NERC
NORTH AMERICAN ELECTRIC RELIABILITY CORPORATION

Technical Rationale for Reliability Standard

MOD-026-2 – Verification of Models and Data for BES Connected Facilities

Introduction

This document is the technical rationale and justification for Reliability Standard MOD-026-2 and includes the rationale for changes in the current proposed version, as well as previous versions of the standard.

It is intended to provide stakeholders and the ERO Enterprise with an understanding of the revisions, technology and technical concepts of Reliability Standard MOD-026-2.[A1] This [A2]is not a Reliability Standard and should not be considered mandatory and enforceable.

Background

The NERC Inverter-based Resource (IBR) Performance Task Force (IRPTF) performed a comprehensive review of all NERC Reliability Standards to identify any potential gaps and/or improvements. The IRPTF discovered several issues as part of this effort and documented its findings and recommendations in the *IRPTF Review of NERC Reliability Standards White Paper*, which was approved in March 2020 by the Operating Committee and the Planning Committee (now part of the Reliability and Security Technical Committee (RSTC)). Among the findings noted in the white paper, the IRPTF identified issues with MOD-026-1 and MOD-027-1 that should be addressed. The RSTC endorsed the standard authorization request (SAR) on June 10, 2020.

Consistent with the IRPTF recommendations, the scope of the proposed SAR includes revisions to NERC Reliability Standards MOD-026-1 and MOD-027-1. These standards require, among other things, Generator Owners to provide verified dynamic models to their Transmission Planner for the purposes of power system planning studies. The project proposed revisions to MOD-026-1 and MOD-027-1 to clarify requirements related to IBRs, and to require sufficient model verification to ensure accurate generator representation in dynamic simulations. The IRPTF recommended revisions to clarify the applicable requirements for synchronous generators and IBRs.

Additionally, the potential risk of increasing amounts of reactive power being supplied by nonsynchronous sources was identified in *NERC's 2017 Long-term Reliability Assessment*. In response to the concern, the Planning Committee (PC) assigned the System Analysis and Modeling Subcommittee (SAMS) to study the issue. The SAMS developed the *Applicability of Transmission-Connected Reactive Devices* white paper, which was approved by the PC at its December 2019 meeting. The PC Executive Committee approved the SAR on February 11, 2020. Recommended revisions to MOD-026-1 and MOD-027-1 outlined in the SAR were undertaken within the scope of this project.

Rationale for Applicability Section - Functional Entities

The purpose of the MOD-026-2 standard is to ensure models used in planning and interconnection analyses are verified and validated, and that these models accurately represent in-service equipment. There are four functional entities that play a role in MOD-026-2 requirements and have an obligation to comply with them. These are:

- Generator Owner
- Transmission Owner that owns a Facility per Section 4.2.4 and 4.2.5
- Transmission Planner
- Planning Authority

The Generator Owner and Transmission Owner are responsible for providing validated and verified models to the Transmission Planner that reflect in-service equipment and power plant performance. These models must reflect the dynamic performance of equipment being installed or already installed in the grid under various expected grid conditions and disturbances. These verified and validated models are needed so that Transmission Planners may assess the impact of the power plant on grid stability and resiliency.

The Transmission Planner and its Planning Authority is responsible for jointly developing and maintaining model requirements and processes and making them available to the Generator Owner or Transmission Owner. These requirements and processes outline the type and criteria of required validated and verified models as well as the process to submit and review them for acceptance. The Transmission Planner, jointly with its Planning Authority, will also specify processes for provision of models to Planning Authorities as well as how Generation Owners and Transmission Owners may obtain models from the Transmission Planner's database. These requirements and processes are needed to clearly articulate validated model acceptance, provision and dissemination by and to all necessary entities.

The Transmission Planner is also responsible for reviewing submitted verified models and accompanying information, updated verified models, and written responses from Generator Owners and Transmission Owners. Transmission Planners are responsible for communicating model acceptance and denial to the Generator Owner or Transmission Owner.

Facilities

A facility that would need to meet the requirements in this standard and be considered an "applicable unit" fall under the characteristics defined by the NERC Bulk Electric System (BES) Definition Inclusion I2 and I4 for generating facilities, Inclusion I5 for dynamic reactive resources (synchronous condenser and FACTS devices), or for high voltage direct current (HVDC) facilities. That is, any unit, plant or resource connected to the BES and meet the unit rating criteria set by the BES definition. This Facilities Applicability is consistent with most other NERC reliability standards being tied to BES-qualified units. The proposed standard links applicability to the BES definition (as opposed to defined rating or other thresholds) to be sure that now and in the future, should the BES definition be modified, the standard is consistent with applicable BES facilities. This avoids the need to modify the standard if definitive thresholds are specified and the BES definition is modified.

Rationale for Requirement R1 - Part 1.1

MOD 026-2 Part R1, 1.1 expands MOD 026-1 R1 bullet 1 to not only require the TP list the acceptable models but also requires the TP to specify the required format and level of detail. The 90 day response time in MOD 026-1 R1 is removed and instead MOD 026-2 M1 requires a document to be maintained for distribution. The intent of Part 1.1 is to require the TP to specify the type of positive sequence models compatible with their planning process. The TP should specify the software tools and version numbers that the model must be compatible with and describe the format and submission requirements. The TP must specify which models are acceptable and may decide to adopt the NERC Unacceptable Model List Regarding format, the TP may specify compatible file types, may request completion of forms or templates, may require example cases where the model is set up to run. The TP should consider requiring complete documentation / user manuals describing model set up, control block topology, tuning, etc. For model set up, it is common to describe the appropriate apparent power (MVA) base, equivalent reactance (Xsource), reactive limits (Qmin and Qmax), and impedances of any low voltage generator step-up transformers. In addition, the TP may have additional requirements to ensure model compatibility, accuracy, or performance and may have specific policies regarding user-defined models versus standard library or generic models.

Part 1.2

MOD-026-2 Requirement R1, Part 1.2 expands requirements of MOD 026-1 R1 bullet 1 to cover EMT models in addition to positive sequence (“dynamic”) models. EMT models are not required of all types of generators, since MOD-026-2 Requirement R6 limits when EMT model need to be submitted by a Generator Owner or Transmission Planner. Requirement R1 Part 1.2 merely requires the TP to document acceptable models, format, and level of detail for situations where EMT models are required. The intent of Part 1.2 is to require the TP to specify the type of electro-magnetic transient (EMT) models compatible with their planning process. The TP should specify the type of software used and version (including compiler version). To ensure the model is compatible with nearby models for larger studies, the TP may define the range of simulation time-step sizes the model must be capable of operating over. Regarding level of detail, the TP may require full detailed modeling of phase-locked-loops (PLL) and fast current controls, power electronic switches or equivalent switching models (as opposed to average source models). For accuracy, the TP may require usage of actual code or require hardware validations / benchmarks or may prohibit models from using certain off-the-shelf library blocks (such as using a generic phase-locked-loop (PLL) control block rather than modeling the actual PLL control block). It is recommended that the TP describe the planned use for the EMT model (such as weak-grid studies, sub synchronous resonance, unbalanced faults, or special islanding or over-voltage protection studies) so that the vendor can ensure an appropriate level of detail. The TP should also indicate if balance-of-plant equipment shall also be included in the model including the Power Plant Controller (PPC). For ease-of-use, the TP may require that certain controls or outputs be easily accessible (such as real or reactive power dispatch controls), require description of trip codes for debugging, or the ability to adjust or disable protection models.

Part 1.3

Part 1.3 incorporates the usability criteria MOD-026-1 R6 (Parts 6.1-6.3) and MOD-027-1 R5 (Parts 5.1-5.3). The intent of Part 1.3 is to allow the TP to define acceptance criteria to determine whether the model is usable and other necessary criteria and makes the acceptance criteria clear to the GO/TO upfront. This defined and known criteria creates efficiency in the review process, reducing review times and submission overheads, and increasing the likelihood that models will be accepted by the TP without multiple revisions from GOs/TOs.

It is recommended that the Transmission Planner is familiar with the most recent industry guidance to inform their acceptance criteria. For example *NERC BPS-Connected IBR Modeling and Studies Technical Report (Chapter 1)* provides a list of recommended questions to ask when receiving dynamic models, which provide a basis for the Transmission Planner when receiving a model and *WECC's Solar Photovoltaic Power Plant Modeling and Validation Guideline*. Transmission Planners may also choose to identify parameters that are technically acceptable, but violate interconnection requirements; such as inappropriate droops, deadbands, protection settings, or control modes.

Part 1.4

Part 1.4 was not directly included in MOD-026-1 or MOD-027-1. Part 1.4 requires that a process for submitting models to the GO and TP is developed jointly by the Transmission Planner and Planning Authority and is made available to submittal parties. This part is an addition to the previous MOD-026-1 standard and is intended to aid in model submittal efficiency by providing clear submittal processes to the GO and TO.

Part 1.5

MOD-026-2 Part 1.5 was not directly included in MOD-026-1 or MOD-027-1. Part 1.5 requires that a process be developed by which verified models are submitted to the Planning Authority, which could be done by the Transmission Planner or a designee, after meeting acceptance criteria of the Transmission Planner. This part is an addition to the previous MOD-026-1 standard and is added to ensure there is a clear process for the Planning Authority to receive acceptable models for their studies. This also allows the Planning Authority to make verified models available for use in Interconnection-wide case(s).

Part 1.6

MOD-026-2 Part 1.6 incorporates MOD-026-1/MOD-027-1 R1 bullet 3, but the timeframe previously required of 90 days is no longer specified. Part 1.6 allows the ability for GOs and TOs to obtain their existing models from the Transmission Planner via a process defined by the TP. This request is essential to GOs and TOs when there is a change in ownership, the model is not on file, or there are discrepancies between model records.

Rationale for Requirement R2

MOD-026-2 R2 incorporates only the synchronous generation aspects of MOD-026-1 R2. This requirement adds more detail about what must be modeled for synchronous generation, such as limiters and protection systems, and that the model represents in-service equipment at the Facility. The representation of the

voltage regulation and dynamic reactive response of synchronous generating units to transmission system voltage disturbances is necessary for accurate evaluation of system stability and reliability in dynamic simulations. Therefore, verified dynamic models and associated parameters representing generators, their excitation systems, and certain limiters and protective functions associated with the voltage regulation and reactive performance are requested.

Rationale for Requirement R3

MOD-026-2 R3 incorporates only the synchronous generation aspects of MOD-027-1 R2. This requirement adds more detail about what must be modeled for synchronous generation, such as limiters and protection systems, and that the model represents in-service equipment at the Facility. The representation of the speed governing and active power response of synchronous generating units to transmission system frequency events is necessary for accurate evaluation of system stability and reliability in dynamic simulations. Therefore, verified dynamic models and associated parameters representing turbine-governors, load controllers, and certain protective functions associated with frequency response and active power performance are requested.

Protection systems modeling for MOD-026-2 R2 and R3: Modeling of protection systems is critical because large disturbance phenomena can cause protection systems to disconnect generating resources from the grid. This can exacerbate grid disturbances, potentially causing cascading failures, islanding scenarios, etc. Additionally, transient behavior can result in the disconnection of units if protection system elements are set with minimal time delays. The Transmission Planner must be able to study this behavior to assess and mitigate the reliability risk. Elements of concern include voltage, V/Hz, loss of field, stator/field overcurrent, as they are recognized as potentially sensitive to large disturbance events and are operating on quantities of direct regulation by the excitation system. Frequency (and speed) elements are of concern due to many entities setting these based on PRC-024 requirements rather than equipment capability. Similarly, many large steam turbines are set with tight protection frequency/speed settings due to the nature of steam turbine design and capability.

Rationale for Requirement R4

MOD-026-2 R4 incorporates the IBR generation aspects of MOD-026-1 R2. This requirement adds information that must be provided and additional details on required models for IBR generation. MOD-026-2 R4 has been drafted with the intent of providing clear modeling requirements for dispersed power producing resources outlined in BES Inclusion I4 (IBR, wind tech, and hybrid plants), power based electronics (FACTS devices), and HVDC terminal equipment, so that models represent in-service equipment at each Facility. R4 is specific to positive sequence modeling and reflects the intent of the SAR to verify both small signal performance via staged testing (termed as validation) and large signal performance via documentation and analysis exercises. This requirement has both verification and validation activities including documentation of manufacture and equipment information, modeling of hardware and control systems, requirement for validation (staged testing or disturbance monitoring), and protection system modeling.

Rationale for Requirement R5

MOD-026-2 R5 incorporates the IBR generation aspects of MOD-027-1 R2. This requirement adds information that must be provided and additional details on required models for IBR generation. The technical rationale for MOD-026-2 R5 is similar to R4, described above. The intent of this requirement is to ensure active power/frequency response of the model reflects in-service equipment at the Facility.

Rationale for Requirement R6

MOD-026-2 R6 has been drafted with the intent of providing clear requirements to verify EMT models represent in-service equipment at each Facility. As inverter-based resources continue to interconnect to the bulk power system (BPS) across North America, Transmission Planners and Planning Authorities are faced with challenges relying solely on the root mean squared (RMS) positive sequence dynamic models to ensure reliable operation of the BPS. The following challenges have been identified in an increasing number of networks across North America and around the world:

- The RMS positive sequence simulation platforms, by design, are generally not suitable for capturing the dynamic response of inverter-based resources for unbalanced fault conditions.
- Due to the aforementioned point, any individual phase-based controls or protection cannot generally be modeled to complete accuracy in an RMS positive sequence simulation platform. For this reason, the RMS positive sequence dynamic models have limitations in precisely assessing ride-through performance during unbalanced faults often performed during interconnection studies.
- In areas of high penetrations of inverter-based resources or low short-circuit strength networks, the existing state-of-the-art generic RMS positive sequence dynamic models may encounter numerical issues that pose challenges for Transmission Planners. TPs,
- The RMS positive sequence dynamics models do not include the real-code behavior of inverter-based resources and often involve engineering judgment based on controller block diagrams used in representing the actual performance of these complex power electronic resources.
- Due to the numerical issues and simplified modeling assumptions described above, the existing state-of-the art generic RMS positive sequence dynamic models are often unable to identify controls instability or controls interactions with neighboring facilities or sub-cycle inverter tripping.

A combination of modeling challenges drives the growing need for EMT modeling and studies for inverter based resources, particularly in areas of growing penetration of inverter-based resources or low short-circuit strength. These areas may be wider areas of the BPS or may be local pockets of inverter-based resources that often do not include any nearby synchronous generation or loads. The *NERC Reliability Guideline: Improvements to Interconnection Requirements for BPS-Connected Inverter-Based Resources* recommends including real-code EMT modeling requirements for all newly interconnecting inverter-based resources to the BPS and also recommends benchmarking the RMS positive sequence dynamic models with those EMT models. All the issues described above are dependent on accurate parameterization of the models to match the installed equipment in the field. Inaccurate parameterization of any model (RMS positive sequence or EMT) can lead to misidentification of potential BPS reliability issues via studies.

An alternate means of large-signal positive sequence model validation is necessary, because the large-signal response of IBRs is dependent on programmable control and protection functions and therefore cannot confidently be extrapolated from small-signal stage testing. Additionally, large-signal validation by staged testing is not feasible and events of a large-signal nature are unlikely to occur at convenient intervals or at all. The use of EMT modeling and simulation as a substitute for large-signal staged testing or actual large disturbance events comprises such alternate means. In Requirement R6, EMT modeling of individual inverter units is first to be attested by the OEM and verified against factory type tests. In the case of the IBR unit, the R6.1 attestation is that the EMT model(s) contains the control modes, control blocks, and protective functions that may be active in disturbance performance. R6.2 device testing then ensures that the IBR unit model response is consistent with or emulates the response of the supplied equipment. Aggregate plant models are then formed by adding other plant element models, including the similarly OEM attested power plant controller model and any auxiliary dynamic device models such as statcoms, to the validated equivalent(s) of the individual inverter units into an overall plant model. The verified/validated EMT plant model then becomes the platform against which the positive sequence plant model may be validated. The specific large-signal simulation tests that may be run on both EMT and positive sequence models for benchmarking comparisons may include balanced and unbalanced faults, delayed clearing phase-ground point of interconnection faults, temporary or transient over-voltages, rates of change of frequency (ROCOF), varying short circuit levels (or ratios), and phase angle jumps as may be specified by the Transmission Planner under R1.3.

Rationale for Requirement R7

MOD-026-2 R7 incorporates the intent and aspects of MOD-026-1 R4 and MOD-027-1 R4. This requirement is intended to ensure that updated verified and validated models are provided to the transmission planner within a reasonable timeframe after any modification to an existing facility that changes the dynamic performance of that facility. This would cover a change in facility ratings or characteristics such as, nameplate rating, control software or parameter adjustments, hardware alterations such as exciter or governor changes, etc. If changes to dynamic performance result from these equipment or facility modifications, the dynamic models used to assess their impact to the grid also need to be revalidated and resubmitted so Transmission Planners may study the reliability impact of the new as-built facility on the grid.

Rationale for Requirement R8

MOD-026-2 R8 incorporates the intent and aspects of MOD-026-1 R3 & R6 and MOD-027-1 R3 & R5. This requirement is intended to ensure that the Transmission Planner reviews the model and accompanying information and provides feedback to the Generator Owner/Transmission Owner within a reasonable time. If the TP determines that the verified model and accompanying information does not meet the acceptance criteria or processes established in Requirement R1 they must provide sufficient information for the Generator Owner or Transmission Owner to understand and correct the deficiency. This requirement is similar to R6 of MOD-026-1 and R5 of MOD-027-1, but with more comprehensive acceptance criteria.

Rationale for Requirement R9

MOD-026-2 R9 incorporates the aspects of MOD-026-1 R3 and R5, and MOD-027-1 R3. This requirement is intended to ensure that the Generator Owner/Transmission Owner responds to the Transmission Planner's

notification of denial or a technically justified request for model review within a reasonable time. If the Generator Owner/Transmission Owner determines that a model update is warranted to address the deficiencies, the Generator Owner/Transmission Owner should respond by either providing an updated model or work out a mutually agreed upon plan with Transmission Planner for changes that require additional testing or data collection. Otherwise, if the Generator Owner/Transmission Owner determines that the current model should be maintained, the Generator Owner/Transmission Owner must provide technical justification and evidence that addresses the model deficiencies or concern identified by the Transmission Planners. This requirement ensures the Generator Owner/Transmission Owner resolves modeling issues identified by the Transmission Planner, whether as part of the initial model review or sometime thereafter, by using one of the disposition options.

Rationale for Removal of MOD-026-1 R6

Portions of MOD-026-1 R6 are covered under two requirements in MOD-026-2. MOD-026-2 R8 covers the response the Transmission Planner is obligated to send to the Generator Owner/Transmission Owner. MOD-026-2 R1 covers the obligation for the Transmission Planner the define acceptance criteria which includes usability, as described in MOD-026-1 Part 6.1-6.3.

Rationale for Retirement of MOD-027-1

MOD-027-1 R1 content is covered in MOD-026-2 R1.

MOD-027-1 R2 content is covered in MOD-026-2 R3 for synchronous generation and MOD-026-2 R5 for inverter based resources or aggregated distributed generation.

MOD-027-1 R3 content is covered in a number of requirements in MOD-026-2. MOD-026-2 R1 Part 1.3 outlines the acceptance criteria define by Transmission Planner, MOD-026-2 R8 gives options for the Transmission Owner to provide a notification of denial, and MOD-026-2 R9 defines the written response options by the Generator Owner after receiving a notification of denial or technical justification for model review.

MOD-027-1 R4 content is covered in MOD-026-2 R7.

MOD-027-1 R5 content is covered in a number of requirements in MOD-026-2. MOD-026-2 R1 Part 1.3 outlines the acceptance criteria define by Transmission Planner, and MOD-026-2 R8 gives options for the Transmission Owner to provide a notification of acceptance of notification of denial based on the acceptance criteria define in Part 1.3. Usability requirements outlined in MOD-027-1 R5 Part 5.1-5.2, would be defined in the acceptance criteria under MOD-026-2 R1 Part 1.3.