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T-NEXUS
The AEP Enterprise Model Management Integrated Solution

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SUMMARY
Utilities today maintain many applications that rely on electrical system network models. This entails multiple systems and databases that require the same data and the activities to generate or update data for these systems are repeated by each department independently. Engineers often spend significant amounts of time entering, synchronizing, validating, and correcting duplicate information. The current maintenance approach leads to process inefficiencies and data inconsistencies that can have adverse effects, both in terms of reliability and cost.

The concept of a Network Model Manager that uses the Common Information Model (CIM) is the foundation to provide a single repository to house a coordinated network model for departments across the utility enterprise. The growing reliance on network analysis, the advent of new regulatory requirements related to model validation and the need for network model sharing between transmission applications, has made the management of transmission network models a required fact of life in utilities and RTOs.

This paper describes the continuing work by AEP to implement an enterprise wide network model manager known as T-Nexus. It allows the exchange of data from multiple sources and produce models and cases for transmission enterprise applications. The primary purpose of T-NEXUS is to manage the models within the AEP Operations, Planning, Protection and Asset Management domains, and gain qualitative benefits across all AEP Transmission footprints.

CIM-based consolidated network model manager and CIM-based integration tools and techniques are used to facilitate systems integration and data exchange required to increase the productivity of the transmission functions at AEP. The goals of T-NEXUS include:

- Unification of the modeling processes across the AEP transmission footprints
- Reduction of manual efforts required to map data between applications
- Improvement of data governance
- Implementation of clear information flows through the AEP transmission organization
- Ability to implement data analytics

During the course of the work, AEP expects to gain the following program benefits:

- Improved efficiencies and reduction in operating costs through the elimination of existing duplicate processes, applications and increased automation.
- Improved overall accuracy of network models
- Reduced likelihood of serious operating / planning errors stemming from incorrect models
- Reduced time required to perform or update studies, which will allow support for post-event analysis
- Tracking of model changes to enable the recreation of cases after changes
- Positions AEP to effectively deal with future process or application changes

KEYWORDS
Network model management
Common Information Model (CIM)
Operations and Planning models
T-NEXUS
Enterprise Integration

BACKGROUND

Beginning in the 1960s, enabled by digital computing platforms and sparse matrix methods, network analysis tools started being used in the planning domain. In the late 70s, driven in part by fallout from the 1965 Northeast blackout, utilities began to add network analysis capability to their transmission control center applications. The 1980s saw the emergence of protection tools. The 1990s brought deregulation and network analysis functions implemented in market systems.

Throughout this history, as new network applications were deployed at utilities, new silos developed. Each application had its independent users, its independent model maintenance group and its individual modeling processes and assumptions. Silos were, and continue to be, technical and organizational, resulting in the lack of coordination reflected in a typical network model data management picture. The network model information flows come from a variety of sources in a variety of forms and go to a number of target systems that are inconsistently triggered by a variety of events.

In 2013, EPRI started an initiative to define what an integrated network model management system might look like and AEP participated in this initial effort. The initiative looked at AEP transmission operations, documented the existing information flows, and defined an initial Network Model Manager (NMM) Vision. This resulted in an EPRI report entitled "Guide to Exploring Centralized Network Model Management". A follow-on EPRI project then developed the NMM tool functional requirements, and this was documented in the EPRI report entitled "Network Model Manager Technical Market Requirements".

Based on these efforts, AEP launched the T-NEXUS program in 2015. The primary technical drivers included:

- Ability to execute all engineering studies from the same core data building blocks.
- Ensure all grid elements (like transformers) are represented in the same way in every study.
- Development of consistent practices across AEP units in ERCOT, SPP and PJM.

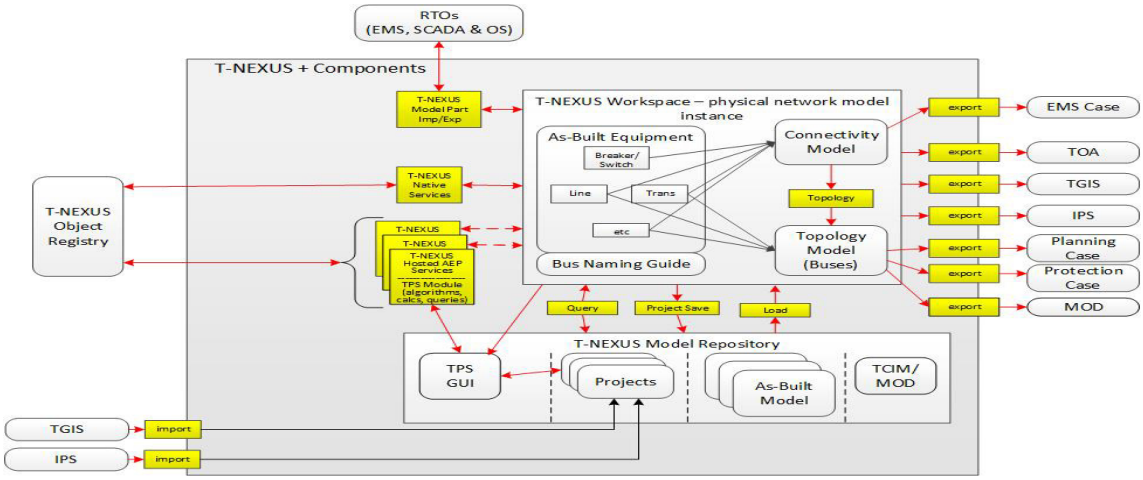
The T-NEXUS program would result in an NMM system that would combine the model maintenance efforts of the Operations, and Planning and Protection business departments. In 2016 the program completed the initiation with the following achievements:

- Charter, stakeholder identification, groups and roles definitions
- Executive approval
- Consultants selected/engaged
- Completion of exploration/documentation of AEP current state
- Articulation of high-level design via Business Scenarios
- Technical training (Common Information Model and integration)
- Product/vendor selection completed

T-NEXUS FUNCTIONAL OVERVIEW

As envisioned by the project, T-NEXUS plays a central role in network model management. Its purpose is to maintain the master data components that are shared by network analysis, analytical applications and other utility software requiring grid equipment and connectivity information. T-NEXUS is the central vehicle for consolidating model data and automating network model management. A nominal functional overview of T-NEXUS is given below.

The T-NEXUS Object Registry module will manage the names of all network modeling objects in different contexts and from different applications.



T-NEXUS Functional Block Diagram

The TGIS import component (shown on the lower left) provides data related to circuits, locations, structures, spans, etc. CIM extensions are required for this import. The IPS import component provides data related to asset information and, again, CIM extensions are required for this import. TGIS and IPS data will be imported into the T-NEXUS model repository in the form of projects. The Transmission Planning teams will access this information from an existing project or create a new project in their workspaces.

The Transmission Planning department is in charge of generating the ratings and impedances for the devices within the network model. This is accomplished using the Transmission Planning Solution (TPS) component within T-NEXUS. Projects will be generated and pulled into the T_NEXUS project repository using data entered via the TPS GUI (shown in the lower part of the T-NEXUS block on the diagram) or from the Asset and GIS models. The TPS module is the calculation engine that houses all the algorithms to perform the line constants calculations and the impedance and MLSE/limits calculations. The calculated values are then stored in the T-NEXUS database for use by the network analysis modules.

Users of T-NEXUS will be able to create or update projects in the workspaces provided. Users will have access to the pertinent data imports. Planning, Protection and Operations users will be able to validate projects by validating models within their workspaces. When a project is complete the users will save the project in the T-NEXUS Project Repository (shown as Projects in the T-NEXUS Model Repository in the diagram) to be handed off to the next user group or baselined into the next As-Built model.

Once a project is handed off to the Operations team, appropriate detail is added to the project for use in a new As-Built model. Planning users will be able to take the breaker/node As-Built model from the model repository and convert it to back to a bus/branch model within their workspace and use this as the basis to add new projects.

The T-NEXUS team will use the baselined As-Built model to generate cases or models for the consuming systems (like EMS, TOA, TGIS, IPS Planning, Protection, or MOD shown on the right side of the diagram). Approved outages are then received from TOA (the Outage Scheduler) and used by Operations and Planning engineers in the network study cases.

The Exported Data <u>(shown on the right side of the diagram)</u>
To support the importing and exporting of models into the T-NEXUS environment, the CIM UML model will be extended and an AEP-specific CIM semantic model, based on CIM16 will be created.

The CIM export for the breaker/node model is an EMS Case, which becomes part of the operations As-Built model. The CIM export for TOA will include breaker/node Connectivity information, from the Operations team.

The CIM export to TGIS will include substations, circuits, and branches. The CIM export to IPS will include the connectivity model. The CIM export to Planning with be the updated planning case in the bus/branch model format. The CIM export to Protection will be the updated protection case in the bus/branch model format. The CIM export to the RTO's from Transmission Planning, is a Model-On-Demand (MOD) file that consists of modeling data, requirements and reporting procedures for Transmission planned cases. The export to the RTO's from the Operations team are the incremental changes to the operations breaker/node model for the changes that are approved for implementation in the future.

IMPLEMENTING THE FIRST DEPLOYMENT OF T-NEXUS

The T-NEXUS program contains 3 major deployments:

1) Planning department – This is the first deployment and provides the initial load of the system with a breaker/node model, alignment of the operations and planning model and a system to track planning projects and cases for new and updated construction.
2) Operations department – This is the second deployment and will provide the functionality for the Operations team to create and update projects for the As-Built model.
3) Protection department – This is the third deployment and will allow the Protection team to generate projects and cases.

To implement the T-NEXUS system, AEP is using a CIM-based integration approach and tools. The network model manager product selected for the T-NEXUS implementation is fully compliant to the CIM standard and can import and export (i.e.- exchange) all data in the CIM XML format. CIM-based integration services are used by T-NEXUS to perform the bulk of integrations with other systems using the IEC CIM model exchange standards. All IEC CIM information modeling and profiling methods are deployed with T-NEXUS to ensure that the integration with other systems is achieved with minimal time and cost. Specifically, T-NEXUS will have interfaces with ASPEN, PSS/E, MOD, IPS-Energy IPS, ERSI-based TGIS and the TOA outage scheduling and logging application from SunNet Consulting.

A current Operations (EMS) model is used to provide the initial load of the network model. The CIM XML connectivity model for the base equipment is exported from the EMS model and imported into T-NEXUS. The remaining data from the EMS native XML export is extracted and converted to CIM Incremental files for import into T-NEXUS. Once the model is prepared and ready to distribute, T-NEXUS uses CIM profiles to generate export files in CIM XML format, base case format, or CIM incremental format. These exchange files may be received by T-NEXUS or sent from T-NEXUS to the AEP external systems.

Initial exchanges are being identified by the implementation teams and mapped to the IEC CIM. If needed, CIM extensions will be added to the T-NEXUS schema, and CIM Adapters/Converters will be generated to import or export the data to the external systems.

T-NEXUS integrates with multiple source and consumer systems. These systems often impose naming requirements that make it impossible to use a single system of identification for network model objects. In T-NEXUS, the mapping data required to manage transformation between T-NEXUS and other systems is managed in an Object Registry. The Registry has all the names from all systems listed along with a single, unique and persistent identifier. When new data is entered into T-NEXUS, the object is registered and stored in the Object Registry. T-NEXUS also allows other systems to read from the Registry to obtain the correct unique, persistent ID for use in their systems. The systems may also enter new entries into the Object Registry as needed to maintain a full set of names and IDs between the systems.

OPERATIONS-PLANNING ALIGNMENT

A stated AEP objective for the T-NEXUS project is to achieve a position where Operations, Planning and Protection applications are all sharing the same master source data for the physical model of the grid. This requires that the master T-NEXUS data contain a union of all data requirements. The goal is

that, to the greatest degree possible, such data shall not duplicate information. To address this objective, the Operations, Planning and Protection models must be aligned such that the cases for each application can be derived from a single master model.

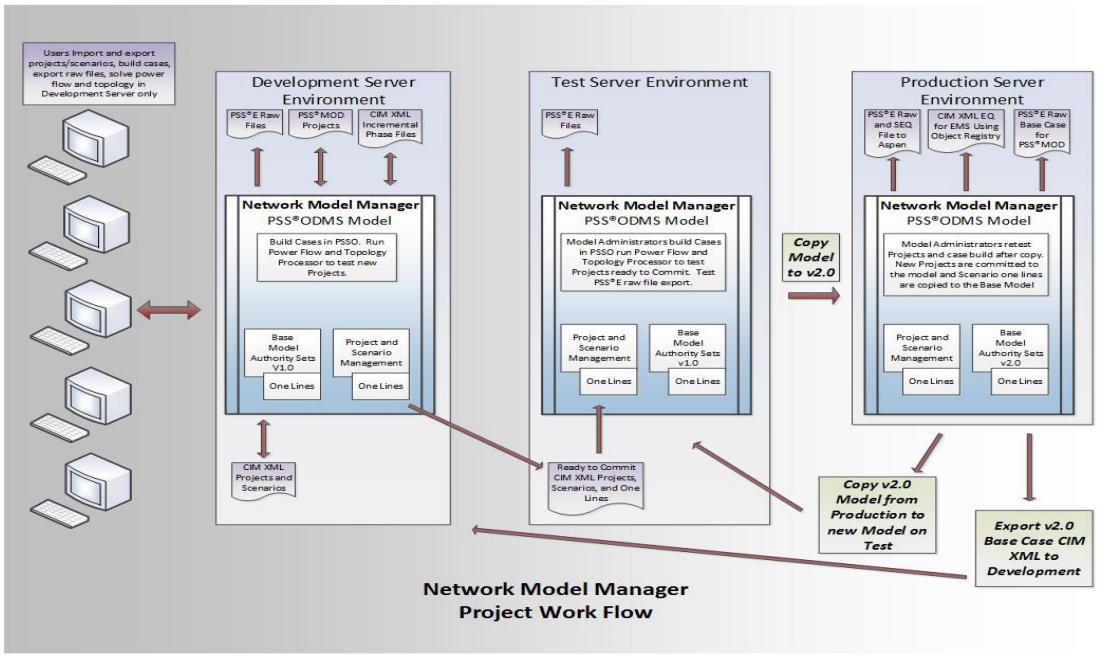
Alignment requires that the Operations and Planning business departments work together to achieve a single model that can be used by all planning and operations users. At a minimum, this will require harmonization of the Operations and Planning modeling guidelines currently utilized by the modelers for each application. As a general principle, T-NEXUS will contain more detail than any single consumer case requires. Based on this philosophy, the following procedure is being used:

1. Build a case using the normal state of the switching devices in the case build options.
2. The topology must be solved at this point. Save the topology back to the model. This will create topological nodes in the model based on the normal state of the switching devices.
3. Generate and export the Bus Mapping Table from T-NEXUS. Alter only the Bus Number Fields to match the bus numbers in the planning base case. Import the updated Bus Mapping Table into T-NEXUS.
4. Build a new case in T-NEXUS, and solve.
5. Create a Planning base case of the T-NEXUS model. This will be the bench mark model.
6. Planning Engineers will compare the T-NEXUS base case to the Planning base case.
7. For any buses incorrectly numbered in the T-NEXUS file, locate the Topological Node for this bus, and type in the bus number in the "Bus Number" attribute, and the bus name in the "Name" attribute.
8. Once all of the mis-identified buses are corrected, build a new case in T-NEXUS and export the Planning file.
9. Repeat steps 1-8 above until all buses are identified and corrected.
10. If additional buses and branches are needed, they should be added to the Operations database. The Operations modelers should be in agreement with this. The purpose is to create one model which works for both organizations.
11. After this process has been completed, the final planning case can be compared to the original planning case to produce a project listing all of the changes which should be made to the RTO Operations models.

T-NEXUS ENVIRONMENTS AND DATA FLOWS

The T-NEXUS system has three main environments; Development, Test, and Production. The Development environment is where all users work to generate projects that will be used to revise and update the master model. The Test environment is used by the T-NEXUS team to test the projects submitted by the users, and validate all input prior to building a new as-built model for release to Production. The Production environment is where the configuration manager stores the baselined models that are released to Operations, Planning, and Protection. The figure below shows the three environments and the data flow of the projects and models generated by the users, and the following paragraph describes the flow between each one.

The left side of the diagram depicts the user community accessing the development server. Each user has their own workspace on the development server and can create copies of the model, create projects to change the model or generate cases and exports from their workspace for use with other systems. Once the user is satisfied with a project and has validated it, they can submit it to the Test environment for further processing and testing. The T-Nexus team will complete visual and programmatic tests to get an initial validation of the project. If there is a problem, the original user that created the project will be notified to correct the problem. If the project passes the first level of inspection, it is released to test. The Power Engineers will then apply the project(s) to the model and run power flow and other tests to further validate the model. Once all validations are complete and the project energization date is reached, the project will be merged into the next release of the As-Built model and promoted to Production for deployment. Once the model is in Production, cases and all other official exports will be created and distributed.



T-NEXUS Environments and Data Flows

REALIZED BENEFITS

The benefits of fully-realized consolidated network model management can be substantial and far-reaching. At this phase of the project, AEP has recognized the following benefits:

- Modeling time is cut substantially as changes are entered only once and all consumer applications receive the same information.
- Model accuracy is improved for all applications. Quality of study results is improved and labor spent identifying/correcting problems is reduced.
- Model maintenance work flow processes are supported. Data completeness and quality are improved and labor spent correcting errors or oversights are reduced.
- Model and case information is produced in CIM standard format, the most recognized data exchange format.
- Ability to support post-event analysis is greatly increased.
- Documentation is improved. Labor spent communicating and managing changes is reduced.

CONCLUSION

T-NEXUS, with its integrated and unified approach to network model management, will reduce engineering labor and increase the accuracy of all AEP full or partial network models. This approach, together with the CIM-based enterprise integration will alleviate the duplication of model entry and maintenance currently required by the silos present in AEP Transmission as well as other TSOs and RTOs today. As of now, AEP is beginning to experience the efficiency and increased productivity of the T-NEXUS system. It is expected that, as the remaining deployments are placed into production, all the goals and benefits will be achieved.

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