Western Interconnection Modeling and Monitoring Common Methodology

1 Introduction and Purpose

The IRO-002-7 WECC regional variance requires Reliability Coordinators (RCs) providing Reliability Coordinator service(s) to entities operating within the Western Interconnection to develop a common Interconnection-wide methodology (henceforth referred to as the Methodology) to determine the modeling and monitoring of BES and non-BES Elements that are internal and external to its Reliability Coordinator Area, necessary for providing operational awareness of the impacts on Bulk Electric System Facilities within its Reliability Coordinator Area.

The variance provides specific requirements for inclusion in the methodology:

D.A.7.1. A method for development, maintenance, and periodic review of a Western Interconnection-wide reference model to serve as the baseline from which Reliability Coordinator's operational models are derived;

D.A.7.2. The impacts of Inter-area oscillations;

D.A.7.3. A method to determine Contingencies included in analyses and assessments;

D.A.7.4. A method to determine Remedial Action Schemes included in analyses and assessments;

D.A.7.5. A method to determine forecast data included in analyses and assessments; and

D.A.7.6. A method for the validation and periodic review of the Reliability Coordinator's operational model for steady state and dynamic/oscillatory system response.

At the root of this standard is an expectation to ensure that each RC has the appropriate level of modeling and monitoring in place to provide "operational awareness" [1] of the items listed.

The Methodology addresses the requirements of the Standard as follows:

- Modeling considerations, including the full Western Interconnection reference model, practices for the derivation of RC operational models used for Real-time Assessments (RTAs) and Operational Planning Analyses (OPAs), and validation and review processes for the RC's operational models. This addresses requirement D.A.7.1 and D.A.7.6.
- Analyses and assessment considerations, including methods for identifying RAS, contingencies and forecast data to be included in RTAs and OPAs. This addresses requirements D.A.7.1, D.A.7.2, D.A.7.3, D.A.7.4, and D.A.7.5.
- Inter-area oscillation considerations, including offline and real-time assessment methods for identifying RC Area risks due to inter-area oscillations. This addresses requirement D.A.7.2.

[1] The term "operational awareness" includes the activities performed by a wide range of operational personnel, including RC System Operators performing real-time RC functions, and Operations Planning Engineers performing outage coordination studies and next-day studies.

- Monitoring considerations, including general BES monitoring of pre- and post-contingency SOLs and IROLs in the RCs Wide Area (including RAS status and impacts), and monitoring the BES for impacts due to inter-area oscillations. This addresses a subset of requirement D.A.7.

The Methodology was developed and agreed upon by AESO, BCRC, RCW, and SPP.

The Methodology requires certain actions of the RCs. Throughout the document these specific actions are **highlighted and bolded** in order to assist in the creation of RC procedures and facilitate completion of NERC Reliability Standard Audit Worksheets (RSAWs).

2 Modeling Considerations

This section will define a method for development, maintenance, and periodic review of a Western Interconnection-wide Model (WIM) that will be used as a reference model to serve as the baseline from which RC's operational models are derived. This does not mean that each RC will use the entire reference model for their RC model; rather, it means that **each RC will utilize the reference model as the primary source for the derivation of its external model.** Each RC will decide how to best integrate the external model details and changes into their RC operational model.

The entity that is performing the model aggregation function to create the WIM is referred to in this document as the Model Administrator.

2.1 Western Interconnection Reference Model

The WIM is a full model of the Western Interconnection, containing both Bulk Electric System (BES) equipment as well as non-BES equipment that may be impactful to the BES. **Each RC will work with their respective TOPs and BAs to determine which non-BES transmission equipment, generation and load are important to model and monitor within their RC Area.** Non-BES equipment that are important for modeling and/or monitoring typically includes:

- Lower voltage (sub-transmission) networks that run parallel to the BES
- Lower voltage networks that have BES impactful generation or load
- Lower voltage networks that have BES impactful Remedial Action Schemes (RAS) or other automatic devices that impact the BES.

Studies performed to assess the impact of non-BES facilities for potential inclusion in the WIM can be performed on WECC operational cases, TOP detailed cases, or a combination of the two. **RCs must review exclusions provided by their TOPs** to ensure that important facilities are not erroneously excluded from modeling and/or monitoring.

The process for assessing BES and non-BES facility impacts and integrating those models into a full interconnection reference model (WIM) is depicted in Figure 1 below.

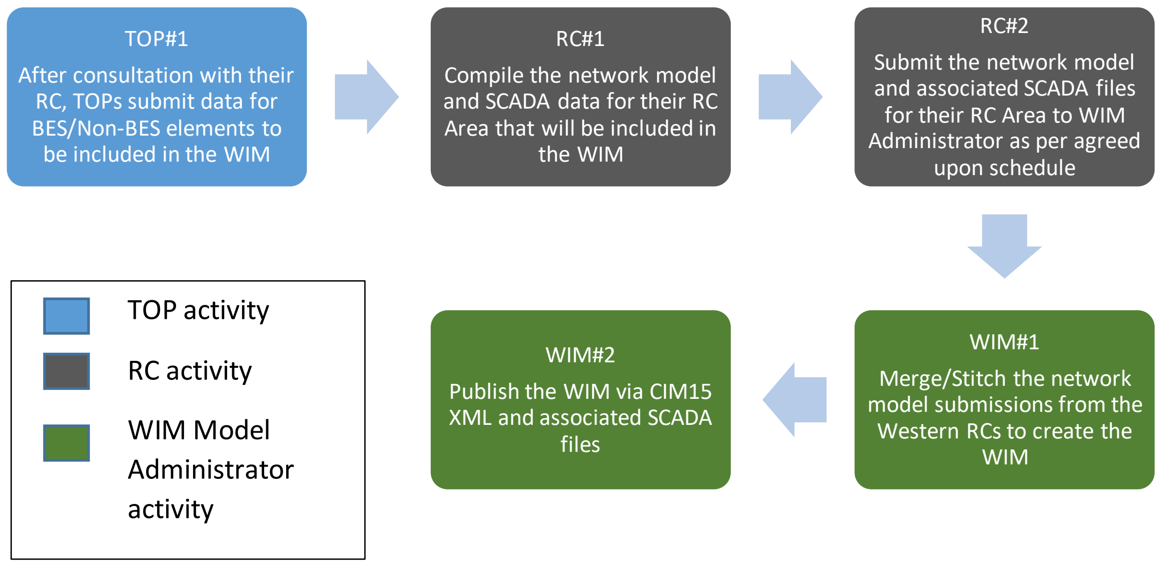

Figure 1: Process for WIM development

For the context of this methodology, the WIM contains the following data sets:

- Network model
- SCADA/ICCP point definitions and mapping to network model

2.1.1 Western Interconnection Reference Model Development and Maintenance

The Model Administrator is responsible for developing and maintaining the WIM. The model is based on the information that all the RCs have compiled for their RC Area.

It is the responsibility of each RC to have an RC data request that clearly defines TOP, BA and GOP model and data submission requirements as well as model and data submission timing. The RC's expectations will clearly address the need to submit updated/modified, new and retired equipment information to the RC in a timely manner. **It is then each RC's responsibility to pass along model changes to the Model Administrator for incorporation into the WIM.**

The process for maintaining the WIM is:

1. Each RC will submit all network model information (CIMXML format) and SCADA/ICCP point changes[2] to the Model Administrator within an agreed to period of time prior to the planned release date of the next WIM.

[2] It is expected that each RC share ICCP mapping tables that link the SCADA points to the ICCP object identifiers for both the BA/TOP names as well as the RC point names.

2. The Model Administrator will integrate all RC provided model updates contained within the CIM models and associated SCADA/ICCP point lists to create a new WIM.
3. The Model Administrator will perform validation and testing activities to ensure the new model has a high degree of quality.

The CIM XML data file includes detailed node breaker model with connectivity, model parameters, names and persistent RDFIDs. When the Model Administrator identifies issues with the model information provided by the other RCs, the Model Administrator will notify that RC as soon as practical to resolve the modeling issue. Due to the short timeframes associated with the WIM build and release cycles, it is expected that the RC will resolve the data issue and resubmit the corrected data set as soon as possible and within a timeline agreed to by the Model Administrator and the RC. If the Model Administrator determines that the issue will not be resolved in time for the current model release, the Model Administrator will coordinate with the RCs to determine if the problematic modeling information should be removed from the current model release, or if a work around solution can be implemented.

Model sharing timelines will follow the agreed upon IRO-010 data request process. Deviations from that standard timeline will require coordination among the RCs.

The Model Administrator will use their own internal business processes including testing, validation, and approval of the modeling changes in order to ensure high quality model performance in the real-time reliability application suites.

2.1.2 Western Interconnection Reference Model Periodic Review

The Model Administrator will publish the WIM and relevant data reports for the entities to review and validate for accuracy and completeness. Any discrepancies that need addressing can be submitted to the Model Administrator with the model changes for the upcoming monthly network model update cycle by the published scope cutoff date.

In addition to the regular Model Administrator validation, testing and model quality review processes, there are regular feedback loops that provide for regular model reviews. **Each RC that uses the WIM (either all or a portion for their external model) will review the model for accuracy as part of their model integration processes.** Any model issues will be provided back to the Model Administrator for addressing in a future WIM release. In the event that a problem that an RC has identified cannot be addressed in a timely fashion, an RC may make enhancements to their copy of the WIM, as they deem necessary.

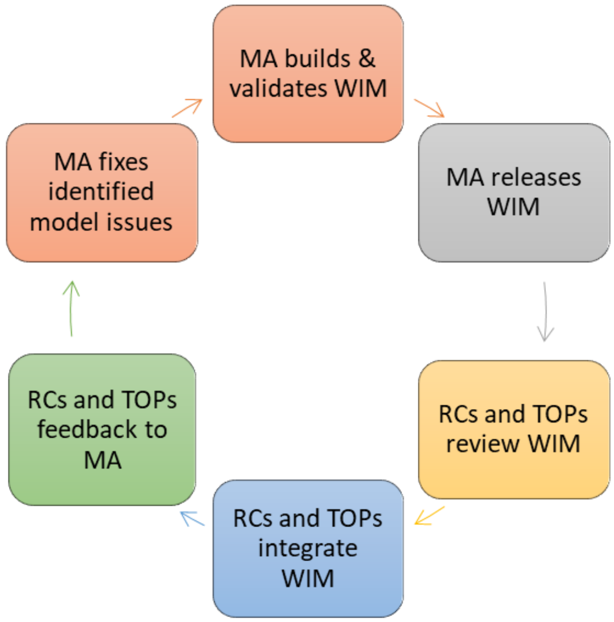

Figure 2: Western Interconnection Model Regular Review Process

2.1.3 WIM Formats and Supplementary Data Sets

Once the WIM is created, it will be made available to RCs, BAs and TOPs in the Western Interconnection. While not part of the WIM, contingency definitions and RAS modeling information are important data sets that need to be shared along with the WIM. **Each RC will provide their contingency list and RAS descriptions, including a mapping between RAS and contingency definitions** (to identify which contingencies trigger which RAS), to the Model Administrator for posting as supplementary information.

The contingency definitions provided by each RC **must contain the following information**:

1. Contingency Name/Description
2. Equipment type of Facility(ies) changing state in the contingency (line, transformer, unit, breaker/switch, etc.)
3. Facility name(s) that change state in the contingency
4. Conditionally credible indication – explanation of conditions leading to credibility is expected.

The RAS lists provided by each RC shall include other automatic protection schemes that the RC has determined are impactful to their RC Area. The combined RAS plus automatic protection scheme list provided by the RC **must contain the following information**:

1. RAS Name/Description
2. RAS Trigger Conditions
3. RAS Actions
4. ICCP arming status information including ICCP object IDs where available

Each RC will make available their respective contingency and RAS lists and corresponding network and SCADA models for review and inclusion into other RC RAS models in accordance with the RC's Reliability Coordinator Data Specification. While detailed RAS information is, generally only available from the RAS operating TOP, the RCs may share the RAS logic and triggering actions that have been incorporated into their OPA and RTA tools.

2.2 RC Operational Models

The RC operational models are those models that form the basis for the OPA and RTAs. This methodology provides each RC with flexibility in determining the appropriate size and detail of the RC operational model, including guidelines supporting model reduction and simplification.

In order to sustain appropriate performance in each RC's footprint and manage the effort/resources to maintain the EMS models and applications, some RCs may choose to develop a reduced external model from the WIM while still ensuring adequacy in terms of operating areas, voltage levels and detailed modeling per the RC's requirements for steady state and stability security assessment applications. Model reduction scope does not include model simplification processes for removing non-BES Facilities within the internal RC Area.

The goal of model reduction is to reach a reasonable balance between:

a) Satisfaction of the requirements of security assessment applications;
b) Sustainability of the effort/resources for maintaining the EMS, models and applications.

2.2.1 Determination of external system boundary

A reduced RC operational model can comprise three main portions as depicted in Figure 3:

- Internal RC Area model: Fully detailed node breaker model of the internal RC Area built in-house based on RC Area BES and non-BES Facilities.
- Tier 1 external model (Buffer zone model): Tier 1 external model consists of equipment external to the RC Area that the RC has determined are impactful to their RC Area. The tier 1 external model is a fully detailed node breaker model taken from the WIM and will be selectively merged with the internal RC Area model. Tie lines between the RC Area model and the tier 1 external buffer zone are explicitly modeled.
- Tier 2 external model (Equivalent model): Tier 2 external model consists of equipment that the RC has determined are not impactful to their RC Area. Initially taken from the WIM, the tier 2 model may be further simplified and merged with the tier 1 external model. The connections between the tier 1 and tier 2 external models, also known as "cut lines", do not have to be RC or BA area tie lines and it is acceptable that they represent the equivalent model connections necessary to drive appropriate model accuracy and quality.

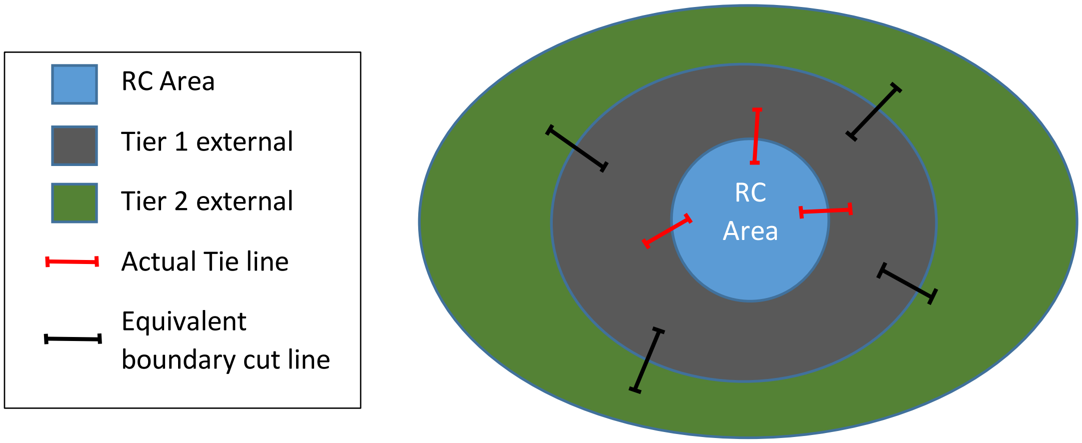

Figure 3: Three model zones of an equivalized RC operational model

All RCs will have these three components in their RC models. It is acceptable for the RC to insert an equivalent to represent the tier 2 external model, which will result in a reduced model only in that tier. If the RC has determined they want to model the entire Western Interconnection, tier 2 will still exist however; it will be a complete node breaker representation of those external areas.

2.2.2 Assessing Steady State Contingency and RAS Impacts when Determining Tier 1 Boundary

The first step in determining the tier 1 boundary due to steady state power flow issues is to perform a power flow-based sensitivity analysis to identify external contingencies and RAS that are impactful to the RC Area. Multiple base cases need to be studied to reflect different load and generation profiles to capture potentially different post-contingency voltage conditions. Details of how contingencies and RAS are selected are described in Section 3.

2.2.3 Assessing Dynamic Contingency and RAS Impacts when Determining Tier 1 Boundary

The tier 1 external portion of the RC model will also contain within the boundary any external contingencies that create unacceptable transient or oscillatory performance within the RC Area.

RCs can perform off-line studies to determine what, if any, transient or oscillatory problems exist within their RC Area and whether those problems are dominant factors in determining or monitoring their SOLs. If not, RCs can determine that only steady state security assessments are required in Operational Planning Assessments and Real-time Assessments timeframes. Under this scenario where no stability assessments are needed for an RC Area, the model reduction process described in this section is not necessary.

Stability study processes include evaluating and comparing post-contingency results for key monitored variables such as transient bus voltage magnitude and angle, MW/Mvar flows on key facilities, frequency and generator rotor speeds.

Once the stability assessment of contingency and RAS impacts is complete, the RC will have a second list of equipment and RAS that are to be included within the tier 1 external model boundary. This may be the same list of equipment and RAS as determined by the steady state assessments or it may be a larger or smaller list. The union of the steady state and stability equipment/RAS lists will define the overall tier 1 external model boundary for the RC operational model.

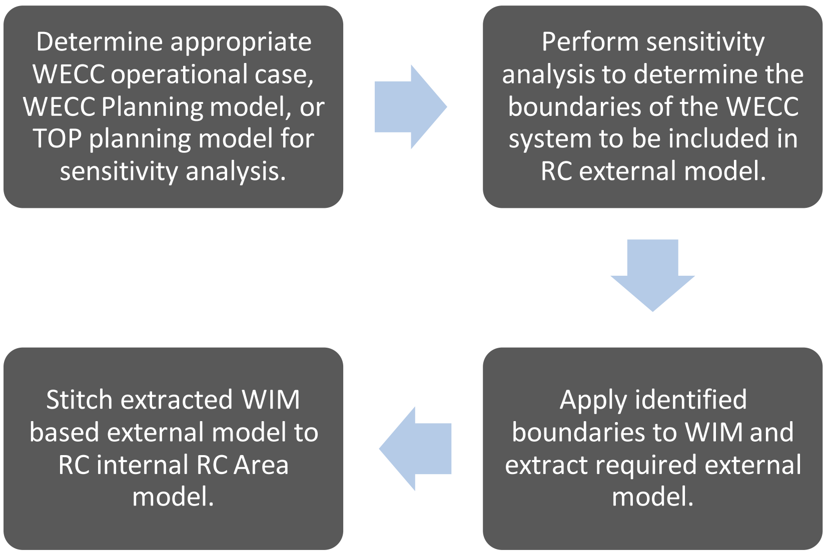

Figure 4: Process for determining RC Area external boundary and developing the RC operational model

2.2.4 Determination of Equivalent Tier 2 Model

Each RC will have some form of an external tier 2 model where the Facilities do not create significant post-contingency impacts on the RC Area, yet is important from a modeling perspective to support the overall accuracy of tools and applications making use of the RC model. Some RCs may wish to insert an equivalent or simplify their tier 2 external network model to a more manageable sized model, yet a model that accurately depicts the behavior of the Western Interconnection and any impacts to the RC Area. For on-line steady state assessment performed by RC, simple injections can be added to the boundary busses to represent equivalent load or generation units.

Based on the external model boundary obtained, model reduction tools can be used to determine the equivalent steady-state power flow model as well as the stability model to be used for the tier 2 external model. This should consider the frequency range of inter-area oscillations as specified in the scope of security assessment.

Again, the boundary and the equivalent models (both steady-state power flow and stability model) may be further refined considering the complexity of the merging process in terms of number of "cut-lines", the size of the equivalent model and complexity of mapping ICCP data with equivalent devices. The final external model boundary will include all facilities that are within both the steady state and stability model boundary.

2.3 Validation of RC Operational Models with Offline Methods

The objective for validation of the RC operational models is to demonstrate that the models perform at a consistent level as compared to a reference model. The basic approach of validation using offline study methods is the comparison of study results derived from the RC operational models and study results from full models.[3] Key monitored variables, including generator rotor angles, bus voltage magnitudes and angle, branch MW/Mvar flows and generator rotor speeds, can be considered in the comparison. A variety of representative operating conditions, covering different loading, transfer, and resource levels, must be selected in order to ensure that the reduced model performance meets a wide range of credible system conditions. Full model cases and RC operational model cases representing the various operating conditions must be aligned to ensure consistent initial conditions (including flows, voltages, generation and load).

Available methods for offline validation of reduced RC operational models include:

- Comparison of contingency/disturbance study results: Comparing the RC operational model and full model (such as WIM or WECC planning/operations model) results for 1) the post contingency steady state power flow results for the key monitored steady state variables (bus voltage magnitude, branch MW/Mvar flows) and 2) the post-disturbance transient results for key monitored variables (bus voltage magnitude and angle, MW/Mvar flows on key facilities, frequency and generator rotor speeds.)
- Comparison of oscillation parameters: Comparing the RC operational model and the “full model” using eigenvalue analysis, time domain simulation (e.g. at least 10 seconds) and/or other approaches to identify and evaluate the dominant modes related to the RC, including mode frequency and damping ratio.

The offline method for validating RC Operational models requires a common set of criteria to be used for assessing model performance.

Minimum comparison acceptance criteria for Internal RC Area Post-Contingency Steady State:

- Branch Flow (MW/Mvar):	Match within 10% of highest available rating;
- BES Bus Voltages:	Match within 0.05 per unit of nominal;

Time domain voltage and frequency comparisons are only applicable to RCs that have determined it necessary to perform stability studies using their RC operational model for their RC Area. Mode frequency and damping applies to dominant modes impacting the RC Area, as determined by the RC. Minimum comparison acceptance criteria for Internal RC Area Stability Acceptance

- System Frequency:	Match within 0.1% of system normal (60Hz)
- BES Bus Voltage Swing:	Match within 0.02 per unit of nominal voltage
- Mode frequency for oscillation:	Match within 5%
- Mode damping	Match within 5%

[3] A “Full Model” in this process refers to either a Bus/Branch model that was derived from the Western Interconnection Reference Model (WIM) and/or a WECC planning model.

An exception to the minimum criteria could be done based on engineering judgement. These exceptions need to be documented by each RC. Ongoing model updates of the WIM will happen monthly, making it important to periodically confirm that results from a reduced RC operational model continue to be aligned with results from the WIM/Full WECC model and that the model acceptance criteria continue to be met. **At a minimum, each RC with a reduced model will validate their operational model at least once per year or more frequently if the boundary area has significant BES topology changes.** If model performance is outside of acceptable ranges **the RC will make corrections to their model in order to correct the performance.**

2.4 Validation of RC Operational Model with Real-time Information

This section describes a method to support existing processes and procedures for validating the quality of the entire RC Operational model, including RC internal model representation, tier 1 external model representation and tier 2 external equivalent model representation (if applicable) using real-time information.

A method for validating the accuracy of an RC's Operational Model is through comparison of contingency analysis results obtained in study mode using state estimator saved solutions as base cases (both steady state and transient stability results) and actual event data. This can be done using an RC operational model to simulate a contingency, then comparing the simulated post-contingency state to actual observed post-contingency system state. For steady state comparison, it is appropriate to compare simulated quantities with actual SCADA quantities. For transient comparison, simulated quantities and actual event data (e.g. PMU/DDR data) can be compared. When validating RC models using real-time state estimator solutions and/or real-time data, RCs should determine reasonable performance criteria given expected differences in state estimator tuning practices as well as starting condition differences that exist using real-time information.

Each RC will validate their operational model against real-time information annually and make corrections to the model accordingly.

3 Analyses and Assessment Considerations

This section discusses processes for determining which external contingencies, RAS and forecast data (load forecasts, generation schedules, and scheduled outages) will be included in OPAs and RTAs.

3.1 Determining External Contingencies

Each RC shall follow these approaches to determine which external contingencies to include in its models, OPAs and RTAs.

1. RC Areas that have a post-contingency steady state thermal impact due to external contingencies shall use a Line Outage Distribution Factor (LODF) approach to identify the set of external contingencies for analyses and assessments.
    a. This process must include identification of external contingency that have LODF impact of greater than 10% on internal facilities.

2. RC Areas that have a post-contingency steady state voltage impact due to external contingencies shall perform analysis on an appropriate range of credible system conditions (generation, load, Interchange, topology) to determine the subset of critical contingencies.
    a. If this process identifies external contingencies that result in a voltage deviation of greater than 10% of nominal, then the RC must include those contingencies in their steady state analysis.
3. RC Areas that have voltage or transient stability concerns[4] due to external contingencies shall perform analysis on an appropriate range of credible system conditions (generation, load, Interchange, and topology) to determine the subset of critical contingencies.
    a. This process must address those sets of contingencies provided by the Planning Coordinator to RC.
    b. If this process identifies external contingencies that result in exceedance of 95% of an internal Facility Rating or a voltage deviation greater than 10% of nominal, then the RC must include those contingencies in their steady state analysis.

If, in the RC's judgement, contingencies identified from any of these approaches are not appropriate for use, **the RC shall document the reason for the exclusion of the contingency**.

Once the RC has completed the process to identify external contingencies, that **RC must coordinate results with adjacent and impacted RCs**.

The RC processes to identify external contingencies **must be performed and coordinated at least annually.**

3.2 Determining Remedial Action Schemes Needed for Assessments and Analysis

This section discusses the criteria by which internal and external Remedial Action Schemes (RAS) are selected for inclusion in models, OPAs and RTAs.

3.2.1 Methodology for RAS Internal to RC Area

In general, all RAS within the RC Area shall be included in analyses and assessments. However, each RC will evaluate the appropriateness of inclusion of RAS within their RC Area in various types of studies that are performed. For example, certain RAS are not applicable to steady state studies and it would only be appropriate to include those RAS models in transient simulations.

3.2.2 Methodology for RAS External to RC Area

Each RC shall include in its models, OPAs and RTAs any external Remedial Action Scheme that impacts one or more BES facilities within its RC area.

If the RC identifies external contingencies to be simulated that have associated RAS, those RAS shall be included in the RC's analyses and assessments.

Non-contingency based RAS that are impactful to the RC Area must also be included in OPAs and RTAs in order to provide operational awareness of the impacts of these RAS.

[4] Voltage stability and transient stability concerns are provided to the RCs by Planning Authorities, Transmission Planners, and Transmission Operators in accordance with FAC-014-2.

3.3 Determining Forecast Data Needed for Assessments and Analysis

Each RC must include appropriate forecast data to perform its OPA.

For each RC, the forecasted data for its internal RC area shall include the following:

- Area Load Forecast (LF)
- Unit commitment / Generation profile forecast
- Outage plan and equipment maintenance schedules

Each RC shall determine what external forecast data is available and needed for OPAs by performing sensitivity analysis or based on operational experience. **Each RC must consider the following in its OPA**:

- Generation and load forecasts for entities included in the RC operational model (Interchange forecasts may also be used).
- Planned transmission and generation outages for equipment included in the RC operational model

Each RC will submit the forecasted and planned outage data for entities within their RC Area to RC West, who will serve as the data hub for WECC forecast data. RC West will make the set of required forecast and planned outage data available to all Western Interconnection RCs.

4 Consideration of impacts of Inter-area oscillations

The intent of this section is to provide guidance regarding how each RC should assess the impacts of and provide operational awareness of inter-area oscillations on the BES within their respective RC Area.

The Western Interconnection currently has identified five inter-area oscillatory modes, otherwise known as system modes. Those system modes include:

1. “North–South Mode A” historically near 0.23 Hz. This was historically termed the “NS Mode.”
2. “North-South Mode B” historically near 0.4 Hz. This was historically termed the “Alberta Mode.”
3. “East-West Mode A” historically near 0.45 Hz. Until 2013, this mode was not observed due to poor PMU coverage.
4. “British Columbia” mode historically near 0.6 Hz.
5. “Montana” mode historically near 0.8 Hz.

The potential impact of inter-area oscillations on BES reliability is primarily associated with risks associated with a lightly damped system mode. Forced oscillations created by events on the system have been shown to result in wide-area resonant oscillations of large amplitude that can contribute to potential disturbances, such as the August 10, 1996 outage in the Western Interconnection.[5] An inter-area oscillation or mode is determined to be impactful to an RC Area when it has the potential to trip generation, cause relay mis-operation because of perceived fault detection, cause large power, voltage and frequency swings across the BES or cause uncontrolled separation or cascading outages.

[5] D. Kosterev, C. Taylor, W. Mittelstadt, “Model Validation for the August 10, 1996 WSCC System Outage,” IEEE Trans. Power Systems, Vol. 14, No. 3, pp. 967-979, Aug 2002

Key parameters used to provide operational awareness of the impacts of inter-area oscillations might include:

1. Inter-area mode frequency: As previously described, inter-area modes generally oscillate at a frequency less than 1Hz. Monitoring inter-area mode frequency validates that RCs are capturing inter-area mode oscillations;
2. Inter-area mode damping: Damping is the key attribute of an oscillation that determines its potential negative impact to the reliability of the BES. Insufficiently damped inter-area modes must be identified and monitored;
3. Mode Shape: Provides information to RCs about which generators are participating in a given mode of oscillation;
4. Participation Factor: A measure of controllability of a given mode at a given location (typically a generator). The participation factor is a direct measure of how much damping a PSS unit at a given generator can damp an oscillation of a given mode.
5. Oscillation energy: If an oscillation interacts with a system mode that has weak damping, it can lead to wide-area resonant oscillations of large amplitude that can contribute to potential disturbances.[6]

Given that this is a wide-area phenomenon, mechanisms are needed for sharing study and real-time information/results in order for RCs to coordinate their respective monitoring of inter-area oscillations, as well as for coordinating adjustments of their inter-area oscillation monitoring strategies, assumptions and parameters. To facilitate this coordination, RCs, WECC Joint Synchronized Information Subcommittee (JSIS) and its Oscillation Analysis Working Group (OAWG) will together determine the oscillatory modes that need to be monitored in the Western Interconnection.

4.1 Offline Determination of RC Area Impacts Due to Inter-area Oscillations

Not all inter-area oscillations directly impact every portion of the Western Interconnection. Therefore, **RCs must perform offline studies if they wish to demonstrate that any of the inter-area modes are not impactful to the reliability of their RC Area.** This section describes the preliminary steps necessary to determine which modes are impactful to the reliability of an RC Area and therefore should be monitored. This section does not address the specific methods for real-time assessment of mode parameters and reliability impacts used for operational awareness.

To do an appropriate offline assessment to determine which inter-area modes are impactful to the reliability of an RC Area, RCs may use a full Western Interconnection model (either the Western Interconnection Reference Model or a WECC planning model) or may develop a reduced model provided steps are taken to ensure the accuracy of the security assessment results is preserved. If a reduced model is utilized, previously discussed model reduction strategies should be applied when developing the model.

[6] NERC Reliability Guideline – Forced Oscillation Monitoring & Mitigation, September 2017

The RC will determine the appropriate frequency for this type of baseline assessment of their RC Area. The RC will perform the following offline analyses at an appropriate periodicity (based on the significance of the changes occurring to the system and models as reviewed and assessed by the RC) to determine the reliability impacts of the inter-area modes and oscillations on their respective RC Area:

1. Determine study model(s), including an appropriate mix of light and heavy load conditions;
2. Determine monitored variables: the responses to the disturbances for system performance evaluation. For an assessment of impacts due to inter-area oscillations, critical monitored variables include at a minimum inter-area mode frequency(ies), and inter-area mode damping.
3. Validate case setup is complete by ensuring that the base model contains stable inter-area modes and to determine which generation participates in the inter-area mode.
4. Perform time domain N-1 and N-1-1 contingency analysis for applicable contingencies to assess post-contingency stability of inter-area modes.

The goal of this offline analysis is to determine if any of the following conditions are true, thus warranting monitoring by the RC:

1. An inter-area mode, if left with low damping, could contribute to significant power, voltage or frequency swings in the RC Area;
2. An inter-area mode, if left with low damping, could contribute to SOL or IROL exceedances in the RC Area;
3. The inter-area mode, if left with low damping, could contribute to uncontrolled separation or cascading outages within the RC Area;
4. Generation within the RC Area that contributes to or participates in the inter-area oscillations;
5. The inter-area mode causes any other reliability issue within the RC Area, as determined by the RC.

It is prudent for an RC to perform this type of offline assessment (individually or jointly with other RCs) to capture reliability impacts due to the changing system topology, generation and load. Any changes identified by the RC to the inter-area modes should be coordinated with the other RCs, WECC JSIS and WECC OAWG.

Each time an RC performs an offline study to determine impactful inter-area modes, **that RC must coordinate the results with the other RCs**. It is important for the RCs to be aware of which RCs are studying and monitoring the Western Interconnection's inter-area modes.

Once the security assessments are complete and each RC understands the risk to their system due to inter-area oscillations, a risk management and situational awareness strategy can be developed. Those strategies may include the implementation of model-based tools as well as model-less tools.

4.2 Model Based Approach to Evaluating the Impacts of Inter-area Oscillations

Near real-time model based methods can be employed to determine if, based on real-time system conditions, an RC Area is at risk due to the impacts of inter-area oscillations. Since the inter-area oscillation issues being addressed through this methodology are small signal stability issues, model based tools focused on small signal stability are appropriate. This is primarily done by using a state estimator save case as input to a small signal stability application and performing near real-time studies.

4.3 Model-less Based Approach to Evaluating the Impacts of Inter-area Oscillations

Model-less applications can be used by an RC as part of a process to determine the impacts due to inter-area oscillations to the BES within their RC Area. Typically, model-less applications require PMU data across a wide area of the Western Interconnection to be able to accurately assess system conditions. WECC JSIS and WECC OAWG maintain a list of the existing PMU signals that are available for the accurate calculation of Western Interconnection inter-area mode parameters. Each RC will determine the PMU signals to monitor and to use as input to model-less applications based on the inter-area modes being monitored by the RC.

5 Monitoring Methods

This methodology will address unique monitoring requirements that are brought on by the existence of multiple RCs in the Western Interconnection. The goal is for each RC to have a common approach to monitoring to ensure clarity and consistency in response to identified impacts on other Western Interconnection RCs.

5.1 Monitoring Western Interconnection SOLs

5.1.1 Internal RC Area SOL Monitoring

Each RC shall monitor pre- and post-contingency conditions in its internal RC Area consistent with its SOL methodology.

5.1.2 External RC Area SOL Monitoring

Each RC must monitor for pre- or post-contingency SOL exceedances on Facilities outside of the RC's area that fall in any of three categories:

1. RC Area tie lines (depicted in Figure 5 as red lines),
2. Directly adjacent Facilities[7] (depicted in Figure 5 as green lines) or Coordinated Facilities (depicted in Figure 5 as yellow lines).

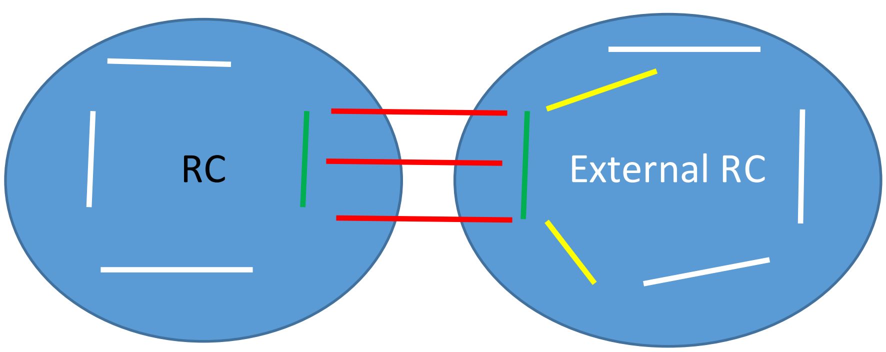

Figure 5: Diagram illustrates the shared responsibility for external monitoring.

[7] All BES transmission lines, transformers, and buses connected to or within the tie substation.

The RCs will identify coordinated Facilities. This coordination will include two steps:

1. Each RC shall identify external contingencies that impact Facilities within their internal RC Area according to the principles described previously in the Determining External Contingencies section. **Each RC will provide the list of its impacted Facilities to the RC creating the impact** (where the contingent element resides), and
2. **Validate and agree upon the lists with the appropriate RC**.

Once the list is coordinated among the RCs, the external RC will implement monitoring for those Facilities. Each RC will utilize the appropriate stability limits, post-contingency Facility ratings and bus voltage limits provided by the external RC where those Facilities reside.

5.1.3 Monitoring Unique System Conditions

Each RC should consider the impact of unique system conditions, which may lead to a need to monitor further into external RC Areas. Unique conditions may include potential open loop, unscheduled flow, coordinated phase shifter operations, major RAS, etc. Unique conditions also include external contingencies where internal RC Area generators, loads, or transmission equipment are named as a part of an IROL definition or are named as part of SOL or IROL exceedance mitigation procedures.

5.2 Monitoring Western Interconnection IROLs

Each RC will have operational awareness of all IROLs that are determined to be impactful to the RC Area or when the RC has a role in mitigating the IROL. For these IROLs, responsible **RCs must monitor**:

1. The flow(s) and limit(s) on the IROL interface/equipment
2. Status of key facilities critical to the derivation of the IROL (generators, shunts, transmission lines, etc.)
3. Status of key facilities critical to the mitigation of the IROL

Those RCs that have an IROL within their RC Area (either completely or partially) are responsible for calculating IROL values and will make those IROL values available to other requesting RCs via ICCP or other mutually agreed to methods.

5.3 Monitoring Inter-Area Oscillations

This section will address monitoring approaches for RCs to monitor inter-area modes that have been determined to be impactful to their RC Area.

RCs can obtain the data necessary for monitoring the impacts of inter-area modes in two ways:

- Calculate the necessary parameters using their own data, tools and processes.
- Receive the data necessary for monitoring from another RC or entity calculating those values. This data can be exchanged using ICCP or other agreed to methods.

The RC must ensure that the methods used for calculating inter-area mode parameters and impacts is consistent with the model-based and model-less methods described in this methodology.

Each RC's monitoring approach must address the following:

1. Alarming for low damping conditions for the inter-area modes as documented in existing processes and procedures. Note that each inter-area mode may have unique characteristics where the definition of "low damping" is different with each mode.
2. Alarming when inter-area mode oscillations have reached pre-determined levels as documented in existing processes and procedures.
3. Providing visualization of the inter-area oscillation (mode shape).

6 Methodology Review Cycle

The RCs must review this Methodology at least one time per year and update it as needed.

Revision History

Version #	Approval Date of Joint Western RCs Executive Committee	Effective Date	Revision History
1.0	2019/12/20	1/1/2020	Initial version
2.0	2020/12/18	1/1/2021	Annual Review: Identified changes to Section 2.1.3, a few formatting changes and recommended deletion of Appendix A. In addition, Methodology was classified as a "Public" document, included RC West procedure reference in header, minor format and grammar updates. 7/14/21 - Errata Change: Corrected approval date for version 1.0 to 2019/12/20.
3.0	2021/12/10	1/1/2022	Annual Review: No content changes to this document were requested. Updated NERC Standard IRO-002 reference (Section 1) and other minor format edits.

Version #	Approval Date of Joint Western RCs Executive Committee	Effective Date	Revision History
4.0	2022/12/15	1/1/2023	Annual Review: No content changes to this document were requested.
5.0	2023/12/08	1/1/2024	Annual Review: No content changes to this document were requested.