EMS External Modeling Reference Document 04/20/17

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Purpose

The NATF *EMS External Modeling Reference Document* provides guidance to those who are working to improve performance of their 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 Reference Document does not create binding norms, establish mandatory reliability standards, or create parameters by which compliance with Reliability Standards is monitored, or enforced. In addition, this reference 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 for their EMS external modeling purposes.

Topic 1: Introduction

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

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 statuses 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 measurement inputs, along with statistical values weighting their confidence, are used in a state estimation mathematical process to calculate the entire state of the power system. This mathematical 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, Amp, kV, etc. measurements.

The State Estimator application is used to supplement the SCADA system by estimating the state of the entire system for which it is monitoring. This solution is then used to provide the following information:

- Fills in where measurements are missing
- Fills in where measurements have failed
- Identifies bad measurements
- Identifies bad topology
- Can be used as an input to other applications

This document will focus 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 will be included along with typical sources of where to obtain information for these models. This paper will also provide guidance for defining contingencies in the external model. Communication of this information between different entities will typically require an agreement to ensure that confidential information is only used for its intended purpose. A sample Non-Disclosure Agreement is included.

To help with proper modeling of the external area, real-time data will also need to be obtained. This data is typically obtained through Inter-Control Center Communication Protocol (ICCP) links. These links allow companies to send and receive SCADA data with other companies. This data is needed to obtain the real-time state of the system to properly monitor it. Determination needs to be made as to how much of the real-time data needs to be obtained to go along with the extent of the external system that is modeled. Guidance for this determination is included in this paper.

Topic 2: Importance of External Model

In an EMS, the main focus area for modeling is the area internal to the company. This area is easy to model, as all of the information should be readily available. Additionally, an external model of neighboring entities' systems is needed to support the EMS solutions and operations of the internal area. The external model is needed for the following reasons:

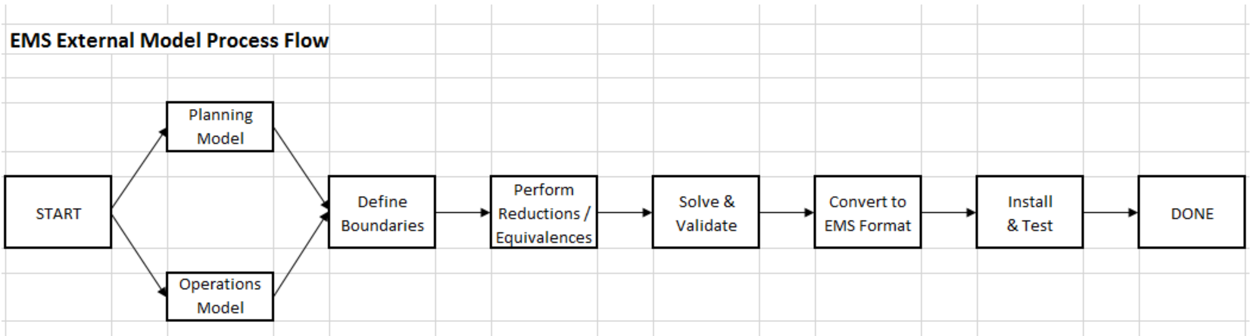
- A State Estimator or Power Flow solution needs to accurately represent the system that is being modeled to obtain an accurate solution. In the power system, there are no hard cuts to where power is flowing at company boundaries. The paths where power can flow need to be modeled to be able to simulate the true power flow.
- Contingent loss of external equipment can affect internal equipment. The external equipment needs to be accurately modeled to be able to model the contingencies.
- To be able to 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 external system that needs to be modeled. To retain accurate monitoring of the external system, the model will periodically need to be updated to reflect any changes that have been made to the power system. (This can be an extensive and time-consuming task.)

The easiest method for creating an external model is to obtain EMS models from other entities. This does not always work out easily, however. For one, there are numerous EMS vendors that all use their own proprietary format for their model. Some conversion will be required in order to be able to use these models. These models may also contain more information than is needed or not enough information. This may require piecing together of different models or creating an equivalent area to model correctly. This will require some coordination and needs to be considered in plans for how to effectively maintain the external model in the future. To help with this, some vendors have the ability to convert the model between common formats (The Common Information Model (CIM)). This format, and how it can be used to help with updating external models, is discussed further in this reference document.

Topic 3: How to update an EMS external model

From time to time, it is useful to update or replace an EMS external model. This is particularly true for large-scale construction projects that will alter regional transmission flows.



Starting
The starting point for developing a new external model to incorporate into an operating EMS system is determining what kind(s) of viable models can be used. This is partly determined by what a particular EMS system 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 "EMS Model." A Planning Model is a bus-branch, steady-state power flow model in common use. The data requirements and structure are well understood. All of the 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. An EMS Model is a far more detailed breaker-node model with substantially increased data. This data tends to be more directly interlinked to available ICCP data for status and analog data.

Among the EMS vendors, there are far wider variances for the datasets that may be used. In addition, there are a variety of tools that EMS vendors may have available to facilitate model development.

Boundary Definition
A crucial portion of the model building is the determination of how large an external model needs to be. This reference document outlines four methods to consider:

1. X busses from the system boundary
2. All first-tier external entity detail
3. Utilize the NERC Book of Flowgates
4. Distribution factors taken from analyzing Planning Model contingencies

    1. First, the "rule of thumb" is to explicitly model X number of buses from the internal system boundary. This method ensures that accurate topology is in place at any internal system borders. The rest of the system will be equivalized utilizing a bus/branch model representation. However, the model may be too small to accurately represent external system influences on the internal entity.

    2. Adding on to the concept of limiting the number of busses, one could explicitly model the entire system of any neighboring entities and equivalize the system at the

neighboring boundary. This could result in a larger external system than internal system, adding unnecessary detail based on your system needs. It also requires continued coordination with all neighbors to maintain the accurate system representation. Conversely, should borders between the neighboring entity and their neighbor be electrically close to the internal system, the needed detail in that "second-tier" would be inadequate.

3. A third option is reviewing the NERC Book of Flowgates for monitored or contingent elements for which an entity is responsible. The external model should be detailed enough to be able to run the external contingency (Contingent Element) for which the company has the Monitored Element. In addition, the external model should be detailed enough to monitor any impacted facility (Monitored Element) for which the company has the Contingent. This may be useful to establishing a minimum size. When analyzing these elements, ensure that an electrical path back to the internal system boundary is present to avoid creating unnecessary islands in the model.

4. A separate review of the distribution factors (DF) of various elements' outages for contingencies on a transmission planning bus/branch case can be used to define reasonable boundary limits. The analysis would entail simulating disturbances (contingencies) in the external system and monitoring the system of interest. Types of external disturbances that could be simulated for the analysis are:
    - Single Contingency (TPL-001-4 P1 through P2) on an element within the external substation (100 kV or above/BES) results in a DF to internal equipment greater than some threshold (suggested threshold of 5%).
    - Multiple Contingency (TPL-001-4 P3 through P7) on an element within the external substation (100 kV or above/BES) results in a DF to internal equipment greater than some threshold (suggested threshold of 5%). Note: This is a widely used industry practice.
    - An additional buffer area of a few substations beyond those meeting the above criteria could be added.
    - Add in 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 some threshold (suggested threshold of 5%)).
- Lower voltage contingent elements as required by system boundary connections

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 is 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 is critical. Load power factor in the equivaliized portions of the model should be consistent or similar to the internal model.

Convert the External Model and Install

For most of the EMS models, there is a distinction between "internal" and "external" largely determined by whether the data points are "real" telemetered values or brought in via ICCP from some other entity. For consistency of the dataset, the external model may need to be "converted" into the format that a particular EMS can read and use. The breadth of such systems and the tools for the conversion of a reduced external model into the compatible format is beyond the scope of this reference document.

Test and Install the New External Model

It is critical that the real-time system is not compromised by the addition of the new external model. Time should be allocated to ensure testing of the model will not adversely impact the EMS's real-time performance.

Topic 4: 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; request for information to the Regional Transmission Organization (RTO), or Reliability Coordinator (RC); and a connection through the Eastern Interconnect Data Sharing Network (EIDSN).

Analog Telemetry Measurements
State estimator accuracy is dependent on the availability of real-time measurements that are mapped to specific model objects with a unique location within the system topology. It is recommended that anywhere node-breaker modeling is represented, real-time analog measurements be in place. A focus should be placed 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 deweighted or ignored during the iterative state estimation calculation. It is imperative that when mapping measurements to model objects that the proper location of instrument transformers is assured for the purpose of determining proper analog representation. Likewise, in cases of ring bus designs, accurate mapping of breaker current transformer telemetry is key to assuring 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, 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 on how the positive flow is set on measurement installations.

Status Telemetry Measurements
An EMS model enabled by state estimation depends upon accurate topology in order to produce accurate load flow results. It is recommended that anywhere node-breaker modeling is represented, real-time switching status measurements be in place. A focus should be placed on measurements within the desired observability area and the higher kV system switching equipment. Stations in the area of interest without node-breaker switching detail, including the absence of status measurements, require the state of these transmission facilities to be maintained manually. As with all modeled topology, unmeasured facilities in parallel with measured facilities are more critical to solution integrity. Radial circuits can be accommodated such that the error created by the incorrect topology is adjusted by flow quantities.

ICCP Connection Considerations
Communication of real-time measurements is accomplished utilizing the Inter Control Center Communications Protocol (ICCP) application and the TASE 2 standard. There are currently three main options to receive external real-time measurements: a direct ICCP link with another entity; request for information to the Regional Transmission Organization (RTO) or Reliability Coordinator (RC); and a connection through the EIDSN.

1. Direct ICCP link

A direct ICCP link with a neighboring entity allows direct access to the information requested at the source. Any modifications to 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 with whom you would 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 without 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 Eastern Interconnect Data Sharing Network (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. Currently, 12 members transfer data through 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.

Topic 5: External Model and Data Maintenance

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

Some available options for exchanging data include sharing models, CIM Model Exchange, or SERC format model exchange. Should neighboring entities utilize the same vendor, sharing the node/breaker level models becomes a feasible option. CIM Model format is becoming more widely utilized in the industry for model exchange. Entities within the SERC reliability region have developed a .csv standard for model exchange. Techniques to automate any model comparisons will provide for more efficient use of engineering study time.

If an entity's model has not been maintained in quite some time, then consideration should be given to replacing the "full" model. This is a time consuming process because one needs to verify the accuracy, do a bit of equivalizing, and making large changes like this can cause reliability issues to the internal system model.

Appendix

One User's experience on exporting the Transmission Planning case to CIM: Converting Planning buses into substations in CIM

Overview

Generally, Common Information Model (CIM) cases have been used to translate an EMS case from one platform to another, even across different platforms. Planning models are bus number dependent, but EMS models are usually bus/substation name dependent. CIM models from Planning Models can be produced, but there may be little relation to any existing EMS models.

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. At the present time, Planning Model cases do not carry MRIDs, so any conversion of 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. In addition, Planning Model cases generally do not carry node-breaker information, so if that detail exists in the present model it can be lost with a future upload.

Potential users of a planning-produced external CIM model

There are instances where conversion from a planning case to CIM to an EMS platform can be useful. The case would have to be modeled out to an appropriate number of buses beyond the internal model, and equivalized and trimmed beyond that. Examples are listed as follows:

1. Initial startup of an EMS model. The ideal time to bring in a model with no node-breaker information or SCADA links is when none exists anywhere else in the model.
2. No external portion exists the EMS model. Adding any external model detail is an improvement, even if no node-breaker information or SCADA links is included.
3. The existing EMS model is very old and there are many changes to be made. The effort to update the external system using CIM should be weighed against the effort to update it manually, especially if there are existing SCADA links or node-breaker data that could be lost. Getting a planning model from a relatively small area, and importing that may be an option if other areas have SCADA links or node-breaker data.
4. Few ties exist between the internal and external models. This can limit the effort needed to tie the model together.

5. Little or no SCADA data is used in the external model, or little or no node-breaker modeling is used in the external model. This can limit the effort needed to tie the model together.

Challenges

When considering whether to use a planning model to add or upgrade the EMS model, there are challenges to be overcome. Examples are listed as follows:

1. In the one case that was given as an example, CIM version 13 did not take six- digit bus numbers, so buses had to be renumbered to five- digits.
2. Setting the boundaries of an EMS model generally includes equivalent lines, generators, loads, or a combination of them. Numerous issues were noted while handling the equivalized portion of the Transmission Planning case.
3. The new CIM-generated external model still has to be manually tied to all of the existing portions of the internal model.
4. If there is an existing model, there can be difficulties in building the new model from PSSE, while maintaining the model in production. These can be minimized by having additional platforms, such as a QA or development system, to build the new CIM-generated external model.
5. How is existing external information preserved into the new external model from a planning-produced CIM model, such as breakers, ICCP analog and status values, etc.

One utility's experience in updating an external model

The purpose of building an external model is to improve state estimator solution quality around tielines and to allow for 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 methology 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 bus – 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 inthe 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 vioiloations 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 100kV- 230kV
    b. 3 bus – Define line, transformer, and generator contingencies that have a voltage level above 230kV
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 model
        ii. All metering and status points are communicating accurately
        iii. All topology is accurate
        iv. All physical model data isaccurate

NDA: Sample Non-Disclosure agreement template to exchange information with the external utilities

MISO Sample Non-Disclosure Agreements are located at:

https://www.misoenergy.org/StakeholderCenter/ClientRelations/Pages/ClientRelations.aspx