custom attributes, support for planning and operational views of the network model, web interface and dynamics models. This was aligned with Powerlink’s strategy to use COTS software to ensure cost effective support and availability of future software improvements.

The vendor also undertook the development of a .NET Application Programming Interface (API) for their product. An easy to use API is a crucial part of the overall solution that implements TNDB as the central repository for the network model to be used by a number of internal and external applications.

Figure 1 shows the software architecture that will be implemented on the project.

The software solution has two components: a network model maintenance tool and a network model analysis tool. An integrated analysis tool will enable Powerlink to validate network model changes by doing the load flow studies as model changes are entered and before exporting the network model to EMS or planning analysis tool.

Although most of the required functionality will be delivered in the base product, custom extensions will be developed to support the exchange of data with the external systems.
VI. USE OF CIM

The design of the underlying database functionality will include the use of the Common Information Model (CIM). The selection of the CIM as the underlying base for the enterprise database was based on a corporate strategy to use industry standards wherever possible to facilitate use of standard, supported applications and interfaces.

VII. PLANNING AND OPERATIONAL VIEWS

TNDB will provide a single network model to be used by Planning, Protection and Operations. Grid Planning and Protection business processes require a network model with a coarser level of detail than the network model that is used to support real-time operation of the network. In order to support different business processes, the vendor software will implement both operational and planning views for the TNDB network model. The operational view will display full substation switching configuration and all equipment in the network model. The planning view will reduce complex substation switching schemas into a simple bus/branch model.

VIII. PROJECT MODELING

In order to support a business requirement to manage preliminary, proposed and approved network changes for up to 12 years ahead of the commissioned network, TNDB will implement concepts of a project, project phase and a scenario.

A. Projects and Project Phases

A project is a set of changes to the network model that can represent an augmentation to the transmission network including the addition of transmission plant, generation or substations. The network changes for the project are grouped in the project phases that match the project commissioning plan. As such each project can have one or many project phases. Each project phase has a single commissioning date. The project status will be managed throughout a project lifecycle. A project will start as a preliminary project that may or may not be retained as a viable alternative. If a project is proposed for implementation, its status will change to Planned and then to Approved upon obtaining project approval.

B. Scenarios

A scenario is a collection of the future projects’ phases. In order to show the future network model, the users will be able to build and activate scenarios. When viewing an approved future network baseline, the user will build a scenario as a collection of all approved project phases that will be commissioned by a selected future date. Activating this scenario will apply the selected future network changes on top of the current network baseline. The displayed future network model can then be modified, analyzed with the power-flow and exported to the planning analysis tool.
or to the EMS.

The concept of scenarios also supports a Grid Planning requirement to manage the network models for their preliminary studies. When doing a preliminary study for a point in time in the future, the planners can build a scenario of all approved and planned projects by that date and manually add one or many preliminary projects to build a future network model version for operational or planning studies.

C. Recording Changes

All changes to the future network will be recorded and stored against a future project and project phase. The following steps will be performed when entering network changes for a future project:

- Create a project and project phase;
- Set project status and the project phase commissioning date;
- Build and activate a scenario to include all network changes prior to the project commissioning date. The network model diagrams and attributes are updated to display the future version of the network model;
- Select the project phase and run Start Recording command;
- Modify the network model diagrams and attributes. All changes will be recorded in the selected project phase.

D. Project Lifecycle

The projects in TNDB will be created many years before they are expected to be built and commissioned. At the time when Grid Planning records proposed project changes in TNDB, the commissioning date is only a rough estimate and the project commissioning plan is not defined. Throughout the project lifecycle, other organizational groups will be adding the detailed network model changes to the project as the design progresses.

TNDB future projects implementation has to be flexible to allow adding project phases and moving recorded modeling changes between phases as well as changing commissioning dates in order to match the changing project commissioning plan. The software will implement dependency checks to ensure that the integrity of the future network model is retained as the future network changes are moved in time.

As the future network project phase is about to be commissioned in the field, the EMS Support team will export the model to the EMS. Upon receipt of the notice of successful commissioning, the EMS Support team will commit the changes to the network baseline in TNDB. The TNDB network baseline will always reflect the current commissioned network.

IX. User Defined Attributes

The vendor data model is fully based on the CIM standard for power systems modeling. A CIM-based data model accounts for the majority of Powerlink’s network modeling requirements. In addition, support of Powerlink corporate applications will require some user defined attributes to be added to the CIM-based data repository in TNDB. Examples of this data include additional plant naming attributes required for the Switching Sheet Program.

The vendor product database will be extended to incorporate custom attributes. One of the product improvements that will be delivered as part of the project is a configurable, XML driven network model editor that will be configured to show Powerlink’s custom attributes and to invoke custom defined forms.

X. Plant Limits and Ratings

TNDB will be used to store and manage seasonal plant ratings and limits. This will include such values as transformer ratings, bay ratings and feeder limits.

In the initial implementation only the most limiting bay ratings will be migrated and managed in TNDB. Powerlink stores all manufacturer continuous current and fault current ratings within the asset management system. A subsequent project to TNDB implementation will focus on ratings management. The ratings management project will look to providing the access to all continuous current and fault ratings from TNDB.

XI. Plant History and Audit

Associated with each major network element in the network model, there will be the capability to record information regarding the history of the each network element. This history may require the storing of notations, emails and other documents outlining the reasons for change to a network element.

XII. Powerlink’s API TNDBNET and Interfaces to Other Applications

One of the main purposes of the TNDB implementation is to provide the network model maintenance and support for Powerlink’s EMS. A custom developed EMS extractor utility will export the network model from TNDB as a set of the flat text files. The existing version of Powerlink’s EMS software is not CIM compliant. An EMS upgrade project which will implement a CIM compliant version of EMS, is about to commence. Upon completion of the upgrade, Powerlink will consider use of CIM-XML for the network model exchange between TNDB and EMS.

Powerlink has a number of applications that maintain a network plant register. The TNDB project is looking to rationalize the landscape of the existing applications and remove data duplication by providing a central repository of the network plant data to be used and accessed by other applications. As part of this project, the following applications will be modified to enable read only access to
the network plant register in TNDB:

- Outage Management System
- Outage Impacts Statistics reporting tool
- Switching Sheet Program.

A number of read-write interfaces to TNDB will also be developed to enable automated import of data that is created in other systems and used in TNDB. The following read-write interfaces will be developed:

- Synchronization of the SCADA measurement points and related measurement tags.
- Automated import of outage schedules from Outage Management System into TNDB. Powerlink will apply imported outage schedules when doing outage planning;
- Manual import of future load profiles from a spreadsheet. Powerlink manages 10 years load forecast data with 6 seasons per year. The import utility will enable Powerlink to continue to use a spreadsheet view for managing the large amount of load forecast data.

![Figure 3 Proposed Architecture Based on TNdbNET](image)

Other organizations such as NEMMCO require access to Powerlink’s network model. Powerlink will work with these companies and investigate the use of CIM/XML for network model exchange.

In order to satisfy these complex system integration requirements and to provide a robust and unified way to integrate with TNDB, Powerlink will implement TNdbNET .NET Application Programming Interface (API) for TNDB. TNdbNET will wrap the low level vendor API calls and expose the compound objects for easy access and use by other Powerlink applications. TNdbNET will abstract all vendor specific calls ensuring that the upgrade to the commercial software does not affect the other applications interfacing to TNDB.

TNdbAPI will provide the foundation for traditional Windows custom applications, web browser thin client applications or implementation of web services to support CIM/XML data exchange between TNDB and the external applications.

XIII. DYNAMICS

TNDB will store the dynamic data models for the generating units, synchronous condensers, static var compensators, inter-connectors, load areas and loads including special loads such as braking resistors. The dynamics data will be exported to the planning dynamics stability analysis tool.

The data model will be extended to include the dynamics model definitions including user defined models and model diagrams.

XIV. WEB VIEWER APPLICATION

Not all users in Powerlink require full functional access to TNDB. Many corporate users require read only access to the network diagrams and plant data for interrogation purposes only. Web Viewer functionality will be included to provide Powerlink users general read only access to TNDB and reporting functions where required.

XV. MIGRATION OF EXISTING DATA

TNDB will provide a central repository for the network model data currently kept in a number of legacy systems. The following existing data will be migrated:

- Current network baseline and future network model data from GridDB, AM/FM database,
- Plant and line ratings from Ratings DB,
- Plant and feeder names from Network Plant Register (NPR),
- Dynamics models.

The existing data is merged and mapped to CIM/XML. Vendor supplied CIM/XML import utility is being used for importing the data.

One of the major challenges of the migration has been the successful transfer of future projects currently stored in the GridDB database to the new structures required by the vendor database. The current approach is to auto-generate incremental CIM/XML that contains the add/delete/modify changes required for each project.

The migration of the schematic diagrams from GridDB could not be fully automated and some manual work in adjusting the diagrams’ layout will be required. The amount of manual work is greatly reduced by migrating object coordinates for the individual bus sections and connectivity nodes from the GridDB AM/FM database.

XVI. VENDOR SCHEMA ENHANCEMENTS

In performing the analysis of the migration and also the
requirements of the TNDB project many required enhancements to the vendor schema were identified. The major schema enhancements proposed as part of this project include:

1. Transformation of the CIM model to a temporal model where all objects are tagged with birth and death dates,
2. Representation of future projects and multiple versions of project phases in the CIM to facilitate entry of planned projects and phases,
3. Enhanced transformer models with correct representation of phasing, earthing connection and vector groups for zero sequence fault calculations;
4. Representation of mutual coupling between adjacent transmission circuits,
5. Enhanced representation of generator dynamic models; incorporating data to support the advanced exciter and stabilizer models for small signal stability studies and the transient stability program,
6. Provision for user defined attributes for objects.

Some of these schema changes will be submitted for consideration as enhancements to the CIM standard model.

**XVII. BENEFITS OF THE TNDB PROJECT**

The following benefits have been identified from this implementation:

- Improved data quality,
- Reduction in data maintenance costs achieved by establishing a single, controlled data repository for the current and future network models for use by EMS, Planning and Protection;
- Savings in development and maintenance costs of associated corporate applications;
- Significant application lifecycle cost savings derived by migrating from a custom internal application to a fully supported, industry standard product maintained by a major vendor.

**XVIII. CONCLUSIONS**

This project represents a major transition of the CIM technology and the vendor product:

- the CIM as an enterprise network database backbone,
- capability to store and maintain future projects,
- full representation of sequence models and dynamic data in the CIM,
- API interfaces from existing corporate applications,
- Export via incremental CIM/XML to the EMS.

The TNDB project allows the maintenance of the data corresponding to planned future projects in a single central database, eliminating the multitude of powerflow case files that are currently used within the organization.

**XIX. ACKNOWLEDGMENT**

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**XX. REFERENCES**


**XXI. BIOGRAPHIES**

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