Detailed Bus Modeling for Enhanced Power System Representation and Network Model Management (NMM) Implementation

With ConEdison

Team

Consolidated Edison of New York - Con Edison

- Benny Varughese
- Naveen Manikarnika
- George Goddard
- Emerson Iannone

Quanta Technology, LLC

- Jorge Vélez
- Ishwarjot Anand
- Xinyang Dong
- Zaeem Amjad
- Justin Schmidt

Node-Breaker Modeling and Network Model Management Integration

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Node-breaker modeling

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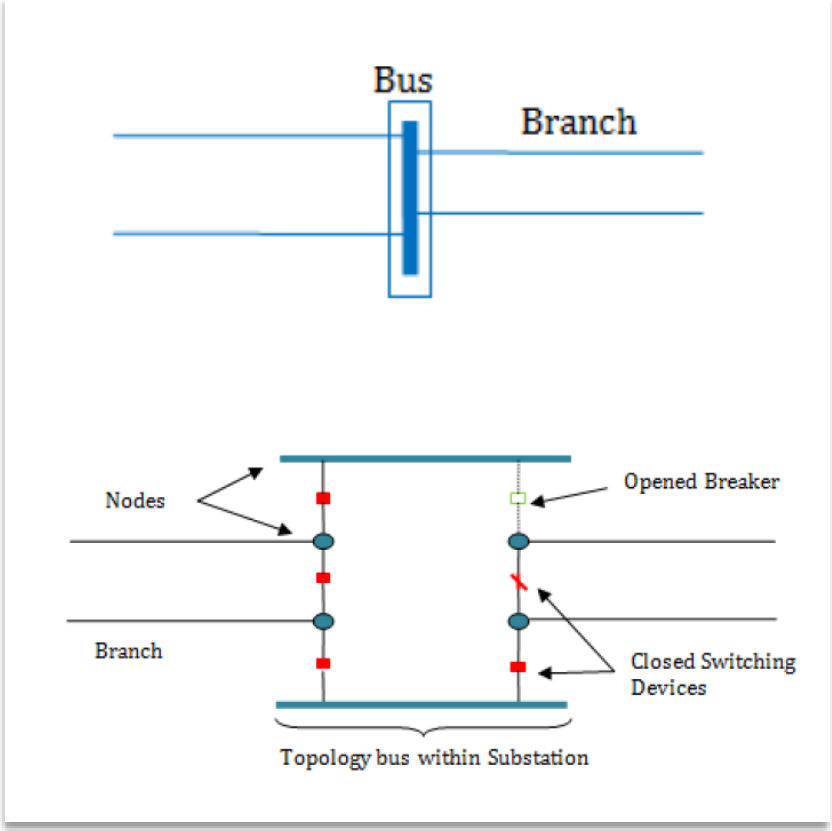
Node-breaker and NMM integration

Node-Breaker Modeling Concept (1/2)

Full representation of substation elements such as breakers, switches, and branches, by individually connecting them via nodes

Objectives:

- **Improve visibility** of substation configuration
- **Simplify simulation** of contingencies such as breaker failure for:
  - Relay settings design
  - Protection coordination assessments
  - Fault analysis
- **Provide a representation** of the system that is consistent with Operations models facilitating Network Model Management implementations

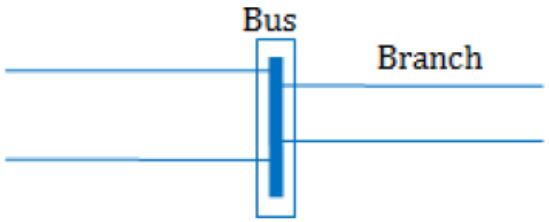


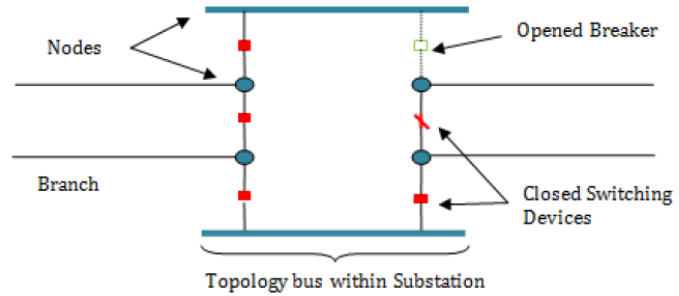
Source: Pictures from PSS®E 34.1 Program Operation Manual

Node-Breaker Modeling Concept (2/2)

Bus-branch vs. node-breaker

- The simplification provided by the **bus-branch modeling** result in some computing efficiency when performing planning simulations
- … but this efficiency is not a considerable benefit nowadays with the available processing capabilities for system studies
- **Node-breaker modeling,** although time consuming at first, is more suitable for model alignment between planning, protection, and operation





Source: Pictures from PSS®E 34.1, Program Operation Manual

Bus-branch model

- Typically used for planning studies
- Contains detailed machine, exciter, governor, and stabilizing models

Node-breaker model

- Typically used for protection studies and real-time system visualization platforms
- Contains relay settings and protection schemes (pilots, BF, etc.)

Node-breaker – Modeling Benefits vs. Challenges

Benefits:

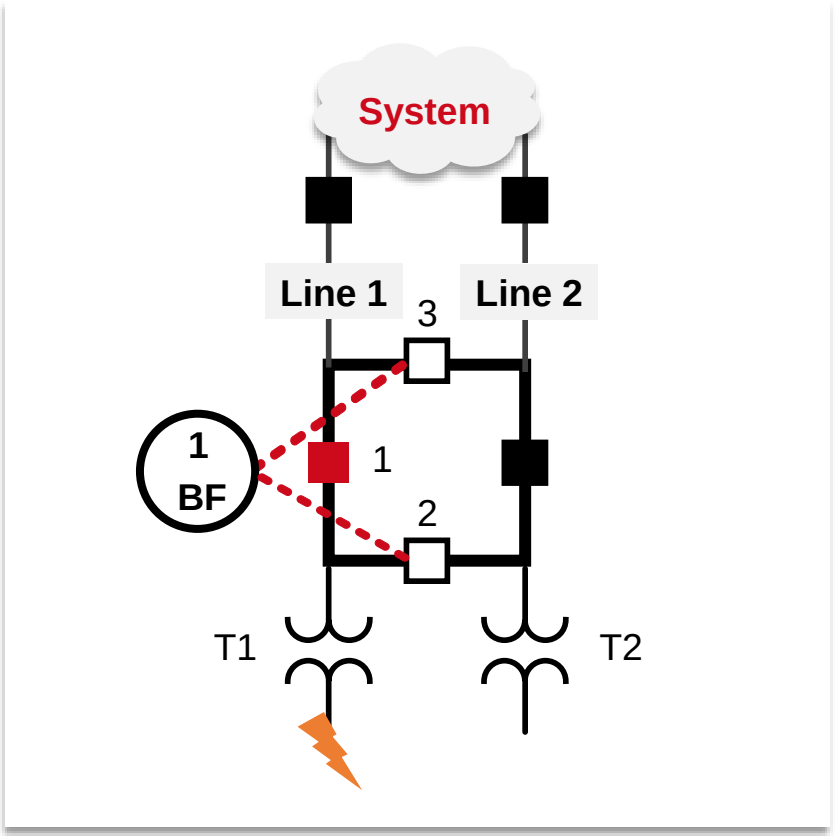
- **Models** the bus structure and protection as it exists in the field
- **Checks** bus differential relay settings for gross setting errors (with the understanding that the bus is a zero-impedance path)
- **Simulates** breaker failure protection behavior of individual breakers in the structure
- **Avoids** the tedious and error-prone task of manually simulate contingencies in a bus-branch topology
- **Facilitates** data alignment with Operation models and Network Model Management platforms

Challenges:

- **Increases** model complexity of the bus due to presence of additional components such as nodes, switches and breakers
    - The display of simulation results on the one-line diagram can get cluttered and necessitate adjusting the spacing between the components of the structure
- **Adds** complications to protection modeling tasks if summation CTs are accounted for
- **Interoperability** with other simulation or Network Model Management platforms require the creation of data adaptors

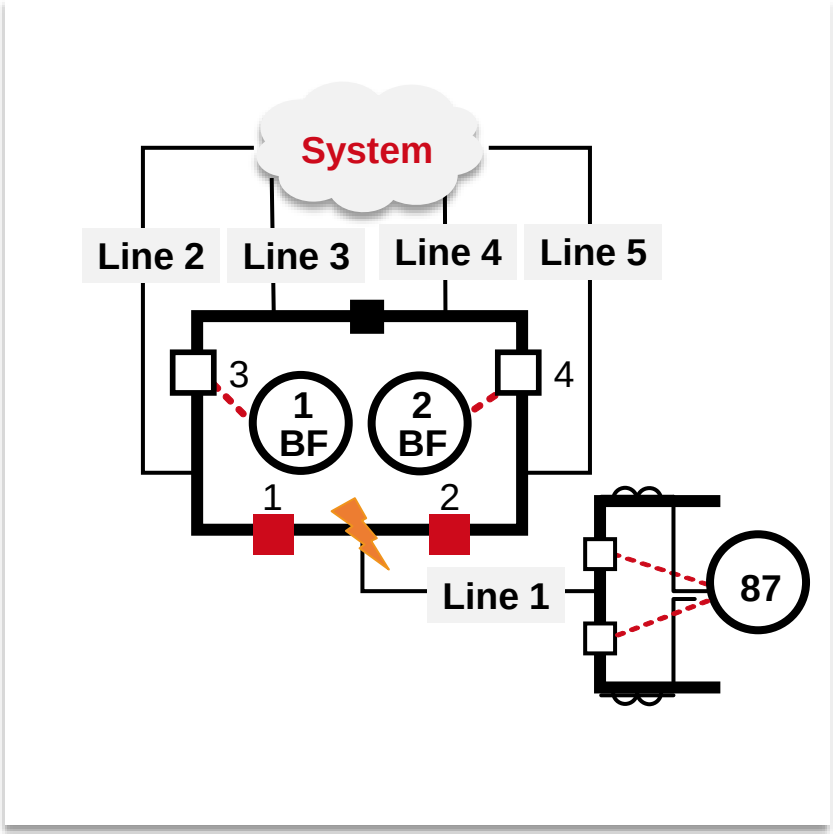
Use Cases of Node-breaker Modeling in Protection Models (1/2)

- A common configuration reflects no dedicated high-side circuit breaker for the transformer
- If no communication is available for breaker failure transfer trip, a large overreach zone may be needed
- Line 1 Zone 3 apparent impedance is affected by splitting the ring
- Zone 3 coverage of low-voltage faults may only be possible after infeed has been removed
- Bus-branch models struggle to model splitting a bus efficiently



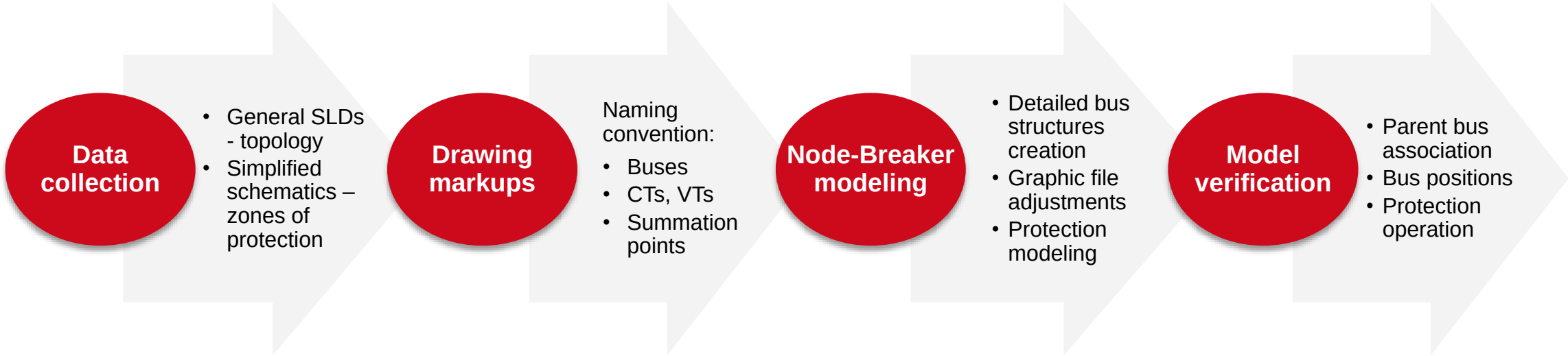
Use Cases of Node-breaker Modeling in Protection Models (2/2)

- TPL-001 P5 control circuit contingency can result in large outages
- Abnormal system configurations can result if multiple breaker failure protections operate
- Splitting buses into multiple sections can be difficult or impossible with bus-branch models
- Planning studies required by TPL-001 P5 will greatly be affected by splitting the ring



Node-Breaker Implementation in Con Edison's System Model (1/5)

100+ substations in 345 kV, 138 kV, 69 kV, 33 kV, 27 kV, and 13 kV



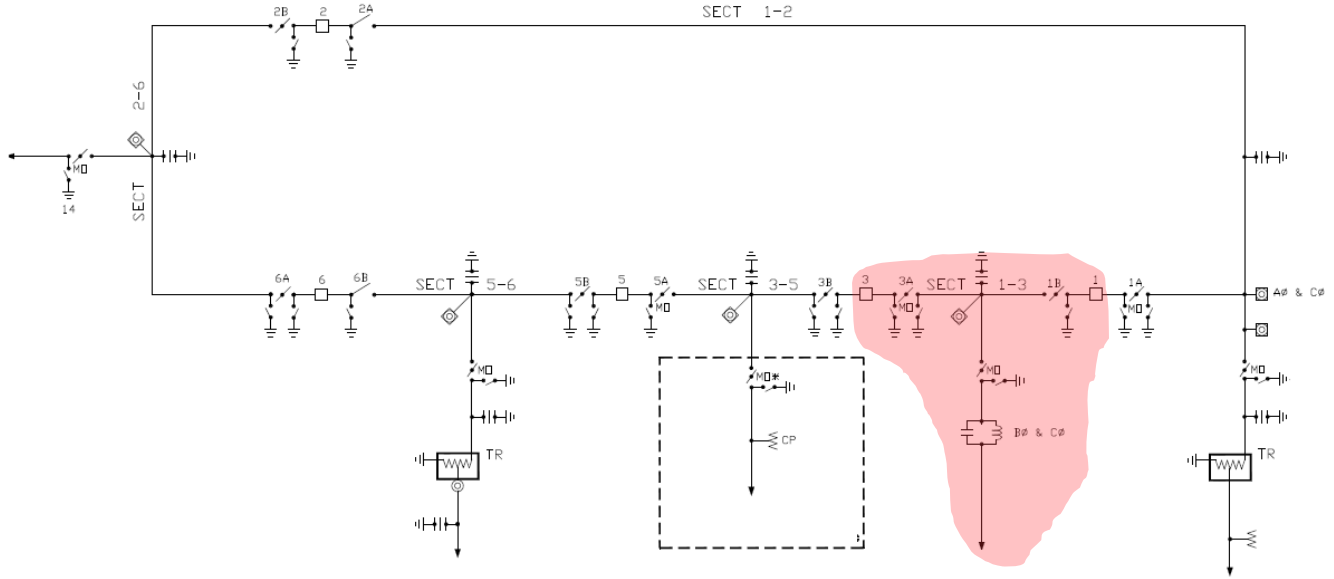
Node-Breaker Implementation in Con Edison's System Model (2/5)

Data collection

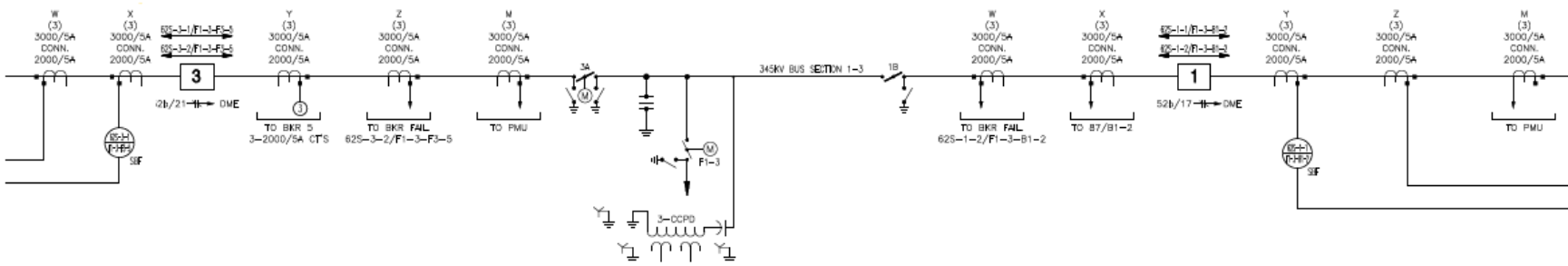
- General SLDs - topology
- Simplified schematics – zones of protection

Data gathering of current versions and field validated drawings

Substation topology – connectivity verification:



Schematic drawings – detailed protection modeling:

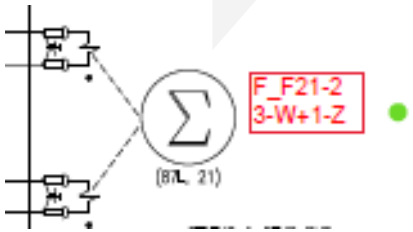


Node-Breaker Implementation in Con Edison's System Model (3/5)

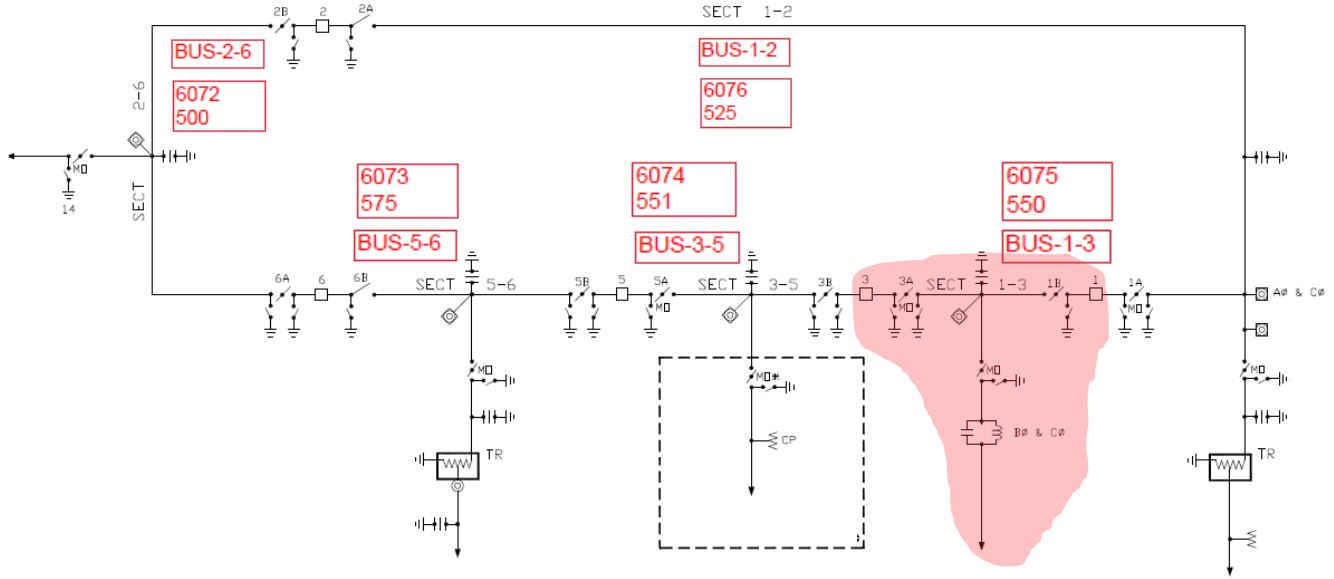
Drawing markups

Naming convention:

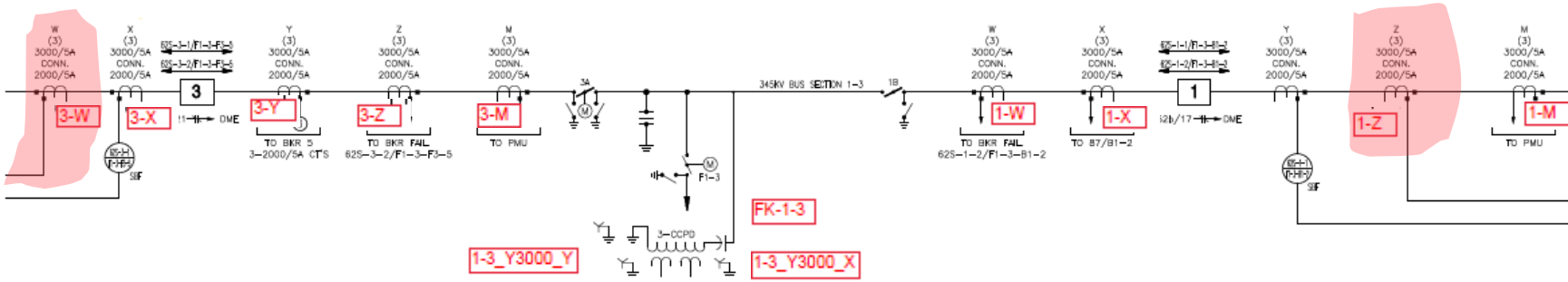
- Buses
- CTs, VTs
- Summation points



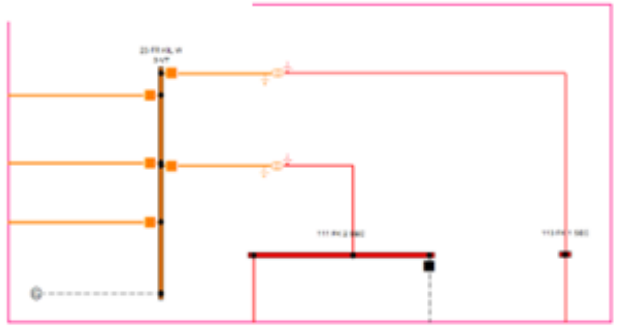
Substation topology – connectivity verification:

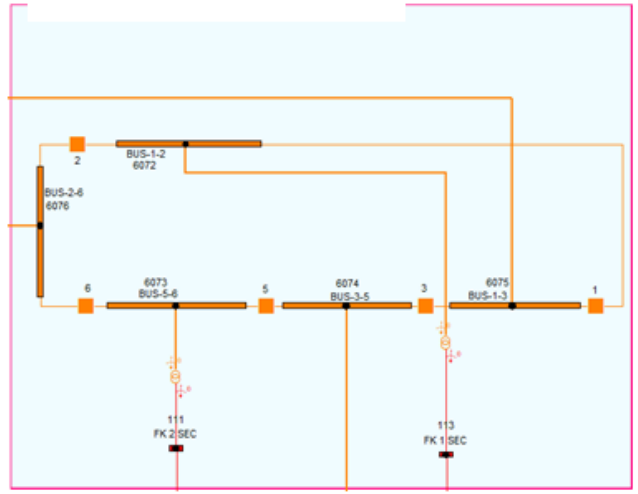


Schematic drawings – detailed protection modeling:



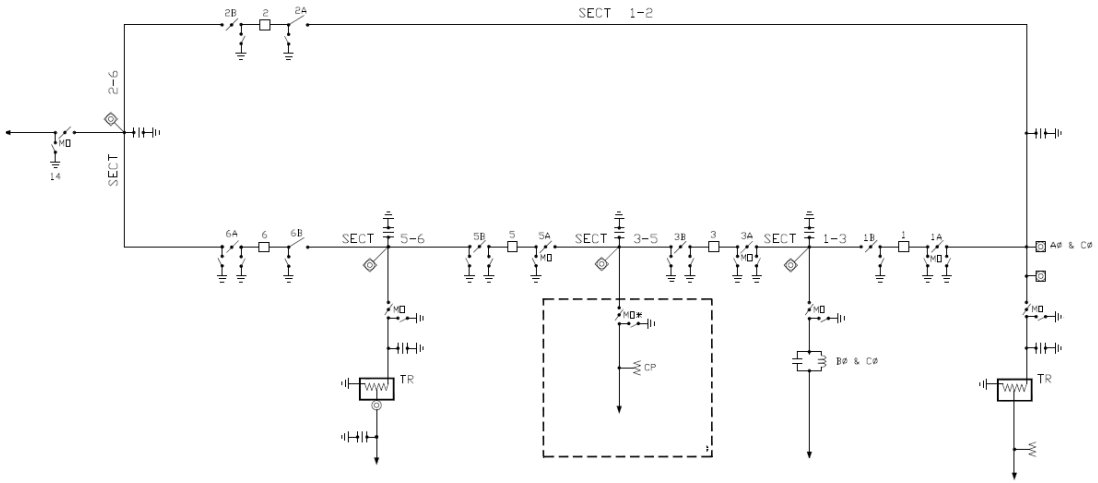
Node-Breaker Implementation in Con Edison's System Model (4/5)





Node-Breaker modeling

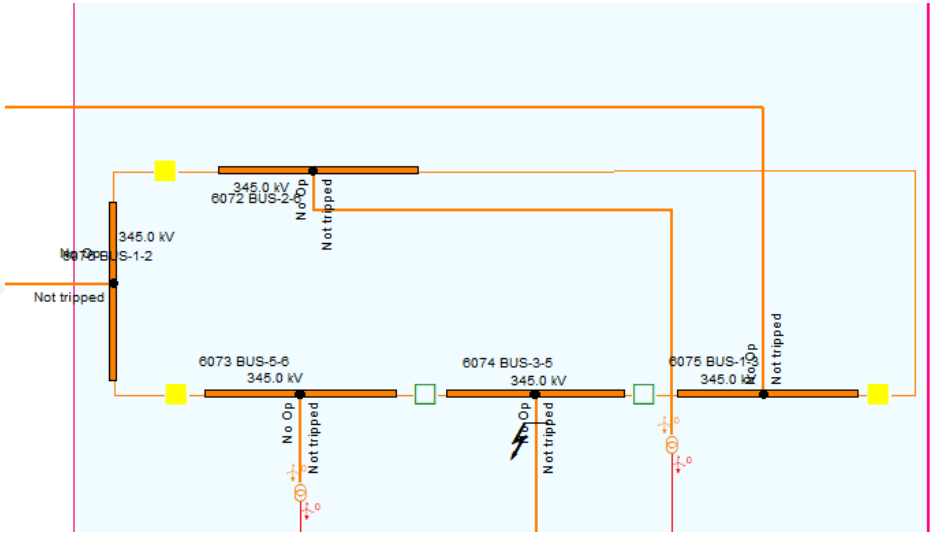
- Detailed bus structures creation
- Graphic file adjustments
- Protection modeling



Node-Breaker Implementation in Con Edison's System Model (5/5)

Model verification

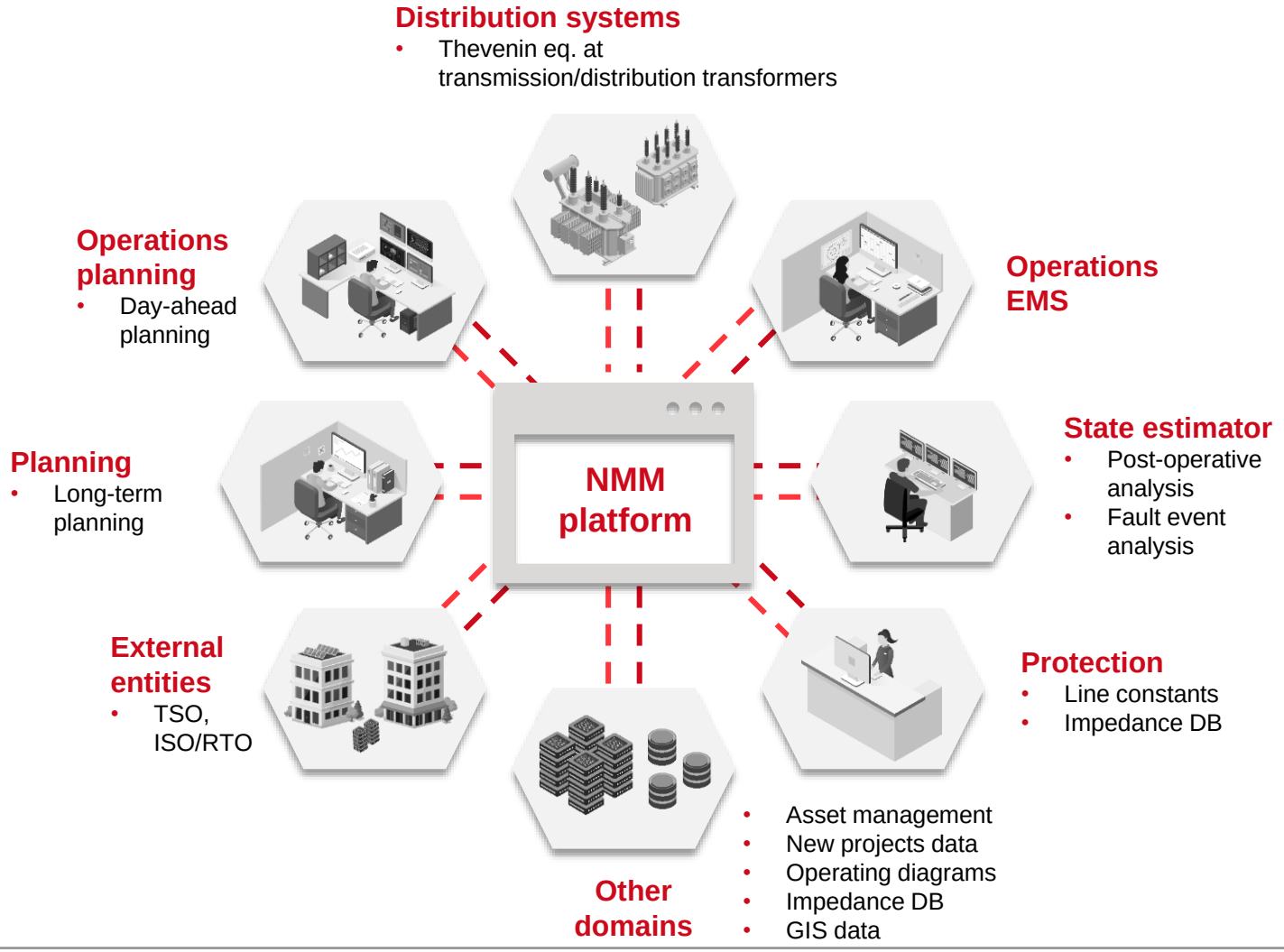
- Parent bus association
- Bus positions
- Protection operation



- Overall QA of node-breaker modeling and consistency with markups
- Graphical consistency of substation's layout in the simulation software and single-line diagrams
- Functional checks of protection operation using stepped analysis features

Network Model Management (NMM) Concept

Tools and **processes** necessary to ensure and maintain a unified representation of the network across different software platforms for protection, planning, and operations of the power system



Why NMM?

Network model availability, dependability, and interoperability is more needed than ever…

Distributed Energy Resources (DERs)

The system operates closer to its limits, therefore a more accurate modeling is required

Less generation overbuilt and decarbonization initiatives

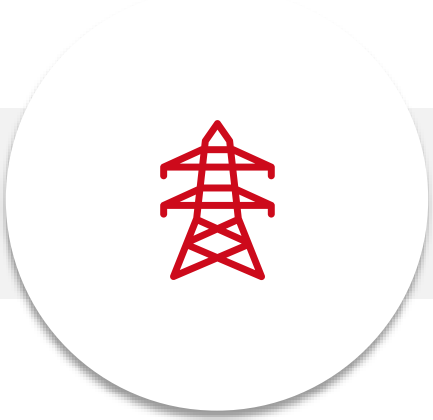
Less inertia forces more refined transient stability studies with “real” relay operation times – planning/protection bridge

Operational efficiency

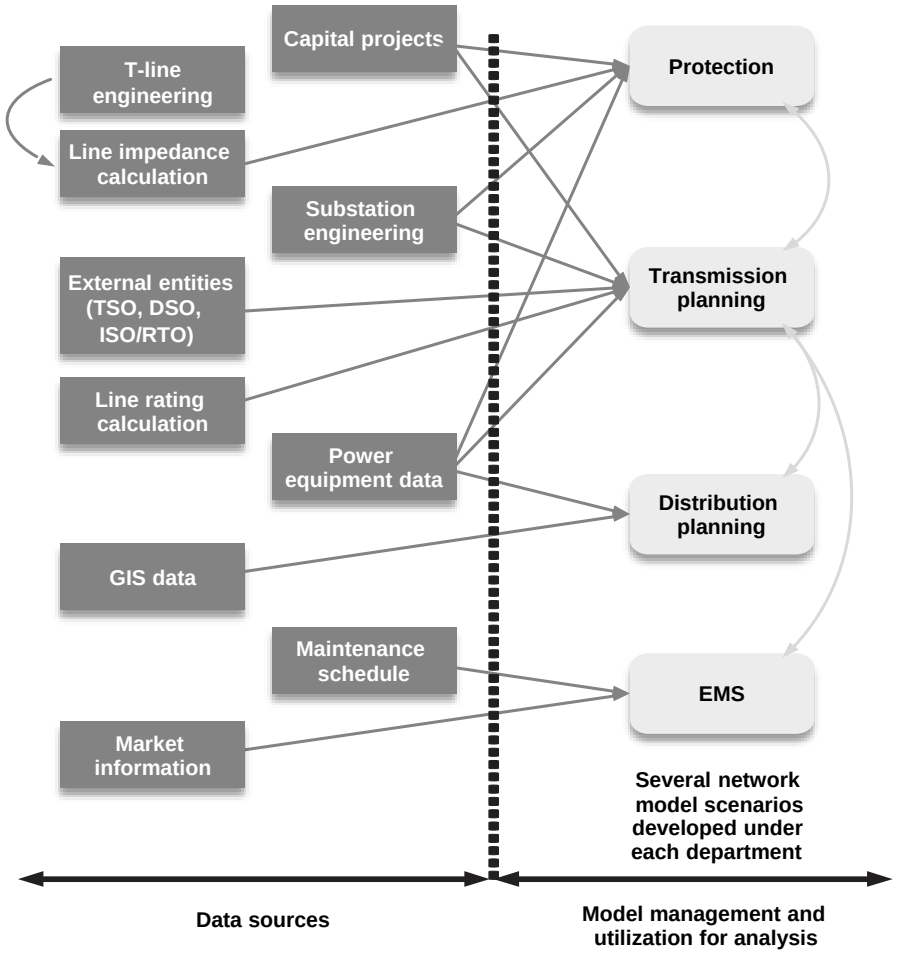
Government and public mandates are growing despite the technical challenges and decreasing expertise in power system operations

More capital

- Infrastructure Investment and Jobs Act (IIJA)
- Inflation Reduction Act (IRA)

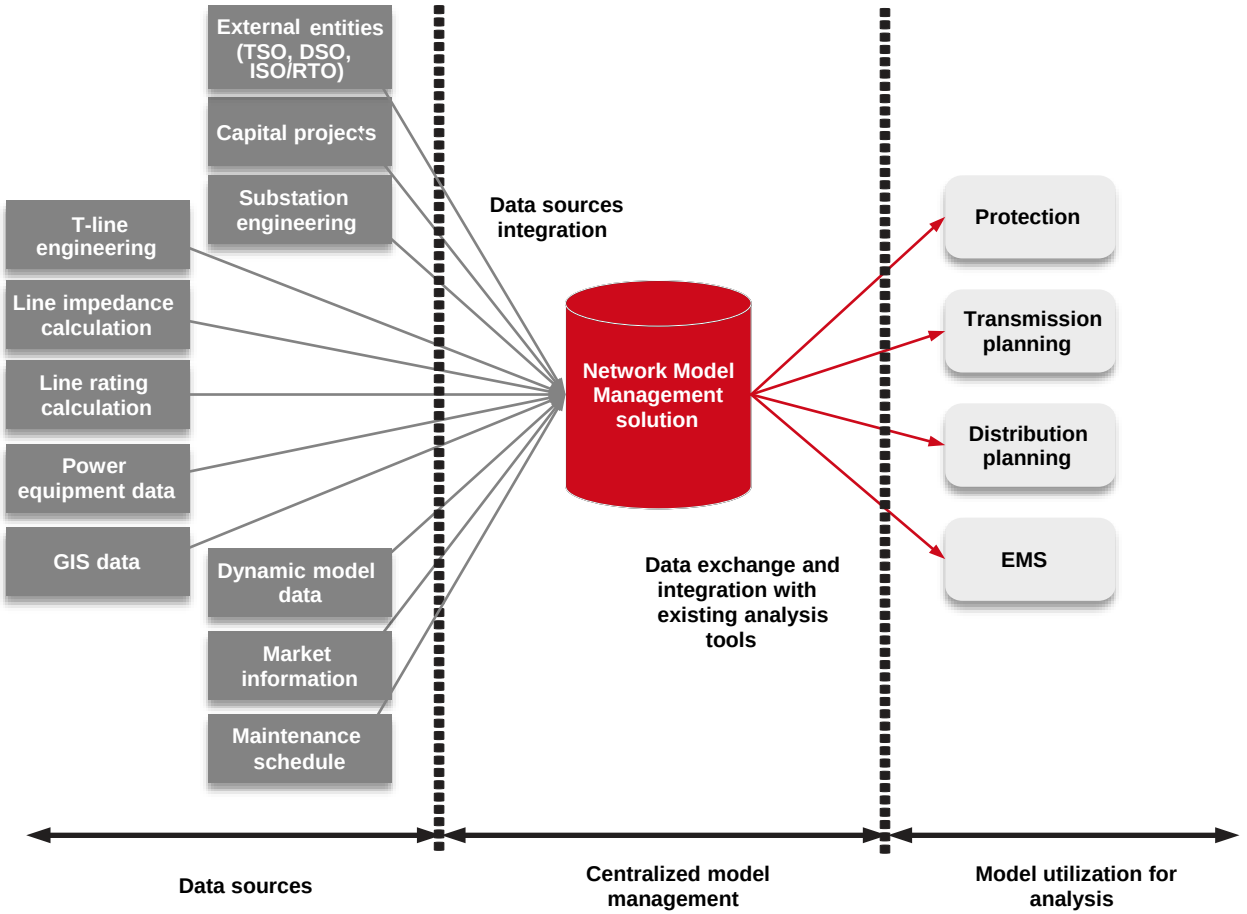


Typical Network Model Practices



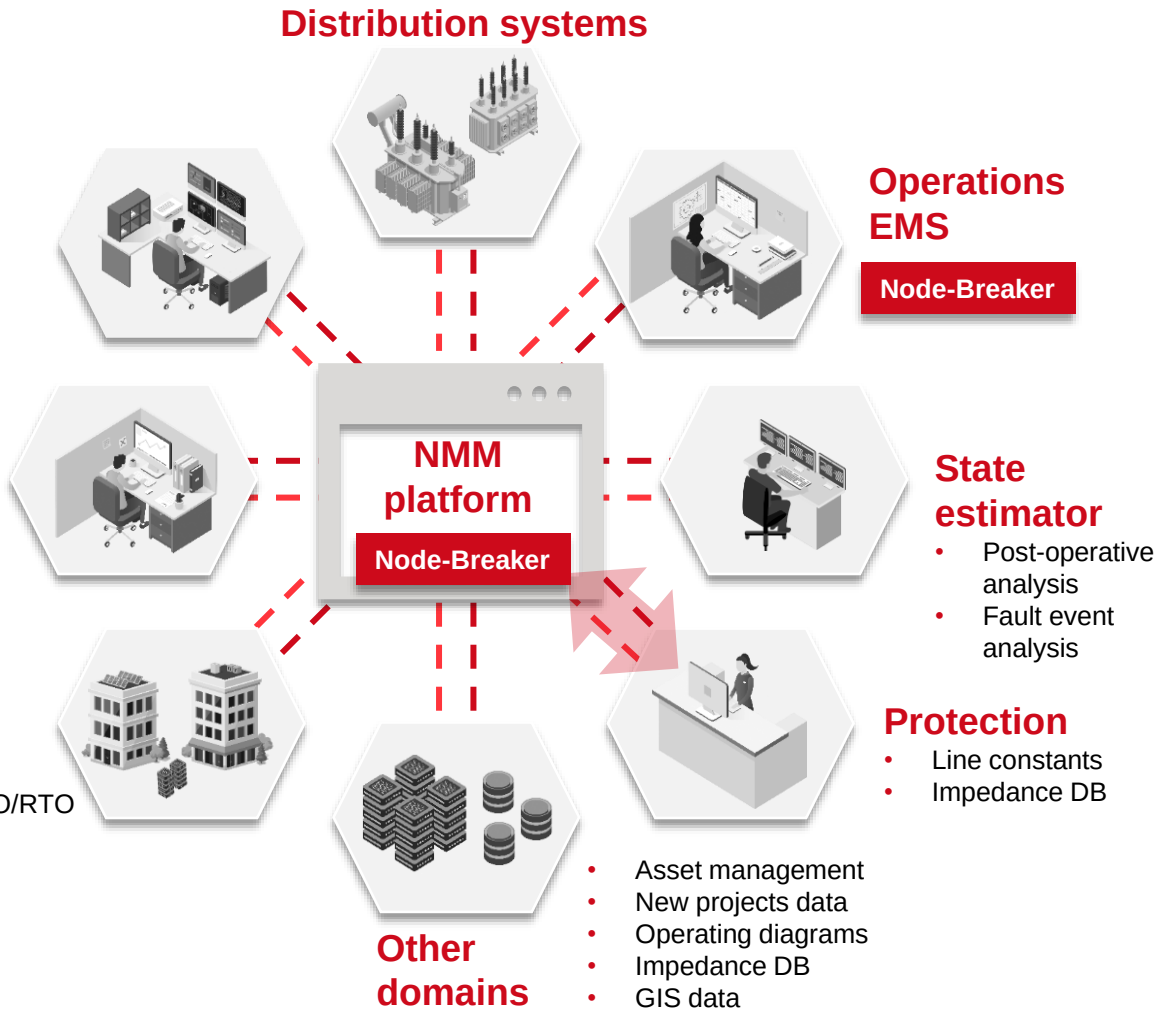
- Different network models are maintained and utilized independently by separate departments (and processes)
- Many parallel processes and data sources
- Potential inconsistencies in data between models
- Update concerns across models
- EMS network model uses node-breaker representation

NMM Target Process



- Align and verify existing network model's **base case**
- Develop tools and processes for unified network model practices and data
- Provide a **“single-source-of-truth”** for network models
- Enhance network model **interoperability**

Node-Breaker Integration to NMM Platform (1/2)



Where to start the network model integration?

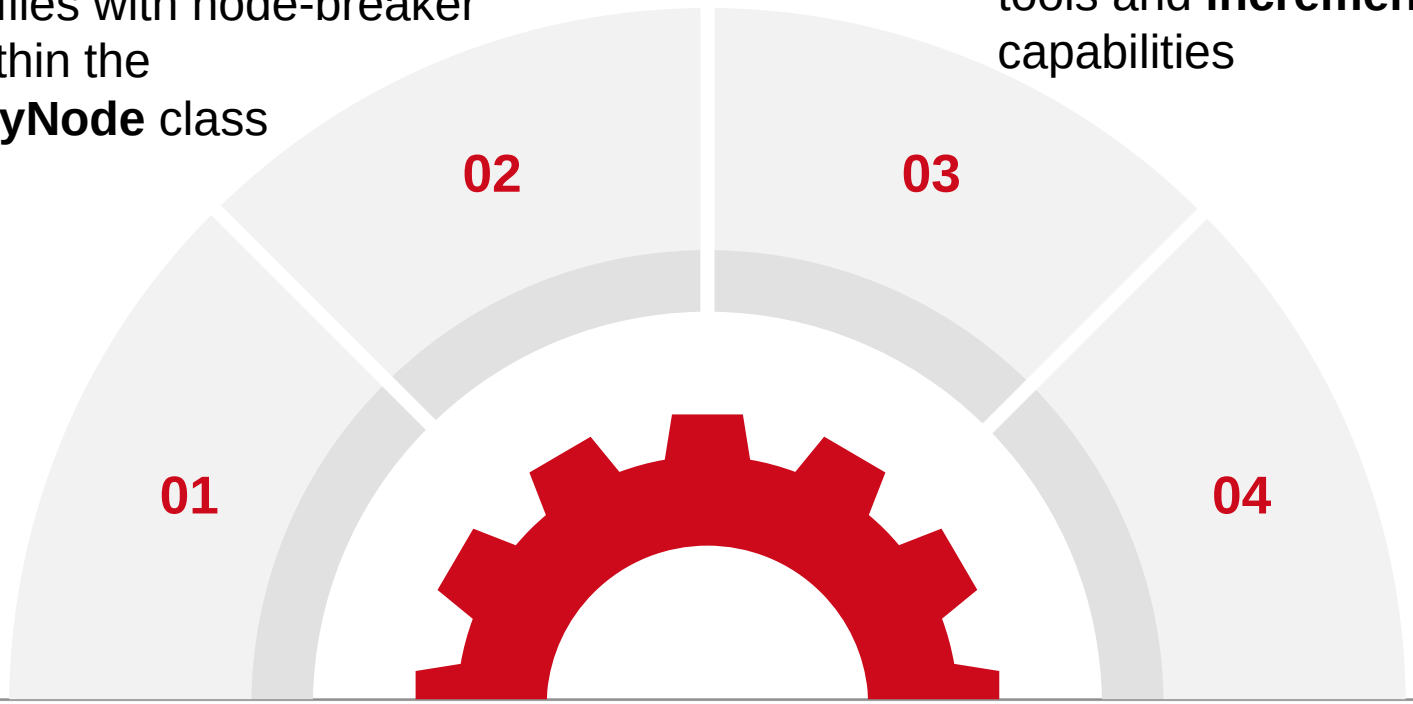
From Protection Models:

- Node-breaker attributes are different between simulation platforms
- NMM solutions might use also unique attributes for node-breaker modeling
- Therefore, data **adaptors** are required for proper integration

Node-Breaker Integration to NMM Platform (2/2)

If CIM16 is intended to be used, node-breaker attributes must be part of the **Topological Node** class – some simulation tools create XML files with node-breaker attributes within the **ConnectivityNode** class

Protection model integration to NMM solutions requires **bi-directional interoperability** from/to simulation tools and **incremental import/export** capabilities



Adaptors to make node-breaker protection models interoperable, can be created **between simulation tools** or use Common Information Model **(CIM)**

After integrating node-breaker protection models to NMM solutions, **planning models can be updated to node-breaker** while keeping bus-branch functionality

Summary

Node-breaker modeling is recommended in protection models since it provides the closest representation of the system as built and benefits advanced studies and NMM integration

Naming convention definition is recommended for node-breaker modeling to facilitate future integration and interoperability with other simulation tools and/or NMM platforms

Integration of node-breaker protection model to NMM platforms requires adaptors to properly transfer node-breaker attributes across simulation tools

Network Model Management (NMM) provides tools and processes to effectively maintain accurate system representation across software model platforms (protection, planning, operations)

Next step after integrating protection models to NMM platforms is model alignment with EMS systems and updates on planning models to include the hybrid node-breaker / bus-branch representation, if available