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NATF EMS External Modeling Reference Document

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Versioning and Acknowledgments

Version History

Date	Version	Notes
4/20/2017	2017-1	Original version
7/03/2018	2018-1	Addition of external model quality topic, update of other topics
06/01/2022	3.0	Five-year review. Removed Foreign System Analog Telemetry and updated Status Telemetry Measurements section. Replaced terms “outside” and “foreign” with “external” for consistency. Updated External Model and Data Maintenance section with consideration for full model replacement. Updated Distribution Factors Taken from Analyzing Planning Model Contingencies section with threshold range. Removed Appendix 1 section on Potential Uses of a Planning-Produced External CIM.

Review and Update Requirements

- Review: every 5 years
- Update: as necessary

Contents

1. Purpose

The “NATF EMS External Modeling Reference Document” provides guidance to those working to improve performance of their energy management system (EMS) external models. The intended audience for the document is persons with responsibility for development and maintenance of EMS models for real-time state estimator and real-time contingency analysis.

This document does not create, replace, or change any requirements in the NERC Reliability Standards or other applicable criteria, nor does it create binding norms by which compliance with NERC Reliability Standards is monitored or enforced. Implementation of NATF practices does not ensure compliance with the NERC Reliability Standards. In addition, this document is not intended to take precedence over any company or regional procedure. It is recognized that individual companies may use alternative and/or more specific approaches that they deem more appropriate.

2. Scope

This document can be used by any transmission organization responsible for building, updating, and maintaining an EMS model representing neighboring facilities and equipment the organization does not own or operate.

Due to the specifications of differing EMS vendors, the tools needed to complete an EMS external model are not specified in this document.

3. Definitions

External Model

The EMS representation of neighboring facilities and equipment a company does not own or operate.

4. Introduction

Energy management systems are used by various entities to monitor their systems and maintain a wide-area view for situational awareness. These systems, at the basic level, typically consist of a computerized model representation of the electrical grid and a SCADA system that is used to retrieve analog measurements and equipment statuses. The EMS functions as the main point of control for devices in the field and can be studied by operations personnel before actually operating equipment.

The model of the electrical grid includes the detailed topology of the system along with the appropriate parameters for the equipment within the system. These parameters can include impedances, line and voltage limits, transformer ratios and controls, generator limits, and reactive capabilities, among others. The SCADA measurements (MW, Mvar, kV, and tap positions), along with the status of switching devices, are added to equipment within the model. Schedules of injections for loads and generators are also included to supplement when measurements are unavailable. These measurements are weighted and used in a mathematical process, state estimation, to calculate the entire state of the power system. This process calculates the voltage magnitude and angle for every bus along with the tap position for every transformer. This calculation is then further processed to calculate MW, Mvar, MVA, current, and voltage.

The state estimator application supplements the SCADA system by estimating the state of the entire system. This solution is then used to provide the following information:

- Calculated values where measurements are missing
- Calculated values where measurements have failed
- Identification of bad measurements
- Identification of bad topology
- Inputs to other applications

This document focuses on the model that is used in the EMS, specifically looking at the external portion of this model. Guidance on how to create and maintain the external model is included, along with typical sources of information for these models.

To properly model the external area, real-time data needs to be obtained. This data is typically obtained through Inter-Control Center Communication Protocol (ICCP) links. These links allow companies to exchange SCADA data with other companies. This data is needed to obtain the real-time state of the system to properly monitor it. Section 7 provides guidance on the amount of the real-time data needed for the external system to be modeled.

5. Importance of the External Model

In an EMS, the main focus area for modeling is the electric system internal to the organization. This area is easy to model, as all of the information should be readily available. Information about a neighboring entities' system is also needed to support the EMS (state estimator/contingency analysis) solutions and operations of the internal area. This external model is needed to:

- obtain an accurate solution. A state estimator or power flow solution needs to appropriately represent the system to obtain an accurate solution. Power flow is not affected by company boundaries. All paths where power can flow need to be modeled to be able to simulate the true power flow;
- ensure any maintenance or outages on external equipment are visible and that the internal impacts can be studied and confirmed with a very high degree of confidence;
- see what is happening in neighboring areas to coordinate and communicate more effectively.

The amount of external modeling that needs to be included in an EMS differs widely by system and company preference. This reference document includes guidance to help with properly determining the amount of the external system that needs to be modeled. To retain accurate monitoring of the external system, the model needs to be periodically updated to reflect changes made to the power system. This can be an extensive and time-consuming task.

6. How to Update an EMS External Model

The starting point for updating the external model is determining if an evaluation of the external system is needed. It is necessary to maintain a current and accurate EMS external model. It is recommended to review and update the external model at least every two years. More frequent reviews are necessary when large-scale construction projects could alter regional transmission flows in ways that impact the local system. Sometimes, an external model evaluation reveals that portions of external areas no longer affect the internal model. In those situations, it is desirable to reduce or remove those areas of the external model.

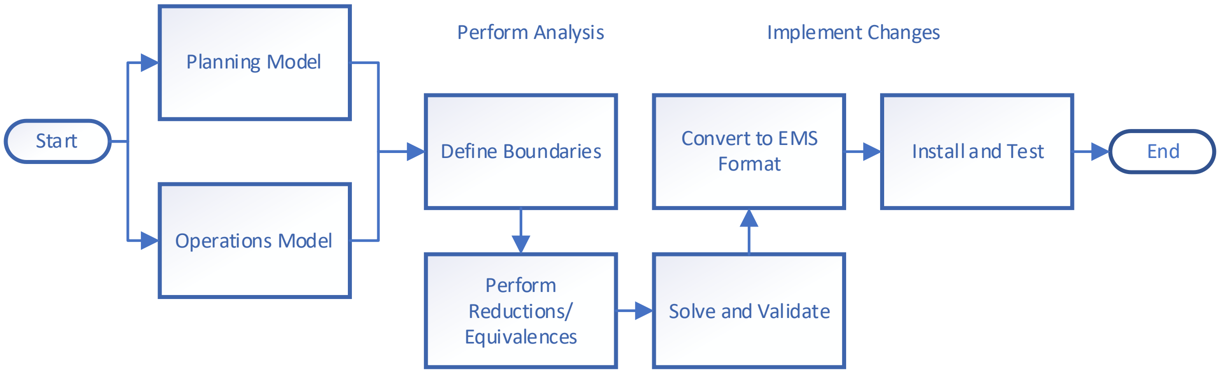

Figure 1: EMS External Model Process Flow

The next step is to determine the type of model that will be used to conduct the analysis. The starting point for developing a new external model to incorporate into an operating EMS is determining what kind(s) of viable models can be used. This is partly determined by what a particular EMS can accept and partly by what tools a user has available. In general, there are two distinct starting points for building an external model: "planning model" or "operations (EMS) model."

A planning model is a bus-branch, steady-state power flow model that can be run using positive sequence power flow software. The data requirements and structure are consistent and well understood. All commercially available power flow programs have the ability to import/export data files of various formats. As such, portability among the platforms is not an issue. It should be noted that power flow programs used for transmission planning are starting to include the capability to provide more detailed breaker-node models.

Typically, the planning models used to perform external model reviews are cases provided by the Reliability Coordinator (RC). Those cases, at a minimum, include detailed models from all the Transmission Owners (TOs) that are under the jurisdiction of the RC. RCs develop those planning load flow models to perform studies on the future system topology. These cases are beneficial for determining external model needs since they include a large representation of the bulk electric system.

To ensure that the planning model case represents the worst-case scenarios needed to identify the necessary external model, the following should be considered:

- Is the case based on the peak load season (summer or winter)?
- Is the case based on light load topology (stability)?
- What interchange is represented (high/low imports/exports)?
- Are future large-scale construction projects included?
- Are the generators dispatched appropriately?

An operations (EMS) model is a far more detailed breaker-node model with substantially increased data. This model option is more directly interlinked to available ICCP data for status and analog data. Generally, obtaining EMS models from other entities is the most direct method for creating an external model. This option can be desirable when companies are using the same EMS vendors, as it is easy to transfer modeling data between the two entities. However, due to EMS vendors using their own proprietary model format, this option may not always be feasible.

When using an operations model, it is necessary to manually piece together different models or create an equivalent area to create the desired model. As with the planning model, operations models may also contain more information than is needed.

Boundary Definition

A crucial portion of model building is the determination of how large an external model needs to be. The size of the external model varies depending on required accuracy and the impact of adjacent external systems to the internal bulk electric transmission system. Some organizations have external models that are larger than the internal model.

This reference document outlines several methods that can be used to define the model boundaries:

- Number of buses away from the system boundary
- All first-tier external entity detail
- Distribution factors taken from analyzing planning model contingencies
- Combination of distribution factor and MW impact

Number of Buses Away from the System Boundary

"Number of buses away from the system boundary" is used as a "rule of thumb" to explicitly model a pre-determined number of buses away from the internal system boundary. This method ensures that accurate topology is in place at the internal system borders. The rest of the system is equivalized using a bus/branch model representation. As this method is clear and discrete, it may be useful for large organizations with large model needs and reduces the need for complex analysis (such as distribution factor) to determine external model boundaries. Another benefit is the minimal analysis time compared to other methods. However, depending on number of buses selected, this method could result in a larger than needed external system, adding unnecessary detail; or, vice versa, the model may be too small to accurately represent external system influences on the internal system. Refer to Appendix 2: Utility Experiences in Updating the External Model for an example use of "number of buses away" methodology used by one utility.

All First-Tier External Entity Detail

Adding to the concept of limiting the number of buses, the "all first-tier external entity detail" method is a way to model the external system by modeling the entire system of neighboring entities and equivalizing the rest of the system at the neighbor's external boundary. Similar to the risks mentioned in the "number of buses away" option, this option could result in a larger external system than the internal system and add unnecessary detail. It also requires continued close coordination with all neighbors to maintain an accurate system representation. Conversely, should borders between the neighboring entity and their neighbor be electrically close to the internal system, modeling the neighboring system alone may be inadequate.

Distribution Factors Taken from Analyzing Planning Model Contingencies

A separate review of the distribution factors (DF) of various element outages for contingencies on a transmission planning bus/branch case can be used to define reasonable boundary limits. The analysis entails simulating disturbances (contingencies) in the external system and monitoring the system of interest. For entities that are extremely intertwined with one another, internal system contingencies may also need to be considered. The following types of disturbances could be simulated for the analysis:

- Single Contingency (TPL-001 P1 through P2) on an element within the external substation (100 kV or above/BES) results in a DF to internal equipment greater than a specific threshold;
- Multiple Contingency (TPL-001 P3 through P7) on an element within the external substation (100 kV or above/BES) results in a DF to internal equipment greater than a pre-determined threshold;

- An additional buffer area of a few substations beyond those meeting the above criteria could be added;
- Add any relevant lower voltage contingent or monitored elements.

Recommended monitored and contingent elements to be included in contingency analysis include:

- Monitored elements
    - Internal element meeting internal criteria (100 kV or above/BES)
    - All tie lines to internal area meeting internal criteria (100 kV or above/BES)
    - Internal voltages meeting internal criteria (100 kV or above/BES)
    - External voltages one substation away from internal area meeting internal criteria (100 kV or above/BES)
    - Lower voltage monitored elements as required by system boundary connections
- Contingent elements
    - Internal element meeting internal criteria (100 kV or above/BES)
    - All tie lines to internal area meeting internal criteria (100 kV or above/BES)
    - Single Contingency (TPL-001-4 P1 through P2) of any element within the external area that results in a DF to internal equipment greater than a specific threshold
    - Lower voltage contingent elements as required by system boundary connections

Distribution-factor threshold levels used to determine whether a device is impactful to the internal model can vary by company. In general, an external device is impactful if the loss of that device causes a change in power flow on any internal system component greater than the threshold. Threshold values used by companies may be a low as 3% or as high as 10%. Distribution-factor threshold values can vary with voltage classes if desired. Also, depending on the desired criteria and results, modeling facilities based on multiple-contingency disturbance impacts or other extreme contingencies could lead to a much larger external model and should be used on an as-needed basis.

In general, distribution-factor studies can be time-consuming to perform but provide the most-detailed information on the external equipment considered impactful to the internal model. Power flow software programs such as TARA, PSS/E, PSLF, and MODELEX can be used to automate the large amount of contingency result compilations needed to perform the “distribution factor” and the “combination of distribution factor with MW impact” analysis options. Refer to Appendix 2: Utility Experiences in Updating the External Model for an example use of “distribution factor and MW impact” methodology used by one utility.

MW Impact

Some companies determine external model boundaries based on threshold levels of MW changes impacting the internal area or tie-lines. The complexities of these studies are similar to the distribution factor option.

Build the External Model Boundary Cuts and Solve

A complex Ward-Hale reduction will create an equivalent line from every boundary bus to every other boundary bus. While such an equivalence is technically accurate and probably useful for detailed power flow and transient stability studies, it may be too detailed for implementation in an EMS system. A generator/load pair at the boundary buses is a simple solution to establish some stability of voltages and allow for variability of boundary flows that are otherwise unobservable. It is critical that as a model is reduced that it retains a valid solution.

In buses that are close to the "internal" model, there should not be widely divergent flows and voltages in either normal or contingent conditions. To maintain the ability to study transfers between different areas, appropriate generation should be retained if it affects the entity's internal model. Such benchmarking of the external model is critical. Load power factor in the equivalized portions of the model should be consistent with or similar to the internal model.

For confirmation that a reduced model is able to solve comparatively close with respect to a full model, an N-1 contingency analysis (TPL-001 P1) should be performed on both the reduced and full model. The results should be compared, and the accuracy of the equivalent model should be within an approved deviation tolerance.

Convert the External Model and Install

Typically, updated external model information is obtained by reaching out to neighboring TOs or to the RCs and requesting model parameters, latest substation or transmission system one-line diagrams, ICCP analog information, etc. This is typically coordinated through the RCs to ensure that the information is transferred to those entities who have signed data confidentiality agreements.

In addition to receiving updated model parameters, the external model conversion effort includes some or all of the following tasks:

- Creating external substation one-line diagrams to internal display standards for operator situational awareness;
- Reviewing and ensuring accurate impedances, ratings, topology, and contingencies for equipment already included as part of the external model;
- Creating new equipment contingencies that need to be added to the model.
- Review the list of remedial action schemes (RAS) in neighboring companies and implement RAS which are on equipment determined to be impactful to the internal system;
- Obtaining ICCP object IDs for all new facilities that are to be added to the EMS.

It is also possible to exchange external models between TOs and RCs if the information is "converted" into a consistent format that a particular EMS can read and use. This will become more important with the increased use of Common Information Model (CIM) exchange. For more information on this topic, refer to Appendix 1: Planning-Produced CIM External Model. The breadth of such systems, and the tools needed to convert a reduced external model into the compatible format, are beyond the scope of this document.

Testing the new external model needs to occur if the model is updated regardless of the method used to convert the information. It is critical that the real-time system is not compromised by the addition of the new external model. Load external model changes into a test system that retrieves real time data to ensure that the updated model will not adversely impact the real-time performance of the EMS.

7. Adding Measurements to Substation Details

Substation Details – Real-Time Measurements

Real-time measurements are transferred between entities utilizing ICCP. There are three main options to receive external real-time measurements: a direct ICCP link with another entity, a request for information to the Regional Transmission Organization (RTO) or RC, and a connection through the Eastern Interconnect Data Sharing Network (EIDSN).

Analog Telemetry Measurements

State estimator accuracy depends on the availability of real-time measurements mapped to specific model objects with a unique location within the system topology. Real-time analog measurements should be in place anywhere node-breaker modeling is used. A focus should be on measurements within the desired observability area and the higher kV system equipment, including transmission lines, transformers, and generating units.

Placement of an analog measurement, such as for a transmission line, at the incorrect terminal end may cause a measurement with good accuracy to be de-weighted or ignored during the iterative state estimation calculation. When mapping measurements to model objects, it is important that instrument transformers are properly located. Likewise, in cases of ring-bus designs, accurate mapping of breaker current transformer telemetry is key to ensuring accurate flow when the system experiences abnormal ring configuration.

In many cases, if a transmission line does not terminate with a breaker, the line may not have analog measurements. When transformers or shunt devices are coupled at the same topological nodal location as a transmission line or breaker string, the associated measurement should be closely scrutinized to determine whether analog telemetry includes or omits devices connected to the node. The flow direction attribute must be correct on the measurements. Most companies have a standard that positive flow is out of the bus on measurement installations.

Typically, the following analog telemetry measurements are used in the external model:

- Active and reactive power for transmission lines
- Voltage measurement for buses
- Active and reactive power, voltage, and tap position for transformers
- Active and reactive power and kV for generating units

Status Telemetry Measurements

An EMS model enabled by state estimation depends upon accurate topology to produce accurate load-flow results. The closer the external system is to the internal system, the more important it is to have analog and status values. Anywhere node-breaker modeling is represented, real-time switching status measurements should be in place. Focus should be on measurements within the desired observability area and the higher kV system switching equipment. The state of stations that do not have node-breaker switching detail, including the absence of status measurements, should be maintained manually.

All external substation analog and status measurements should provide enough information for the state estimator model to solve and properly match SCADA-telemetered values. There may be instances when the external telemetry is incorrect or is applied incorrectly in the model. The state estimator can determine if measurements are suspect or anomalous if the estimated values do not match other telemetered measurements.

ICCP Connection Considerations

Communication of real-time measurements is accomplished utilizing the ICCP application and the TASE 2 standard. There are currently three main options to receive external real-time measurements

1. Direct ICCP link

   A direct ICCP link with a neighboring entity allows direct access to the requested information at the source. Any errors in this data would likely cause issues with the neighbor's system and thus be communicated almost immediately to other parties. Establishing a new ICCP link for each neighbor from whom to request data could incur significant connection costs and thus prove financially prohibitive.

2. RTO or RC link

   The ICCP connection to the RTO or RC is already established. It allows the customer to request information from several neighbors, both within and outside the RTO/RC footprint, through the same path at no additional setup cost. However, the information is flowing via one link, so any time there is an issue, all external data is compromised. Additionally, there may be a notification lag on any modifications coming to the RTO/RC via the neighboring entity.

3. EIDSN link (Eastern Interconnect Only)

   The EIDSN mission is to develop an "effective network for the sharing of operating reliability data, including both SCADA and synchrophasor data, among appropriate entities to promote the reliable and efficient operation of the Eastern and Quebec Interconnections." The EInet was created to accomplish the transfer of data between members. Entities with a NERC designation of Reliability Coordinator, Transmission Owner, Transmission Operator, or Balancing Authority may establish a link through this network. All Reliability Coordinators in the Eastern Interconnection exchange data on EInet. This may limit the amount of data that can be accessed by an individual entity. Additionally, this will require a new ICCP connection to be set up. Information on the EInet can be found at https://eidsn.org.

8. External Model and Data Maintenance

Regardless of the method utilized to transfer model data and information between entities, a protocol for updates should be established. The protocol should clearly outline the timing and format of information exchanged and establish regular communication checkpoints. The information exchanged should include any modifications to system topology, existing equipment parameters, existing ICCP object ID, and addition of new measurements within a substation or removal of physical or monitoring equipment. Without this protocol, entities risk using out-of-date information within their state estimator programs.

Some options for exchanging data include sharing models, sharing system one-line diagrams, CIM exchange, or SERC format model exchange. Should neighboring entities utilize the same vendor, sharing the node-breaker level models becomes a feasible option. CIM format is becoming more widely utilized in the industry for model exchange. Refer to Appendix 1: Planning-Produced CIM External Model for more information on CIM. Entities within the SERC reliability region have developed a .csv standard for model exchange. Techniques to automate model comparisons make more efficient use of engineering study time.

It is important to draw a distinction between the equivalent and non-equivalent areas of the external model and imperative that the non-equivalent areas of the external model be maintained continually. Issues may arise if telemetered portions of the external model change and updates to the internal model are not made immediately. If an entity’s model has not been maintained for a period of time (e.g., greater than two years), consider replacing the “full” model. This is time-consuming because one needs to verify the accuracy and perform some equivalizing. Note that making large changes like this can cause performance issues to the internal system model that will need to be addressed.

From a model validation standpoint, a good practice is to load changes in a test environment before placing the changes into production. The test environment allows proper vetting of changes in a real-time-like environment while not compromising the reliability of the production system should there be an error. Another good practice to reduce the risk of modeling error is to perform changes in a piece-meal fashion rather than load bulk changes all at once. This piece-meal fashion also encourages detailed model review that may be missed from loading a bulk file.

Use internal resources for modeling and data maintenance, as they are more likely to have refined knowledge on the modeling environment and its various intricacies. External contractors can be used, provided they receive proper training on modeling processes.

9. External Model Quality

Background

The EMS network model must accurately represent the electrical power system for the state estimator to provide situational awareness. Equipment status changes are dynamic, and the EMS model should be designed to provide visibility of all necessary internal and external system equipment.

The lack of an accurate external system model can negatively impact the results of network applications (state estimation, contingency analysis, study applications, and stability applications). Quality state estimator results are essential to the success of operating the electric power system. For stability purposes, it is important to a have large, detailed external model for accurate results. Therefore, the inputs to the state estimator (SCADA measurements and network model) need to be constantly reviewed for accuracy.

The state estimator uses SCADA measurements and the power system model to provide the best estimate of power system status. The state estimator is the base function for all real-time network applications. If the state estimator does not converge or is provided with insufficient or incorrect measurements that dramatically skew results, those negative results will carry over to other applications.

Errors in the external model (missing equipment, incorrect topology, or incorrect measurement mapping) can cause an invalid solution of the state estimator or cause a large mismatch on external or tie-line buses. Even if estimation results for the internal system are valid, errors in the external model can invalidate solution results and reduce the accuracy of the state estimator solution.

Contingency analysis is an EMS network application used to analyze the impact on power system security of a specific set of simulated events, such as unplanned outages of transmission lines, generators, or other transmission system elements. For each individual event (contingency) in the set of simulated events, contingency analysis identifies any problems, such as branch overloads or voltage limit violations, that will occur if that event takes place.

State Estimator Mismatches

EMS network application results provide information about the quality of the model. Those results can indicate errors in both the internal and external model and direct the operator to a node, bus, or area where that error or mismatch occurs. State estimator results can show convergence issues or where there are large busbar mismatches (i.e., deviation between SCADA and state estimator).

Several methods exist to identify if there are errors in the external model, such as comparing the model with single-line diagrams from the owner of the external system and/or comparing state estimator results with results from the RC or the external utility.

Residuals represent the difference between estimated and measured values. A state estimator can calculate residuals for all external measurements, which are part of a cost calculation for a completely modeled system (internal and external). The “cost index” is the sum of residuals for all measurements (MW and MVAR) in the system. Therefore, the cost index indicates how close the state estimator is to actual SCADA telemetered measurements. An increase in “cost” can be caused by measurement or model errors. Large contributors to the cost should be investigated as soon as possible to ensure there are no modeling issues.

To ensure the state estimator is solving accurately, frequently monitor and review all modeled external areas that contain large mismatches. In lieu of a full detailed review, however, some organizations simply track state estimator results on tie lines or from the first external utility substations and compare those values with SCADA measurements.

Contingency Analysis Mismatches

In the case of contingency violations, results can be compared with those from neighbor TO companies and/or RCs. If mismatches exist, operators and reliability engineers should reach out to the relevant external parties and discuss the differences. Many times, equipment changes or modeling issues can be identified from these discussions.

To ensure good situational awareness for operators, all contingencies that are impactful to the internal model should be accurate with neighboring utilities and/or the RC within established guidelines (e.g., +/- 3%). A higher difference in contingency analysis results could be caused by some error in the external model.

Some companies import external company outages through the NERC System Data Exchange (SDX) [1] to use as part of their outage studies. This tool can be used to proactively identify mismatches in external models that could be impactful to the internal area.

10. References

[1] North American Electric Reliability Corporation, [Online]. Available: https://www.sdx.oati.com/sdxui/sys-login.wml.

Appendix 1: Planning-Produced CIM External Model

CIM Overview

Common Information Model (CIM) cases are platform-independent cases that can be used to translate EMS model data between entities without needing to convert between their respective EMSs. The CIM uses a standardized extensible markup language (XML) format. This standard is set and maintained by IEC 61970.

CIM models can also be produced from planning models, but there may be little relation to any existing EMS models.

Challenges

When considering whether to use a planning model to add or upgrade the EMS model, there are challenges to overcome.

1. Planning models are often bus-number dependent, but EMS models are usually bus-substation-name dependent.
2. CIM version 13 does not accept six-digit bus numbers, so buses from planning models using longer bus numbers may have to be renumbered to five digits.
3. The existing external EMS model generally includes equivalent lines, generators, loads, or a combination of them. The boundaries of the model may need to be redefined in order to apply a new external CIM.
4. Existing external topology may also have associated telemetry, such as data via ICCP, that may need to be preserved or even reworked to fit the expansion of the external model.
5. The new CIM-generated external model still has to be manually tied to all of existing portions of the internal model.
6. If there is an existing model, it may be necessary to handle the planning-model-derived CIM data and conversion efforts outside of the production system to avoid conflicts.
7. Master Resource Identifiers (MRIDs) in CIM, sometimes called object identifiers or OIDs, are used to link one model update to existing items in the existing model. New MRIDs indicate new equipment has been added or changes to existing equipment have occurred. If the MRIDs stay the same, nothing for that piece of equipment has changed. Presently, many planning model cases do not carry MRIDs, so any conversion of such a planning model to CIM will produce all new MRIDs. This will result in a loss of integrity of the external model from one planning case upload to the next upload.

Appendix 2: Utility Experiences in Updating the External Model

Company A's Experience in Updating an External Model

The purpose of building an external model is to improve state estimator solution quality around tie-lines and to allow contingency analysis to generate more accurate results. This provides better situational awareness on external equipment outages that can impact one's internal footprint. Below is the methodology used to update the external model.

1. Methodology used to determine how many bus tiers into the neighboring system that will be modeled. This methodology is a guideline and is adjusted on an as-needed basis to improve state estimator solution quality.
    a. 1-4 buses – model with virtually full detail, with all status, and all telemetered analog data available
    b. 5-6 buses – model with virtually full detail, with all status, and no telemetered analog data available
    c. 7-9 buses – model stations in an equivalized manner, with no status, and no telemetered analog data available
    d. 10 buses – model lines with one unit and one load, with no status, and no telemetered analog data available
2. Methodology used to determine when contingencies should be modeled in the neighboring system. The purpose of defining external model contingencies is to determine if the loss of equipment outside of the internal model can cause voltage or thermal violations within the internal model. This methodology is a guideline and is adjusted on an as needed basis.
    a. 1-2 buses – define line, transformer, and generator contingencies that have a voltage level from 100 kV to 230 kV
    b. 3 buses – define line, transformer, and generator contingencies that have a voltage level above 230 kV
3. Methodology used to determine the effectiveness of the external model.
    a. State estimation should closely track metering at the tie lines. Areas that do not closely track metering are evaluated and a mitigation plan is created to resolve the issue.
    b. When switching by an external company occurs, the state estimation solution quality should not be impacted. This assumes the following:
        i. Metering and status are appropriately mapped within the external mode
        ii. All metering and status points are communicating accurately
        iii. All topology is accurate
        iv. All physical model data is accurate

Company B's Criteria for External Model Changes

Company B models facilities that impact any internal transmission line based on the criteria in Table 1.

Table 1

External company voltage line (kV)	Typical max power flow (MW)	Company B facility voltage (kV)	Distribution factor cutoff on Company B Facility	Load Cutoff on Company B Facility (MW)
500	1500	500	5%	75
500	1500	230	2%	30
345	1000	500	8%	75
345	1000	230	3%	30
230	500	500	15%	75
230	500	230	6%	30
138/115	150	230	20%	30
138/115	150	138	10%	15