ELECTRIC POWER RESEARCH INSTITUTE

Leading Practices of Network Model Management

An Exploration of the Current State and Future Direction of Transmission Network Model Data Management

2018 TECHNICAL REPORT

Leading Practices of Network Model Management

An Exploration of the Current State and Future Direction of Transmission Network Model Data Management

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Abstract

At utilities, a wide variety of network model-based applications are used in support of reliable, safe, and efficient transmission system operation. These applications include those used for real-time grid operation, expansion and generator interconnect planning, outage studies, electricity market operation, protection system design, and training. These applications are implemented locally by utilities and at the regional, national, and interconnection level by utilities, independent system operators (ISOs), regional transmission operators (RTOs), transmission system operators (TSOs), reliability coordinators (RCs), market operators, and similar organizations worldwide.

Applications at each of these organizations require a model of the transmission system, typically in the application's own structure and format. The single transmission grid thus ends up being represented by hundreds of models maintained by dozens of working groups across multiple entities. Engineers often spend significant amounts of time entering, synchronizing, validating, and correcting information, which is inefficient and creates grid reliability and financial risk as well. Transmission entities are aware of these inefficiencies and risks, and many are eager to take steps to mitigate them.

This white paper will share the experience EPRI has gained working with leading organizations in this space. It will use that experience to summarize how a utility or ISO might address the problems commonly found in the network model data management domain and how vendors and standards development communities are making this the right time to initiate an improvement effort.

Keywords
Network model manager (NMM)
Common Information Model (CIM)
Integrated network model management (INMM)
Data management
Grid operation

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PRIMARY AUDIENCE: Network model managers, transmission planners, system engineers, energy management system support staff

SECONDARY AUDIENCE: Transmission utility information technology staff and executive leadership

KEY RESEARCH QUESTION

How are leading transmission system operators solving the most challenging problems in network model management, and how are vendors responding to their needs?

RESEARCH OVERVIEW

This technical report provides an overview of the most challenging problems faced by the entities responsible for planning, protecting, and operating the electric transmission grid in the area of transmission network model management. It addresses how transmission entities are solving those problems, what the vendor landscape looks like now, and how the landscape is evolving to meet those challenges. For the purposes of this paper, transmission entities include utilities, independent system operators (ISOs), regional transmission operators (RTOs), transmission system operators (TSOs), reliability coordinators (RCs), market operators, and similar organizations worldwide.

KEY FINDINGS

- Transmission entities have similar practices in network model management:
  - Each function that uses network analysis has its own grid representation.
  - Model updates from a variety of sources are entered manually.
  - Operating conditions are translated and entered manually.
- Such similar practices lead to similar problems including the following:
  - Duplicated, manual, error-prone data gathering and entry
  - Long lead times for engineers to create case studies
  - Valuable information trapped inside silos
- Leading organizations are employing a coordinated, enterprise-wide approach to network model management in order to:
  - Eliminate duplicative modeling and tracking
  - Replace low-value data preparation activities with high-value analysis tasks
  - Shorten the response time for studies
  - Provide a single, high-quality picture of the grid shared across applications and organizations
  - Position themselves for deployment of new or enhanced network analysis applications or data analytics tools
- Six viable network model data management tools are available on the market and continue to add new capabilities.

- The Common Information Model (CIM) standard is mature in its support for network analysis data exchange and is actively being extended in the few areas where enhancement is needed.
- The improvement of network model management across a transmission utility enterprise is a major undertaking, requiring significant amounts of executive sponsorship, funding, and technical staff engagement over multiple years. Such improvement also requires a unique combination of technical skill sets spanning engineering, information technology, and project management. Lessons learned from early adopters can be leveraged into a strategy that increases the chance of utility success in implementing a network model management improvement initiative.

WHY THIS MATTERS

EPRI research has shown that transmission entities of all kinds share very common inefficiencies in the area of network model management. Collectively solving these problems and influencing the evolution of the vendor landscape in this critical area can play a major part in reducing a utility's costs and increasing its agility.

HOW TO APPLY RESULTS

This EPRI white paper provides background and guidance on how an interested utility or ISO can approach a network model data management improvement initiative, identify requirements, and produce a request for proposal (RFP).

LEARNING AND ENGAGEMENT OPPORTUNITIES

- EPRI has sponsored a variety of research projects in the area of network model data management over the last five years and continues to focus activities in this area.
- Currently, EPRI's *Integrated Network Model Management* supplemental report is available (3002008646).
- Other opportunities for engagement, including a Network Model Manager (NMM) Interest Group, are being explored with members of multiple EPRI programs.

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Section 1: Introduction

At utilities, a wide variety of network model-based applications are used in support of reliable, safe, and efficient transmission system operation. These applications include those used for real-time grid operation, expansion and generator interconnect planning, outage studies, electricity market operation, protection system design, and training. These applications are implemented locally by utilities and at the regional, national, and interconnection level by utilities, independent system operators (ISOs), regional transmission operators (RTOs), transmission system operators (TSOs), reliability coordinators (RCs), market operators, and similar organizations worldwide (collectively referred to as transmission entities in this paper).

Applications at each of these organizations require a model of the transmission system, typically in application's own structure and format. The single transmission grid thus ends up being represented by hundreds of models maintained by dozens of working groups across multiple entities. Engineers often spend significant amounts of time entering, synchronizing, validating, and correcting information instead of executing their core business function.

This distributed, uncoordinated approach to network model data management is inefficient, and its manual, unsynchronized nature creates grid reliability and financial risk as well. Transmission entities are aware of these inefficiencies and risks, and many are eager to take steps to mitigate them.

This white paper will share the experience EPRI has gained working with leading organizations in this space. It will use that experience to summarize how a utility or ISO might address the problems commonly found in a network model data management domain and how vendors and standards development communities are making this the right time to initiate an improvement effort.

Section 2: The Problem

Historically, transmission entities have been separated into operations and planning silos. Network analysis tools have mirrored that separation with different data formats and management tools. In the mid-1990s, protection engineering tools and energy markets increased the scope of the problem and the importance of accurate and consistent network models. More recently, legislation and business practice changes in both the USA and Europe have required tighter coordination between transmission entities across increasingly large geographic areas. Now we are seeing the advent of new resource types: demand response, storage, solar, wind at distributed and utility scale, which bring new owners, operators and market participants into the picture. Each of these new developments requires new data exchanges and new modeling techniques. In addition, the changes caused by these new developments occur much more quickly than was typical with old style central power generation causing the need for more varied and more frequent network analysis studies.

The increasing size, complexity and speed of change have highlighted the cost and ungainliness of the numerous model creation and exchange processes in place at transmission entities today. In a typical utility there are a variety of data sources for model information. Each of these is accessed separately by each of the model creation functions and data is transferred manually, coordinated (or not) by a matrix of personal connections. The core consumers of network model data include Transmission Planning, Protection Systems, Outage Analysis, State Estimation, Contingency Analysis, Voltage and Dynamic Stability Analysis, Congestion Revenue and Energy markets. In addition, many related functions require the same equipment information even if they're not interested in the connectivity.

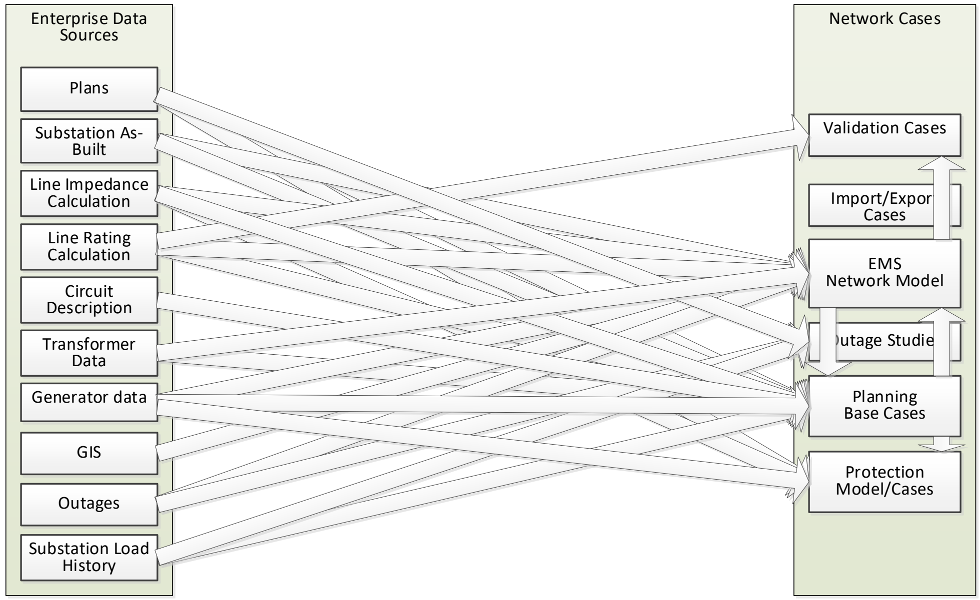

Figure 2-1
Existing Data Flows at a Typical Utility/ISO

Section 3: The Vision

The long-term vision is a coordinated network model data management capability that consists of process, people and technology to effectively gather, manage and exchange high quality network model data to every interested internal and external consumer. The capability will be delivered by a combination of well-defined processes, seasoned network modelers, and a robust, feature rich network model data management tool supported by the IEC CIM data exchange standards.

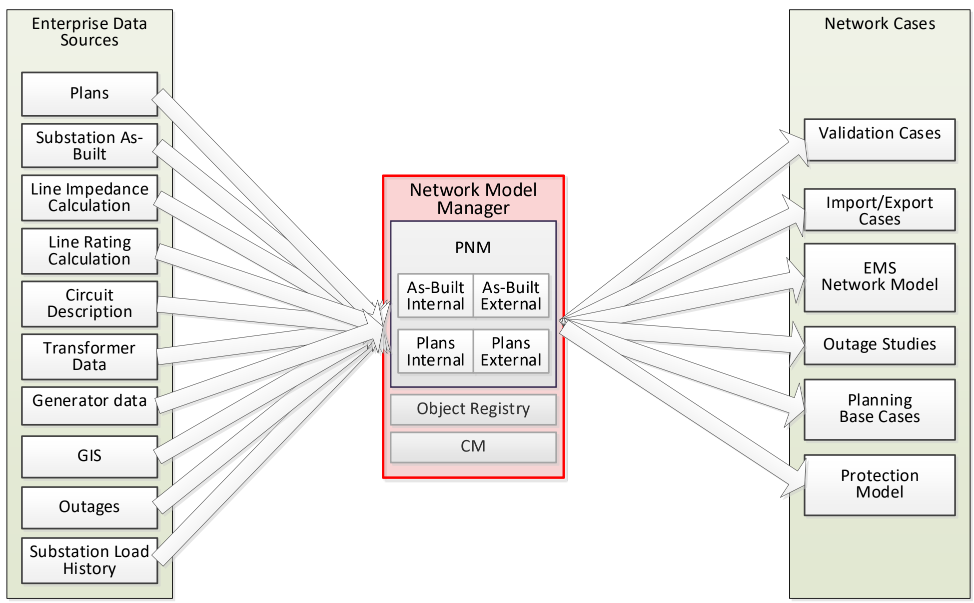

Figure 3-1
Data Flow with Model Data Manager

Process

A well-functioning capability will be driven by carefully defined business processes with clear boundaries and handoffs. Separating the network model data management process from the power flow functions will make both areas much simpler and more efficient. Further differentiating the data management process into separate master model data maintenance and case assembly functions allows tasks to be accomplished by the most capable party.

People

A crucial pillar of any capability is the people who deliver it. While the network model data management capability will be centralized, the people need not be. The capability should have a responsible business owner and application support but the contributors to the data management processes could be distributed throughout the organization and even outside the organization e.g. for interactions between transmission entities. What is key is to establish data responsibility at the granularity necessary to remove ambiguity.

Technology

A robust, feature-rich network model data management tool is required to support the network model data management vision outlined above. Section 4: below details EPRI research into the functionality required and how such applications may evolve to meet future needs.

Section 4: The Network Model Manager

EPRI's report entitled Network Model Manager Technical Market Requirements: The Transmission Perspective outlined the major requirements that a Network Model Manager (NMM) should fulfill to implement the NMM vision. They fall into five main categories:

- The master data repository which provides a single source of truth for network model data for the enterprise
- Multi-User Workspaces & Navigating Model Data where multiple users concurrently perform a variety of model maintenance and case assembly tasks
- Maintaining Master Data, the basic information from which the network model needs of all consumers can be satisfied
- Building Analytical Models for External Consumers, where detailed data is processed and assembled into a form appropriate for specific network model consumers
- Extensibility, which allows the NMM to be seamlessly extended to support different configurations and new types of data

Additional detail on each of the requirement groups is given below.

The Master Data Repository

At its core, the NMM strategy is to serve all network modeling users from a shared repository of network model data. An NMM is therefore expected to support a repository with the following key design elements:

- The territory being modeled may be divided into a 'network model framework' of non-overlapping geographic regions according to principles established in CIM standards. This serves two purposes:
  - Modeling separated according to its logical model authority. E.g. each TSO, is a separate part.
  - Analytical cases with different coverage can be assembled by identifying the geographic regions that are to be included.
- The representation of each model part covers past, present and future as follows:
  - A base version of each model part represents the complete current state of its territory.

  - Older versions of the base model part are retained for reproducing past states of the grid.
  - Future hypothetical model states are supported by 'projects', which are descriptions of proposed changes.
- An Object Registry
  - Object identity mapping across applications.

An important effect of the master data repository is to divide NMM business processes into those that maintain master model data and those that use master model data to produce assemblies to be provided to consumers.

Multi-User Workspaces & Navigating Model Data

The NMM must support independent activity by multiple users, so each user must have the ability to view and work with a different collection of model parts and projects. Each user can direct the system to initialize its workspace with a selected 'assembly' of the network – in other words, a selected set of model parts and projects appropriate for the user's purpose.

The NMM will provide an effective user interface for navigating an assembly. This will include typical presentations for large data structures, such as hierarchies of objects, filterable tables of objects, detailed object property sheets and navigation via associations. It must also include specialized schematic presentations of the electrical grid, with auto-generation of schematic layouts.

Maintaining Master Data

The set of model parts and projects in an NMM will consist of those that are locally maintained by users of that NMM and those that are derived or imported.

Locally mastered model parts are maintained by editing a workspace assembly to produce projects that represent changes. If the project represents real proposed work, it is typically created when new work is being planned and will remain as an NMM project as it proceeds through various stages of engineering design and implementation. A different and more highly authorized user will be responsible for incorporating the project into an update of the base model part.

An important alternative to manual editing is for NMM to integrate with engineering design sources, such as GIS-based transmission line or feeder information sources. These integrations are actively being discussed and have already expanded our view of NMM. For example, we now believe that NMM data schema should support more detailed modeling that allows NMM to compute circuit loading limits and to compute line impedance models from line construction information.

It is also possible to create a model part that is derived from other model parts using a set of rules executed by the application. A common example of this is a simplified, equivalent representation of a neighboring geographic region.

Model parts that are maintained elsewhere can also be imported into the application for incorporation into new models.

Building Network Models for External Consumers

In its simplest form, the data supplied to a consumer of a network model is the result of a) initializing the workspace with the correct model parts, as previously described, and b) exporting the result formatted according to the CIM standard.

Unfortunately, most real processes require additional functionality. Users need to be able to invoke other operations beside the basic 'load model part or project into workspace'. These might include:

- Running validation logic to check for modeling problems.
- Running network equivalencing logic to create a simplified model.
- Dynamic reduction of lower-voltage parts into load.
- Running a topology processor to create a bus/branch model from a node/breaker.
- Defining power flow hypothesis like switch position or load profiles.
- Running power flow to check convergence properties.

The NMM must support scripts that automate common processes, such as 'build a summer peak case for year xxxx'. These scripts must be able execute any of the installed NMM operations and must be capable of being parameter driven.

A case must maintain an audit trail of the operations performed to create the case, including the version of each model part and project used.

Extensibility

In addition to the data management functionality described in the foregoing, there are very important requirements dealing with the NMM software architecture. NMM fails if it cannot be easily extended to provide new kinds of information for new kinds of analytical requirements. It also fails if it cannot be integrated in a cost-effective way with other systems and adapt those integrations over time as those partners evolve. The following are particularly important:

- The NMM must have the ability to be extended with new equipment types and attributes without requiring revision of the NMM software. NMM customers should be able to make schema changes without help from their NMM vendors.
- This NMM should have the ability to extend its interfaces so that it can exchange new datatypes and attributes with other applications.
- The NMM must support a strategy for incorporating new versions of the IEC CIM without losing any previous datatype or attribute enhancements.

Section 5: Leading Practices

Leading transmission entities recognize the duplicative, error prone and low-value work that each network analysis modeling group must perform before they can execute the high value work of power system simulation and analysis. Furthermore, they have identified inconsistencies between planning, operational, protection, and financial models as a significant risk to their organizations. At the very least, inconsistencies between simulation and operational results (often between transmission and market operators) require investigation and explanation. The highly qualified engineers currently performing this work can be better utilized in the much higher value work of executing the engineering studies that underlie effective grid planning, protection, and operation.

Leading organizations are seeing the value of a coordinated network model data management capability enabled by a dedicated network model data management application. Over the last ten years, several organizations have implemented such solutions.

ERCOT

The Electric Reliability Council of Texas (ERCOT), is a notable case in which the solution scope covered both regional coordination of members and intra-ERCOT unification around a centralized baseline model. The ERCOT solution is based on CIM and has been successfully supporting planning, operations and market processes for several years. One of the interesting features is that the model manager is available to member utilities so that they can take advantage of the model change process directly. This is especially useful for smaller utilities that may not have their own modeling capability.

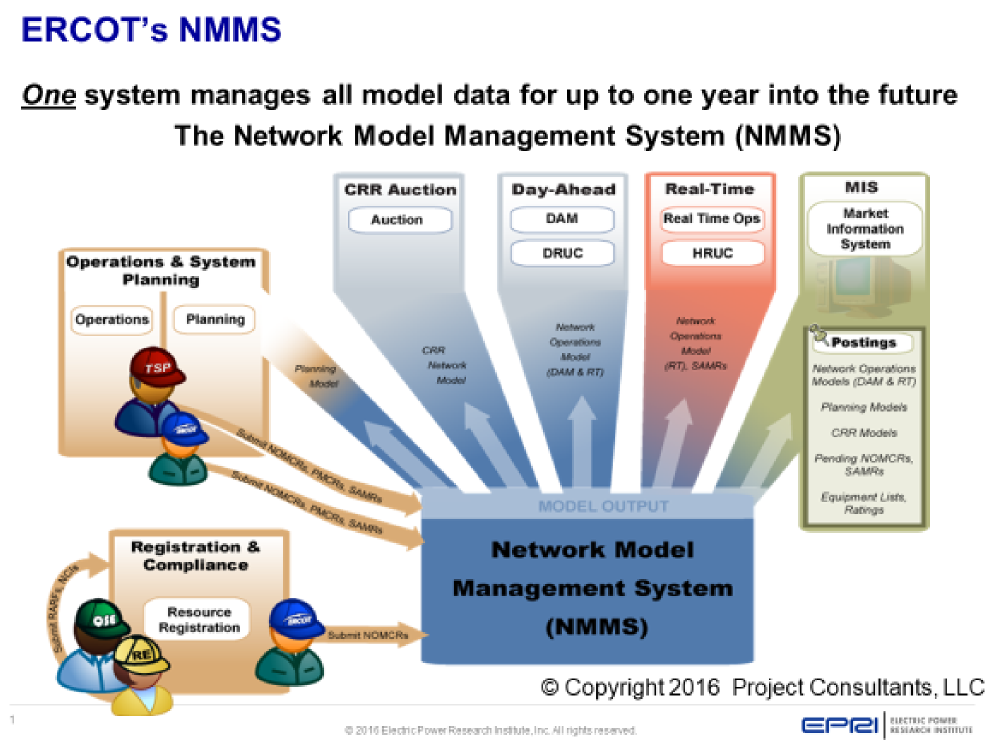

Figure 5-1
ERCOT Centralized Model Data Management

ENTSO-E

The European Network of Transmission System Operators for Electricity (ENTSO-E) has developed a very advanced implementation of regional coordination modeling using CIM. Each member TSO provides the model for its region as a model part that is coordinated with the neighboring TSOs via an agreed upon set of boundary equipment. In this way ENTSO-E is able to automatically assemble model updates from 43 TSOs covering 36 countries.

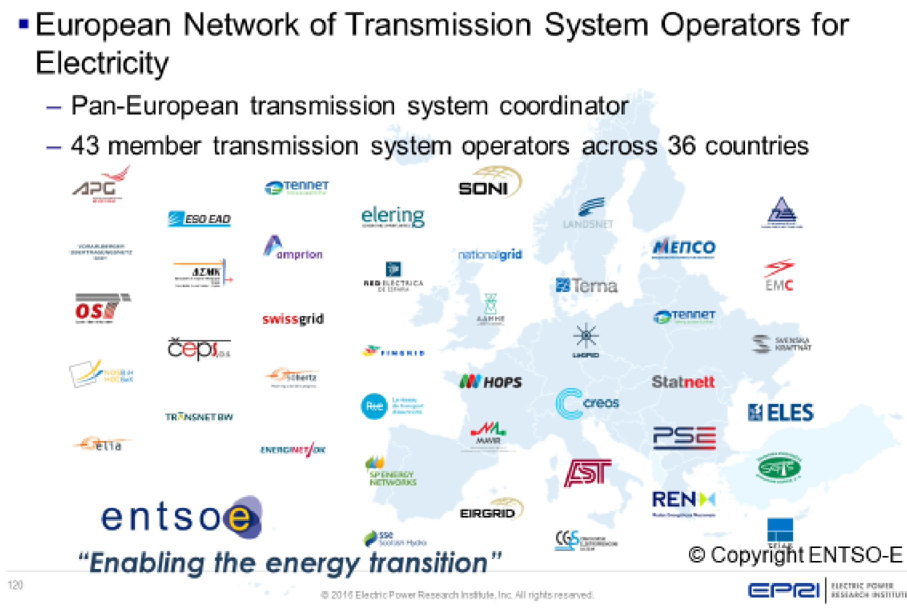

Figure 5-2
ENTSO-E's Common Grid Model Exchange Standard (CGMES)

AEP

With its T-Nexus project, American Electric Power (AEP) is currently applying CIM for a cross Transmission Operator re-organization of information flow, culminating several years of collaborative work with EPRI on several NMM-focused EPRI projects. AEP is the first to automate the exchange of input data from the engineering design systems.

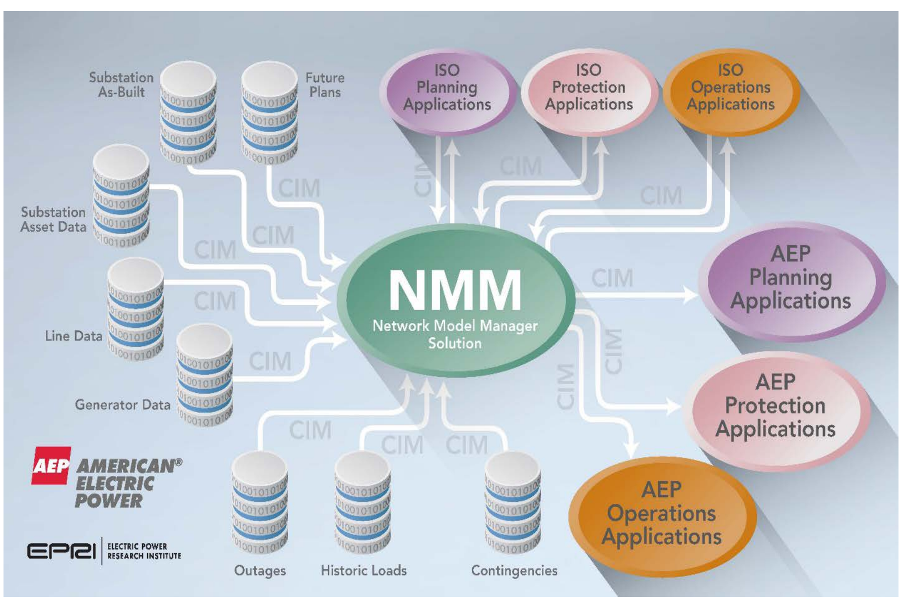

Figure 5-3
AEP's Network Model Manager Solution

Section 6: Vendor Landscape

There are at least six vendors (as of mid-2018) that provide stand-alone model management systems. The vendors and their products identified by EPRI so far are:

- DigSILENT PowerFactory
- GE e-Terrasource
- Siemens ODMS and IMM
- Open Grid Systems CIMphony
- PowerInfo CIMDesk/M3
- IPS INMM

No NMM application yet meets all of the requirements outlined in Section 4 above, but all the listed tools offer a basic set of functions on which a utility could start to build an NMM solution. To provide the reader with a sense of the general maturity of the listed products, some observations can be made about the overall patterns of functionality available from NMM tools. The vast majority of the tools support the definition of master data in a CIM-like structure with the ability to group data into model parts maintained by a logical model authority. A small number support the definition of boundaries. Most support versioning of models or model parts and nearly all support the notion of 'projects' describing incremental changes to the grid over time. All have individual workspaces and schematic-based data viewing and editing and nearly all have some sort of auto-generation feature. The ability to assemble cases from any logical combination of model parts and projects is very common. Sophisticated work process support (notifications, access via user roles) is less common though present in some tools. Import and export of CIM-based models is universal. Interfacing with engineering design applications, that contain construction and material details, is very rare. Simplification functionality, other than topology processing, is not yet well-developed. Many of the NMM applications have built in power flow analysis capability and all have multi-layered data validity checking. The ability to write scripts to automate routine processes is provided by at least half the tools. Support for audit trails is limited. Schema extensibility without vendor assistance is a feature of over half of the NMM products.

It should be noted that this is a very active product space. New vendors are entering the market and existing product functionality is continually being enhanced. Each utility undertaking a network model data management improvement effort should define and prioritize its own requirements for each capability. Furthermore, an organization should understand their own roadmap for model management and identify a vendor that can provide those future capabilities either because they exist or have their roadmap that will enhance their product to meet the need.

Section 7: Standards Support

The CIM standard provides the underlying information model, which both informs and supports the data management philosophies of the NMM approach. The network model portion of the CIM is the oldest and most deployed. It grew out of EPRI work done in the early 1990s on standardizing EMS data interfaces and has been enhanced and extended continuously since then.

Existing CIM Standards for Network Model Data Management

There is a set of core network model data exchange standards that describe various portions of the CIM data model:

- IEC 61970-452 for the physical transmission network model, including short circuit characteristics
- IEC 61968-13 for the physical distribution network model
- IEC 61970-456 for solved power flow results
- IEC 61970-457 for dynamics
- IEC 61970-453 for diagram layout

Areas Where the CIM is Being Enhanced

All current standards are being enhanced on an ongoing basis. In addition, the working groups, which include representation from around the world (and count a number of EPRI staff as members), have identified new areas for standardization. Activities include:

- Inclusion of specifications for network model parts and boundaries frameworksin the CIM UML.
- A new IEC 61970-459 standard which will include:
  - Improved profiles for model parts referencing the network model framework information.
  - Profile for exchange of assemblies and constituent model parts.
- A new IEC 61970-460 which will include:
  - Profile for exchange of projects.
- An update to IEC 61970-552 to describe metadata for exchanged models or model parts.

- A special task force coordinating the requirements for standardizing DER facility modeling.
- A special task force coordinating the relationship between IEC 61850 standards for facility design and CIM network models.

The community also continues to enhance CIM for related capabilities e.g. asset management and health.

Section 8: Approach to Moving Forward

Improving the network model data management capability is not so different from other improvement efforts. Define the current situation, identify the biggest pain points or opportunities and implement solutions to address them. However, the network model data management problem is more challenging than most because of the variety of the users, the long history of silos at transmission entities, and the complex nature of network model data. This makes it even more critical to approach the problem holistically, giving equal attention to the business processes as to the technical solution, and to leverage the knowledge gained within previous network model data management initiatives.

The major steps in the process are:

Define the Scope of the Investigation

During the investigation phase it is important to include as much scope as resources allow. Accurately documenting all data sources, consumers and users will allow the project to identify the most valuable targets for improvement. If possible include all users of models and cases, both internal and external.

Engage the Stakeholders

Improved model management at a transmission utility is a cross-workgroup collaborative exercise and active participation by each workgroup responsible for maintaining a network model is truly essential. In many cases this will include external data sources and model consumers. One of the things that make network model data management most challenging is the ingrained differences between the users of grid models. Planning, protection and operations have been separate groups with their own data and tools for decades. The inertia that this creates should not be underestimated. Bringing the teams together in common forums for both the current state definition and solution brainstorming will go a long way toward attaining an understanding of the shared benefits of a centralized approach. The resulting buy-in is critical to the success of the long-term program.

Document the "As-Is"

With assistance from stakeholders, document the data that is used by each of the applications requiring a network model: where the data is sourced, and how and by whom it is gathered, transformed and entered. Carefully define how data is identified, named and exchanged. Identify multiple sources of the same data, they are often separated only by their position in the timeline of the change. Include timing requirements, update triggers and model formats.

Explore the Solution Space

Use the "as-is" data flows to identify problematic areas and uncover requirements. Use business scenarios (or use cases) to explore what the future might look like. The solution in this case is combining of people, processes and technologies that deliver a capability that solves the biggest problems. It is important at this stage not to constrain the team's potential for transformative ideas with pre-conceived notions or decisions. Utilizing an external experienced facilitator with domain experience will help. Examples of scenarios or use cases can be found in the Case Study on Network Model Management Solution Design [5].

Define the "to-be" Architecture

Define a "to-be" architecture that addresses the most problematic areas. This will represent the desired end state of a long-term transition. Create and refine artifacts that capture all the concepts necessary to define the desired state covering people, process and technology. These could include organization charts, process models, data flow diagrams (for processes and applications), sequence diagrams and collaboration diagrams.

Define the Implementation Roadmap

Define a roadmap that delivers the long-term solution in small increments. While the increments should be small enough to be successful they should add real value to the organization. As the value becomes apparent to the whole organization the subsequent increments will become easier.

Requirements Definition

Define the requirements for the NMM solution technology. The business scenarios or use cases developed as part of defining the "to-be" architecture can help tease out difficult-to-uncover requirements. EPRI has produced sample requirements for an NMM, including use cases, that can be a guide to defining the organization-specific requirements [2].

Select a Vendor/Partner

Only when the long-term vision and requirements are defined should the vendor selection begin. This is a rapidly evolving market with new vendors and capabilities appearing much more quickly that has been true for the typical utility-focused applications. Each organization should utilize the best available knowledge in this space to provide an up-to-date picture of the vendor landscape. The vendor selection should include comparison of the implementation roadmap with the vendors current capability and plans for the product. This domain is evolving rapidly so it is especially important to select a vendor that can become a partner in the journey. To accelerate the Request for Proposal (FRP) process, EPRI has provided a sample RFP [3].

Launch the First Phase

Adjust the roadmap and first implementation plan to coincide with the strengths, weaknesses and product roadmap of the chosen vendor. Implement the first set of required people, process and technology changes necessary to achieve the initial business value. As much as possible limit the tool and integration changes to the minimum necessary to achieve the desired value. On completion of the first phase use the lessons learned to re-evaluate the roadmap and future implementation plans and adjust as necessary for the next phase.

Section 9: Conclusion

The rapid evolution of consumer and grid technologies and the changing regulatory environment have placed increased focus on cost-reduction and agility at transmission entities across the world. Transmission entities have identified network model data management as an area that is key to several areas of utility operations and is a prime target for efficiency and data quality improvement. At the same time new vendors are joining the larger players in producing stand-alone network model data management applications to solve many of the model-related data management problems. Their work has been enhanced by very active technical working groups at the IEC that continue to produce new and enhanced standardized interfaces that enable the integration of these stand-alone systems with many kinds of consuming systems.

There is a groundswell of interest at transmission entities in optimizing the area of network model data management and exchange, with the understanding that this is the right time to take advantage of new products and to influence the direction of the vendor and standards communities to address the shared problems of the industry.

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