NERC

NORTH AMERICAN ELECTRIC
RELIABILITY CORPORATION

Case Quality Metrics

Annual Interconnection-Wide Model Assessment

October 2021

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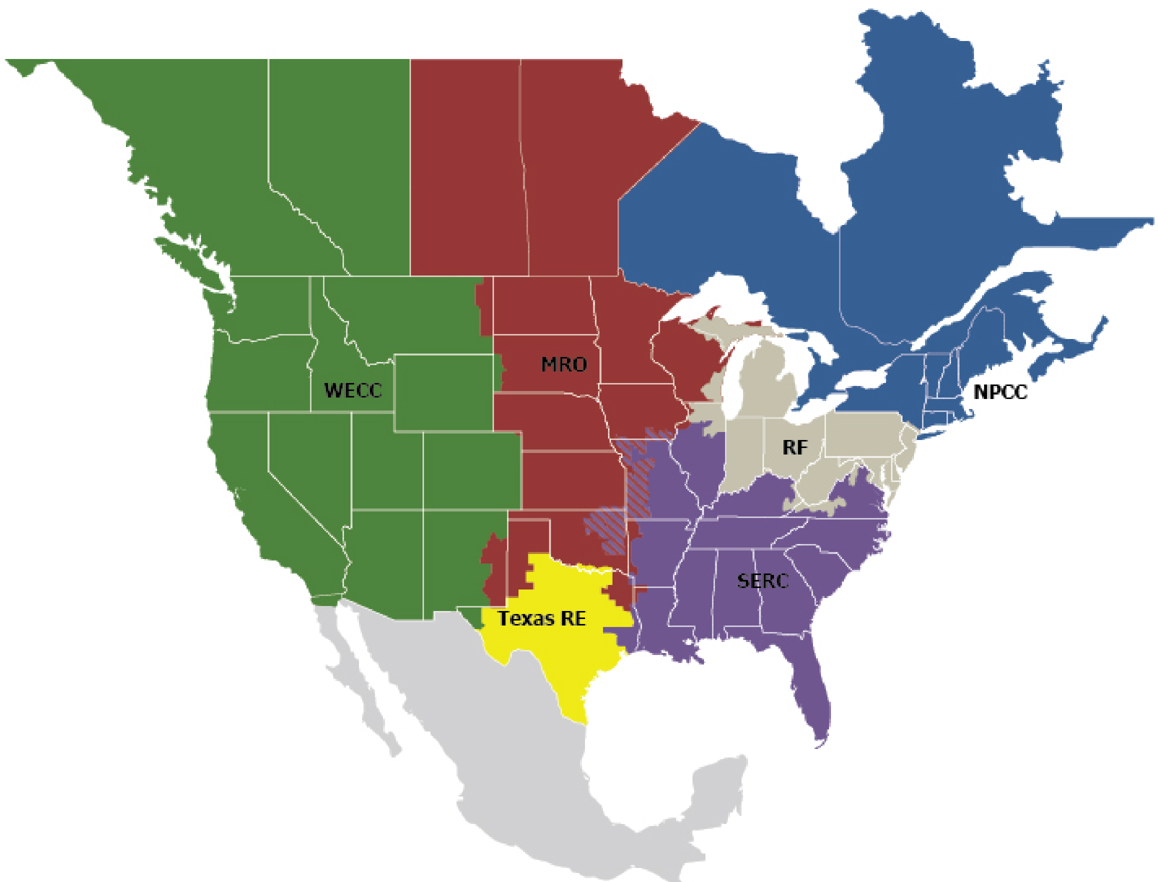
Table of Contents

Preface

Electricity is a key component of the fabric of modern society and the Electric Reliability Organization (ERO) Enterprise serves to strengthen that fabric. The vision for the ERO Enterprise, which is comprised of the North American Electric Reliability Corporation (NERC) and the six Regional Entities (REs), is a highly reliable and secure North American bulk power system (BPS). Our mission is to assure the effective and efficient reduction of risks to the reliability and security of the grid.

Reliability | Resilience | Security
Because nearly 400 million citizens in North America are counting on us

The North American BPS is made up of six RE boundaries as shown in the map and corresponding table below. The multicolored area denotes overlap as some load-serving entities participate in one RE while associated Transmission Owners/Operators participate in another.



MRO	Midwest Reliability Organization
NPCC	Northeast Power Coordinating Council
RF	ReliabilityFirst
SERC	SERC Reliability Corporation
Texas RE	Texas Reliability Entity
WECC	WECC

Executive Summary

Powerflow and dynamics cases are the foundation of virtually all power system studies. Calculations of operating limits, planning studies, and performance analyses for various operating conditions all depend on mathematical representations of transmission topology, generation, and load. Case quality refers to the reasonableness of the data in the individual equipment models that comprise the Base Case for the characteristics and operating states desired for study. A reasonable model contains information that is mathematically correct, does not contain suspicious data entries in part or at a whole, and presumes that sufficient procedures are in place to ensure that the equipment models that have been provided are reasonable representations of the physical equipment the models are meant to represent. This *2021 Case Quality Metrics: Annual Interconnection-Wide Model Assessment* provides an unbiased and technically justified review of the powerflow and dynamics cases created for Interconnection-wide modeling purposes for the Eastern Interconnection[1] (EI), Western Interconnection (WI), and Texas Interconnection (TI).

Based on the results of the *2021 Case Quality Metrics Assessment*, NERC has provided the following list of observations for the MOD-032 designees with recommendations on which metrics to focus on to help improve model quality for base cases developed in the future:

- For the WI and EI, there are many records consistently flagged for the Generator Reactive at Limits, Generator Terminal Voltage, Natural Gas Generator, and Reactive Capability Curve metrics. The TI is an exception that has generally improved in these metrics since last year. All of these metrics are related to case dispatch or suspect data that involves generator reactive capability. Additionally, the WI's natural gas generation in the case does not reflect the ambient thermal impact to changes in steady-state active power limits for natural gas generators due to the effect of ambient temperature differences between the seasonal cases; all such data is suspect.
- The Generator Reactive Capability Curve check for the EI or TI remains at 0.00 due to the lack of provided generator curves. Further, no DER_A models exist in the cases and the DER_A tripping parameter check is still 0.00 for that reason.
- A majority of the metrics are below 5% while some are improving year-over-year as conversations between NERC and the MOD-032 designees continue.

Table ES.1 gives a "scorecard" for performance based on the overall assessment of cases for each Interconnection. Some metrics flag data that are more sensitive[2] to a study's results than others; however, each metric has similar weight in determining model quality. One of NERC's goals is to collaboratively improve model quality via various modeling improvements and initiatives while working with MOD-032 designees, utility members, and subject matter experts. It is not intended for the metrics to have a 0% in all instances as legitimate modeling differences exist; however, these are uncommon and should not be prevalent in the Base Case. For this report, the performance is evaluated so that a higher percentage signifies more records flagged in the metric, and the goal is to trend towards 0%. The scorecard colors represent those trends.

[1] The Quebec Interconnection is included in these model builds and is represented by the EI MOD-032 designees.

[2] For example, some metrics flag conditions that will prevent dynamic initialization and thus prevent dynamic stability simulations. This influences dynamic stability results more than the Erroneous Power Development Fractions metric. Both are important to improving Interconnection-wide Base Case quality.

Based on the observations listed in **Table ES.1**, this report provides direct recommendations to each respective Interconnection's MOD-032 designee. The general recommendation is to continue tracking this year-over-year assessment and improve the metrics by engaging relevant subject matter experts.

Table ES.1: Interconnection Scorecard

Interconnection	Metrics	Evaluation
Eastern	Powerflow	Most metrics below 5% 1 metric with major improvement 2 metrics worsening or consistent high score in non-light load cases Voltage schedule conflicts major increase
	Dynamics	Most metrics below 5% 4 metrics consistent high score 3 metrics worsening (1 still under 5%) 1 new metric high score
Texas	Powerflow	Most metrics below 5% 1 metric worsening 1 metric consistent worsening or improving 1 metric consistent high score or improving
	Dynamics	Most metrics below 5% 2 metrics consistent high score 3 metrics worsening 1 metric improving
Western	Powerflow	Most metrics below 5% 2 metrics improving, worsening, or consistent high score 2 metrics worsening 1 metric improving
	Dynamics	Most metrics below 5% 3 metrics worsening in light load case Many metrics have a consistently high score 1 metric improving or consistent high score

Introduction

A powerflow case is a collection of steady-state models for system topology, load, generation, dispatch, and interchange that constitute a snapshot of the selected set of operating conditions. A dynamics case is a collection of dynamic models used in conjunction with a powerflow case to perform a stability analysis of system performance.

This *2020 Case Quality Metrics Assessment* tracks the quality of the base cases created by the MOD-032 designees for the purposes of Interconnection-wide modeling and subsequent system studies. The assessment reviews each of the major Interconnections (i.e., EI,[3] WI, and TI). NERC works with the MOD-032 designees to select appropriate near-term base cases for each assessment. Trending the metrics provides an objective trend of Base Case quality by using technically justified metrics.

Base case quality has two principal aspects:

- **Case Data Quality:** Reasonableness of the data in the individual equipment models that comprise the case for the characteristics and operating states desired
- **Case Fidelity:** The ability of the case to accurately model measured power system behavior for the following:
  - The type of system conditions the case is intended to model such as heavy summer loads, light loads, etc.
  - The conditions measured during a distinct system event or disturbance

The metrics focus solely on the case data quality of the individual component models comprising the Base Case. Validation of case fidelity or overall model performance requires comparison of the cases to actual measured system conditions and are not included in this report. Planning Coordinators are encouraged to consider these metrics in their MOD-033 evaluation and to also include metrics on case fidelity.

[3] The EI powerflow and dynamics cases include the Québec Interconnection.

Chapter 1: Case Quality Metrics

The following metrics have been developed by NERC and vetted by industry through engagement with relevant subject matter experts and previous industry stakeholder committees.[4] The metrics are divided between steady state and dynamics to characterize what type of study the metric is most relevant for checking the quality of the case data. The metrics are updated annually by the NERC Advanced System Analytics and Modeling group. This process will change for future assessments to reflect appropriate oversight given the evolving ERO committee structure.

Steady-State Powerflow Metrics

The following list describes the steady-state powerflow metrics found under the heading **Metric Categorization**, in **Table 1.1**. These descriptions are provided for those metrics applied to the powerflow data of the Interconnection-wide Base Case models. As the metrics change, the specific number assigned to each description may change as metrics are added or retired. The steady-state powerflow metrics are as follows:

1. Dispatched generator real power output should not exceed the maximum real power capability of the unit (P_{gen} <= P_{max}). Note: Although small exceedances of this P_{max} rule appear trivial, the result is the same for all exceedances: the case will not initialize in dynamics.
2. Dispatched generator real power output should not be less than the minimum real power capability of the unit (P_{gen} >= P_{min}). Note: Although small exceedances of this P_{min} rule appear trivial, the result is the same for all exceedances: the case will not initialize in dynamics.
3. Scheduled area interchanges should sum to zero MW.
4. Active voltage control devices controlling the same bus should not have conflicting voltage regulation set points.
5. Transformers controlling voltage should have a voltage bandwidth that is sufficiently large in relation to the tap step of the transformer. Voltage bandwidths that are too small (or tap steps that are erroneously too large) may result in the lack of existence of a powerflow solution. The ratio of tap step (p.u.) to voltage bandwidth (p.u.) should be no less than 1.6; ratios below 1.0 are considered severe as they are extremely likely to prevent a powerflow solution from being found.[5]
6. The continuous (Rate A) and emergency (Rate B) ratings of a branch should be consistent. The continuous rating (Rate A) of the branch circuit should be less than or equal to the emergency rating (Rate B), and the ratio between the emergency rating (Rate B) and the continuous rating (Rate A) is checked against a threshold value (3.0) to identify probable errors. Selection of this ratio is based on engineering judgment.
7. Branch circuit loading should not exceed the circuit's continuous rating (Rate A); 100% of Rate A is used to identify exceedances; 105% of Rate A is used to identify severe exceedances.
8. Generator reactive power output should not be dispatched at Q_{max} or Q_{min} (if $Q_{max} \neq Q_{min}$).[6]
9. Generator reactive power limits (Q_{max} and Q_{min}) should have reasonable power factor[7] compared with maximum active power (P_{max}) within +0.80 (producing Vars) and -0.85 (consuming Vars).
10. Parallel transformers should not have positive sequence circulating current.[8]

[4] Such as the legacy NERC Planning Committee and the NERC Systems Analysis and Modeling Subcommittee

[5] This metric was changed in the *2017 Case Quality Metrics Assessment* from thresholds of 2 and 1.25 for normal and severe thresholds, respectively, to 1.6 and 1.0.

[6] Wind machines and units with P_{gen} <= 0 will be omitted from this check.

[7] Generators with P_{max} = 0 will be omitted to skip synchronous condensers.

[8] Opposite direction of positive sequence current flow

11. Individual aggregate loads greater than 2 MVA[9] and with positive active and reactive power consumption[10] should have a power factor with absolute value greater than 0.5 pf.
12. The ratio of generator R_{source}: X_{source} should be less than 1.0.[11]
13. Generator terminal bus voltages should be between 0.95 and 1.05 when regulating a non-terminal bus.[12]
14. For all generator capability curves provided, no part of the piecewise function can limit a box defined by the P_{max}, P_{min}, Q_{max}, Q_{min} box. A sample figure of a correctly constructed piecewise function is in **Figure 1.1** where the green box is not limited by the black curve.

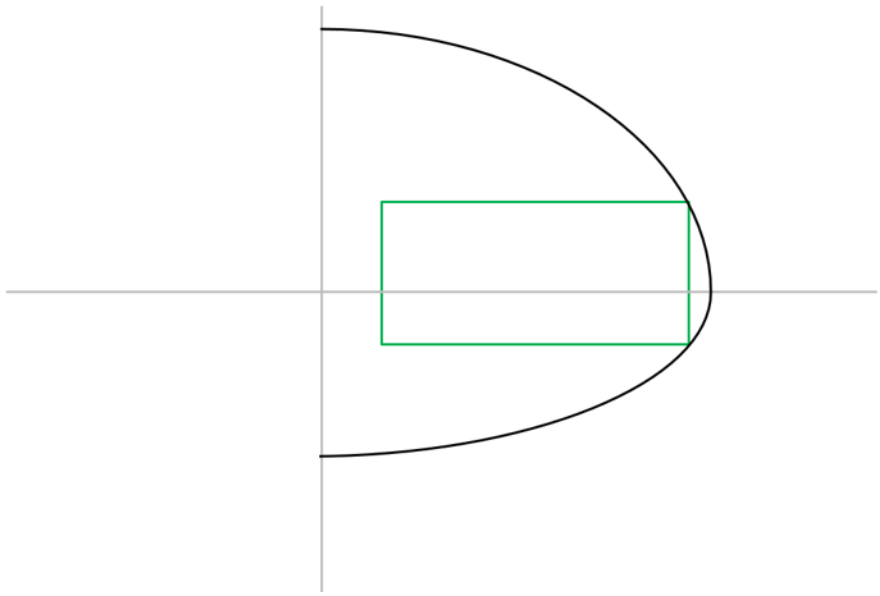


Figure 1.1: Generator Reactive Capability Box Overview

15. All non-jumper transformers should have an X/R ratio between 5 and 2,000, and transmission lines should have an X/R ratio of less than 100. Exclusions include resistances with a value of zero, and when reactance or resistance is less than zero.
16. All natural gas generators in seasonal cases should change their maximum power available due to their relationship to ambient temperature conditions. All summer P_{max} values should be less than the winter P_{max} values.

Transient Dynamics Metrics

Continuing on from the steady-state list is the transient dynamics metrics. The numbers here continue as part of the entire set of metrics applied to the Interconnection-wide base cases and focus on the dynamics portion of data provided in such cases. Hence, the numbered list does not restart at number one. Some of these metrics require both

[9] This threshold is used to omit small loads that have little impact on the performance of the model; the focus is on pf of larger loads.
[10] This avoids shunt capacitor issues (negative reactive power) and net generators (negative active power value) represented in the load values.
[11] Except for X_{source} = 9999
[12] Non-synchronous devices are excluded from this check.

powerflow and dynamic data to be loaded in the software in order to check the quality of the data and, as such, require longer processing time for larger data sets:

17. Generating units larger than the criteria threshold established for each Interconnection[13] should have a generator model included in their dynamics record; units without a generator model are flagged as not meeting this modeling criteria.
18. Generating units larger than the criteria threshold established for each Interconnection and that have a model (but are load netted anyway) are also tallied. This additional metric is needed to help identify all generating units without active models in the case as Item 17 overlooks generators that have models but are load netted anyway, and Item 19 below overlooks generators that lack models and are dispatched out-of-service in the case.
19. Generating units larger than the criteria threshold established for each Interconnection should not be netted as negative load; any such units that are netted are flagged.
20. Generating units larger than the criteria threshold established for each Interconnection[14] should not be modeled with a classical generator model.
21. User written model penetration is also tallied for use in the MOD-032 case creation process.
22. Generating units should have consistent generator reactance values. For example, the following measures are used to assess consistency of round rotor generators:
    a. D-axis synchronous reactance (X_d) should not be less than d-axis transient reactance (X_d').
    b. D-axis transient reactance (X_d') should not be less than d-axis subtransient reactance (X_d'').
    c. Subtransient reactance (X_d'') should not be less than stator leakage reactance (X_l).
    d. Q-axis synchronous reactance (X_q) should not be less than q-axis transient reactance (X_q').
    e. Q-axis transient reactance (X_q') should not be less than q-axis subtransient reactance (X_q'').
23. Generator time constants should be consistent: $T''_{d0} \leq T'_{d0}$ and $T''_{q0} \leq T'_{q0}$ [15] and $T'_{q0} \leq T'_{d0}$ [16].
24. Generator inertia constants should be within reasonable ranges: $1.5 \leq H \leq 9.0$ for all generators greater than 20 MVA, and $1.0 \leq H \leq 10.0$ for machines less than 20 MVA.[17]
25. Saturation factors S (1.0) and S (1.2) should be reasonable:[18]
    a. $0.03 \leq S(1.0) \leq 0.18$
    b. $0.2 \leq \mathrm{S}(1.2) \leq 0.85$
    c. S(1.2) should be within 2 to 8 times S(1.0).
    d. Severe saturation factor check:
        i. S(1.0) and S(1.2) should be greater than zero.
        ii. S(1.0) and S(1.2) should be less than 1.0.

[13] 20 MVA for the EI; 10 MVA for the WI and TI
[14] 50 MVA for the EI and TI; 0 MVA for the WI
[15] GENTPJ (and gentpf in PSLF) has an exception to these rules since a salient pole machine is represented with $T'_{q0} = 0$. For this case, the only check used is $T''_{d0} \leq T'_{d0}$.
[16] This check is not applied to GENSAL and GENSAE generator models.
[17] These ranges were adopted based on industry feedback on the *2017 Case Quality Metrics Assessment*.
[18] This metric was changed in the *2017 Case Quality Metrics Assessment* from an S (1.0) maximum of .12 to .18 and an S (1.2) maximum of .80 to .85.

iii. S(1.0) should be less than or equal to S(1.2).

26. Units with a power system stabilizer (PSS) should have an excitation system model.

27. Generator speed damping coefficient should be equal to zero for non-classical machine models.

28. Turbine-governor models should have lead-time constants less than lag time constants.[19]

29. Turbine power development fractions should add up to 1.0.[20] An example of these fractions in the block diagrams for a turbine governor model is in **Figure 1.2**.

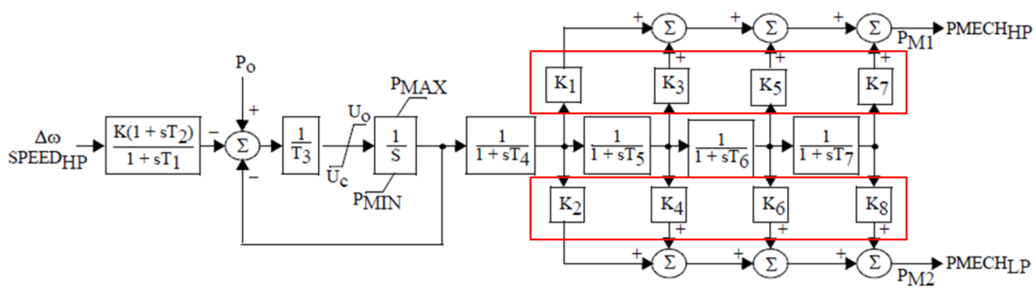


Figure 1.2: IEEEG1 Model Block Diagram (Source: Siemens PTI)

30. DC exciter model self-excitation parameter K_E[21] should be a small negative number unless K_E = 0 (automatically calculated by program) or K_E = 1 (separately excited exciter). A sample block diagram for this parameter is highlighted in **Figure 1.3**.

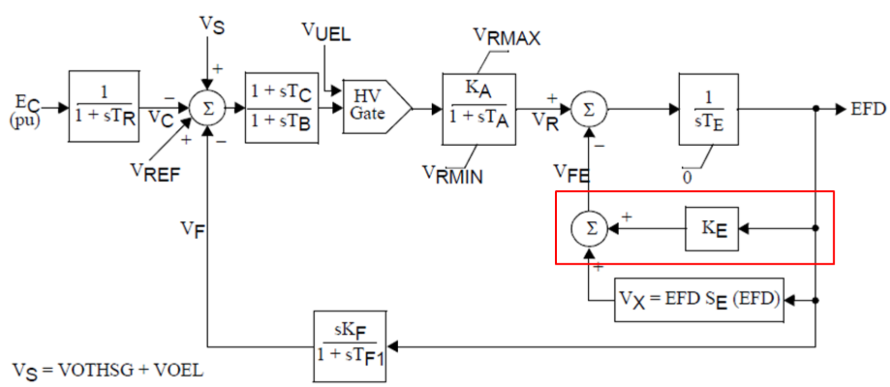


Figure 1.3: ESDC1A Model Block Diagram (Source: Siemens PTI)

31. Wind turbine electrical model WT3E should have $\omega_{Pmin} < \omega_{P20} < \omega_{P40} < \omega_{P60} < \omega_{P100}$.

32. PSS models should have reasonable parameters for the forward integration models. If Ks3 = 1, the parameters should be Ks1 > 0, V_{stmax} > 0, V_{stmin} < 0, Tw4 = 0, T7 = Tw2, T6 > 0.033, T8 = m*T9, and the input signals should be generator speed and generator electrical power. All such models that don't have these parameters or have Ks3 not equal to one are flagged for review. The PSS2A model, a forward integration PSS model, is found in **Figure 1.4**.

[19] This stabilizes the model as it reduces the forward path gain for high frequency changes in the input.

[20] This metric was corrected in the *2017 Case Quality Metrics Assessment* to check if K1+K2+K3+ . . . +K8 = 1.0.

[21] K_E reflects setting the shunt field rheostat for zeroing out the voltage regulator, often a small negative number.

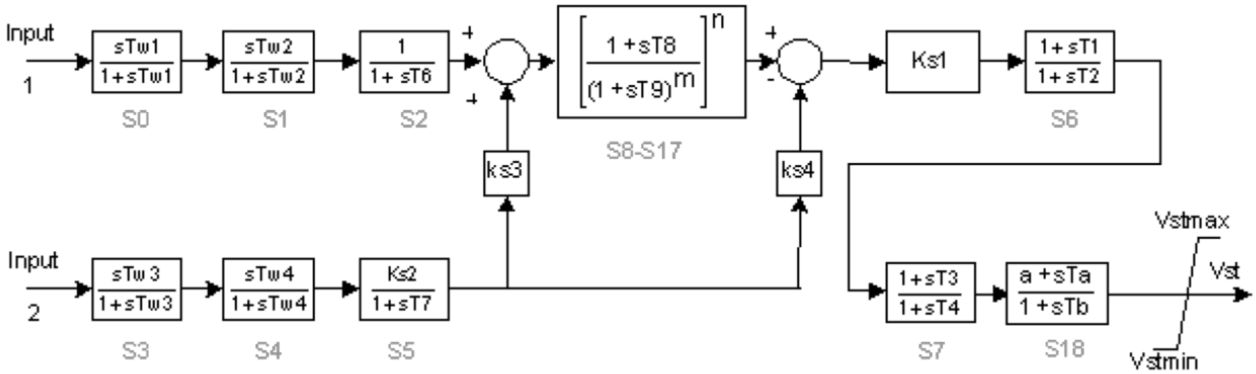


Figure 1.4: PSS2A Block Diagram [Source: GE PSLF]

33. Models should not be listed as unacceptable or not recommended on the NERC Acceptable Model List:[22]
    a. Unacceptable models are tallied for all generator, exciter, stabilizer, and turbine-governor models.
    b. Not recommended models are tallied for all generator, exciter, stabilizer, and turbine-governor models.
34. Second generation renewable models should be parameterized to site-specific conditions, namely as follows:
    a. Renewable generator models (REGC) should have a difference between the “lvpnt0” and “lvpnt1” settings that are greater than 0.1 p.u.
    b. REGCs should have a difference between the “zerox” and “brkpt” settings that are greater than 0.1 p.u.
    c. REGCs should have a setting of “Tg” less than 0.2 seconds.
    d. Renewable electrical models (REEC) should have a P_{max} setting of less than 1.0 p.u. of its dynamic MVA base.
    e. REECs should have a Q_{max} setting of less than 1.0 p.u. of its dynamic MVA base.
    f. REECs should have a Q_{min} setting of greater than -1.0 p.u. of its dynamic MVA base.
    g. REECs should have a non-default K_{qv} setting.
    h. REECs for battery energy storage systems should have a large Ts value.
        i. It is a suspect condition for a “Ts” value under 1,000 seconds.
        ii. It is a severely suspect condition for a “Ts” value under 30 seconds.
    i. Renewable plant models (REPC) should have a voltage control bus (or buses) and a monitored bus.
    j. Wind turbine pitch controllers should not have identical parameters to another installation.

[22] All disclosures regarding ‘acceptability’ are documented in the spreadsheet on the Modeling Assessment Page here. If not listed on the spreadsheet, models are considered “acceptable.”

Metric Categorization

All of the case quality metrics are categorized by their impact to the Interconnection Base Case creation process in **Table 1.1**. These categorization demonstrate how severe each metric is in impacting the data quality of the case. Metrics that are "bad data" are ones that find data that is blatantly incorrect and should be corrected. For example, reactance or time constant inconsistencies that are not physically possible. The term "suspect data" indicates data that looks abnormal and may or may not be in error. This should be reviewed by the MOD-032 designees more closely and addressed accordingly. "Case setup issues" are issues with how the individual elements are compiled (e.g., powerflow case or dynamics data file) and applied to create the initial operating state from which simulations would then be performed. Some metrics may have more than one indication of data (e.g., generators with a lack of modeling). These generators cannot be tracked in dynamics outside of load netting due to a lack of generator model, indicating a case setup issue. Since all Interconnections have a modeling threshold for explicit modeling, generators above that threshold also are suspect if they do not contain a dynamics model in the case.

Table 1.1: Bad and Suspect Data Metrics			
Steady-State Metrics			
Metric	**Bad Data**	**Suspect Data**	**Case Setup Issue**
P_{max} Exceedances			X
P_{min} Exceedances			X
Scheduled Interchange Sum			X
Voltage Schedule Conflicts			X
Tap Step Conflicts		X	
Tap Step Conflicts (Severe)		X	
Low Emergency Rating		X	
High Emergency Rating		X	
Thermal Overloads			X
Thermal Overloads (Severe)			X
Gen Reactive at Limits			X
Gen Reactive Limit Power Factor		X	
Positive Sequence TX Circulating Current		X	
Poor Load Power Factor		X	
Generator R_{source}:X_{source} Ratio	X		
Generator Terminal Voltage			X
Generator Reactive Capability Curve		X	
X/R Ratio Check		X	
Natural Gas Generator P_{max}	X	X	
Gens without Models		X	X
Netted Gens with Models		X	X
Netted Generators		X	
Gens with Classical Models		X	
Unacceptable Models	X		
Not Recommended Models		X	
User-Written Models[23]		(X)	
Inconsistent Reactances	X		
Inconsistent Time Constants	X		
Unreasonable Inertia Constants		X	

[23] These are not affecting Interconnection performance. This is listed here based on discussions with MOD-032 designees.

Table 1.1: Bad and Suspect Data Metrics			
Steady-State Metrics			
Metric	**Bad Data**	**Suspect Data**	**Case Setup Issue**
Unreasonable Saturation Factors		X	
Severe Saturation Factors	X		
PSS but no Excitation		X	
Inconsistent Speed Damping	X		
Inconsistent Lead-Lag Time Constant	X		
Erroneous Power Dev Fractions	X		
DC Exciter Self-Excitation Errors	X		
Inconsistent Type III Wind Speeds	X		

Numerical Scores for Case Metrics

Generally, the raw count of each of the instances of data issues specified in the criteria above is not, by itself, a suitable metric. Most of these raw counts need to be scaled to reflect the size of the Interconnection being evaluated. This scaling is done by expressing each of the raw counts as a percentage of the total number of elements to which the corresponding criteria is applicable in the case. Each metric is reported as a count and performance is expressed as a percentage of all data issues identified[24] as a percentage of all applicable models.

Note that the denominator of the fractional values will differ for each metric tested based on the number of models under test. For example, the threshold values for applicable units may be different or the metric may relate to specific types of dynamic models.

Dynamics Cases

There are some specific qualifications on a few of the dynamic metrics that are noted in the following list:

- **Generators without models**: the number of generators meeting Interconnection size criteria for modeling with no dynamics model, expressed as a percentage of total number of generators (in-service and out-of-service), meeting Interconnection size criteria for modeling
- **Netted generators with models**: the number of generators meeting Interconnection size criteria for modeling with a dynamics model but load netted anyway, expressed as a percentage of total number of in-service generators meeting Interconnection size criteria for modeling
- **Netted generators**: the number of generators meeting Interconnection size criteria for modeling that are load netted and expressed as a percentage of total number of in-service generators meeting Interconnection size criteria
- **Generators with classical models**: the number of generators meeting Interconnection size criteria for non-classical modeling with a classical model expressed as a percentage of total number of generators (in-service and out-of-service) meeting Interconnection size criteria for non-classical modeling
- **Generators with faulty reactances**: the number of generators with inconsistent reactance data (e.g., $X_d'' < X_l$) expressed as a percentage of total number of generators (in-service and out-of-service) with models for which the reactance criteria is applicable (e.g., genrou, gentpj)

In addition, for each of the dynamic metrics, the maximum real and reactive power limits for each unit found to violate the criteria are totaled. When units were whitelisted by feedback from the MOD-032 designees, these sums were not altered; however, the percentage scores were altered. The total percentage is listed for all respective

[24] Generally, this is a one to one relationship with the number of models associated with an identified data issue.

(generator, exciter, etc.) models in the case in terms of total number applicable for the check. For instance, a check that involves only generators will only check generator dynamic models.

Chapter 2: Software Differences and Considerations

Software Differences

Two software platforms are primarily used for assembling Interconnection-wide cases: Power Systems Simulator (PSS®E) from Siemens PTI (for the EI and TI) and Positive Sequence Load Flow (PSLF) from GE (for the WI). Because of differences in the handling of data by these two programs, the method for calculating the number of instances of criteria not being met may vary between Interconnections for some of the metrics:

- PSS®E stores voltage set point for generators and static VAR systems with the device data record whereas PSLF stores voltage set point for these devices with the bus data record. In PSLF, it is not possible to have voltage schedule conflicts for multiple generators and static VAR systems that are regulating a common location. However, transformer data records in PSLF have their own voltage regulation data.
- PSLF has a turbine type flag in the generator data to indicate if a generating unit is a wind unit.[25] However, this flag is not completely populated in WI base cases. Therefore, to eliminate wind units from the reactive limits check (Q_{gen} at Q_{max} or Q_{min}), the dynamics data file has to be loaded and the corresponding dynamic models have to be checked. The units with the any of the following wind generator models were eliminated from the check: genwri, gewtg, gewtgx, regc_a, regc_c, wt1g, wt2g, wt3g, and wt4g. It is recommended that the turbine type flag be utilized to improve the code's speed and complexity in identifying unit fuels.
- The names of the dc exciter models differ between PSS®E and PSLF. Hence, for the check on parameter KE in dc exciters, the following models were checked in PSLF: esdc1a, esdc2a, esdc3a, esdc4b, exdc1, exdc2, exdc2a, exdc4, ieeet1, and rexs.
- PSLF has the generator MVA base specified in both the powerflow and dynamics data files. All dynamic data is then taken on the per-unit MVA base specified in the dynamics data file. In PSS®E, one value of MVA base is specified and located in the powerflow file. In evaluating generator inertia constants for the WI base cases (using PSLF), the inertia constant has been evaluated on the MVA base specified in the powerflow file unless the specified powerflow base was the default 100 MVA. This calculated constant is an MVA base transfer between the dynamic and powerflow MVAs if the powerflow MVA is not 100 MVA.
- Fuel types are not capable of being accessed in PSS®E. As such, for this current year's metrics, a N/A score is produced for the natural gas P_{max} check. Supplemental information may be required to check these cases for Interconnections that use PSS®E.

Other Considerations

In reading the data for a generator to determine its size, the generator MVA base value in the powerflow data record (MBASE) is not a reliable value to use for generator size since many small generators have the program default value of 100 MVA entered for this parameter. Therefore, a more comprehensive approach is used; generator MVA size is determined as the maximum value of the following:

- Dispatched MVA of the unit $\left(\sqrt{P_{gen}^2 + Q_{gen}^2}\right)$ where P_{gen} and Q_{gen} are the dispatched real and reactive output of the unit in the case
- MVA of the unit at maximum real and reactive limits $\left(\sqrt{P_{max}^2 + Q_{max}^2}\right)$ where P_{max} and Q_{max} are the maximum real and reactive output limits of the unit in the powerflow data
- MBASE value unless value is 100.0 MVA (default value) in which case this parameter is ignored

[25] For that matter, a variety of unit types can be specified and are used accordingly for multiple metrics.

Chapter 3: Case Quality Metric Assessment

The goal of the case quality metrics assessment is to promote good modeling practices and to strive to reduce data errors in Interconnection-wide base cases. Since the performance score is the percentage of elements that have data errors, the goal translates into attempting to drive performance scores towards zero. However, it is not expected that all performance scores reach zero. There are legitimate modeling reasons why some of the generic metrics developed by NERC in this *2021 Case Quality Metrics Assessment* could be violated (e.g., equivalencing or back-to-back dc ties between Interconnections). This information is provided to industry to gauge the quality of Interconnection-wide base cases for use in studies and assessments. A more detailed report is provided to the MOD-032 designees with the goal of assisting in improving the quality of the cases.

This assessment brings to light some of the modeling issues that have been identified by working with utility members, MOD-032 designees, and modeling groups in the electric utility industry. Some metrics serve to highlight more significant modeling errors that should be addressed directly. Other metrics serve to track modeling improvements that NERC is driving such as the Modeling Notifications Process developed by the NERC Systems Analysis and Modeling Subcommittee[26] and now maintained by NERC staff.

The following subsections describe the performance scores for the assessment of each powerflow and dynamics case analyzed in the EI, TI, and WI. Note that performance scores greater than 5% are marked in **red**.

Notable Changes from Past Metrics

As the metrics are not infallible, many changes and alterations are supplied by industry to help gauge the quality Interconnection-wide base cases. Industry experts are able to send in suggestions and alterations to these metrics as the implementation of the scripts are posted alongside this report. Notable changes for this report are the following:

- Fixed an error when checking PSS2A and PSS2B models in PSLF for cross compound units that the wrong generator ID in the models table was used
- Fixed floating point to integer comparisons for the powerflow metrics
- Added a new metric that checks parameterization of the second generation renewable models
- Fixed an error for printing violations for cases built in PSS®E version 34 that printed an entire list rather than one entry of the list
- Added a requested feature for MOD-032 designees to see the nominal KV in the detailed report for items that did not pass each metric
- Fixed an error on the power factor when using qtable information in PSLF that was causing power factor to be 0 in calculation

[26] NERC System Analysis and Modeling Subcommittee: https://www.nerc.com/comm/PC/Pages/System-Analysis-and-Modeling-Subcommittee-(SAMS)-2013.aspx

Eastern Interconnection Case Quality Metrics Assessment

The performance and score, evaluated as a percentage, for all of the Eastern Interconnection cases are tabulated in Tables 3.1 to 3.9. Tables 3.1 to 3.3 are for the 2021SUM Base Case; Tables 3.4 to 3.6 are for the 2021WIN Base Case; Tables 3.7 to 3.9 are for the 2021SLL Base Case.

2021 Summer Peak Case: 2021SUM

Table 3.1: Steady-State Metrics

Metric	Performance	Score (%)
P_{max} Exceedances	4/6,759	0.06
P_{min} Exceedances	1/6,759	0.01
Scheduled Interchange Sum	0	-
Voltage Schedule Conflicts	102	-
Tap Step Conflicts	37/21,616	0.17
Tap Step Conflicts (Severe)	19/21,616	0.09
Low Emergency Rating	19/98,449	0.02
High Emergency Rating	0/98,449	0.00
Thermal Overloads	152/98,449	0.15
Thermal Overloads (Severe)	116/98,449	0.12
Generator Reactive at Limits	701/4,464	15.70
Generator Reactive Limit Power Factor	130/5,472	2.38
Positive Sequence TX Circulating Current	0/2,689	0.00
Poor Load Power Factor	161/49,426	0.33
Generator R_{source}:X_{source} Ratio	3/6,759	0.04
Generator Terminal Voltage	117/2,817	4.15
Generator Reactive Capability Curve	0/0	0.00
X/R Ratio Check	212/91,879	0.23
Natural Gas Generator Pmax	N/A	N/A
Natural Gas Generator Pmax (Severe)	N/A	N/A

Table 3.2: Dynamics Metrics

Metric	Performance	Score (%)	P_{max} (MW)	Q_{max} (MVAR)
Generators without Models	161/6,800	2.37	5,340	1,427
Netted Generators with Models	18/4,923	0.37	861	228
Netted Generators	122/4,923	2.48	4,023	1,030
Generators with Classical Models	14/5,121	0.27	6,890	3,830
Unacceptable Models (total)	2,585/19,622	13.17	-	-
Not Recommended Models (total)	3,899/19,622	19.87	-	-
User-Written Models[27]	1,222/22,554	-	-	-
Inconsistent Reactances	43/4,079	1.05	3,005	1,478
Inconsistent Time Constants	4/4,310	0.09	576	351
Unreasonable Inertia Constants	413/5,312	7.77	29,160	18,706
Unreasonable Saturation Factors	478/4,310	11.09	51,834	26,602
Severe Saturation Factors	39/4,310	0.90	4,632	2,574
PSS but no Excitation	4/6,800	0.06	97	278

[27] These are not affecting Interconnection performance. This is listed here based on discussions with MOD-032 designees.

Table 3.2: Dynamics Metrics				
Metric	Performance	Score (%)	P_{max} (MW)	Q_{max} (MVAR)
Inconsistent Speed Damping	117/5,127	2.28	7,025	3,175
Inconsistent Lead-Lag Time Constant	29/1,525	1.90	8,065	3,438
Erroneous Power Dev Fractions	17/489	3.48	4,450	1,749
DC Exciter Self-Excitation Errors	126/940	**13.40**	4,080	2,718
Inconsistent Type III Wind Speeds	0/232	0.00	0	0
Suspect PSS2A/2B parameters	339/1,828	**18.54**	71,247	39,191
Incorrect DER_A Tripping Parameters	0/0	0.00	0	0
Second Generation Renewable Model Parameterization[28]	255/1,451	**17.57**	-	-

Table 3.3: Unacceptable and Not Recommended Model Breakdown			
Category	Subcategory	Performance	Score (%)
Unacceptable Models	Generator	1,250/6,639	**18.83**
	Exciter	443/6,291	**7.04**
	Stabilizer	218/2,578	**8.46**
	Turbine Governor	674/4,114	**16.38**
Not Recommended Models	Generator	3,417/6,639	**51.47**
	Exciter	0/6,291	0.00
	Stabilizer	0/2,578	0.00
	Turbine Governor	482/4,114	**11.72**
User Written Models*	Generator	337/8,043	4.19
	Exciter	118/7,233	1.63
	Stabilizer	139/2,877	4.83
	Turbine Governor	628/4,401	**14.27**

*Due to how PSS®E distinguishes "user-written" models in their software, this number may be higher and alters based on version of the software.

2021–2022 Winter Peak Case: 2021WIN

Table 3.4: Steady-State Metrics		
Metric	Performance	Score (%)
P_{max} Exceedances	2/5,724	0.03
P_{min} Exceedances	0/5,724	0.00
Scheduled Interchange Sum	0	-
Voltage Schedule Conflicts	107	-
Tap Step Conflicts	37/21,591	0.17
Tap Step Conflicts (Severe)	19/21,591	0.09
Low Emergency Rating	19/98,823	0.02
High Emergency Rating	0/98,823	0.00
Thermal Overloads	136/98,823	0.14
Thermal Overloads (Severe)	110/98,823	0.11
Generator Reactive at Limits	663/3,897	**17.01**
Generator Reactive Limit Power Factor	117/4,754	2.46
Positive Sequence TX Circulating Current	0/2,703	0.00

[28] The way this metric is scored does not lend itself to producing sums of active and reactive power, so an asterisk is used

Table 3.4: Steady-State Metrics

Metric	Performance	Score (%)
Poor Load Power Factor	126/47,504	0.27
Generator R_{source}:X_{source} Ratio	3/5,724	0.05
Generator Terminal Voltage	135/255	**5.28**
Generator Reactive Capability Curve	0/0	0.00
X/R Ratio Check	215/92,201	0.23
Natural Gas Generator Pmax	N/A	N/A
Natural Gas Generator Pmax (Severe)	N/A	N/A

Table 3.5: Dynamics Metrics

Metric	Performance	Score (%)	P_{max} (MW)	Q_{max} (MVAR)
Generators without Models	173/6,900	2.59	6,183	1,645
Netted Generators with Models	15/4,353	0.34	690	199
Netted Generators	91/4,353	2.09	3,071	864
Gens with Classical Models	14/5,197	0.27	6,890	3,805
Unacceptable Models (total)	2,608/19,835	**13.15**	-	-
Not Recommended Models (total)	3,906/19,835	**19.69**	-	-
User-Written Models[29]	1,249/23,722	-	-	-
Inconsistent Reactances	45/4,087	1.10	3,777	1,921
Inconsistent Time Constants	4/4,318	0.09	577	351
Unreasonable Inertia Constants	416/5,320	**7.76**	30,049	18,917
Unreasonable Saturation Factors	480/4,318	**11.12**	53,510	27,039
Severe Saturation Factors	39/4,318	0.90	4,651	2,563
PSS but no Excitation	4/6,900	0.06	97	278
Inconsistent Speed Damping	117/5,134	2.28	7,062	3,180
Inconsistent Lead-Lag Time Constant	29/1,539	1.88	8,171	3,438
Erroneous Power Dev Fractions	17/489	3.48	4,451	1,749
DC Exciter Self-Excitation Errors	126/938	**13.43**	4,089	2,860
Inconsistent Type III Wind Speeds	0/232	0.00	0	0
Suspect PSS2A/2B parameters	343/1,841	**18.63**	72,814	38,985
Incorrect DER_A Tripping Parameters	0/0	0.00	0	0
Second Generation Renewable Model Parameterization	283/1,524	**18.57**	-	-

Table 3.6: Unacceptable and Not Recommended Model Breakdown

Category	Subcategory	Performance	Score (%)
Unacceptable Models	Generator	1,263/6,721	**18.79**
	Exciter	453/6,369	**7.11**
	Stabilizer	218/2,605	**8.37**
	Turbine Governor	674/4,140	**16.28**
Not Recommended Models	Generator	3,422/6,721	**50.92**
	Exciter	0/6,369	0.00
	Stabilizer	0/2,605	0.00
	Turbine Governor	484/4,140	**11.69**

[29] These are not affecting Interconnection performance. This is listed here based on discussions with MOD-032 Designees.

Table 3.6: Unacceptable and Not Recommended Model Breakdown			
Category	Subcategory	Performance	Score (%)
User Written Models*	Generator	348/8,089	4.30
	Exciter	130/7,293	1.78
	Stabilizer	143/2,899	4.93
	Turbine Governor	628/5,441	**11.54**

*Due to how PSS®E distinguishes "user-written" models in their software, this number may be higher and alters based on version of the software

2021 Spring Light Load: 2021SLL

Table 3.7: Steady-State Metrics		
Metric	Performance	Score (%)
P_{max} Exceedances	0/3,869	0.00
P_{min} Exceedances	2/3,869	0.05
Scheduled Interchange Sum	0	-
Voltage Schedule Conflicts	70	-
Tap Step Conflicts	37/21,320	0.17
Tap Step Conflicts (Severe)	19/21,320	0.09
Low Emergency Rating	22/97,960	0.02
High Emergency Rating	1/97,960	0.00
Thermal Overloads	40/97,960	0.04
Thermal Overloads (Severe)	30/97,960	0.03
Generator Reactive at Limits	407/2,397	**16.98**
Generator Reactive Limit Power Factor	78/3,192	2.44
Positive Sequence TX Circulating Current	0/2,661	0.00
Poor Load Power Factor	128/45,743	0.28
Generator R_{source}:X_{source} Ratio	3/3,869	0.08
Generator Terminal Voltage	93/1,527	**6.09**
Generator Reactive Capability Curve	0/0	0.00
X/R Ratio Check	214/91,444	0.23
Natural Gas Generator Pmax	N/A	N/A
Natural Gas Generator Pmax (Severe)	N/A	N/A

Table 3.8: Dynamics Metrics				
Metric	Performance	Score (%)	P_{max} (MW)	Qmax (MVAR)
Generators without Models	178/6,782	2.62	6,557	1,908
Netted Gens with Models	21/2,894	0.73	798	222
Netted Generators	64/2,894	2.21	2,473	748
Generators with Classical Models	13/5,098	0.26	6,390	3,805
Unacceptable Models (total)	2,580/19,504	**13.23**	-	-
Not Recommended Models (total)	3,891/19,504	**19.95**	-	-
User-Written Models[30]	1,224/23,406	-	-	-
Inconsistent Reactances	43/4,073	1.06	3,014	1,504
Inconsistent Time Constants	4/4,304	0.09	576	351
Unreasonable Inertia Constants	413/5,298	**7.80**	29,797	18,623

[30] These are not affecting Interconnection performance. This is listed here based on discussions with MOD-032 designees.

Table 3.8: Dynamics Metrics				
Metric	**Performance**	**Score (%)**	**P_{max} (MW)**	**Qmax (MVAR)**
Unreasonable Saturation Factors	473/4,304	**10.99**	50,925	25,779
Severe Saturation Factors	39/4,304	0.91	4,632	2,563
PSS but no Excitation	5/6,782	0.07	131	294
Inconsistent Speed Damping	117/5,114	2.29	7,025	3,280
Inconsistent Lead-Lag Time Constant	29/1,513	1.92	8,065	3,438
Erroneous Power Dev Fractions	17/487	3.49	4,451	1,749
DC Exciter Self-Excitation Errors	126/937	**13.45**	4,080	2,722
Inconsistent Type III Wind Speeds	0/232	0.00	0	0
Suspect PSS2A/2B parameters	354/1,811	**19.55**	71,062	38,509
Incorrect DER_A Tripping Parameters	0/0	0.00	0	0
Second Generation Renewable Model Parameterization	247/1,427	**17.31**	-	-

Table 3.9: Unacceptable and Not Recommended Model Breakdown			
Category	**Subcategory**	**Performance**	**Score (%)**
Unacceptable Models	Generator	1,246/6,604	**18.87**
	Exciter	444/6,257	**7.10**
	Stabilizer	218/2,553	**8.54**
	Turbine Governor	672/4,090	**16.43**
Not Recommended Models	Generator	3,413/6,604	**51.68**
	Exciter	0/6,257	0.00
	Stabilizer	0/2,553	0.00
	Turbine Governor	478/4,090	**11.69**
User Written Models*	Generator	335/8,023	4.18
	Exciter	117/7,208	1.62
	Stabilizer	137/2,858	4.79
	Turbine Governor	635/5,317	**11.94**

*Due to how PSS®E distinguishes "user-written" models in their software, this number may be higher and alters based on version of the software

Texas Interconnection Case Quality Metrics Assessment

The performance and score, evaluated as a percentage, for all of the Texas Interconnection cases are tabulated in **Tables 3.10** to **3.18**. **Tables 3.10** to **3.12** are for the 2023_SP_Final_NonCnv Base Case; **Tables 3.13** to **3.15** are for the 2024_HWLL_Final_NonCnv Base Case; **Tables 3.16** to **3.18** are for the 2027_SP_Final_NonCnv Base Case.

2023 Summer Peak Case: 2023_SP_Final_NonCnv

Table 3.10: Steady-State Metrics		
Metric	**Performance**	**Score (%)**
P_{max} Exceedances	1/942	0.11
P_{min} Exceedances	0/942	0.00
Scheduled Interchange Sum	0	-
Voltage Schedule Conflicts	31	-
Tap Step Conflicts	60/1,640	3.66
Tap Step Conflicts (Severe)	0/1,640	0.00

Table 3.10: Steady-State Metrics		
Metric	**Performance**	**Score (%)**
Low Emergency Rating	0/10,584	0.00
High Emergency Rating	2/10,584	0.02
Thermal Overloads	25/10,584	0.24
Thermal Overloads (Severe)	24/10,584	0.23
Generator Reactive at Limits	60/704	**8.52**
Generator Reactive Limit Power Factor	86/919	**9.36**
Positive Sequence TX Circulating Current	0/49	0.00
Poor Load Power Factor	1/5,635	0.02
Generator R_{source}:X_{source} Ratio	4/942	0.42
Generator Terminal Voltage	4/694	0.58
Generator Reactive Capability Curve	0/0	0.00
X/R Ratio Check	30/8,901	0.34
Natural Gas Generator Pmax	N/A	N/A
Natural Gas Generator Pmax (Severe)	N/A	N/A

Table 3.11: Dynamics Metrics				
Metric	**Performance**	**Score (%)**	**P_{max} (MW)**	**Q_{max} (MVAR)**
Generators without Models	30/1,040	2.88	*6,454	*3,767
Netted Generators with Models	0/899	0.00	0	0
Netted Generators	0/899	0.00	0	0
Generators with Classical Models	10/822	1.22	4,723	4,492
Unacceptable Models (total)	45/2,429	1.85	-	-
Not Recommended Models (total)	488/2,429	**20.09**	-	-
User-Written Models[31]	1,153/3,087	-		
Inconsistent Reactances	6/459	1.31	573	353
Inconsistent Time Constants	4/549	0.73	58	549
Unreasonable Inertia Constants	92/591	**16.40**	3,615	2,309
Unreasonable Saturation Factors	74/546	**13.55**	9,870	4,915
Severe Saturation Factors	9/546	1.65	763	380
PSS but no Excitation	0/1,001	0.00	0	0
Inconsistent Speed Damping	16/550	2.91	636	340
Inconsistent Lead-Lag Time Constant	0/208	0.00	0	0
Erroneous Power Dev Fractions	1/41	2.44	336	167
DC Exciter Self-Excitation Errors	6/53	**11.31**	513	257
Inconsistent Type III Wind Speeds	0/0	0.00	0	0
Suspect PSS2A/2B parameters	47/290	**16.21**	3,133	1,861
Incorrect DER_A Tripping Parameters	0/0	0.00	0	0
Second Generation Renewable Model Parameterization	0/223	0.00	-	-

* This total is not indicative of the units identified score as the score can be modified by whitelisted units. This sum indicates the total Pmax and Qmax of units that are flagged by the check rather than the subset of remaining units after the exempted models are removed.

[31] These are not affecting Interconnection performance. This is listed here based on discussions with MOD-032 designees. Further, the MOD-032 designee, TexasRE, allows User Written Models for the TI base cases.

Table 3.12: Unacceptable and Not Recommended Model Breakdown			
Category	**Subcategory**	**Performance**	**Score (%)**
Unacceptable Models	Generator	31/921	3.37
	Exciter	14/790	1.77
	Stabilizer	0/359	0.00
	Turbine Governor	0/359	0.00
Not Recommended Models	Generator	467/921	**50.71**
	Exciter	21/790	2.66
	Stabilizer	0/359	0.00
	Turbine Governor	0/359	0.00
User Written Models*	Generator	439/981	-
	Exciter	280/968	-
	Stabilizer	56/385	-
	Turbine Governor	378/753	-

*Due to how PSS®E distinguishes "user-written" models in their software, this number may be higher and alters based on version of the software. Further, the MOD-032 designee, TexasRE, allows User Written Models for the TI base cases.

2024 Light Load Case: 2024_HWLL_Final_NonCnv

Table 3.13: Steady-State Metrics		
Metric	**Performance**	**Score (%)**
P_{max} Exceedances	1/589	0.17
P_{min} Exceedances	0/589	0.00
Scheduled Interchange Sum	0	-
Voltage Schedule Conflicts	43	-
Tap Step Conflicts	49/1,630	3.01
Tap Step Conflicts (Severe)	0/1,630	0.00
Low Emergency Rating	0/10,607	0.00
High Emergency Rating	2/10,607	0.02
Thermal Overloads	18/10,607	0.17
Thermal Overloads (Severe)	14/10,607	0.13
Generator Reactive at Limits	38/412	**9.16**
Generator Reactive Limit Power Factor	37/567	**6.53**
Positive Sequence TX Circulating Current	0/48	0.00
Poor Load Power Factor	3/5,653	0.05
Generator R_{source}:X_{source} Ratio	4/589	0.68
Generator Terminal Voltage	3/396	0.76
Generator Reactive Capability Curve	0/0	0.00
X/R Ratio Check	30/8,917	0.34
Natural Gas Generator Pmax	N/A	N/A
Natural Gas Generator Pmax (Severe)	N/A	N/A

Table 3.14: Dynamics Metrics				
Metric	Performance	Score (%)	P_{max} (MW)	Q_{max} (MVAR)
Generators without Models	32/1,040	3.08	*6,537	*3,817
Netted Generators with Models	0/554	0.00	0	0
Netted Generators	0/554	0.00	0	0
Generators with Classical Models	10/823	1.22	4,823	4,492
Unacceptable Models (total)	45/2,429	1.85	-	-
Not Recommended Models (total)	488/2,429	**20.09**	-	-
User-Written Models[32]	1,144/3,080	-	-	-
Inconsistent Reactances	6/459	1.31	593	353
Inconsistent Time Constants	4/546	0.73	94	58
Unreasonable Inertia Constants	92/561	**16.40**	3,786	2,309
Unreasonable Saturation Factors	74/546	**13.55**	10,567	4,925
Severe Saturation Factors	9/546	1.65	781	380
PSS but no Excitation	0/1,001	0.00	0	0
Inconsistent Speed Damping	16/550	2.91	645	340
Inconsistent Lead-Lag Time Constant	0/208	0.00	0	0
Erroneous Power Dev Fractions	1/41	2.44	340	167
DC Exciter Self-Excitation Errors	6/53	**11.32**	518	258
Inconsistent Type III Wind Speeds	0/0	0.00	0	0
Suspect PSS2A/2B Parameters	47/290	**16.21**	3,285	1,871
Incorrect DER_A Tripping Parameters	0/0	0.00	0	0
Second Generation Renewable Model Parameterization	0/223	0.00	-	-

* This total is not indicative of the units identified score as the score can be modified by whitelisted units. This sum indicates the total Pmax and Qmax of units that are flagged by the check rather than the subset of remaining units after the exempted models are removed.

Table 3.15: Unacceptable and Not Recommended Model Breakdown			
Category	Subcategory	Performance	Score (%)
Unacceptable Models	Generator	31/919	3.37
	Exciter	14/788	1.78
	Stabilizer	0/359	0.00
	Turbine Governor	0/359	0.00
Not Recommended Models	Generator	467/919	**50.82**
	Exciter	21/788	2.66
	Stabilizer	0/359	0.00
	Turbine Governor	0/359	0.00
User Written Models*	Generator	436/978	-
	Exciter	277/967	-
	Stabilizer	56/385	-
	Turbine Governor	375/750	-

*Due to how PSS®E distinguishes “user-written” models in their software, this number may be higher and alters based on version of the software. Further, the MOD-032 designee, TexasRE, allows User Written Models for the TI base cases.

[32] These are not affecting Interconnection performance. This is listed here based on discussions with MOD-032 designees. Further, the MOD-032 designee, TexasRE, allows User Written Models for the TI base cases.

2027 Summer Peak Case: 2027_SP_Final_NonCnv

Table 3.16: Steady-State Metrics		
Metric	**Performance**	**Score (%)**
P_{max} Exceedances	1/941	0.11
P_{min} Exceedances	0/941	0.00
Scheduled Interchange Sum	0	-
Voltage Schedule Conflicts	39	-
Tap Step Conflicts	59/1,638	3.60
Tap Step Conflicts (Severe)	0/1,638	0.00
Low Emergency Rating	0/10,641	0.00
High Emergency Rating	2/10,641	0.02
Thermal Overloads	31/10,641	0.29
Thermal Overloads (Severe)	27/10,641	0.25
Generator Reactive at Limits	94/703	**13.37**
Generator Reactive Limit Power Factor	84/918	**9.15**
Positive Sequence TX Circulating Current	0/48	0.00
Poor Load Power Factor	1/5,683	0.02
Generator R_{source}:X_{source} Ratio	4/941	0.43
Generator Terminal Voltage	2/680	0.29
Generator Reactive Capability Curve	0/0	0.00
X/R Ratio Check	30/8,955	0.34
Natural Gas Generator Pmax	N/A	N/A
Natural Gas Generator Pmax (Severe)	N/A	N/A

Table 3.17: Dynamics Metrics				
Metric	**Performance**	**Score (%)**	**P_{max} (MW)**	**Q_{max} (MVAR)**
Generators without Models	34/1,043	3.26	7,915	4,270
Netted Generators with Models	0/899	0.00	0	0
Netted Generators	0/899	0.00	0	0
Generators with Classical Models	10/825	1.21	4,823	4,492
Unacceptable Models (total)	45/2,429	1.85	-	-
Not Recommended Models (total)	488/2,429	**20.09**	-	-
User-Written Models[33]	1,144/2,942	-	-	-
Inconsistent Reactances	6/459	1.31	573	353
Inconsistent Time Constants	4/546	0.73	94	58
Unreasonable Inertia Constants	92/561	**16.40**	3,615	2,277
Unreasonable Saturation Factors	74/546	**13.55**	9,870	4,925
Severe Saturation Factors	9/546	1.65	763	380
PSS but no Excitation	0/1,004	0.00	0	0
Inconsistent Speed Damping	16/550	2.91	636	340
Inconsistent Lead-Lag Time Constant	0/208	0.00	0	0
Erroneous Power Dev Fractions	1/41	2.44	336	167
DC Exciter Self-Excitation Errors	6/53	**11.32**	513	258
Inconsistent Type III Wind Speeds	0/0	0.00	0	0

[33] These are not affecting Interconnection performance. This is listed here based on discussions with MOD-032 designees. Further, the MOD-032 designee, TexasRE, allows User Written Models for the TI base cases.

Table 3.17: Dynamics Metrics				
Metric	Performance	Score (%)	P_{max} (MW)	Q_{max} (MVAR)
Suspect PSS2A/2B Parameters	47/290	16.21	3,133	1,847
Incorrect DER_A Tripping Parameters	0/0	0.00	0	0
Second Generation Renewable Model Parameterization	0/223	0.00	-	-

* This total is not indicative of the units identified score as the score can be modified by whitelisted units. This sum indicates the total Pmax and Qmax of units that are flagged by the check rather than the subset of remaining units after the exempted models are removed.

Table 3.18: Unacceptable and Not Recommended Model Breakdown			
Category	Subcategory	Performance	Score (%)
Unacceptable Models	Generator	31/919	3.37
	Exciter	14/788	1.78
	Stabilizer	0/359	0.00
	Turbine Governor	0/359	0.00
Not Recommended Models	Generator	467/919	50.82
	Exciter	21/788	2.66
	Stabilizer	0/359	0.00
	Turbine Governor	0/359	0.00
User Written Models*	Generator	436/978	-
	Exciter	277/829	-
	Stabilizer	56/385	-
	Turbine Governor	375/750	-

*Due to how PSS®E distinguishes "user-written" models in their software, this number may be higher and alters based on version of the software. Further, the MOD-032 designee, TexasRE, allows User Written Models for the TI base cases.

Western Interconnection Case Quality Metrics Assessment

The performance and score, evaluated as a percentage, for all of the Western Interconnection cases are tabulated in **Tables 3.19** to **3.27**. **Tables 3.19** to **3.21** are for the 21HS3a Base Case; **Tables 3.22** to **3.24** are for the 22HW2a Base Case; **Tables 3.25** to **3.27** are for the 21LS1a Base Case.

2021 Summer Peak Case: 21HS3a

Table 3.19: Steady-State Metrics		
Metric	Performance	Score (%)
P_{max} Exceedances	9/3,259	0.28
P_{min} Exceedances	7/3,259	0.21
Scheduled Interchange Sum	0.0	-
Voltage Schedule Conflicts	58	-
Tap Step Conflicts	49/9,102	0.54
Tap Step Conflicts (Severe)	6/9,102	0.07
Low Emergency Rating	8/27,189	0.03
High Emergency Rating	2/27,189	0.01
Thermal Overloads	20/28,940	0.07
Thermal Overloads (Severe)	15/28,940	0.05
Generator Reactive at Limits	121/2,332	5.19
Generator Reactive Limit Power Factor	339/3,519	9.63
Positive Sequence TX Circulating Current	0/1,856	0.00

Table 3.19: Steady-State Metrics		
Metric	**Performance**	**Score (%)**
Poor Load Power Factor	4/7,333	0.05
Generator R_{source}:X_{source} Ratio	4/4,450	0.09
Generator Terminal Voltage	101/1,395	**7.24**
Generator Reactive Capability Curve	0/539	0.00
X/R Ratio Check	100/52,163	0.19
Natural Gas Generator Pmax	572/718	**79.67**
Natural Gas Generator Pmax (Severe)	46/718	**6.41**

Table 3.20: Dynamics Metrics				
Metric	**Performance**	**Score (%)**	**P_{max} (MW)**	**Q_{max} (MVAR)**
Generators without Models	253/3,532	**7.16**	16,681	10,033
Netted Generators with Models	9/3,636	0.34	472	206
Netted Generators	105/2,635	3.98	5,253	1,767
Generators with Classical Models	0/4,450	0.00	0	0
Unacceptable Models (total)	418/12,944	3.23	-	-
Not Recommended Models (total)	1,182/12,944	**9.13**	-	-
User-Written Models[34]	4/27,801	-	-	-
Inconsistent Reactances	107/3,198	3.35	2,819	1,481
Inconsistent Time Constants	197/3,198	**6.16**	3,357	1,735
Unreasonable Inertia Constants	324/3,198	**10.13**	*16,875	*10,459
Unreasonable Saturation Factors	567/3,198	**17.73**	*28,221	*13,934
Severe Saturation Factors	183/3,198	**5.72**	*5,948	*2,919
PSS but no Excitation	14/1,832	0.76	1,659	716
Inconsistent Speed Damping	225/3,198	**7.04**	4,982	2,228
Inconsistent Lead-Lag Time Constant	41/1,318	3.11	3,333	1,990
Erroneous Power Dev Fractions	5/183	2.73	552	220
DC Exciter Self-Excitation Errors	30/522	**5.75**	1,431	625
Inconsistent Type III Wind Speeds	0/79	0.00	0	0
Suspect PSS2A/2B Parameters	61/1,630	3.74	32,770	14,454
Incorrect DER_A Tripping Parameters	0/0	0.00	0	0
Second Generation Renewable Model Parameterization	419/1,346	**31.13**	-	-

* This total is not indicative of the units identified score as the score can be modified by whitelisted units. This sum indicates the total Pmax and Qmax of units that are flagged by the check rather than the subset of remaining units after the exempted models are removed.

Table 3.21: Unacceptable and Not Recommended Model Breakdown			
Category	**Subcategory**	**Performance**	**Score (%)**
Unacceptable Models	Generator	132/4,450	2.97
	Exciter	119/4,151	2.87
	Stabilizer	70/1,912	3.66
	Turbine Governor	97/2,431	**3.99**
Not Recommended Models	Generator	883/4,450	**19.84**
	Exciter	240/4,151	**5.78**
	Stabilizer	0/1,912	0.00

[34] These are not affecting Interconnection performance. This is listed here based on discussions with MOD-032 designees.

Table 3.21: Unacceptable and Not Recommended Model Breakdown			
Category	Subcategory	Performance	Score (%)
	Turbine Governor	59/2,431	2.43
User Written Models	Generator	0/4,450	0.00
	Exciter	0/4,151	0.00
	Stabilizer	0/1,912	0.00
	Turbine Governor	0/2,431	0.00

2021–2022 Winter Peak Case: 22HW2a

Table 3.22: Steady-State Metrics		
Metric	Performance	Score (%)
P_{max} Exceedances	12/2,717	0.44
P_{min} Exceedances	9/2,717	0.33
Scheduled Interchange Sum	0.0	-
Voltage Schedule Conflicts	64	-
Tap Step Conflicts	34/9,860	0.34
Tap Step Conflicts (Severe)	8/9,860	0.08
Low Emergency Rating	100/28,878	0.35
High Emergency Rating	7/28,878	0.02
Thermal Overloads	11/30,699	0.04
Thermal Overloads (Severe)	3/30,699	0.01
Generator Reactive at Limits	95/1,878	**5.06**
Generator Reactive Limit Power Factor	343/3,631	**9.45**
Positive Sequence TX Circulating Current	0/1,882	0.00
Poor Load Power Factor	3/6,914	0.04
Generator R_{source}:X_{source} Ratio	9/4,584	0.20
Generator Terminal Voltage	180/1,773	**10.15**
Generator Reactive Capability Curve	0/491	0.00
X/R Ratio Check	112/55,668	0.20
Natural Gas Generator Pmax	N/A	N/A
Natural Gas Generator Pmax (Severe)	N/A	N/A

Table 3.23: Dynamics Metrics				
Metric	Performance	Score (%)	P_{max} (MW)	Q_{max} (MVAR)
Generators without Models	286/3,632	**7.87**	37,731	8,748
Netted Generators with Models	5/3,704	0.23	108	47
Netted Generators	72/2,184	3.30	2,420	824
Generators with Classical Models	0/4,584	0.00	0	0
Unacceptable Models (total)	402/16,182	2.48	-	-
Not Recommended Models (total)	1,066/16,182	**6.59**	-	-
User-Written Models[35]	4/26,980	-	-	-
Inconsistent Reactances	110/3,188	3.45	3,128	1,508
Inconsistent Time Constants	207/3,188	**6.49**	5,638	2,659
Unreasonable Inertia Constants	328/3,188	**10.29**	*17,055	*10,506
Unreasonable Saturation Factors	565/3,188	**17.72**	*27,479	*13,565

[35] These are not affecting Interconnection performance. This is listed here based on discussions with MOD-032 designees.

Table 3.23: Dynamics Metrics				
Metric	**Performance**	**Score (%)**	**P_{max} (MW)**	**Q_{max} (MVAR)**
Severe Saturation Factors	180/3,188	5.65	*5,206	*2,496
PSS but no Excitation	18/1,841	0.98	1,657	708
Inconsistent Speed Damping	219/3,188	6.87	4,268	1,892
Inconsistent Lead-Lag Time Constant	42/1,284	3.27	2,970	1,681
Erroneous Power Dev Fractions	5/186	2.69	552	220
DC Exciter Self-Excitation Errors	26/512	5.08	1,194	508
Inconsistent Type III Wind Speeds	0/76	0.00	0	0
Suspect PSS2A/2B Parameters	61/1,642	3.71	32,702	14,218
Incorrect DER_A Tripping Parameters	0/0	0.00	0	0
Second Generation Renewable Model Parameterization	540/1,558	34.66	-	-

* This total is not indicative of the units identified score as the score can be modified by whitelisted units. This sum indicates the total Pmax and Qmax of units that are flagged by the check rather than the subset of remaining units after the exempted models are removed.

Table 3.24: Unacceptable and Not Recommended Model Breakdown			
Category	**Subcategory**	**Performance**	**Score (%)**
Unacceptable Models	Generator	120/4,584	2.62
	Exciter	119/4,253	2.80
	Stabilizer	68/1,917	3.55
	Turbine Governor	95/2,428	3.91
Not Recommended Models	Generator	831/4,584	18.13
	Exciter	179/4,253	4.21
	Stabilizer	0/1,917	0.00
	Turbine Governor	56/2,428	2.31
User Written Models	Generator	0/4,584	0.00
	Exciter	0/4,253	0.00
	Stabilizer	0/1,917	0.00
	Turbine Governor	0/2,428	0.00

2021 Summer Light Load Case: 21LS1a

Table 3.25: Steady-State Metrics		
Metric	**Performance**	**Score (%)**
P_{max} Exceedances	2/2,389	0.08
P_{min} Exceedances	6/2,389	0.25
Scheduled Interchange Sum	0.0	-
Voltage Schedule Conflicts	58	-
Tap Step Conflicts	48/9,099	0.53
Tap Step Conflicts (Severe)	6/9,099	0.07
Low Emergency Rating	8/27,183	0.03
High Emergency Rating	2/27,183	0.01
Thermal Overloads	13/28,932	0.04
Thermal Overloads (Severe)	3/28,932	0.01
Generator Reactive at Limits	89/1,640	5.43
Generator Reactive Limit Power Factor	344/3,510	9.80

Table 3.25: Steady-State Metrics		
Metric	**Performance**	**Score (%)**
Positive Sequence TX Circulating Current	0/1,856	0.00
Poor Load Power Factor	5/6,361	0.08
Generator R_{source}:X_{source} Ratio	4/4,453	0.09
Generator Terminal Voltage	101/1,941	**5.20**
Generator Reactive Capability Curve	0/379	0.00
X/R Ratio Check	100/52,698	0.19
Natural Gas Generator Pmax	N/A	N/A
Natural Gas Generator Pmax (Severe)	N/A	N/A

Table 3.26: Dynamics Metrics				
Metric	**Performance**	**Score (%)**	**P_{max} (MW)**	**Q_{max} (MVAR)**
Generators without Models	258/3,534	**7.30**	16,867	10,313
Netted Generators with Models	6/3,598	0.32	260	109
Netted Generators	65/1,880	3.46	2,470	497
Generators with Classical Models	0/4,453	0.00	0	0
Unacceptable Models (total)	442/12,950	3.41	-	-
Not Recommended Models (total)	1,180/12,950	**9.11**	-	-
User-Written Models[36]	4/25,052	-	-	-
Inconsistent Reactances	110/3,195	3.44	3,285	1733
Inconsistent Time Constants	24/840	**2.86**	878	353
Unreasonable Inertia Constants	88/840	**10.48**	*4,256	*2,755
Unreasonable Saturation Factors	111/840	**13.21**	*7,278	*3,391
Severe Saturation Factors	13/840	1.55	*7,278	*3,391
PSS but no Excitation	0/455	0.00	0	0
Inconsistent Speed Damping	85/540	**10.12**	1,766	834
Inconsistent Lead-Lag Time Constant	12/338	3.55	949	562
Erroneous Power Dev Fractions	1/67	1.49	16	5
DC Exciter Self-Excitation Errors	8/113	**7.08**	235	109
Inconsistent Type III Wind Speeds	0/38	0.00	0	0
Suspect PSS2A/2B Parameters	61/1,628	3.75	32,724	14,625
Incorrect DER_A Tripping Parameters	0/0	0.00	0	0
Second Generation Renewable Model Parameterization	416/1,354	**30.72**	-	-

* This total is not indicative of the units identified score as the score can be modified by whitelisted units. This sum indicates the total Pmax and Qmax of units that are flagged by the check rather than the subset of remaining units after the exempted models are removed.

Table 3.27: Unacceptable and Not Recommended Model Breakdown			
Category	**Subcategory**	**Performance**	**Score (%)**
Unacceptable Models	Generator	132/4,453	2.96
	Exciter	131/4,168	3.14
	Stabilizer	70/1,906	3.67
	Turbine Governor	109/2,423	**4.50**
Not Recommended Models	Generator	879/4,453	**19.74**
	Exciter	242/5,168	**5.81**

[36] These are not affecting Interconnection performance. This is listed here based on discussions with MOD-032 designees.

Table 3.27: Unacceptable and Not Recommended Model Breakdown			
Category	**Subcategory**	**Performance**	**Score (%)**
	Stabilizer	0/1,906	0.00
	Turbine Governor	59/2,423	2.43
User Written Models	Generator	0/4,453	0.00
	Exciter	0/5,168	0.00
	Stabilizer	0/1,906	0.00
	Turbine Governor	0/2,423	0.00

Chapter 4: Observations and Recommendations

For the summer peak cases, **Table 4.1** demonstrates the number of metrics above 5% according to the categories identified in **Table 1.1**. Additional trending information between past NERC case quality metrics assessments and this year's version can be found in **Appendix A**.

Table 4.1: Interconnection Issues Categorized According to Table 1.1			
Interconnection	**Number of Bad Data Metrics above 5%**	**Number of Suspect Data Metrics above 5%**	**Number of Case Setup Issues above 5%**
East	2	5	2
Texas	1	5	1
West	4	6	3

Observations

Based on the results of the case quality metrics assessment, the following observations are made:

- Generators dispatched at reactive limits remains an issue across the Interconnections even though this metric has improved since the *2017 Case Quality Metrics: Annual Interconnection-Wide Model Assessment* when it was first implemented. These generators in the Base Case are dispatched in a suspect manner.
- Generators with reactive limits that have relatively low power factor (i.e., large reactive limits relative to active power limits) are still an issue for the TI and WI Interconnections. The flagged data is suspect.
- Unreasonable inertia constants are still an issue for all Interconnections even when widening the range of reasonable data. The trend for this data either contains a degradation of performance or a constant elevated performance across all Interconnections. The flagged data is suspect.
- Unreasonable saturation factors are still an issue for all Interconnections, but the severe version of this metric has seen improvement. The saturation factors with severe inaccuracies should be a priority for the WI; however, both severe and non-severe metrics are consistently high score. In general, this metric is trending towards improvement. For those generators flagged, their modeled saturation factor values are suspect.
- Generator speed damping parameters with values other than zero are still an issue in the WI but not in the EI or TI. Furthermore, a general trend towards improvement was made in the EI and TI. These generator models contain bad data.
- The dc exciter self-excitation errors are still an issue for all Interconnections with only the TI showing improvements in the score. These generator models contain bad data.
- A general decline in performance regarding generators above the modeling threshold not having generator models have been observed. Generators flagged are indicative of a case setup issue in addition to being a suspect condition for such generators.
- A slight increasing score for inclusion of netted generation in the EI and WI has been observed; however, the trend has historically stayed below a score of 5%. The EI has only demonstrated this increase in the light load case.
- In the unacceptable or not recommended model metrics, all Interconnections demonstrate either a consistent performance or worsening score. Of special note is that the TI and WI have maintained the unacceptable model score below 5% while the EI has increased its score significantly. The majority of models that are not recommended use the GENROU generator model.
- The TI corrected the large increase of Generator Reactive Limit Power Factor metric in the summer case from 2020.

- For the WI and EI, there is a consistent high performance or worsening score for the Generator Reactive at Limits, Generator Terminal Voltage, Natural Gas Generator, and Reactive Capability Curve metrics. The TI is an exception that has generally improved in these metrics since last year. All of these metrics are related to case dispatch or suspect data that involve reactive capability of generators. Additionally, the WI's natural gas generation in the case does not reflect the ambient thermal impact to changes in steady-state active power limits for natural gas generators due to the effect of ambient temperature differences between the seasonal cases; all such data is suspect.
- The Generator Reactive Capability Curve check for the EI or TI remains at 0.00 due to no generator curves provided. Further, no DER_A models exist in the cases and the DER_A tripping parameter check is still 0.00 for that reason.

Table 4.2 gives a "scorecard" for performance based on the overall assessment of cases for each Interconnection. This performance is based on highlights from the specific observations above and the performance tables identified in **Appendix A**.

Table 4.2: Interconnection Scorecard

Interconnection	Metrics	Evaluation
Eastern	Powerflow	Most metrics below 5% 1 metric with major improvement 2 metrics worsening or consistent high score in non-light load cases Voltage schedule conflicts major increase
	Dynamics	Most metrics below 5% 4 metrics consistent high score 3 metrics worsening (1 still under 5%) 1 new metric high score
Texas	Powerflow	Most metrics below 5% 1 metric worsening 1 metric consistent worsening or improving 1 metric consistent high score or improving
	Dynamics	Most metrics below 5% 2 metrics consistent high score 3 metrics worsening 1 metric improving
Western	Powerflow	Most metrics below 5% 2 metrics improving, worsening, or consistent high score 2 metrics worsening 1 metric improving
	Dynamics	Most metrics below 5% 3 metrics worsening in light load case Many metrics have a consistently high score 1 metric improving or consistent high score

Recommendations

Based on the previously listed observations, NERC recommends the following:

- NERC should continue performing the NERC case quality metrics assessment each year to assess the overall performance of case quality for the Interconnection-wide planning cases developed. NERC should then provide such feedback to the MOD-032 designees for year-over-year improvement.
- NERC should continue working with subject matter experts to improve both the Powerflow and Dynamics metrics.
- The MOD-032 designees for the EI and TI should focus on verifying the saturation factor curves and provide exceptions for verified generator parameters via a whitelist. The WI should focus on the severe saturation factor generators as a priority. Each MOD-032 designee should review the listed units with unreasonable saturation factors and work with their respective Generator Owners (GOs) to review model validation test reports to ensure accuracy.
- Generators above the modeling threshold for each Interconnection should have a model, one that conforms to the MOD-032 designees modeling practices (and all models should adhere to the NERC Acceptable Model List). The MOD-032 designees should review their model building process and enforce their modeling thresholds. The large majority of not recommended models is the generator model GENROU. MOD-032 designees are encouraged to read the *Modeling Notification: Use of GENTPJ Generator Model*[37] for recommended models to better represent the effect of stator current on saturation.
- The MOD-032 designees for each Interconnection should review the generators identified in the Generator Reactive Limit Power Factor to determine if the power factor is correct and provide verified exceptions via a whitelist.
- The MOD-032 designee for the WI should actively work with its GOs to correct units with inconsistent time constants. The metric is flagging generator model parameters that are not physically realistic.
- The MOD-032 designee for the WI should work with its respective GOs to correct the use of speed damping coefficients on units that are not modeled as classical machines. These values should be zero for generation units flagged.
- Each MOD-032 designee should work with their respective GOs to correct issues associated with the dc exciter self-excitation errors. This report provides some information in the description of the metric on how to correct these issues.
- The MOD-032 designees for the WI and EI should monitor the generator terminal bus voltages when dispatching their Interconnection-wide Base Case and ensure such voltages remain in the 0.95 to 1.05 range. Generators outside those boundaries signify a poor dispatch based on discussions with the NERC PPMVTF, and as such signify a suspect dispatch in the Interconnection-wide Base Case.
- The MOD-032 designees should ensure their natural gas generator thermal rates are represented in the Interconnection wide base cases. When software inputs exist to determine fuel type, such fields should be filled out accordingly. Where such fields do not exist, supplemental data or requests to software venders should be made to encourage identification of generators with possibly large capacity changes due to ambient temperature. The MOD-032 designee for the WI should determine how feasible it is to request seasonal thermal limits in their ratings for natural gas generation facilities. The MOD-032 designees for the EI and TI should determine how to best include seasonal natural gas generator capacities into their base case packages.

[37] A link to the notification is provided here.

- The MOD-032 designees should utilize the unacceptable and not recommended model generators flagged in those metrics to begin targeting efforts for model improvement and replacement.
- The MOD-032 designee for the WI should review their case dispatch procedure and ensure that generator reactive capability curves are entered properly, that generator bus voltages stay within 0.95 and 1.05 p.u. and that generators are not dispatched to their reactive maximum capability.
- The MOD-032 designees for the WI and EI should ensure that the parameterization for second-generation renewable models is reflective of plant specific parameters. Generators flagged in the check have one or more model with parameters that are suspect.
- The MOD-032 designee for the WI should review their light summer cases to correct suspect generation data as more generation (as a percentage of all generators online) with suspect data seems to be used year-over-year.

Appendix A: Yearly Comparison

The metrics for each case were assessed to compare this year's performance against prior years' performance. The results of this assessment are shown in **Tables A.1** to **A.9**. The color coding used in the tables denotes the following.

(dark green)	Consistent performance under 5% performance score, or performance score moved from greater than 5% to less than 5%
(light green)	Positive performance improvements (decrease in score of 2% or more from previous year)
(orange)	Continued performance above 5% performance score with no noticeable improvement
(red)	Noticeable performance degradation (increase of 1% or more from previous year), or performance score moved from less than 5% to greater than 5%

Many of the metrics are below 5 percent (dark green) signifying that the overall case quality of the Interconnection-wide base cases are consistently of good quality. Similar in Chapter 3, scores in **red** indicate a higher than 5 percent score for that year. A few metrics obtained light green scores indicating an improvement of case quality and the few scores that had the orange score, indicating a stable, but high score. It is good to note that the EI Base Case Creation Process has a series number associated with the Base Case that will not line up with the year listed in the tables. Thus, there is a year difference between the series number and the case quality metrics assessment year. To further clarify, the case quality metrics assessment year is X, and the EI builds their models for year X in year X-1.

Eastern Interconnection

Table A.1: Heavy Summer Cases

Type of Metric	Metric	2017 Score (%)	2018 Score (%)	2019 Score (%)	2020 Score (%)	2021 Score (%)	Performance
Powerflow	P_{max} Exceedances	0.06	0.15	0.10	0.05	0.06	(dark green)
	P_{min} Exceedances	0.03	0.10	0.1	0.02	0.01	(dark green)
	Scheduled Interchange Sum	-0.001	0	0.01	0	0	(dark green)
	Voltage Schedule Conflicts	22	27	14	29	102	(red)
	Tap Step Conflicts	0.07	0.07	0.07	0.16	0.17	(dark green)
	Tap Step Conflicts (Severe)	0.03	0.03	0.01	0.09	0.09	(dark green)
	Low Emergency Rating	0	0.00	0.00	0.02	0.02	(dark green)
	High Emergency Rating	0.1	0.03	0.00	0.00	0.00	(dark green)
	Thermal Overloads	0.1	0.17	0.19	0.13	0.15	(dark green)
	Thermal Overloads (Severe)	0.07	0.13	0.15	0.11	0.12	(dark green)
	Generator Reactive at Limits	**25.34**	**18.82**	**18.88**	**16.52**	**15.70**	(orange)
	Generator Reactive Limit Power Factor	**13.63**	**13.16**	**12.14**	**10.30**	2.38	(dark green)
	Positive Sequence TX Circulating Current	0.00	0.00	0.00	0.00	0.00	(dark green)
	Poor Load Power Factor	0.32	0.35	0.29	0.30	0.33	(dark green)
	Generator R_{source}:X_{source} Ratio	0.00	0.00	0.00	0.06	0.04	(dark green)

Table A.1: Heavy Summer Cases							
Type of Metric	**Metric**	**2017 Score (%)**	**2018 Score (%)**	**2019 Score (%)**	**2020 Score (%)**	**2021 Score (%)**	**Performance**
	Generator Terminal Voltage	N/A	N/A	**6.33**	**5.53**	4.15	
	Generator Reactive Capability Curve	N/A	N/A	0.00	0.00	0.00	
	X/R Ratio Check	N/A	N/A	0.25	0.25	0.23	
	Natural Gas Generator Pmax	N/A	N/A	N/A	N/A	N/A	
	Natural Gas Generator Pmax (Severe)	N/A	N/A	N/A	N/A	N/A	
Dynamics	Generators without Models	1.31	1.62	1.96	2.26	2.37	
	Netted Generators with Models	0.36	0.26	0.64	0.47	0.37	
	Netted Generators	1.5	3.58	2.65	2.79	2.48	
	Generators with Classical Models	0.32	0.26	0.25	0.28	0.27	
	Unacceptable Models	N/A	N/A	**11.83**	**11.81**	**13.17**	
	Not Recommended Models	N/A	N/A	**23.56**	**21.09**	**19.87**	
	User-Written Models[38]	N/A	N/A	N/A	-	-	
	Inconsistent Reactances	0.21	0.23	0.24	0.82	1.05	
	Inconsistent Time Constants	0.11	0.11	0.11	0.13	0.09	
	Unreasonable Inertia Constants	**10.14**	**8.04**	**8.44**	**8.06**	**7.77**	
	Unreasonable Saturation Factors	**21.92**	**22.22**	**10.76**	**11.00**	**11.09**	
	Severe Saturation Factors	0.94	0.94	0.81	0.90	0.90	
	PSS but no Excitation	0.14	0.11	0.06	0.10	0.06	
	Inconsistent Speed Damping	4.06	3.33	3.13	2.22	2.28	
	Inconsistent Lead-Lag Time Constant	2.01	1.64	2.06	1.82	1.90	
	Erroneous Power Dev Fractions	1.00	1.02	1.27	1.20	3.48	
	DC Exciter Self-Excitation Errors	**11.35**	**10.34**	**10.58**	**12.83**	**13.40**	
	Inconsistent Type III Wind Speeds	0.25	0.00	0.00	0.00	0.00	
	Suspect PSS2A/2B parameters	N/A	**16.41**	**16.69**	**17.01**	**18.54**	
	Incorrect DER_A Tripping Parameters	N/A	N/A	0.00	0.00	0.00	

38 Performance not tracked

Table A.1: Heavy Summer Cases							
Type of Metric	Metric	2017 Score (%)	2018 Score (%)	2019 Score (%)	2020 Score (%)	2021 Score (%)	Performance
	Second Generation Renewable Model Parameterization	N/A	N/A	N/A	N/A	**17.57**	

Table A.2: Heavy Winter Cases							
Type of Metric	Metric	2017 Score (%)	2018 Score (%)	2019 Score (%)	2020 Score (%)	2021 Score (%)	Performance
Powerflow	P_{max} Exceedances	0.18	0.31	0.10	0.02	0.03	
	P_{min} Exceedances	0.07	0.08	0.16	0.02	0.00	
	Scheduled Interchange Sum	-0.001	0	0	0	0	
	Voltage Schedule Conflicts	22	31	16	36	107	
	Tap Step Conflicts	0.06	0.07	0.07	0.16	0.17	
	Tap Step Conflicts (Severe)	0.01	0.02	0.00	0.09	0.09	
	Low Emergency Rating	0.00	0.00	0.00	0.03	0.02	
	High Emergency Rating	0.09	0.03	0.00	0.00	0.00	
	Thermal Overloads	0.09	0.13	0.18	0.15	0.14	
	Thermal Overloads (Severe)	0.06	0.11	0.14	0.12	0.11	
	Generator Reactive at Limits	**23.20**	**18.35**	**17.99**	**14.48**	**17.01**	
	Generator Reactive Limit Power Factor	**12.11**	**11.28**	**11.14**	**8.54**	2.46	
	Positive Sequence TX Circulating Current	0.00	0.00	0.00	0.00	0.00	
	Poor Load Power Factor	0.25	0.27	0.24	0.25	0.27	
	Generator R_{source}:X_{source} Ratio	0.00	0.00	0.00	0.05	0.05	
	Generator Terminal Voltage	N/A	N/A	**7.75**	4.50	**5.28**	
	Generator Reactive Capability Curve	N/A	N/A	0.00	0.00	0.00	
	X/R Ratio Check	N/A	N/A	0.26	0.24	0.23	
	Natural Gas Generator Pmax	N/A	N/A	N/A	N/A	N/A	
	Natural Gas Generator Pmax (Severe)	N/A	N/A	N/A	N/A	N/A	
Dynamics	Gens without Models	1.38	1.72	2.07	2.39	2.59	
	Netted Generators with Models	0.29	0.23	0.71	0.26	0.34	
	Netted Generators	1.16	4.07	2.45	2.17	2.09	
	Gens with Classical Models	0.32	0.25	0.27	0.28	0.27	
	Unacceptable Models	N/A	N/A	**13.87**	**10.33**	**13.15**	

Table A.2: Heavy Winter Cases

Type of Metric	Metric	2017 Score (%)	2018 Score (%)	2019 Score (%)	2020 Score (%)	2021 Score (%)	Performance
	Not Recommended Models	N/A	N/A	**23.48**	**20.94**	**19.69**	
	User-Written Models[39]	N/A	N/A	N/A	-	-	
	Inconsistent Reactances	0.21	0.23	0.27	0.64	1.10	
	Inconsistent Time Constants	0.11	0.11	0.11	0.13	0.09	
	Unreasonable Inertia Constants	**10.19**	**8.11**	**8.49**	**8.07**	**7.76**	
	Unreasonable Saturation Factors	**21.87**	**22.19**	**10.75**	**10.99**	**11.12**	
	Severe Saturation Factors	0.97	0.94	0.81	0.91	0.90	
	PSS but no Excitation	0.16	0.11	0.06	0.10	0.06	
	Inconsistent Speed Damping	4.05	3.33	3.12	2.22	2.28	
	Inconsistent Lead-Lag Time Constant	1.99	1.63	2.16	1.81	1.88	
	Erroneous Power Dev Fractions	1.00	1.36	1.27	1.20	3.48	
	DC Exciter Self-Excitation Errors	**11.40**	**10.54**	**10.77**	**12.59**	**13.43**	
	Inconsistent Type III Wind Speeds	0.25	0.00	0.00	0.00	0.00	
	Suspect PSS2A/2B parameters	N/A	**16.51**	**16.67**	**17.32**	**18.63**	
	Incorrect DER_A Tripping Parameters	N/A	N/A	0.00	0.00	0.00	
	Second Generation Renewable Model Parameterization	N/A	N/A	N/A	N/A	**18.57**	

Table A.3: Light Spring Cases

Type of Metric	Metric	2017 Score (%)	2018 Score (%)	2019 Score (%)	2020 Score (%)	2021 Score (%)	Performance
Powerflow	P_{max} Exceedances	0.03	0.11	0.06	0.17	0.00	
	P_{min} Exceedances	0.03	0.06	0.21	0.11	0.05	
	Scheduled Interchange Sum	-0.3	0	0	0.001	0	
	Voltage Schedule Conflicts	21	32	13	38	70	
	Tap Step Conflicts	0.07	0.06	0.06	0.16	0.17	
	Tap Step Conflicts (Severe)	0.03	0.02	0.00	0.09	0.09	
	Low Emergency Rating	0.00	0.00	0.00	0.02	0.02	
	High Emergency Rating	0.1	0.03	0.00	0.00	0.00	

[39] Performance not tracked

Table A.3: Light Spring Cases							
Type of Metric	**Metric**	**2017 Score (%)**	**2018 Score (%)**	**2019 Score (%)**	**2020 Score (%)**	**2021 Score (%)**	**Performance**
	Thermal Overloads	0.04	0.06	0.07	0.05	0.04	
	Thermal Overloads (Severe)	0.03	0.05	0.06	0.05	0.03	
	Generator Reactive at Limits	**30.03**	**23.62**	**20.87**	**19.64**	**16.98**	
	Generator Reactive Limit Power Factor	**13.99**	**13.65**	**13.65**	**9.29**	2.44	
	Positive Sequence TX Circulating Current	0.00	0.00	0.00	0.00	0.00	
	Poor Load Power Factor	0.31	0.38	0.38	0.35	0.28	
	Generator R_{source}:X_{source} Ratio	0.00	0.00	0.00	0.08	0.08	
	Generator Terminal Voltage	N/A	N/A	**13.51**	**6.07**	**6.09**	
	Generator Reactive Capability Curve	N/A	N/A	0.00	0.00	0.00	
	X/R Ratio Check	N/A	N/A	0.25	0.24	0.23	
	Natural Gas Generator Pmax	N/A	N/A	N/A	N/A	N/A	
	Natural Gas Generator Pmax (Severe)	N/A	N/A	N/A	N/A	N/A	
Dynamics	Generators without Models	1.25	1.68	1.81	2.36	2.62	
	Netted Gens with Models	0.40	0.24	1.05	0.31	0.73	
	Netted Generators	1.29	**5.40**	2.75	2.06	2.21	
	Generators with Classical Models	0.32	0.26	0.23	0.28	0.26	
	Unacceptable Models	N/A	N/A	**13.95**	**11.86**	**13.23**	
	Not Recommended Models	N/A	N/A	**23.79**	**21.15**	**19.95**	
	User-Written Models[40]	N/A	N/A	N/A	-	-	
	Inconsistent Reactances	0.21	0.24	0.25	0.82	1.06	
	Inconsistent Time Constants	0.11	0.11	0.11	0.13	0.09	
	Unreasonable Inertia Constants	**10.15**	**8.01**	**8.32**	**8.01**	**7.80**	
	Unreasonable Saturation Factors	**21.83**	**22.12**	**10.78**	**11.04**	**10.99**	
	Severe Saturation Factors	0.90	0.94	0.81	0.91	0.91	
	PSS but no Excitation	0.14	0.11	0.06	0.11	0.07	
	Inconsistent Speed Damping	4.07	3.35	3.12	2.23	2.29	

40 Performance not tracked

Table A.3: Light Spring Cases							
Type of Metric	Metric	2017 Score (%)	2018 Score (%)	2019 Score (%)	2020 Score (%)	2021 Score (%)	Performance
	Inconsistent Lead-Lag Time Constant	2.01	1.64	2.08	1.83	1.92	
	Erroneous Power Dev Fractions	1.00	1.02	1.09	1.21	3.49	
	DC Exciter Self-Excitation Errors	**11.27**	**10.27**	**10.58**	**12.84**	**13.45**	
	Inconsistent Type III Wind Speeds	0.25	0.00	0.00	0.00	0.00	
	Suspect PSS2A/2B parameters	N/A	**17.85**	**17.73**	**18.09**	**19.55**	
	Incorrect DER_A Tripping Parameters	N/A	N/A	0.00	0.00	0.00	
	Second Generation Renewable Model Parameterization	N/A	N/A	N/A	N/A	**17.31**	

Texas Interconnection

Table A.4: Heavy Summer Peak Cases							
Type of Metric	Metric	2017 Score (%)	2018 Score (%)	2019 Score (%)	2020 Score (%)	2021 Score (%)	Performance
Powerflow	P_{max} Exceedances	0.00	0.00	0.00	0.00	0.11	
	P_{min} Exceedances	0.00	0.00	0.00	0.00	0.00	
	Scheduled Interchange Sum	0.0	0	0	0	0	
	Voltage Schedule Conflicts	3	0	5	47	31	
	Tap Step Conflicts	3.33	3.21	0.07	1.33	3.66	
	Tap Step Conflicts (Severe)	0.08	0.00	0.00	0.00	0.00	
	Low Emergency Rating	0.00	0.00	0.00	0.00	0.00	
	High Emergency Rating	0.01	0.02	0.03	0.00	0.02	
	Thermal Overloads	0.22	0.13	0.06	0.10	0.24	
	Thermal Overloads (Severe)	0.17	0.10	0.04	0.04	0.23	
	Generator Reactive at Limits	**20.24**	**14.11**	**6.37**	**6.78**	**8.52**	
	Generator Reactive Limit Power Factor	**11.33**	**11.11**	**13.73**	**31.83**	**9.36**	
	Positive Sequence TX Circulating Current	0.00	0.00	0.00	0.00	0.00	
	Poor Load Power Factor	**19.71**	0.11	0.13	0.06	0.02	
	Generator R_{source}:X_{source} Ratio	0.00	0.00	0.13	0.00	0.42	

Table A.4: Heavy Summer Peak Cases							
Type of Metric	**Metric**	**2017 Score (%)**	**2018 Score (%)**	**2019 Score (%)**	**2020 Score (%)**	**2021 Score (%)**	**Performance**
	Generator Terminal Voltage	N/A	N/A	1.92	0.30	0.58	
	Generator Reactive Capability Curve	N/A	N/A	0.00	0.00	0.00	
	X/R Ratio Check	N/A	N/A	0.43	0.44	0.34	
	Natural Gas Generator Pmax	N/A	N/A	N/A	N/A	N/A	
	Natural Gas Generator Pmax (Severe)	N/A	N/A	N/A	N/A	N/A	
Dynamics	Generators without Models	3.07	4.07	**5.20**	2.52	2.88	
	Netted Gens with Models	1.26	0.00	0.00	0.00	0.00	
	Netted Generators	2.16	0.14	0.00	0.00	0.00	
	Generators with Classical Models	0.31	1.55	2.15	0.00	1.22	
	Unacceptable Models	N/A	N/A	2.96	2.10	1.85	
	Not Recommended Models	N/A	N/A	**24.37**	**21.77**	**20.09**	
	User-Written Models[41]	N/A	N/A	N/A	-	-	
	Inconsistent Reactances	1.50	1.25	0.62	1.07	1.31	
	Inconsistent Time Constants	0.40	0.42	0.40	0.79	0.73	
	Unreasonable Inertia Constants	**15.33**	**11.30**	**14.01**	**15.31**	**16.40**	
	Unreasonable Saturation Factors	**20.08**	**20.12**	**13.17**	**12.82**	**13.55**	
	Severe Saturation Factors	2.21	1.45	1.20	1.18	1.65	
	PSS but no Excitation	0.00	0.00	0.00	0.00	0.00	
	Inconsistent Speed Damping	**11.01**	3.78	3.10	2.82	2.91	
	Inconsistent Lead-Lag Time Constant	0.00	0.00	0.00	0.00	0.00	
	Erroneous Power Dev Fractions	0.00	0.00	0.00	0.00	2.44	
	DC Exciter Self-Excitation Errors	**9.86**	**11.67**	**12.50**	**13.46**	**11.31**	
	Inconsistent Type III Wind Speeds	0.00	0.00	0.00	0.00	0.00	
	Suspect PSS2A/2B parameters	N/A	**12.5**	**16.92**	**14.07**	**16.21**	
	Incorrect DER_A Tripping Parameters	N/A	N/A	0.00	0.00	0.00	

[41] Performance not tracked.

Table A.4: Heavy Summer Peak Cases							
Type of Metric	**Metric**	**2017 Score (%)**	**2018 Score (%)**	**2019 Score (%)**	**2020 Score (%)**	**2021 Score (%)**	**Performance**
	Second Generation Renewable Model Parameterization	N/A	N/A	N/A	N/A	0.00	

Table A.5: Heavy Wind Light Load Cases							
Type of Metric	**Metric**	**2017 Score (%)**	**2018 Score (%)**	**2019 Score (%)**	**2020 Score (%)**	**2021 Score (%)**	**Performance**
Powerflow	P_{max} Exceedances	0.00	0.00	0.00	0.00	0.17	
	P_{min} Exceedances	0.00	0.00	0.00	0.37	0.00	
	Scheduled Interchange Sum	0.0	0	0	0	0	
	Voltage Schedule Conflicts	6	0	12	62	43	
	Tap Step Conflicts	3.34	3.21	0.00	1.60	3.01	
	Tap Step Conflicts (Severe)	0.00	0.00	0.00	0.00	0.00	
	Low Emergency Rating	0.00	0.00	0.00	0.00	0.00	
	High Emergency Rating	0.01	0.02	0.03	0.00	0.02	
	Thermal Overloads	0.19	0.25	0.05	0.03	0.17	
	Thermal Overloads (Severe)	0.15	0.18	0.04	0.01	0.13	
	Generator Reactive at Limits	**29.31**	**17.34**	**12.59**	**14.01**	**9.16**	
	Generator Reactive Limit Power Factor	**10.66**	**12.39**	**7.82**	**7.84**	**6.53**	
	Positive Sequence TX Circulating Current	0.00	0.00	0.00	0.00	0.00	
	Poor Load Power Factor	**16.07**	0.20	0.19	0.06	0.05	
	Generator R_{source}:X_{source} Ratio	0.00	0.00	0.21	0.00	0.68	
	Generator Terminal Voltage	N/A	N/A	0.00	0.00	0.76	
	Generator Reactive Capability Curve	N/A	N/A	0.00	0.00	0.00	
	X/R Ratio Check	N/A	N/A	0.43	0.43	0.34	
	Natural Gas Generator Pmax	N/A	N/A	N/A	N/A	N/A	
	Natural Gas Generator Pmax (Severe)	N/A	N/A	N/A	N/A	N/A	
Dynamics	Generators without Models	3.18	**6.62**	**8.55**	2.93	3.08	
	Netted Gens with Models	2.00	0.00	0.00	0.38	0.00	
	Netted Generators	3.00	0.22	0.00	0.38	0.00	
	Generators with Classical Models	0.31	1.55	1.43	0.00	1.22	
	Unacceptable Models	N/A	N/A	2.79	2.11	1.85	

Table A.5: Heavy Wind Light Load Cases							
Type of Metric	**Metric**	**2017 Score (%)**	**2018 Score (%)**	**2019 Score (%)**	**2020 Score (%)**	**2021 Score (%)**	**Performance**
	Not Recommended Models	N/A	N/A	**24.68**	**21.67**	**20.09**	
	User-Written Models[42]	N/A	N/A	N/A	-	-	
	Inconsistent Reactances	1.50	1.25	1.23	1.07	1.31	
	Inconsistent Time Constants	0.40	0.41	0.39	0.79	0.73	
	Unreasonable Inertia Constants	**15.32**	**11.30**	**13.98**	**15.31**	**16.40**	
	Unreasonable Saturation Factors	**20.08**	**20.12**	**13.19**	**12.85**	**13.55**	
	Severe Saturation Factors	2.21	1.45	1.18	1.19	1.65	
	PSS but no Excitation	0.00	0.00	0.00	0.00	0.00	
	Inconsistent Speed Damping	**11.01**	3.78	3.07	2.82	2.91	
	Inconsistent Lead-Lag Time Constant	0.00	0.00	0.00	0.00	0.00	
	Erroneous Power Dev Fractions	0.00	0.00	0.00	0.00	2.44	
	DC Exciter Self-Excitation Errors	**9.86**	**11.67**	**12.5**	**13.46**	**11.32**	
	Inconsistent Type III Wind Speeds	0.00	0.00	0.00	0.00	0.00	
	Suspect PSS2A/2B parameters	N/A	**12.5**	**16.92**	**14.07**	**16.21**	
	Incorrect DER_A Tripping Parameters	N/A	N/A	0.00	0.00	0.00	
	Second Generation Renewable Model Parameterization	N/A	N/A	N/A	N/A	0.00	

Table A.6: Second Summer Peak Cases							
Type of Metric	**Metric**	**2017 Score (%)**	**2018 Score (%)**	**2019 Score (%)**	**2020 Score (%)**	**2021 Score (%)**	**Performance**
Powerflow	P_{max} Exceedances	0.00	0.00	0.00	0.00	0.11	
	P_{min} Exceedances	0.00	0.00	0.00	0.00	0.00	
	Scheduled Interchange Sum	0.0	0	0	0	0	
	Voltage Schedule Conflicts	5	0	23	37	39	
	Tap Step Conflicts	3.45	3.35	0.94	1.40	3.60	
	Tap Step Conflicts (Severe)	0.00	0.00	0.80	0.00	0.00	
	Low Emergency Rating	0.00	0.00	0.00	0.00	0.00	
	High Emergency Rating	0.01	0.02	0.03	0.00	0.02	

[42] Performance not tracked.

Table A.6: Second Summer Peak Cases							
Type of Metric	**Metric**	**2017 Score (%)**	**2018 Score (%)**	**2019 Score (%)**	**2020 Score (%)**	**2021 Score (%)**	**Performance**
	Thermal Overloads	0.24	0.22	0.04	0.05	0.29	
	Thermal Overloads (Severe)	0.22	0.15	0.04	0.04	0.25	
	Generator Reactive at Limits	**25.37**	**16.24**	**9.14**	**16.28**	**13.37**	
	Generator Reactive Limit Power Factor	**11.64**	**10.97**	**13.35**	**12.59**	**9.15**	
	Positive Sequence TX Circulating Current	0.00	0.00	0.00	0.00	0.00	
	Poor Load Power Factor	**20.10**	0.11	0.13	0.04	0.02	
	Generator R_{source}:X_{source} Ratio	0.00	0.00	0.13	0.00	0.43	
	Generator Terminal Voltage	N/A	N/A	0.00	0.30	0.29	
	Generator Reactive Capability Curve	N/A	N/A	0.00	0.00	0.00	
	X/R Ratio Check	N/A	N/A	0.43	0.44	0.34	
	Natural Gas Generator Pmax	N/A	N/A	N/A	N/A	N/A	
	Natural Gas Generator Pmax (Severe)	N/A	N/A	N/A	N/A	N/A	
Dynamics	Generators without Models	3.07	3.94	**5.19**	3.35	3.26	
	Netted Gens with Models	1.24	0.00	0.00	0.24	0.00	
	Netted Generators	2.13	0.14	0.00	0.24	0.00	
	Gens with Classical Models	0.46	1.55	1.43	0.00	1.21	
	Unacceptable Models	N/A	N/A	2.72	2.10	1.85	
	Not Recommended Models	N/A	N/A	**24.57**	**21.76**	**20.09**	
	User-Written Models[43]	N/A	N/A	N/A	-	-	
	Inconsistent Reactances	1.50	1.25	1.23	1.07	1.31	
	Inconsistent Time Constants	0.40	0.41	0.39	0.79	0.73	
	Unreasonable Inertia Constants	**15.30**	**11.30**	**13.98**	**15.31**	**16.40**	
	Unreasonable Saturation Factors	**20.08**	**20.12**	**13.21**	**12.85**	**13.55**	
	Severe Saturation Factors	2.21	1.45	1.18	1.19	1.65	
	PSS but no Excitation	0.00	0.00	0.00	0.00	0.00	
	Inconsistent Speed Damping	**11.01**	3.78	3.07	2.82	2.91	
	Inconsistent Lead-Lag Time Constant	0.00	0.00	0.00	0.00	0.00	

[43] Performance not tracked.

Table A.6: Second Summer Peak Cases							
Type of Metric	Metric	2017 Score (%)	2018 Score (%)	2019 Score (%)	2020 Score (%)	2021 Score (%)	Performance
	Erroneous Power Dev Fractions	0.00	0.00	0.00	0.00	2.44	
	DC Exciter Self-Excitation Errors	**9.86**	**11.67**	**12.50**	**13.46**	**11.32**	
	Inconsistent Type III Wind Speeds	0.00	0.00	0.00	0.00	0.00	
	Suspect PSS2A/2B parameters	N/A	**12.5**	**16.92**	**14.07**	**16.21**	
	Incorrect DER_A Tripping Parameters	N/A	N/A	0.00	0.00	0.00	
	Second Generation Renewable Model Parameterization	N/A	N/A	N/A	N/A	0.00	

Western Interconnection

Table A.7: Heavy Summer Cases							
Type of Metric	Metric	2017 Score (%)	2018 Score (%)	2019 Score (%)	2020 Score (%)	2021 Score (%)	Performance
Powerflow	P_{max} Exceedances	0.00	0.03	0.00	0.23	0.28	
	P_{min} Exceedances	0.30	0.03	0.03	0.32	0.21	
	Scheduled Interchange Sum	0.0	0	0.0	-0.0	0.0	
	Voltage Schedule Conflicts	78	80	63	55	58	
	Tap Step Conflicts	0.62	0.66	0.72	0.62	0.54	
	Tap Step Conflicts (Severe)	0.07	0.10	0.45	0.05	0.07	
	Low Emergency Rating	0.14	0.13	0.40	0.37	0.03	
	High Emergency Rating	0.01	0.02	0.01	0.01	0.01	
	Thermal Overloads	0.00	0.01	0.01	0.05	0.07	
	Thermal Overloads (Severe)	0.00	0.00	0.00	0.04	0.05	
	Generator Reactive at Limits	**22.47**	**6.53**	4.84	**5.50**	**5.19**	
	Generator Reactive Limit Power Factor	**14.43**	**25.11**	**28.35**	**10.06**	**9.63**	
	Positive Sequence TX Circulating Current	0.00	0.00	0.00	0.00	0.00	
	Poor Load Power Factor	0.14	0.04	0.07	0.05	0.05	
	Generator R_{source}:X_{source} Ratio	0.17	0.21	0.05	0.05	0.09	
	Generator Terminal Voltage	N/A	N/A	3.90	**6.03**	**7.24**	
	Generator Reactive Capability Curve	N/A	N/A	0.00	3.47	0.00	

Table A.7: Heavy Summer Cases							
Type of Metric	Metric	2017 Score (%)	2018 Score (%)	2019 Score (%)	2020 Score (%)	2021 Score (%)	Performance
	X/R Ratio Check	N/A	N/A	0.18	0.19	0.19	
	Natural Gas Generator Pmax	N/A	N/A	**72.30**	**84.13**	**79.67**	
	Natural Gas Generator Pmax (Severe)	N/A	N/A	**5.94**	4.35	**6.41**	
Dynamics	Generators without Models	4.66	4.73	4.89	**6.69**	**7.16**	
	Netted Gens with Models	0.04	0.20	1.07	0.16	0.34	
	Netted Generators	2.01	2.01	3.57	3.22	3.98	
	Generators with Classical Models	0.07	0.00	0.00	0.00	0.00	
	Unacceptable Models	N/A	N/A	4.19	3.73	3.23	
	Not Recommended Models	N/A	N/A	**11.93**	**10.88**	**9.13**	
	User-Written Models[44]	N/A	N/A	N/A	-	-	
	Inconsistent Reactances	3.23	3.34	3.54	3.24	3.35	
	Inconsistent Time Constants	**6.07**	**5.96**	**5.87**	**5.74**	**6.16**	
	Unreasonable Inertia Constants	**18.99**	**13.03**	**13.06**	**11.90**	**10.13**	
	Unreasonable Saturation Factors	**26.83**	**27.08**	**19.74**	**19.00**	**17.73**	
	Severe Saturation Factors	**6.81**	**6.86**	**6.65**	**6.12**	**5.72**	
	PSS but no Excitation	0.73	0.39	0.00	0.72	0.76	
	Inconsistent Speed Damping	**8.44**	**8.23**	**7.22**	**7.24**	**7.04**	
	Inconsistent Lead-Lag Time Constant	1.81	1.86	2.49	2.48	3.11	
	Erroneous Power Dev Fractions	3.18	3.74	2.91	2.69	2.73	
	DC Exciter Self-Excitation Errors	**7.04**	**5.78**	4.98	**5.34**	**5.75**	
	Inconsistent Type III Wind Speeds	0.00	0.00	1.27	1.32	0.00	
	Suspect PSS2A/2B parameters	N/A	4.19	3.52	3.16	3.74	
	Incorrect DER_A Tripping Parameters	N/A	N/A	0.00	0.00	0.00	
	Second Generation Renewable Model Parameterization	N/A	N/A	N/A	N/A	**31.13**	

[44] Performance not tracked.

Table A.8: Heavy Winter Cases

Type of Metric	Metric	2017 Score (%)	2018 Score (%)	2019 Score (%)	2020 Score (%)	2021 Score (%)	Performance
Powerflow	P_{max} Exceedances	0.24	0.08	0.08	0.55	0.44	
	P_{min} Exceedances	0.48	0.35	0.41	0.59	0.33	
	Scheduled Interchange Sum	0.0	0.0	0	-0.0	0.0	
	Voltage Schedule Conflicts	82	77	63	54	64	
	Tap Step Conflicts	0.98	0.62	0.61	0.57	0.34	
	Tap Step Conflicts (Severe)	0.07	0.06	0.06	0.06	0.08	
	Low Emergency Rating	0.14	0.27	0.14	0.35	0.35	
	High Emergency Rating	0.02	0.04	0.02	0.03	0.02	
	Thermal Overloads	0.09	0.00	0.01	0.02	0.04	
	Thermal Overloads (Severe)	0.06	0.00	0.00	0.02	0.01	
	Generator Reactive at Limits	**24.99**	**5.82**	3.81	4.69	**5.06**	
	Generator Reactive Limit Power Factor	**13.87**	**12.31**	**27.41**	**10.28**	**9.45**	
	Positive Sequence TX Circulating Current	0.00	0.00	0.00	0.00	0.00	
	Poor Load Power Factor	0.25	0.06	0.06	0.13	0.04	
	Generator R_{source}:X_{source} Ratio	0.15	0.28	0.16	0.11	0.20	
	Generator Terminal Voltage	N/A	N/A	3.90	**6.18**	**10.15**	
	Generator Reactive Capability Curve	N/A	N/A	0.00	3.37	0.00	
	X/R Ratio Check	N/A	N/A	0.18	0.19	0.20	
	Natural Gas Generator Pmax	N/A	N/A	N/A	N/A	N/A	
	Natural Gas Generator Pmax (Severe)	N/A	N/A	N/A	N/A	N/A	
Dynamics	Gens without Models	4.36	**5.15**	4.38	**8.26**	**7.87**	
	Netted Gens with Models	0.14	0.20	0.40	0.20	0.23	
	Netted Generators	1.86	1.43	2.00	2.93	3.30	
	Generators with Classical Models	0.07	0.00	0.00	0.00	0.00	
	Unacceptable Models	N/A	N/A	4.66	3.38	2.48	
	Not Recommended Models	N/A	N/A	**12.36**	**10.18**	**6.59**	
	User-Written Models[45]	N/A	N/A	N/A	-	-	
	Inconsistent Reactances	3.24	3.35	3.32	3.52	3.45	
	Inconsistent Time Constants	**6.16**	**5.84**	**6.02**	**6.15**	**6.49**	

[45] Performance not tracked.

Table A.8: Heavy Winter Cases

Type of Metric	Metric	2017 Score (%)	2018 Score (%)	2019 Score (%)	2020 Score (%)	2021 Score (%)	Performance
	Unreasonable Inertia Constants	**19.05**	**13.10**	**13.32**	**12.48**	**11.86**	
	Unreasonable Saturation Factors	**26.72**	**27.09**	**19.75**	**19.85**	**17.72**	
	Severe Saturation Factors	**6.93**	**6.97**	**6.70**	**6.39**	**5.65**	
	PSS but no Excitation	0.29	0.34	0.11	0.66	0.98	
	Inconsistent Speed Damping	**8.69**	**8.51**	**7.03**	**7.19**	**6.87**	
	Inconsistent Lead-Lag Time Constant	1.69	1.82	2.59	2.39	3.27	
	Erroneous Power Dev Fractions	3.18	3.67	2.86	3.26	2.69	
	DC Exciter Self-Excitation Errors	**7.57**	**6.98**	**5.86**	**5.88**	**5.08**	
	Inconsistent Type III Wind Speeds	0.00	0.00	0.00	1.52	0.00	
	Suspect PSS2A/2B parameters	N/A	4.01	3.95	4.05	3.71	
	Incorrect DER_A Tripping Parameters	N/A	N/A	0.00	0.00	0.00	
	Second Generation Renewable Model Parameterization	N/A	N/A	N/A	N/A	**34.66**	

Table A.9: Light Summer Cases

Type of Metric	Metric	2017 Score (%)	2018 Score (%)	2019 Score (%)	2020 Score (%)	2021 Score (%)	Performance
Powerflow	P_{max} Exceedances	0.61	0.00	0.19	0.14	0.08	
	P_{min} Exceedances	0.33	0.00	0.05	0.87	0.25	
	Scheduled Interchange Sum	0.0	0	0.0	-0.0	0.0	
	Voltage Schedule Conflicts	74	75	62	56	58	
	Tap Step Conflicts	0.65	0.61	0.45	0.60	0.53	
	Tap Step Conflicts (Severe)	0.07	0.07	0.06	0.07	0.07	
	Low Emergency Rating	0.14	0.14	0.39	0.37	0.03	
	High Emergency Rating	0.02	0.03	0.02	0.01	0.01	
	Thermal Overloads	0.01	0.01	0.01	0.01	0.04	
	Thermal Overloads (Severe)	0.00	0.00	0.00	0.01	0.01	
	Generator Reactive at Limits	**24.94**	**6.76**	**5.99**	**5.67**	**5.43**	
	Generator Reactive Limit Power Factor	**17.48**	**25.24**	**28.43**	**10.60**	**9.80**	

Table A.9: Light Summer Cases							
Type of Metric	Metric	2017 Score (%)	2018 Score (%)	2019 Score (%)	2020 Score (%)	2021 Score (%)	Performance
	Positive Sequence TX Circulating Current	0.00	0.00	0.00	0.00	0.00	
	Poor Load Power Factor	0.13	0.03	0.06	0.08	0.08	
	Generator R_{source}:X_{source} Ratio	0.19	0.21	0.05	0.05	0.09	
	Generator Terminal Voltage	N/A	N/A	**7.30**	4.74	**5.20**	
	Generator Reactive Capability Curve	N/A	N/A	0.00	2.18	0.00	
	X/R Ratio Check	N/A	N/A	0.17	0.19	0.19	
	Natural Gas Generator Pmax	N/A	N/A	N/A	N/A	N/A	
	Natural Gas Generator Pmax (Severe)	N/A	N/A	N/A	N/A	N/A	
Dynamics	Generators without Models	4.85	4.79	4.96	**6.84**	**7.30**	
Dynamics	Netted Gens with Models	0.11	0.12	0.40	0.29	0.32	
Dynamics	Netted Generators	2.07	1.76	2.94	2.83	3.46	
Dynamics	Generators with Classical Models	0.00	0.00	0.00	0.00	0.00	
Dynamics	Unacceptable Models	N/A	N/A	4.17	3.79	3.41	
Dynamics	Not Recommended Models	N/A	N/A	**11.85**	**10.82**	**9.11**	
Dynamics	User-Written Models[46]	N/A	N/A	N/A	-	-	
Dynamics	Inconsistent Reactances	3.10	3.33	3.55	3.24	3.44	
Dynamics	Inconsistent Time Constants	**5.94**	**5.95**	**5.88**	**5.74**	2.86	
Dynamics	Unreasonable Inertia Constants	**19.10**	**13.16**	**13.01**	**12.00**	**10.48**	
Dynamics	Unreasonable Saturation Factors	**26.96**	**27.15**	**19.72**	**19.39**	**13.21**	
Dynamics	Severe Saturation Factors	**6.89**	**6.85**	**6.68**	**6.35**	1.55	
Dynamics	PSS but no Excitation	0.45	0.45	0.28	0.55	0.00	
Dynamics	Inconsistent Speed Damping	**8.42**	**8.22**	**7.19**	**7.24**	**10.12**	
Dynamics	Inconsistent Lead-Lag Time Constant	1.82	1.85	2.48	2.47	3.55	
Dynamics	Erroneous Power Dev Fractions	4.02	3.74	2.90	3.21	1.49	
Dynamics	DC Exciter Self-Excitation Errors	**7.08**	**5.83**	**5.22**	**5.53**	**7.08**	
Dynamics	Inconsistent Type III Wind Speeds	0.00	0.00	1.28	1.27	0.00	

[46] Performance not tracked.

Table A.9: Light Summer Cases							
Type of Metric	Metric	2017 Score (%)	2018 Score (%)	2019 Score (%)	2020 Score (%)	2021 Score (%)	Performance
	Suspect PSS2A/2B parameters	N/A	4.19	3.76	3.17	3.75	
	Incorrect DER_A Tripping Parameters	N/A	N/A	0.00	0.00	0.00	
	Second Generation Renewable Model Parameterization	N/A	N/A	N/A	N/A	**30.72**	