NERC
NORTH AMERICAN ELECTRIC RELIABILITY CORPORATION

Supporting Paper: EMT Models in NERC MOD, TPL, and FAC Standards

NERC Inverter-Based Resource Performance Subcommittee (IRPS)
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Industry Need

The bulk power system (BPS) in North America is undergoing a rapid evolution towards high penetrations of inverter-based resources. Interconnection queues, interconnection studies, and planning assessments across all Transmission Planner (TP) and Planning Coordinator (PC) footprints are grappling with ensuring reliable operation of the BPS based on reliability studies conducted during the interconnection process and long-term planning horizon. The rapid growth of inverter technology has pushed conventional planning tools to their limits, in many ways, and TPs and PCs are now faced with the need to conduct more detailed studies using electromagnetic transient (EMT) models (referred to herein as "EMT studies) for issues related to inverter-based resource integration issues. EMT studies have been used since the mid-1970s, and are now commonly used for studying possible reliability issues related to the interconnection of inverter-based resources. These inverter-based resource issues may include, but are not limited to, the following:

- Integration of inverter-based resources into low short circuit strength networks
- Sub-synchronous control interactions (plant-to-grid)
- Inverter-based resource controls interactions (plant-to-plant and within the plant)
- Inverter-based resource controls stability (large and small disturbance)
- Benchmarking RMS positive sequence dynamic models
- Inverter-based resource frequency and voltage ride-through capability and performance
- Inverter-based resource short-circuit current analysis
- Potential protection system operation
- Power quality studies
- Plant startup studies
- Unbalanced power flow studies

Industry experience has shown that areas with high or increasing levels of inverter-based resources have a strong need to perform EMT studies to ensure reliable operation of the BPS. As interconnection queues are almost entirely filled with inverter-based resources in many areas, these issues are only likely to become more prominent and exacerbated in the future by growing levels of this technology. The issues presented by growing amounts of inverter-based resources drive the demand for EMT studies to correctly identify any possible reliability issues during real-time operations.

To successfully accomplish these studies, TPs and PCs must gather EMT models and modeling information from applicable entities to build EMT cases in the areas where possible reliability issues may exist. The studies in which TPs and PCs may need EMT models span the interconnection study process (NERC FAC-002) and the long-term planning studies (NERC TPL-001). TPs and PCs can establish interconnection requirements to ensure EMT models are provided and verified during the interconnection studies, TPs and PCs rely on NERC MOD-032 to gather necessary information to conduct studies in the planning horizon. IRPS has determined that the functional requirement to gather EMT models, on a case-by-case basis, is necessary for reliability assessments; however, IRPS believes the standard drafting team should determine whether MOD-032 should be modified or if a new NERC Standard should be developed specifically for EMT model collection in the planning horizon. The presented SAR describes this in more detail.

Industry has also recognized that the collection of EMT models during the interconnection process is the most effective means of gathering these models for newly connecting facilities. Requiring EMT models after interconnection presents some challenges for the TP, PC, GO, and equipment manufacturers. As more inverter-based resources are connected to the BPS without collecting high quality EMT models for these facilities, the risk of future BPS reliability challenges increases. However, existing facilities may be required to provide an EMT model if a future reliability issue presents itself that requires an EMT study. Therefore, collection of EMT models in the long-term planning process is also necessary for ensuring reliable operation of the BPS.

While each TP and PC may be at a different place regarding their need to conduct EMT studies, the collection of EMT models from equipment owners is needed early. Industry has highlighted that collecting high quality EMT models of the generation fleet after-the-fact (e.g., after a large-scale outage) poses significant challenges and risks to successfully conducting EMT studies. Further, some TPs may need to conduct EMT studies for every interconnection today while others may only need to conduct EMT studies for specific localized areas or issues (e.g., SSR issues or low short-circuit strength areas). Therefore, IRPS believes TPs and PCs need assurance that they can gather suitable models to build EMT study cases when needed, and should ensure that appropriate EMT studies are conducted in areas where existing positive sequence dynamic studies are not adequately identifying possible reliability issues.

Drivers for EMT Modeling and Study SAR

NERC has been analyzing widespread solar loss events for many years dating back to the Blue Cut Fire disturbance in 2016, and has published multiple disturbance reports documenting the key findings and recommendations from those analyses. More recently, NERC published the San Fernando report (2020), the Odessa report (2021), and the California 2021 events report (2022). Each disturbance report provided strong recommendations for industry action to make updates to enhance the NERC Standards in these areas. Those requirements include:

Table 1: Recommendations from NERC Disturbance Reports
2021 California Disturbances
EMT Modeling and Model Quality Checks: NERC FAC-002, MOD-032, and TPL-001 should be revised to ensure that they adequately address the need for EMT modeling and studies during the interconnection study process and during annual planning assessments, as needed. As the penetration of inverter-based resources is growing across North America, all TPs and PCs should have clear requirements to gather EMT models at the time of interconnection and execute EMT studies to ensure proper ride-through performance for BPS fault events. Presently, the approaches taken by industry are leading to modeling and study gaps and consequently unreliable performance of inverter-based resources once interconnected. Furthermore, requirements specifically focused on model quality checks should be introduced to ensure that the TP and PC have validated the models submitted by the GO with sufficient supporting documentation to demonstrate model quality.
Odessa Disturbance
Requirements for Accurate EMT Models at Time of Interconnection: The existing NERC FAC-001 and NERC FAC-002 standards provide too much leverage and have led to inconsistency in how TPs and PCs are gathering modeling information and conducting interconnection studies. As the penetration of inverter-based resources is growing across North America, all TPs and PCs should have clear requirements to gather EMT models at the time of interconnection and execute EMT studies to ensure proper ride-through performance for BPS fault events. Presently, the approaches taken by industry are leading to modeling and study gaps and consequently unreliable performance of inverter-based resources once interconnected. The FAC-001 and FAC-002 standards more clearly align with the FERC GIP and GIA to clearly specify the models required and the studies to be conducted at the time of interconnection.
Update to NERC MOD-032 to Include EMT: The NERC MOD-032 standard is used by TPs and PCs to ensure appropriate models for performing system studies are provided by equipment and data owners. Presently, it is unclear how EMT models are treated in this standard and this lack of clarity needs to be addressed with a standard revision. EMT models should be made available by GOs to ensure system studies are conducted in the planning horizon for growing levels of inverter-based resources, not just for newly interconnecting facilities. Larger-scale EMT studies will likely be needed in the future as penetration levels continue to rise.
Updates to Ensure Model Quality Checks and Model Improvements: GOs need to provide accurate models to the TPs and PCs based on existing requirements. A feedback loop to ensure model accuracy (for any type of model) is only an optional specification in the existing MOD-032 standard. Model quality checks should be conducted by all TPs and PCs, and any modeling errors should be addressed by the equipment owner (i.e., the GO) in a timely manner. Model quality reviews should include more than just model usability—they should check for model parameterization issues or inconsistencies against plant performance to real events.
San Fernando Disturbance (IRPWG Follow-Up Recommendation)
Modeling and study standards (e.g., MOD and TPL) should be reviewed by IRPWG to consider the inclusion of EMT models for study purposes by the TP and PC. Currently these studies that would be used to identify possible tripping or abnormal performance from inverter-based resources are not required and are performed only in certain occasions where the TP or PC has identified issues with other modeling tools. However, the issues identified in these disturbances have not been identified or highlighted by the TPs or PCs in their respective area. IRPWG is working on an EMT modeling reliability guideline; however, this does not ensure any one entity actually executes EMT studies, when needed.

Purpose or Goal

This project addresses the reliability-related need and benefit by ensuring TPs and PCs have the models and tools necessary to adequately conduct reliability assessments under increasing levels of inverter-based resources. This requires the collection of EMT models by applicable entities and TPs and PCs to conduct EMT studies where needed. Furthermore, this proposed project addresses reliability issues identified in the NERC disturbance reports by accomplishing the following:

- Ensure that the interconnection study process is clear on the modeling and study requirements needed to ensure reliable operation of the BPS, inclusive of EMT modeling and studies (NERC FAC-002).
- Ensure that EMT models are available to TPs and PCs for the purposes of reliability studies – interconnection studies per FAC-002 and planning assessments per TPL-001 (using MOD-032 as the modeling data standard, or a new standard if deemed necessary)
- Ensure that model quality issues are addressed both during interconnection studies (FAC-002) and during annual case creation and planning assessments (MOD-032/TPL-001)
- Ensure that EMT studies are conducted by TPs and PCs during the interconnection study process (FAC-002) and during annual planning assessments (TPL-001) if the TP or PC identifies a reliability need to conduct these studies (i.e., on an as-needed basis with technical justification).

Project Considerations

The following are important considerations and details that the future NERC Standard Drafting Team should consider in the development of standards modifications:

- The inclusion of EMT models should not supersede or replace the need for other types of models (e.g., positive sequence models).
- In many cases, synchronous generating resources can be modeled in EMT by converting their positive sequence dynamic models and therefore are not expected to be significantly impacted by EMT modeling. However, some instances may arise (e.g., subsynchronous control interactions or torsional interaction) where more detailed information from select generating resource may be needed for reliability purposes.
- Model accuracy is critical for both EMT and positive sequence dynamic modeling. In either case, the validity of the study is incumbent on having accurate and representative models of the equipment installed in the field. Incorrect models or model parameters lead to inaccurate study results in both situations. Simply having an EMT model of a facility does not mean that the simulation is necessarily more accurate.
- The GO has the responsibility of providing a high quality, accurate model (EMT and positive sequence). The TP and PC need to check submitted models for any possible errors and will also need to ensure that the level of detail is defined in their modeling requirements documentation based on the types of studies being conducted. For example, subsynchronous torsional interaction studies may require a much more detailed model of certain components than inverter-based resource ride-through studies. Conversely, ride-through assessments will need detailed modeling of inverter protections and controls. These types of modeling requirements established by the TP and PC based on studies needed for reliability purposes are presently developed for positive sequence dynamic modeling; these concepts would also apply to EMT modeling and studies.
- EMT simulations will require representation of generating resource equipment and controls, electrical transmission system elements, transmission-connected devices and controls (e.g., HVDC and FACTS devices), and some representation of end-use loads. Therefore, the TP and PC will need access to information for EMT modeling purposes if and when needed for EMT studies.

- TPs and PCs will need to ensure model usability (efficiency, interoperability, etc.) as part of their modeling requirements documentation. Since many EMT models are black-boxed, the TP and PC will need associated documentations clearly describing steps to setup the model, available parameters accessible to the end user (with prior agreement with OEMs), and available outputs that are needed for overall plant design evaluation and planning studies. TPs and PCs may seek clarifications regarding overall control performance to understand the model and its use in studies.
- EMT models should be provided as part of the interconnection study process for all newly interconnecting generating resources. Gathering these models and modeling information at the time of interconnection is the most effective and efficient way to create, evaluate their performance based on applicable requirements and submit these models. However, existing plants which are already in service may also need to provide EMT models in the future. The need for these models is usually driven by changing system conditions in the project region; therefore, we cannot rely solely on FAC-002 as the venue for which EMT models are submitted. TPs and PCs need capabilities to gather EMT models for all facilities, and should have the authority to request those models for any BES resource if needed. Therefore, modifications to MOD-032 are also introduced.
    - It may be cumbersome to modify MOD-032 to include EMT modeling in sufficient detail; therefore, the teams leaves it up to the future Standard Drafting Team to determine whether a new standard may be needed or if modifications to MOD-032 are sufficient.
- EMT simulations are necessary to identify possible ride-through issues (assuming an accurate EMT model is provided) for inverter-based resources. This has been highlighted in NERC disturbance reports multiple times. However, it is not pragmatic at this time for all TPs and PCs to conduct EMT studies for every newly interconnecting resource. Therefore, TPs and PCs will need to apply objective risk-based measures to identify situations where EMT studies are needed.

Technical References to Support Project Need

The following is a list of reference materials that strongly demonstrate the need for NERC Standards modifications regarding the inclusion of EMT modeling and EMT studies to identify reliability issues associated with increasing penetrations of BPS-connected inverter-based resources. The NERC reports and guidelines strongly emphasize the need for EMT modeling and studies and serve as the technical basis for the SAR presented. The other industry references show that there is significant industry experience and focus in this area today with additional improvements in EMT capability moving forward.

NERC Documents

- NERC 2021 California Disturbances Report (2022)
- NERC Odessa Disturbance Report (2021)
- NERC San Fernando Disturbance Report (2020)
- NERC Palmdale Roost and Angeles Forest Disturbances Report (2019)
- NERC Canyon 2 Fire Disturbance Report (2018)

- NERC Blue Cut Fire Disturbance Report (2017)
- NERC-WECC Technical Report on Inverter-Based Resource Modeling (2020)
- NERC Reliability Guideline: Integrating Inverter-Based Resources into Low Short-Circuit Strength Networks (2018)
- NERC Reliability Guideline: Improvements to Interconnection Requirements for BPS-Connected Inverter-Based Resources (2019)
- NERC Reliability Guideline: BPS-Connected Inverter-Based Resource Performance (2018)

Industry Documents

- AEMO Investigation Into System Strength Frameworks in the NEM (2020)
- AEMO Power System Model Guidelines (2018)
- AEMO Dynamic Model Acceptance Test Guideline (2021)
- Review of AEMO's Power System Model Guidelines and System Strength Impact Assessment Guidelines (2018)
- ERCOT 2018 Panhandle and South Texas Stability and System Strength Assessment (2018)
- ERCOT 2020 Panhandle Regional Stability Study (2020)
- ORNL High Penetration Power Electronics Grid: Modeling and Simulation Gap Analysis (2020)
- CIGRE Guide for Electromagnetic Transient Studies Involving VSC Converters (2021)
- CIGRE C4.56: "Electromagnetic transient simulation models for large-scale system impact studies in power systems having a high penetration of inverter connected generation" (Expected 2022)
- CIGRE B4.82: "Guidelines for Use of Real-Code in EMT Models for HVDC, FACTS and Inverter based generators in Power Systems Analysis" (Expected 2023)
- CIGRE C4-60: "Generic EMT-Type Modelling of Inverter-Based Resources for Long Term Planning Studies" (Expected 2023)
- Hawaiian Electric Facility Technical Model Requirements and Review Process (2021)
- Hawaiian Electric Island-Wide PSCAD Studies (2021)
- Hydro Quebec TransEnergie Technical Requirements for the Connection of Generating Stations to the Hydro-Quebec Transmission System (2019)
- Electranix EMT Requirements Documentation (2021)