NERC

NORTH AMERICAN ELECTRIC RELIABILITY CORPORATION

Case Quality Metrics

Annual Interconnection-Wide Model Assessment

November 2022

RELIABILITY | RESILIENCE | SECURITY




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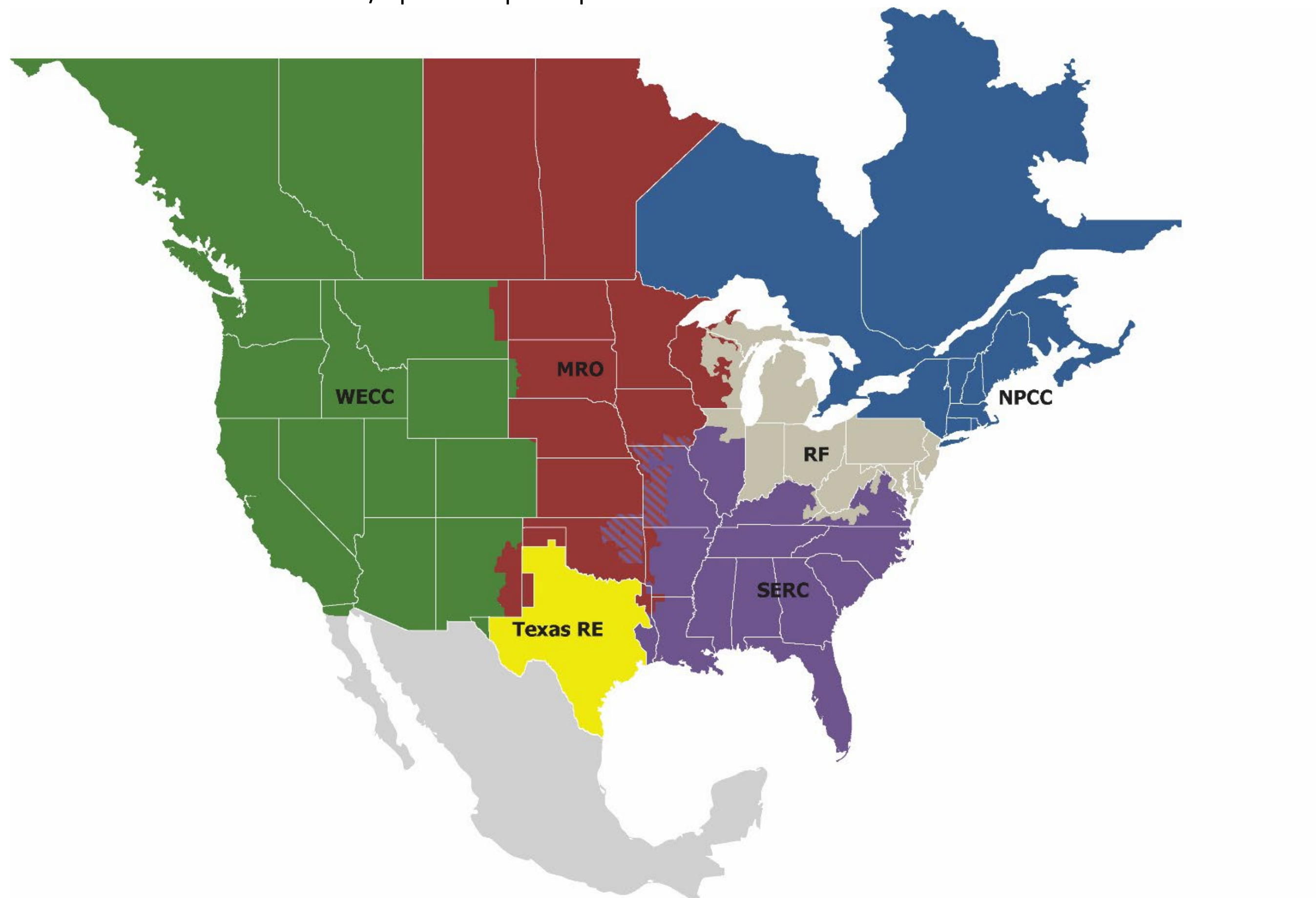
Preface

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 NERC and the six Regional Entities, is a highly reliable, resilient, 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 Regional Entity boundaries as shown in the map and corresponding table below. The multicolored area denotes overlap as some load-serving entities participate in one Regional Entity 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 accurate representations of the physical equipment the models are meant to represent. This *2022 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 *2022 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 EI, there are many records consistently flagged for the Generator Reactive at Limits, Generator Terminal Voltage, Natural Gas Generator Pmax, and Reactive Capability Curve metrics. All of these metrics are related to case dispatch or suspect data that involve 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[2] 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 is more sensitive[3] 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] That is, in the generator tables.

[3] 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% 2 metrics worsening, or consistent high score Voltage schedule conflicts major increase
	Dynamics	Most metrics below 5% 6 metrics consistent high score 1 metric worsening
Texas	Powerflow	Most metrics below 5% 1 metric worsening 1 metric consistent worsening or improving 1 metric consistent high score
	Dynamics	Most metrics below 5% 3 metrics consistent high score 2 metrics worsening 1 metric improving
Western	Powerflow	Most metrics below 5% 5 metrics improving, 4 metrics worsening
	Dynamics	Most metrics below 5% 3 metrics improving, 8 metrics worsening

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 *2022 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,[4] 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 details:
  - The type of system conditions the case is intended to model, such as heavy summer loads, light loads
  - The conditions measured during a distinct system event or disturbance

The metrics focus solely on the case data quality of the individual component models that comprise 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.

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

Chapter 1: Case Quality Metrics

NERC has developed the following metrics that have vetted by industry through engagement with relevant subject matter experts and previous industry stakeholder committees.[5] The metrics are divided between steady-state and dynamics to characterize what type of study the metric is most relevant for checking case data quality. 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.[6]
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 $Q_{max} \neq Q_{min}$).[7]
9. Generator reactive power limits (Q_{max} and Q_{min}) should have reasonable power factor[8] 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.[9]

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

[6] 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.

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

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

[9] Opposite direction of positive sequence current flow

11. Individual aggregate loads greater than 2 MVA[10] and with positive active and reactive power consumption[11] 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.[12]
13. Generator terminal bus voltages should be between 0.95 and 1.05 when regulating a non-terminal bus.[13]
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.

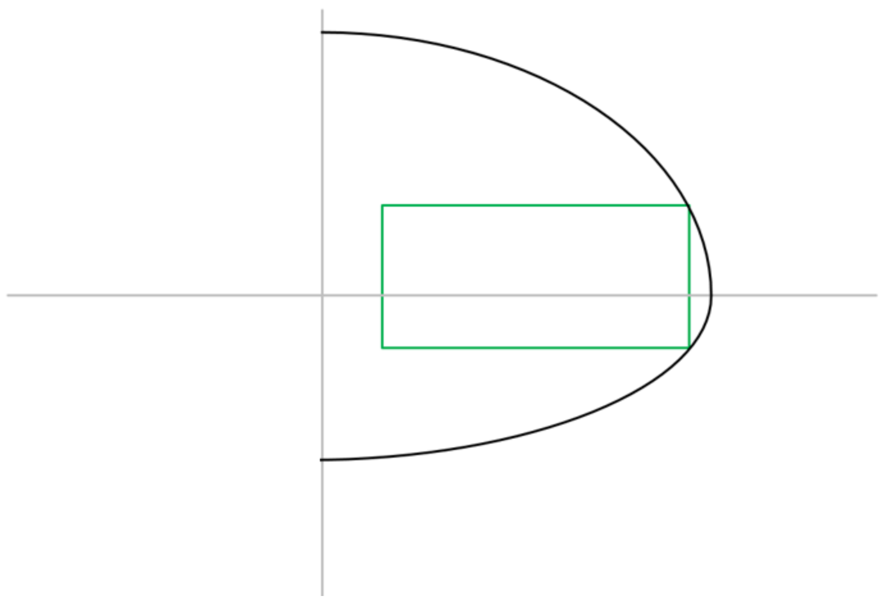


Figure 1.1: Generator Reactive Capability Box Overview

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 metrics are 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 1. Some of these metrics require both powerflow

[10] 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.
[11] This avoids shunt capacitor issues (negative reactive power) and net generators (negative active power value) represented in the load values.
[12] Except for X_{source} = 9999
[13] Non-synchronous devices are excluded from this check.

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, indicated as follows:

1. Generating units larger than the criteria threshold established for each Interconnection[14] should have a generator model included in their dynamics record; units without a generator model are flagged as not meeting this modeling criteria.
2. 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.
3. 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.
4. Generating units larger than the criteria threshold established for each Interconnection[15] should not be modeled with a classical generator model.
5. User written model penetration is also tallied for use in the MOD-032 case creation process.
6. 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'').
7. Generator time constants should be consistent: $T''_{d0} \leq T'_{d0}$ and $T''_{q0} \leq T'_{q0}$ [16] and $T'_{q0} \leq T'_{d0}$.[17]
8. 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.[18]
9. Saturation factors S (1.0) and S (1.2) should be reasonable:[19]
    a. $0.03 \leq S(1.0) \leq 0.18$
    b. $0.2 \leq S(1.2) \leq 0.85$
    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.

[14] 20 MVA for the EI; 10 MVA for the WI and TI

[15] 50 MVA for the EI and TI; 0 MVA for the WI

[16] 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 $T''_{d0} \leq T'_{d0}$.

[17] This check is not applied to GENSAL and GENSAE generator models.

[18] These ranges were adopted based on industry feedback on the *2017 Case Quality Metrics Assessment*.

[19] 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).

10. Units with a power system stabilizer (PSS) should have an excitation system model.
11. Generator speed damping coefficient should be equal to zero for non-classical machine models.
12. Turbine-governor models should have lead-time constants less than lag time constants.[20]
13. Turbine power development fractions should add up to 1.0.[21] An example of these fractions in the block diagrams for a turbine governor model is in **Figure 1.2**.

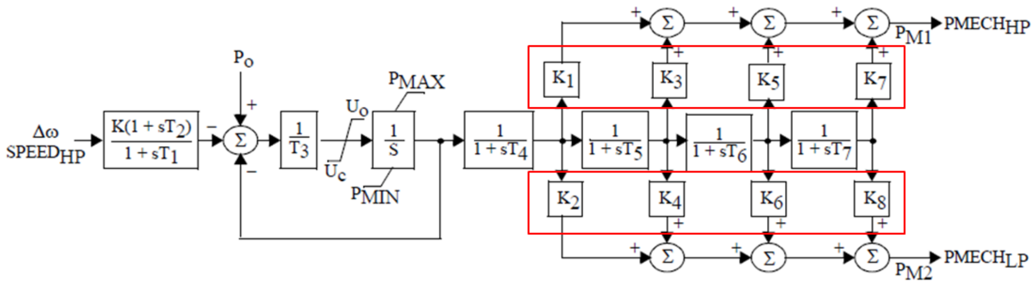


Figure 1.2: IEEEG1 Model Block Diagram (Source: Siemens PTI)

14. DC exciter model self-excitation parameter K_E[22] 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**.

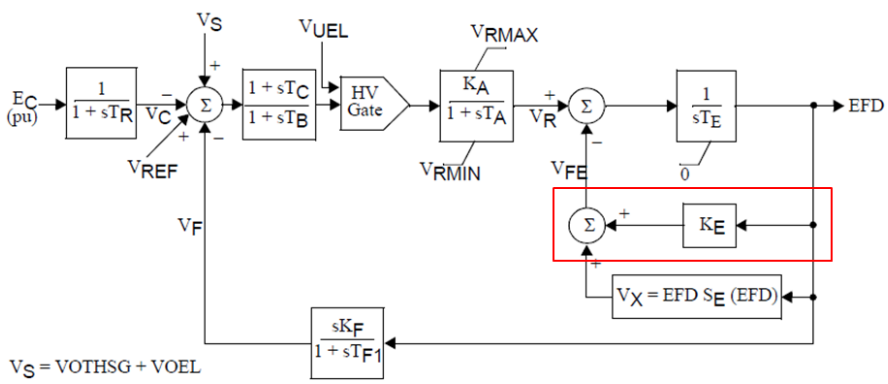


Figure 1.3: ESDC1A Model Block Diagram (Source: Siemens PTI)

15. Wind turbine electrical model WT3E should have $\omega_{Pmin} < \omega_{P20} < \omega_{P40} < \omega_{P60} < \omega_{P100}$.
16. 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**.

[20] This stabilizes the model as it reduces the forward path gain for high frequency changes in the input.
[21] This metric was corrected in the *2017 Case Quality Metrics Assessment* to check if K1+K2+K3+ . . . +K8 = 1.0.
[22] K_E reflects setting the shunt field rheostat for zeroing out the voltage regulator, often a small negative number.

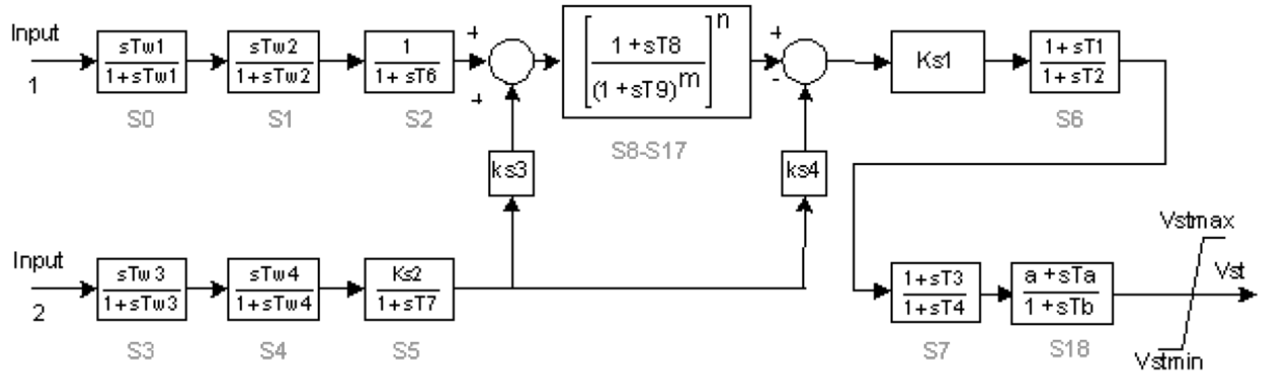


Figure 1.4: PSS2A Block Diagram [Source: GE PSLF]

17. Models should not be listed as unacceptable or not recommended on the NERC Acceptable Model List:[23]
    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.
18. 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.

[23] 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 categorizations 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. 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” involve how 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[24]		(X)	
Inconsistent Reactances	X		
Inconsistent Time Constants	X		
Unreasonable Inertia Constants		X	

[24] 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[25] 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

[25] 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. This is outlined in greater detail as follows:

- 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.[26] 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 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

[26] 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 *2022 Case Quality Metrics Assessment* could be violated (e.g., equivalence 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[27] 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:

- No script alterations made from 2021 report

[27] 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 **Table 3.9**. **Tables 3.1** to **Table 3.3** are for the 2022SUM Base Case; **Tables 3.4** to **Table 3.6** are for the 2022WIN Base Case; **Tables 3.7** to **Table 3.9** are for the 2022SLL Base Case.

2022 Summer Peak Case: 2022SUM

Table 3.1: EI Steady-State Metrics

Metric	Performance	Score (%)
P_{max} Exceedances	4/6,991	0.06
P_{min} Exceedances	1/6,759	0.01
Scheduled Interchange Sum	0.001	-
Thermal Overloads	195/100,262	0.19
Thermal Overloads (Severe)	146/100,262	0.15
Low Emergency Rating	27/100,262	0.03
High Emergency Rating	89/100,262	0.09
Voltage Schedule Conflicts	118	-
Tap Step Conflicts	39/21,810	0.18
Tap Step Conflicts (Severe)	14/21,810	0.06
Generator Reactive at Limits	734/4,469	**16.42**
Generator Reactive Limit Power Factor	99/5,627	1.76
Positive Sequence TX Circulating Current	0/2,634	0.00
Poor Load Power Factor	175/50,271	0.35
Generator Reactive Capability Curve	0/0	0
Generator R_{source}:X_{source} Ratio	8/6,991	0.11
X/R Ratio Check	215/93,569	0.23
Generator Terminal Voltage	114/2,789	4.07
Natural Gas Generator Pmax	N/A	N/A
Natural Gas Generator Pmax (Severe)	N/A	N/A

Table 3.2: EI Dynamics Metrics

Metric	Performance	Score (%)	P_{max} (MW)	Q_{max} (MVAR)
Generators without Models	205/6,881	2.98	7,389	2201
Generators with Classical Models	14/5,214	0.27	6,920	3,805
Netted Generators	126/5,023	2.51	4,670	1,163
Netted Gens with Models	9/5,023	0.18	390	228
Inconsistent Reactances	40/3,770	1.06	3869	1909
Unacceptable Models (total)	2,476/20,200	**12.26**	-	-
Not Recommended Models (total)	3,694/20,200	**18.29**	-	-
User-Written Models[28]	1,410/23,980	-	-	-
Inconsistent Time Constants	3/4,018	0.07	312	186
Unreasonable Inertia Constants	411/5,027	**8.18**	28,744	19,012
Unreasonable Saturation Factors	482/4,018	**12.00**	53,152	27,539
Severe Saturation Factors	41/4,018	1.02	3,807	2,011
PSS but no Excitation	4/6,881	0.06	97	278

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

Table 3.2: EI Dynamics Metrics				
Metric	Performance	Score (%)	P_{max} (MW)	Q_{max} (MVAR)
Inconsistent Speed Damping	122/4,847	2.52	8,035	3,785
Inconsistent Lead-Lag Time Constant	33/1,689	1.94	8,843	3,911
Erroneous Power Dev Fractions	20/525	3.81	4,644	2,157
DC Exciter Self-Excitation Errors	120/885	**13.56**	3,805	2,577
Inconsistent Type III Wind Speeds	0/206	0.00	0	0
Suspect PSS2A/2B parameters	335/1,908	**17.56**	72,064	40,996
Incorrect DER_A Tripping Parameters	0/0	0.00	0	0
Second Generation Renewable Model Parameterization[29]	354/1,619	**21.87**	-	-

Table 3.3: EI Unacceptable and Not Recommended Model Breakdown			
Category	Subcategory	Performance	Score (%)
Unacceptable Models	Generator	1,174/6,676	**17.59**
	Exciter	429/6,351	**6.75**
	Stabilizer	203/2,715	**7.48**
	Turbine Governor	670/4,458	**15.48**
Not Recommended Models	Generator	3,193/6,676	**47.83**
	Exciter	0/6,351	0.00
	Stabilizer	0/2,715	0.00
	Turbine Governor	501/4,458	**11.24**
User Written Models*	Generator	344/8,351	4.12
	Exciter	140/7,512	1.86
	Stabilizer	172/3,055	**5.63**
	Turbine Governor	754/5,062	**14.90**

*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.

2022–2023 Winter Peak Case: 2022WIN

Table 3.4: EI Steady-State Metrics		
Metric	Performance	Score (%)
P_{max} Exceedances	1/5,718	0.02
P_{min} Exceedances	0/5,718	0.00
Scheduled Interchange Sum	0	-
Thermal Overloads	136/100,651	0.14
Thermal Overloads Severe	107/100,651	0.11
Low Emergency Rating	24/100,651	0.02
High Emergency Rating	1/100,651	0.00
Voltage Schedule Conflicts	118	-
Tap Step Conflicts	39/21,845	0.18
Tap Step Conflicts (Severe)	14/21,845	0.06
Generator Reactive at Limits	647/3,858	**16.77**
Generator Reactive Limit Power Factor	68/4,755	1.43
Positive Sequence TX Circulating Current	0/2,666	0.00
Poor Load Power Factor	204/47,816	0.34

[29] 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: EI Steady-State Metrics		
Metric	**Performance**	**Score (%)**
Generator Reactive Capability Curve	0/0	0.05
Generator R_{source}:X_{source} Ratio	9/5,718	0.16
X/R Ratio Check	222/93,900	0.00
Generator Terminal Voltage	104/2,515	4.13
Natural Gas Generator Pmax	N/A	N/A
Natural Gas Generator Pmax (Severe)	N/A	N/A

Table 3.5: EI Dynamics Metrics				
Metric	**Performance**	**Score (%)**	**P_{max} (MW)**	**Q_{max} (MVAR)**
Generators without Models	226/7,050	3.21	7,580	2,358
Generators with Classical Models	15/5,344	0.28	7,420	3,830
Netted Generators	78/4,306	1.81	3,074	782
Netted Gens with Models	9/4,306	0.21	844	220
Inconsistent Reactances	40/3,801	1.05	3,888	1,884
Unacceptable Models (total)	2,522/20,567	**12.26**	-	-
Not Recommended Models (total)	3,732/20,567	**18.15**	-	-
User-Written Models[30]	1,420/24,208	-	-	-
Inconsistent Time Constants	5/4,049	0.12	1,055	624
Unreasonable Inertia Constants	410/5,048	**8.12**	29,562	18,740
Unreasonable Saturation Factors	484/4,049	**11.95**	54,132	27,610
Severe Saturation Factors	41/4,049	1.01	3,828	2,011
PSS but no Excitation	5/7,050	0.06	97.1	278
Inconsistent Speed Damping	122/4,867	2.51	8,072	3,782
Inconsistent Lead-Lag Time Constant	33/1,713	1.93	8,942	3,911
Erroneous Power Dev Fractions	20/530	3.77	4,657	2,157
DC Exciter Self-Excitation Errors	119/888	**13.40**	3,958	2,585
Inconsistent Type III Wind Speeds	0/206	0.00	0	0
Suspect PSS2A/2B parameters	338/1,921	**17.60**	74,420	41,469
Incorrect DER_A Tripping Parameters	0/0	0.00	0	0
Second Generation Renewable Model Parameterization	421/1,738	**24.22**	-	-

Table 3.6: EI Unacceptable and Not Recommended Model Breakdown			
Category	**Subcategory**	**Performance**	**Score (%)**
Unacceptable Models	Generator	1,183/6,824	**17.33**
	Exciter	437/6,496	**6.73**
	Stabilizer	203/2,746	**8.37**
	Turbine Governor	699/4,501	**15.53**
Not Recommended Models	Generator	3,224/6,824	**47.25**
	Exciter	0/6,496	0.00
	Stabilizer	0/2,746	0.00
	Turbine Governor	508/4,501	**11.29**
User Written Models*	Generator	353/8,423	4.19
	Exciter	148/7,592	1.95

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

Table 3.6: EI Unacceptable and Not Recommended Model Breakdown			
Category	Subcategory	Performance	Score (%)
	Stabilizer	169/3,056	5.53
	Turbine Governor	750/5,137	14.60

*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

2022 Spring Light Load: 2022SLL

Table 3.7: EI Steady-State Metrics		
Metric	Performance	Score (%)
P_{max} Exceedances	0/4,054	0.00
P_{min} Exceedances	0/4,054	0.00
Scheduled Interchange Sum	-0.1	-
Thermal Overloads	27/99,651	0.04
Severe Thermal Overloads	20/99,651	0.03
Low Emergency Rating	25/99,651	0.03
High Emergency Rating	0/99,651	0.00
Voltage Schedule Conflicts	117	-
Tap Step Conflicts	38/21,480	0.18
Tap Step Conflicts (Severe)	14/21,480	0.07
Generator Reactive at Limits	473/2,549	18.56
Generator Reactive Limit Power Factor	138/3,390	4.07
Positive Sequence TX Circulating Current	0/2,622	0.00
Poor Load Power Factor	187/46,161	0.41
Generator Reactive Capability Curve	0/0	0.00
Generator R_{source}:X_{source} Ratio	6/4,054	0.15
X/R Ratio Check	214/93,037	0.23
Generator Terminal Voltage	242/1,722	14.05
Natural Gas Generator Pmax	N/A	N/A
Natural Gas Generator Pmax (Severe)	N/A	N/A

Table 3.8: EI Dynamics Metrics				
Metric	Performance	Score (%)	P_{max} (MW)	Qmax (MVAR)
Generators without Models	196/6,857	2.86	8,308	2,389
Generators with Classical Models	14/5,209	0.27	6,920	3,805
Netted Generators	65/3,065	2.12	2,666	840
Netted Gens with Models	7/3,065	0.23	246	120
Inconsistent Reactances	40/3,775	1.06	3,878	1,880
Unacceptable Models (total)	2,681/20,652	12.98	-	-
Not Recommended Models (total)	3,809/20,652	18.44	-	-
User-Written Models[31]	1,439/25,402	-	-	-
Inconsistent Time Constants	3/4,024	0.07	312	186
Unreasonable Inertia Constants	411/5,024	8.18	29,352	18,959
Unreasonable Saturation Factors	481/4,024	11.95	53,180	27,030
Severe Saturation Factors	41/4,024	1.02	3,808	2,000

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

Table 3.8: EI Dynamics Metrics				
Metric	**Performance**	**Score (%)**	**P_{max} (MW)**	**Qmax (MVAR)**
PSS but no Excitation	4/6,857	0.06	97	278
Inconsistent Speed Damping	122/4,844	2.52	8,035	3,961
Inconsistent Lead-Lag Time Constant	43/1,939	2.22	10,142	4,552
Erroneous Power Dev Fractions	24/587	4.09	5,027	2,397
DC Exciter Self-Excitation Errors	120/884	**13.57**	3,661	2,577
Inconsistent Type III Wind Speeds	0/206	0.00	0	0
Suspect PSS2A/2B parameters	359/1,905	**18.85**	74,665	40,867
Incorrect DER_A Tripping Parameters	0/0	0.00	0	0
Second Generation Renewable Model Parameterization	345/1,595	**21.63**	-	-

Table 3.9: EI Unacceptable and Not Recommended Model Breakdown			
Category	**Subcategory**	**Performance**	**Score (%)**
Unacceptable Models	Generator	1,172/6,661	**17.59**
	Exciter	425/6,337	**6.71**
	Stabilizer	203/2,706	**7.50**
	Turbine Governor	881/4,948	**17.81**
Not Recommended Models	Generator	3,197/6,661	**48.00**
	Exciter	0/6,337	0.00
	Stabilizer	0/2,706	0.00
	Turbine Governor	612/4,948	**12.37**
User Written Models*	Generator	343/8,320	4.12
	Exciter	140/7,482	1.87
	Stabilizer	172/3,046	**5.65**
	Turbine Governor	784/6,554	**11.96**

*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 **Table 3.18**. **Tables 3.10** to **Table 3.12** are for the 2023_SP_Final_NonCnv Base Case; **Tables 3.13** to **Table 3.15** are for the 2024_HWLL_Final_NonCnv Base Case; **Tables 3.16** to **Table 3.18** are for the 2027_SP_Final_NonCnv Base Case.

2024 Summer Peak Case: 2024_SP_Final_NonCnv

Table 3.10: TI Steady-State Metrics		
Metric	**Performance**	**Score (%)**
P_{max} Exceedances	0/1133	0.00
P_{min} Exceedances	1/1133	0.08
Scheduled Interchange Sum	0	-
Thermal Overloads	28/11,399	0.25
Thermal Overloads (Severe)	28/11,399	0.25
Low Emergency Rating	0/11,399	0.00
High Emergency Rating	2/11,399	0.02
Voltage Schedule Conflicts	47	-

Table 3.10: TI Steady-State Metrics		
Metric	**Performance**	**Score (%)**
Tap Step Conflicts	66/1,849	3.57
Tap Step Conflicts (Severe)	0/1,849	0.00
Generator Reactive at Limits	102/734	**13.90**
Generator Reactive Limit Power Factor	98/1054	**9.30**
Positive Sequence TX Circulating Current	0/46	0.00
Poor Load Power Factor	3/5,645	0.05
Generator R_{source}:X_{source} Ratio	7/1133	0.62
X/R Ratio Check	39/9,300	0.42
Generator Terminal Voltage	0/740	0.00
Generator Reactive Capability Curve	0/0	0.00
Natural Gas Generator Pmax	N/A	N/A
Natural Gas Generator Pmax (Severe)	N/A	N/A

Table 3.11: TI Dynamics Metrics				
Metric	**Performance**	**Score (%)**	**P_{max} (MW)**	**Q_{max} (MVAR)**
Generators without Models	13/1,059	1.23	*4,199	*2,896
Generators with Classical Models	10/915	1.09	4,824	4,492
Netted Generators with Models	3/1,010	0.30	232	58
Netted Generators	3/1,010	0.30	232	58
Inconsistent Reactances	5/444	1.13	333	187
Unacceptable Models (total)	39/2,746	1.42	-	-
Not Recommended Models (total)	469/2,746	**17.08**	-	-
User-Written Models[32]	1192/3,087	-		
Inconsistent Time Constants	4/579	0.69	94.4	56.8
Unreasonable Inertia Constants	112/594	**18.86**	4,517	2,985
Unreasonable Saturation Factors	76/579	**13.13**	10,135	4,817
Severe Saturation Factors	9/579	1.55	763	371
PSS but no Excitation	0/1,151	0.00	0	0
Inconsistent Speed Damping	17/583	2.92	719	431
Inconsistent Lead-Lag Time Constant	0/244	0.00	0	0
Erroneous Power Dev Fractions	4/51	**7.84**	2746	827
DC Exciter Self-Excitation Errors	4/38	**10.53**	491	240
Inconsistent Type III Wind Speeds	0/0	0.00	0	0
Suspect PSS2A/2B parameters	57/319	**17.87**	3,534	2,171
Incorrect DER_A Tripping Parameters	0/0	0.00	0	0
Second Generation Renewable Model Parameterization	0/382	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.

[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.

Table 3.12: TI Unacceptable and Not Recommended Model Breakdown			
Category	**Subcategory**	**Performance**	**Score (%)**
Unacceptable Models	Generator	29/1,040	2.79
	Exciter	10/890	1.12
	Stabilizer	0/408	0.00
	Turbine Governor	0/408	0.00
Not Recommended Models	Generator	448/1,040	**43.08**
	Exciter	21/890	2.36
	Stabilizer	0/408	0.00
	Turbine Governor	0/408	0.00
User Written Models*	Generator	481/1,025	-
	Exciter	281/865	-
	Stabilizer	2/413	-
	Turbine Governor	233/784	-

*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.

2025 Light Load Case: 2025_HWLL_Final_NonCnv

Table 3.13: TI Steady-State Metrics		
Metric	**Performance**	**Score (%)**
P_{max} Exceedances	1/842	0.12
P_{min} Exceedances	0/842	0.00
Scheduled Interchange Sum	0	-
Thermal Overloads	30/11,419	0.26
Thermal Overloads (Severe)	27/11,419	0.24
Low Emergency Rating	0/11,419	0.00
High Emergency Rating	2/11,419	0.02
Voltage Schedule Conflicts	79	0.02
Tap Step Conflicts	66/1,850	3.57
Tap Step Conflicts (Severe)	0/1,850	0.00
Generator Reactive at Limits	27/553	4.88
Generator Reactive Limit Power Factor	55/764	**7.20**
Positive Sequence TX Circulating Current	0/46	0.00
Poor Load Power Factor	5/5,638	0.09
Generator R_{source}:X_{source} Ratio	7/842	0.83
X/R Ratio Check	39/9,321	0.42
Generator Terminal Voltage	5/537	0.93
Generator Reactive Capability Curve	0/0	-
Natural Gas Generator Pmax	N/A	N/A
Natural Gas Generator Pmax (Severe)	N/A	N/A

Table 3.14: TI Dynamics Metrics

Metric	Performance	Score (%)	P_{max} (MW)	Q_{max} (MVAR)
Generators without Models	13/1,059	1.23	*4,199	*2,895
Generators with Classical Models	10/917	1.09	4,824	4,492
Netted Generators with Models	3/727	0.41	232	58
Netted Generators	3/727	0.41	232	58
Inconsistent Reactances	5/444	1.13	335	187
Unacceptable Models (total)	39/2,746	1.42	-	-
Not Recommended Models (total)	469/2,746	**17.08**	-	-
User-Written Models[33]	1,612/3,503	-	-	-
Inconsistent Time Constants	4/579	0.69	94	57
Unreasonable Inertia Constants	112/594	**18.85**	4,724	2,984
Unreasonable Saturation Factors	76/579	**13.12**	10,810	4,817
Severe Saturation Factors	9/579	1.55	781	371
PSS but no Excitation	0/1,152	0.00	0	0
Inconsistent Speed Damping	17/583	2.92	728	431
Inconsistent Lead-Lag Time Constant	0/244	0.00	0	0
Erroneous Power Dev Fractions	4/51	**7.84**	2795	827
DC Exciter Self-Excitation Errors	4/38	**10.52**	491	240
Inconsistent Type III Wind Speeds	0/0	0.00	0	0
Suspect PSS2A/2B parameters	57/319	**17.87**	3,686	2,171
Incorrect DER_A Tripping Parameters	0/0	0.00	0	0
Second Generation Renewable Model Parameterization	0/382	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: TI Unacceptable and Not Recommended Model Breakdown

Category	Subcategory	Performance	Score (%)
Unacceptable Models	Generator	29/1,040	2.79
	Exciter	10/890	1.12
	Stabilizer	0/408	0.00
	Turbine Governor	0/408	0.00
Not Recommended Models	Generator	448/1,040	**43.08**
	Exciter	21/890	2.36
	Stabilizer	0/408	0.00
	Turbine Governor	0/408	0.00
User Written Models*	Generator	642/1,184	-
	Exciter	397/979	-
	Stabilizer	77/434	-
	Turbine Governor	496/906	-

*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.

[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.

2028 Summer Peak Case: 2028_SP_Final_NonCnv

Table 3.16: TI Steady-State Metrics		
Metric	**Performance**	**Score (%)**
P_{max} Exceedances	0/1,143	0.00
P_{min} Exceedances	0/1,143	0.00
Scheduled Interchange Sum	0	-
Thermal Overloads	29/11,462	0.25
Thermal Overloads (Severe)	26/11,462	0.23
Low Emergency Rating	0/11,462	0.00
High Emergency Rating	2/11,462	0.02
Voltage Schedule Conflicts	37	-
Tap Step Conflicts	64/1,854	3.45
Tap Step Conflicts (Severe)	0/1,854	0.00
Generator Reactive at Limits	156/746	**20.91**
Generator Reactive Limit Power Factor	99/1064	**9.30**
Positive Sequence TX Circulating Current	0/46	0.00
Poor Load Power Factor	3/5,714	0.05
Generator R_{source}:X_{source} Ratio	7/1,143	0.61
X/R Ratio Check	39/9,366	0.42
Generator Terminal Voltage	5/748	0.67
Generator Reactive Capability Curve	0/0	0.00
Natural Gas Generator Pmax	N/A	N/A
Natural Gas Generator Pmax (Severe)	N/A	N/A

Table 3.17: TI Dynamics Metrics				
Metric	**Performance**	**Score (%)**	**P_{max} (MW)**	**Q_{max} (MVAR)**
Generators without Models	13/1,059	1.23	4,199	2,896
Generators with Classical Models	10/916	1.09	4,824	4,492
Netted Generators with Models	3/1,021	0.29	232	58
Netted Generators	3/1,021	0.29	232	58
Inconsistent Reactances	5/436	1.15	333	187
Unacceptable Models (total)	39/2,746	1.42	-	-
Not Recommended Models (total)	461/2,746	**16.79**	-	-
User-Written Models[34]	1,612/3,503	-	-	-
Inconsistent Time Constants	4/579	0.69	94	57
Unreasonable Inertia Constants	112/594	**18.86**	4,517	2,985
Unreasonable Saturation Factors	76/579	**13.13**	10,135	4,817
Severe Saturation Factors	9/579	1.55	763	371
PSS but no Excitation	0/1,151	0.00	0	0
Inconsistent Speed Damping	17/583	2.92	719	431
Inconsistent Lead-Lag Time Constant	0/244	0.00	0	0
Erroneous Power Dev Fractions	4/59	**6.78**	2,746	827
DC Exciter Self-Excitation Errors	4/38	**10.52**	491	440
Inconsistent Type III Wind Speeds	0/0	0.00	0	0

[34] 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: TI Dynamics Metrics				
Metric	**Performance**	**Score (%)**	**P_{max} (MW)**	**Q_{max} (MVAR)**
Suspect PSS2A/2B parameters	65/319	**20.38**	3,890	2,557
Incorrect DER_A Tripping Parameters	0/0	0.00	0	0
Second Generation Renewable Model Parameterization	0/382	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: TI Unacceptable and Not Recommended Model Breakdown			
Category	**Subcategory**	**Performance**	**Score (%)**
Unacceptable Models	Generator	29/1,040	2.79
	Exciter	10/890	1.12
	Stabilizer	0/408	0.00
	Turbine Governor	0/408	0.00
Not Recommended Models	Generator	440/1,040	**42.31**
	Exciter	21/890	2.36
	Stabilizer	0/408	0.00
	Turbine Governor	0/408	0.00
User Written Models*	Generator	943/1,978	-
	Exciter	517/1,674	-
	Stabilizer	79/772	-
	Turbine Governor	713/1,549	-

*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 **Table 3.27**. **Tables 3.19** to **Table 3.21** are for the 22HS3a Base Case; **Tables 3.22** to **Table 3.24** are for the 22HW2a Base Case; **Tables 3.25** to **Table 3.27** are for the 22LS1a Base Case.

2022 Summer Peak Case: 22HS3Sa

Table 3.19: WI Steady-State Metrics		
Metric	**Performance**	**Score (%)**
P_{max} Exceedances	13/3484	0.37
P_{min} Exceedances	9/3484	0.26
Scheduled Interchange Sum	0.0	-
Voltage Schedule Conflicts	64	0.64
Tap Step Conflicts	6/9,987	0.26
Tap Step Conflicts (Severe)	6/9,987	0.06
Low Emergency Rating	5/29,138	0.02
High Emergency Rating	1/29,138	0.00
Thermal Overloads	20/31,010	0.06
Thermal Overloads (Severe)	12/31,010	0.04
Generator Reactive at Limits	246/3699	**6.65**
Generator Reactive Limit Power Factor	350/3,699	**9.46**
Positive Sequence TX Circulating Current	0/1874	0

Table 3.19: WI Steady-State Metrics		
Metric	**Performance**	**Score (%)**
Poor Load Power Factor	3/7,553	0.04
Generator R_{source}:X_{source} Ratio	8/4,678	0.17
Generator Terminal Voltage	96/2,393	4.01
Generator Reactive Capability Curve	30/597	**5.03**
X/R Ratio Check	33/55,750	0.20
Natural Gas Generator Pmax	740/977	**75.74**
Natural Gas Generator Pmax (Severe)	38/977	3.89

Table 3.20: WI Dynamics Metrics				
Metric	**Performance**	**Score (%)**	**P_{max} (MW)**	**Q_{max} (MVAR)**
Generators without Models	300/3,720	**8.06**	27,479	13,517
Netted Generators with Models	5/2,805	0.18	281	18
Netted Generators	141/2,805	**5.03**	9,995	3,769
Inconsistent Reactances	110/3191	3.45	2,739	1,363
Generators with Classical Models	0/4,678	0.00	0.0	0.0
Unacceptable Models (total)	364/13,288	2.74	-	-
Not Recommended Models (total)	1,015/13,288	**7.64**	-	-
User-Written Models[35]	0/29,352	-	-	-
Units with Inconsistent Time Constant	202/3,191	**6.33**	4,108	2,110
Inconsistent Inertia Constants	327/3,191	**10.25**	*15,157	*9,940
Unreasonable Saturation factors	540/3,191	**16.92**	*25,392	*12,279
Severe Saturation Factors	174/3,191	**5.45**	*4,305	*1,963
PSS with NO Excitation System model:	36/1,818	1.98	3,518	1,601
Units with Bad Speed Damping:	215/3,191	**6.74**	3,408	1,516
Units with Bad Lead Lag Time Constants	69/1,279	**5.39**	4,589	2,036
Erroneous Power Dev Fractions	3/159	1.89	337	89
DC Exciter Self-Excitation Errors	27/469	**5.76**	1,221	523
Inconsistent Type III Wind Speeds	0/72	0.00	0.0	0.0
Suspect PSS2A/2B Parameters	52/1,653	3.15	29,128	12,679
Incorrect DER_A Tripping Parameters	0/0	0.00	0	0
Second Generation Renewable Model Parameterization	666/1,832	**36.35**	-	-

* 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	108/4,678	2.31
	Exciter	106/4,299	2.47
	Stabilizer	65/1,893	3.43
	Turbine Governor	85/2,418	3.52
Not Recommended Models	Generator	807/4,678	**17.25**
	Exciter	152/4,299	3.54
	Stabilizer	0/1,893	0.00

[35] 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	56/2,418	2.32
User Written Models	All	0/29,352	0.0

2021–2022 Winter Peak Case: 22HW2a

This case is repeated from the 2021 version of this report.

Table 3.22: WI 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)	8/9860	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	319/3,631	**8.78**
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	180/1,779	**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: WI Dynamics Metrics				
Metric	**Performance**	**Score (%)**	**P_{max} (MW)**	**Q_{max} (MVAR)**
Generators without Models	286/3,632	**7.87**	3,7731	8,748
Netted Generators with Models	5/2,184	0.23	107	47
Netted Generators	72/2,184	3.30	2,419	823
Inconsistent Reactances	110/3,188	3.45	3,128	1,508
Generators with Classical Models	0/4,584	0.00	0	0
Unacceptable Models (total)	402/13,182	3.05	-	-
Not Recommended Models (total)	1,066/13,182	**8.08**	-	-
User-Written Models[36]	4/20,654	-	-	-
Units with Inconsistent Time Constant	207/3,188	**6.49**	5,638	2,659
Inconsistent Inertia Constants	315/3,188	**9.88**	17,055	10,506
Unreasonable Saturation factors	531/3,188	**16.66**	2,419	823
Severe Saturation Factors	179/3,188	**5.61**	5,205	2,495
PSS with NO Excitation System model:	120/4,584	**16.66**	18,326	5,396
Units with Bad Speed Damping:	219/3,188	**6.87**	4,268	1,892

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

Table 3.23: WI Dynamics Metrics				
Metric	Performance	Score (%)	P_{max} (MW)	Q_{max} (MVAR)
Units with Bad Lead Lag Time Constants	42/1,284	3.27	2,970	1,680
Erroneous Power Dev Fractions	5/186	2.69	552	219
DC Exciter Self-Excitation Errors	26/512	**5.80**	1194	508
Inconsistent Type III Wind Speeds	0/76	0.00	0	0
Suspect PSS2A/2B Parameters	61/1,642	3.71	32,701	14,218
Incorrect DER_A Tripping Parameters	0/0	0.00	0	0
Second Generation Renewable Model Parameterization	540/1,560	34.62	N/A	N/A

* 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	3.54
	Stabilizer	0/1,917	0.00
	Turbine Governor	56/2,428	2.31
User Written Models	DC Lines	4/20,654	0.30

2022 Summer Light Load Case: 22LS2a

Table 3.25: WI Steady-State Metrics		
Metric	Performance	Score (%)
P_{max} Exceedances	10/2,397	0.42
P_{min} Exceedances	32/2,397	1.34
Scheduled Interchange Sum	0	-
Voltage Schedule Conflicts	61	-
Tap Step Conflicts	33/9,957	0.33
Tap Step Conflicts (Severe)	7/9,957	0.07
Low Emergency Rating	34/29,107	0.12
High Emergency Rating	2/29,107	0.01
Thermal Overloads	14/30,974	0.05
Thermal Overloads (Severe)	2/30,974	0.01
Generator Reactive at Limits	107/1,550	**6.90**
Generator Reactive Limit Power Factor	338/3,694	**9.15**
Positive Sequence TX Circulating Current	0/1,876	0.00
Poor Load Power Factor	4/6440	0.06
Generator R_{source}:X_{source} Ratio	10/4,550	0.22
Generator Terminal Voltage	130/1,919	**6.77**
Generator Reactive Capability Curve	15/399	3.76
X/R Ratio Check	117/56,264	0.21

Table 3.25: WI Steady-State Metrics		
Metric	**Performance**	**Score (%)**
Natural Gas Generator Pmax	N/A	N/A
Natural Gas Generator Pmax (Severe)	N/A	N/A

Table 3.26: WI Dynamics Metrics				
Metric	**Performance**	**Score (%)**	**P_{max} (MW)**	**Q_{max} (MVAR)**
Generators without Models	313/3,698	**8.46**	19,564	9,202
Netted Generators with Models	14/1,890	0.74	130	133
Netted Generators	115/1,890	**6.08**	5,434	1,673
Inconsistent Reactances	107/3,179	3.37	2,644	1,331
Generators with Classical Models	0/,650	0.00	0	0
Unacceptable Models (total)	369/13,307	2.77	-	-
Not Recommended Models (total)	1,016/13,307	**7.64**	-	-
User-Written Models[37]	2/26,003	-	-	-
Units with Inconsistent Time Constant	202/3,191	**6.33**	4,107	2,110
Inconsistent Inertia Constants	326/3,191	**9.84**	15,157	9,940
Unreasonable Saturation factors	536/3,191	**16.80**	25,392	12,279
Severe Saturation Factors	179/3,191	**5.61**	25,392	12,279
PSS with NO Excitation System model:	10/1,836	0.54	354	1,836
Units with Bad Speed Damping:	214/3,176	**6.74**	3,550	1,576
Units with Bad Lead Lag Time Constants	44/1,279	3.47	4,589	2,036
Erroneous Power Dev Fractions	3/1,59	1.89	337	89
DC Exciter Self-Excitation Errors	27/469	**5.76**	1,221	523
Inconsistent Type III Wind Speeds	0/72	0.00	0	0
Suspect PSS2A/2B Parameters	54/1,654	3.26	32,510	14,159
Incorrect DER_A Tripping Parameters	0/0	0.00	0	0
Second Generation Renewable Model Parameterization	620/1,747	**35.49**	-	-

* 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	110/4,650	2.37
	Exciter	107/4,323	2.48
	Stabilizer	66/1,912	3.45
	Turbine Governor	86/2,422	3.55
Not Recommended Models	Generator	792/4,650	**17.03**
	Exciter	168/4,323	3.89
	Stabilizer	0/1,912	0.00
	Turbine Governor	56/2,422	2.31
User Written Models	DC Lines	2/26,003	0.21

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

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 has been observed. Flagged generators indicate 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 of below 5% while the EI has increased its score significantly.
- 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.
- EI generator modeled buses impact the accuracy of protection when the generator bus voltage is input.
- The WI had many metrics in their Light Load Base Case that worsened between 2021 and 2022 version of this assessment

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% 2 metrics worsening, or consistent high score Voltage schedule conflicts major increase
	Dynamics	Most metrics below 5% 6 metrics consistent high score 1 metric worsening
Texas	Powerflow	Most metrics below 5% 1 metric worsening 1 metric consistent worsening or improving 1 metric consistent high score
	Dynamics	Most metrics below 5% 3 metrics consistent high score 2 metrics worsening 1 metric improving
Western	Powerflow	Most metrics below 5% 5 metrics improving, 4 metrics worsening
	Dynamics	Most metrics below 5% 3 metrics improving, 8 metrics worsening

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 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*[38] 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 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.
- The MOD-032 designees should utilize the unacceptable and not recommended model generators adjusted for GENROU as flagged in those metrics to begin targeting efforts for model improvement and replacement.
- The MOD-032 designee for the WI should review their case cases to 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.

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

- 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 on-line) 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.

	Consistent performance under 5% performance score, or performance score moved from greater than 5% to less than 5%
	Positive performance improvements (decrease in score of 2% or more from previous year)
	Continued performance above 5% performance score with no noticeable improvement
	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% (dark green) signifying that the overall case quality of the Interconnection-wide base cases are consistently of good quality. Similar to **Chapter 3**, scores in **red** indicate a higher than 5% 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: EI Heavy Summer Cases

Type of Metric	Metric	2018 Score (%)	2019 Score (%)	2020 Score (%)	2021 Score (%)	2022 Score (%)	Performance
Powerflow	P_{max} Exceedances	0.15	0.10	0.05	0.06	0.06	
	P_{min} Exceedances	0.10	0.1	0.02	0.01	0.01	
	Scheduled Interchange Sum	0	0.01	0	0	0	
	Thermal Overloads	0.17	0.19	0.13	0.15	0.19	
	Thermal Overloads (Severe)	0.13	0.15	0.11	0.12	0.15	
	Low Emergency Rating	0.00	0.00	0.02	0.02	0.03	
	High Emergency Rating	0.03	0.00	0.00	0.00	0.09	
	Voltage Schedule Conflicts	27	14	29	102	118	
	Tap Step Conflicts	0.07	0.07	0.16	0.17	0.18	
	Tap Step Conflicts (Severe)	0.03	0.01	0.09	0.09	0.06	
	Generator Reactive at Limits	**18.82**	**18.88**	**16.52**	**15.70**	**16.42**	
	Generator Reactive Limit Power Factor	**13.16**	**12.14**	**10.30**	2.38	**8.09**	
	Positive Sequence TX Circulating Current	0.00	0.00	0.00	0.00	0.00	
	Poor Load Power Factor	0.35	0.29	0.30	0.33	0.44	
	Generator Reactive Capability Curve	N/A	0.00	0.00	0.00	0	
	Generator R_{source}:X_{source} Ratio	0.00	0.00	0.06	0.04	0.11	
	X/R Ratio Check	N/A	0.25	0.25	0.23	0.23	
	Generator Terminal Voltage	N/A	**6.33**	**5.53**	4.15	4.07	
	Natural Gas Generator Pmax	N/A	N/A	N/A	N/A	N/A	

Table A.1: EI Heavy Summer Cases

Type of Metric	Metric	2018 Score (%)	2019 Score (%)	2020 Score (%)	2021 Score (%)	2022 Score (%)	Performance
	Natural Gas Generator Pmax (Severe)	N/A	N/A	N/A	N/A	N/A	
Dynamics	Generators without Models	1.62	1.96	2.26	2.37	2.98	
	Generators with Classical Models	0.26	0.25	0.28	0.27	0.27	
	Netted Generators with Models	0.26	0.64	0.47	0.37	2.51	
	Netted Generators	3.58	2.65	2.79	2.48	0.18	
	Inconsistent Reactance	0.23	0.24	0.82	1.05	1.06	
	Unacceptable Models	N/A	**11.83**	**11.81**	**13.17**	**12.36**	
	Not Recommended Models	N/A	**23.56**	**21.09**	**19.87**	**18.29**	
	User-Written Models[39]	N/A	N/A	-	-	-	
	Inconsistent Time Constants	0.11	0.11	0.13	0.09	0.07	
	Unreasonable Inertia Constants	**8.04**	**8.44**	**8.06**	**7.77**	**8.18**	
	Unreasonable Saturation Factors	**22.22**	**10.76**	**11.00**	**11.09**	**12.00**	
	Severe Saturation Factors	0.94	0.81	0.90	0.90	1.02	
	PSS but no Excitation	0.11	0.06	0.10	0.06	0.06	
	Inconsistent Speed Damping	3.33	3.13	2.22	2.28	2.52	
	Inconsistent Lead-Lag Time Constant	1.64	2.06	1.82	1.90	1.94	
	Erroneous Power Dev Fractions	1.02	1.27	1.20	3.48	3.81	
	DC Exciter Self-Excitation Errors	**10.34**	**10.58**	**12.83**	**13.40**	**13.56**	
	Inconsistent Type III Wind Speeds	0.00	0.00	0.00	0.00	0.00	
	Suspect PSS2A/2B parameters	**16.41**	**16.69**	**17.01**	**18.54**	**17.56**	
	Incorrect DER_A Tripping Parameters	N/A	0.00	0.00	0.00	0.00	
	Second Generation Renewable Model Parameterization	N/A	N/A	N/A	**17.57**	**21.87**	

39 Performance not tracked

Table A.2: EI Heavy Winter Cases							
Type of Metric	**Metric**	**2018 Score (%)**	**2019 Score (%)**	**2020 Score (%)**	**2021 Score (%)**	**2022 Score (%)**	**Performance**
Powerflow	P_{max} Exceedances	0.31	0.10	0.02	0.03	0.02	
	P_{min} Exceedances	0.08	0.16	0.02	0.00	0.00	
	Scheduled Interchange Sum	0	0	0	0	0	
	Thermal Overloads	0.13	0.18	0.15	0.14	0.14	
	Thermal Overloads (Severe)	0.11	0.14	0.12	0.11	0.11	
	Low Emergency Rating	0.00	0.00	0.03	0.02	0.02	
	High Emergency Rating	0.03	0.00	0.00	0.00	0.00	
	Voltage Schedule Conflicts	31	16	36	107	118	
	Tap Step Conflicts	0.07	0.07	0.16	0.17	0.18	
	Tap Step Conflicts (Severe)	0.02	0.00	0.09	0.09	0.06	
	Generator Reactive at Limits	**18.35**	**17.99**	**14.48**	**17.01**	**16.77**	
	Generator Reactive Limit Power Factor	**11.28**	**11.14**	**8.54**	2.46	**7.17**	
	Positive Sequence TX Circulating Current	0.00	0.00	0.00	0.00	0.00	
	Poor Load Power Factor	0.27	0.24	0.25	0.27	0.43	
	Generator Reactive Capability Curve	N/A	0.00	0.00	0.00	0.05	
	Generator R_{source}:X_{source} Ratio	0.00	0.00	0.05	0.05	0.16	
	X/R Ratio Check	N/A	0.26	0.24	0.23	0.00	
	Generator Terminal Voltage	N/A	**7.75**	4.50	**5.28**	4.13	
	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	1.72	2.07	2.39	2.59	3.21	
	Gens with Classical Models	0.25	0.27	0.28	0.27	0.28	
	Netted Generators	4.07	2.45	2.17	2.09	1.81	
	Netted Generators with Models	0.23	0.71	0.26	0.34	0.21	
	Inconsistent Reactance	0.23	0.27	0.64	1.10	1.05	
	Unacceptable Models	N/A	**13.87**	**10.33**	**13.15**	**12.26**	
	Not Recommended Models	N/A	**23.48**	**20.94**	**19.69**	**18.15**	
	User-Written Models[40]	N/A	N/A	-	-	-	
	Inconsistent Time Constants	0.11	0.11	0.13	0.09	0.12	

[40] Performance not tracked

Table A.2: EI Heavy Winter Cases							
Type of Metric	**Metric**	**2018 Score (%)**	**2019 Score (%)**	**2020 Score (%)**	**2021 Score (%)**	**2022 Score (%)**	**Performance**
	Unreasonable Inertia Constants	**8.11**	**8.49**	**8.07**	**7.76**	**8.12**	
	Unreasonable Saturation Factors	**22.19**	**10.75**	**10.99**	**11.12**	**11.95**	
	Severe Saturation Factors	0.94	0.81	0.91	0.90	1.01	
	PSS but no Excitation	0.11	0.06	0.10	0.06	0.06	
	Inconsistent Speed Damping	3.33	3.12	2.22	2.28	2.51	
	Inconsistent Lead-Lag Time Constant	1.63	2.16	1.81	1.88	1.93	
	Erroneous Power Dev Fractions	1.36	1.27	1.20	3.48	3.77	
	DC Exciter Self-Excitation Errors	**10.54**	**10.77**	**12.59**	**13.43**	**13.40**	
	Inconsistent Type III Wind Speeds	0.00	0.00	0.00	0.00	0.00	
	Suspect PSS2A/2B parameters	**16.51**	**16.67**	**17.32**	**18.63**	**17.60**	
	Incorrect DER_A Tripping Parameters	N/A	0.00	0.00	0.00	0.00	
	Second Generation Renewable Model Parameterization	N/A	N/A	N/A	**18.57**	**24.22**	

Table A.3: EI Light Spring Cases							
Type of Metric	**Metric**	**2018 Score (%)**	**2019 Score (%)**	**2020 Score (%)**	**2021 Score (%)**	**2022 Score (%)**	**Performance**
Powerflow	P_{max} Exceedances	0.11	0.06	0.17	0.00	0.00	
	P_{min} Exceedances	0.06	0.21	0.11	0.05	0.00	
	Scheduled Interchange Sum	0	0	0.001	0	-0.1	
	Thermal Overloads	0.06	0.07	0.05	0.04	0.04	
	Thermal Overloads (Severe)	0.05	0.06	0.05	0.03	0.03	
	Low Emergency Rating	0.00	0.00	0.02	0.02	0.03	
	High Emergency Rating	0.03	0.00	0.00	0.00	0.00	
	Voltage Schedule Conflicts	32	13	38	70	117	
	Tap Step Conflicts	0.06	0.06	0.16	0.17	0.18	
	Tap Step Conflicts (Severe)	0.02	0.00	0.09	0.09	0.07	
	Generator Reactive at Limits	**23.62**	**20.87**	**19.64**	**16.98**	**18.56**	
	Generator Reactive Limit Power Factor	**13.65**	**13.65**	**9.29**	2.44	**8.32**	

Table A.3: EI Light Spring Cases							
Type of Metric	Metric	2018 Score (%)	2019 Score (%)	2020 Score (%)	2021 Score (%)	2022 Score (%)	Performance
	Positive Sequence TX Circulating Current	0.00	0.00	0.00	0.00	0.00	
	Poor Load Power Factor	0.38	0.38	0.35	0.28	0.41	
	Generator Reactive Capability Curve	N/A	0.00	0.00	0.00	0.00	
	Generator R_{source}:X_{source} Ratio	0.00	0.00	0.08	0.08	0.15	
	X/R Ratio Check	N/A	0.25	0.24	0.23	0.23	
	Generator Terminal Voltage	N/A	**13.51**	**6.07**	**6.09**	**14.05**	
	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	1.68	1.81	2.36	2.62	2.86	
	Generators with Classical Models	0.26	0.23	0.28	0.26	0.27	
	Netted Generators	**5.40**	2.75	2.06	2.21	2.12	
	Netted Gens with Models	0.24	1.05	0.31	0.73	0.23	
	Inconsistent Reactances	0.24	0.25	0.82	1.06	1.06	
	Unacceptable Models	N/A	**13.95**	**11.86**	**13.23**	**17.59**	
	Not Recommended Models	N/A	**23.79**	**21.15**	**19.95**	**48,00**	
	User-Written Models[41]	N/A	N/A	-	-	-	
	Inconsistent Time Constants	0.11	0.11	0.13	0.09	0.07	
	Unreasonable Inertia Constants	**8.01**	**8.32**	**8.01**	**7.80**	**8.18**	
	Unreasonable Saturation Factors	**22.12**	**10.78**	**11.04**	**10.99**	**11.95**	
	Severe Saturation Factors	0.94	0.81	0.91	0.91	1.02	
	PSS but no Excitation	0.11	0.06	0.11	0.07	0.06	
	Inconsistent Speed Damping	3.35	3.12	2.23	2.29	2.52	
	Inconsistent Lead-Lag Time Constant	1.64	2.08	1.83	1.92	2.22	
	Erroneous Power Dev Fractions	1.02	1.09	1.21	3.49	4.09	
	DC Exciter Self-Excitation Errors	**10.27**	**10.58**	**12.84**	**13.45**	**13.57**	
	Inconsistent Type III Wind Speeds	0.00	0.00	0.00	0.00	0.00	

[41] Performance not tracked

Table A.3: EI Light Spring Cases							
Type of Metric	Metric	2018 Score (%)	2019 Score (%)	2020 Score (%)	2021 Score (%)	2022 Score (%)	Performance
	Suspect PSS2A/2B parameters	**17.85**	**17.73**	**18.09**	**19.55**	**18.85**	
	Incorrect DER_A Tripping Parameters	N/A	0.00	0.00	0.00	0.00	
	Second Generation Renewable Model Parameterization	N/A	N/A	N/A	**17.31**	**21.63**	

Texas Interconnection

Table A.4: TI Heavy Summer Peak Cases							
Type of Metric	Metric	2018 Score (%)	2019 Score (%)	2020 Score (%)	2021 Score (%)	2022 Score (%)	Performance
Powerflow	P_{max} Exceedances	0.00	0.00	0.00	0.11	0.00	
	P_{min} Exceedances	0.00	0.00	0.00	0.00	0.08	
	Scheduled Interchange Sum	0	0	0	0	0	
	Thermal Overloads	0.13	0.06	0.10	0.24	0.25	
	Thermal Overloads (Severe)	0.10	0.04	0.04	0.23	0.25	
	Low Emergency Rating	0.00	0.00	0.00	0.00	0.00	
	High Emergency Rating	0.02	0.03	0.00	0.02	0.02	
	Voltage Schedule Conflicts	0	5	47	31	47	
	Tap Step Conflicts	3.21	0.07	1.33	3.66	3.57	
	Tap Step Conflicts (Severe)	0.00	0.00	0.00	0.00	0.00	
	Generator Reactive at Limits	**14.11**	**6.37**	**6.78**	**8.52**	**13.90**	
	Generator Reactive Limit Power Factor	**11.11**	**13.73**	**31.83**	**9.36**	**9.30**	
	Positive Sequence TX Circulating Current	0.00	0.00	0.00	0.00	0.00	
	Poor Load Power Factor	0.11	0.13	0.06	0.02	0.05	
	Generator R_{source}:X_{source} Ratio	0.00	0.13	0.00	0.42	0.62	
	X/R Ratio Check	N/A	0.43	0.44	0.34	0.42	
	Generator Terminal Voltage	N/A	1.92	0.30	0.58	0.00	
	Generator Reactive Capability Curve	N/A	0.00	0.00	0.00	0.00	
	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	

Table A.4: TI Heavy Summer Peak Cases

Type of Metric	Metric	2018 Score (%)	2019 Score (%)	2020 Score (%)	2021 Score (%)	2022 Score (%)	Performance
Dynamics	Generators without Models	4.07	**5.20**	2.52	2.88	1.79	
	Generators with Classical Models	1.55	2.15	0.00	1.22	1.09	
	Netted Gens with Models	0.00	0.00	0.00	0.00	0.30	
	Netted Generators	0.14	0.00	0.00	0.00	0.30	
	Inconsistent Reactances	1.25	0.62	1.07	1.31	1.13	
	Unacceptable Models	N/A	2.96	2.10	1.85	1.42	
	Not Recommended Models	N/A	**24.37**	**21.77**	**20.09**	**17.08**	
	User-Written Models[42]	N/A	N/A	-	-	-	
	Inconsistent Time Constants	0.42	0.40	0.79	0.73	0.69	
	Unreasonable Inertia Constants	**11.30**	**14.01**	**15.31**	**16.40**	**18.86**	
	Unreasonable Saturation Factors	**20.12**	**13.17**	**12.82**	**13.55**	**13.13**	
	Severe Saturation Factors	1.45	1.20	1.18	1.65	1.55	
	PSS but no Excitation	0.00	0.00	0.00	0.00	0.00	
	Inconsistent Speed Damping	3.78	3.10	2.82	2.91	2.92	
	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	2.44	**7.84**	
	DC Exciter Self-Excitation Errors	**11.67**	**12.50**	**13.46**	**11.31**	**10.53**	
	Inconsistent Type III Wind Speeds	0.00	0.00	0.00	0.00	0.00	
	Suspect PSS2A/2B parameters	**12.5**	**16.92**	**14.07**	**16.21**	**17.87**	
	Incorrect DER_A Tripping Parameters	N/A	0.00	0.00	0.00	0.00	
	Second Generation Renewable Model Parameterization	N/A	N/A	N/A	N/A	N/A	

Table A.5: TI Heavy Wind Light Load Cases

Type of Metric	Metric	2018 Score (%)	2019 Score (%)	2020 Score (%)	2021 Score (%)	2022 Score (%)	Performance
Powerflow	P_{max} Exceedances	0.00	0.00	0.00	0.17	0.12	
	P_{min} Exceedances	0.00	0.00	0.37	0.00	0.00	

[42] Performance not tracked.

Table A.5: TI Heavy Wind Light Load Cases

Type of Metric	Metric	2018 Score (%)	2019 Score (%)	2020 Score (%)	2021 Score (%)	2022 Score (%)	Performance
	Scheduled Interchange Sum	0	0	0	0	0	
	Thermal Overloads	0.25	0.05	0.03	0.17	0.26	
	Thermal Overloads (Severe)	0.18	0.04	0.01	0.13	0.24	
	Low Emergency Rating	0.00	0.00	0.00	0.00	0.00	
	High Emergency Rating	0.02	0.03	0.00	0.02	0.18	
	Voltage Schedule Conflicts	0	12	62	43	79	
	Tap Step Conflicts	3.21	0.00	1.60	3.01	3.57	
	Tap Step Conflicts (Severe)	0.00	0.00	0.00	0.00	0.00	
	Generator Reactive at Limits	**17.34**	**12.59**	**14.01**	**9.16**	4.88	
	Generator Reactive Limit Power Factor	**12.39**	**7.82**	**7.84**	**6.53**	**7.20**	
	Positive Sequence TX Circulating Current	0.00	0.00	0.00	0.00	0.00	
	Poor Load Power Factor	0.20	0.19	0.06	0.05	0.09	
	Generator R_{source}:X_{source} Ratio	0.00	0.21	0.00	0.68	0.83	
	X/R Ratio Check	N/A	0.43	0.43	0.34	0.42	
	Generator Terminal Voltage	N/A	0.00	0.00	0.76	0.93	
	Generator Reactive Capability Curve	N/A	0.00	0.00	0.00	0.00	
	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	**6.62**	**8.55**	2.93	3.08	1.79	
	Generators with Classical Models	1.55	1.43	0.00	1.22	1.09	
	Netted Gens with Models	0.00	0.00	0.38	0.00	0.41	
	Netted Generators	0.22	0.00	0.38	0.00	0.41	
	Inconsistent Reactances	1.25	1.23	1.07	1.31	1.13	
	Unacceptable Models	N/A	2.79	2.11	1.85	1.42	
	Not Recommended Models	N/A	**24.68**	**21.67**	**20.09**	**17.08**	
	User-Written Models[43]	N/A	N/A	N/A	N/A	N/A	
	Inconsistent Time Constants	0.41	0.39	0.79	0.73	0.69	
	Unreasonable Inertia Constants	**11.30**	**13.98**	**15.31**	**16.40**	**18.85**	

[43] Performance not tracked.

Table A.5: TI Heavy Wind Light Load Cases							
Type of Metric	**Metric**	**2018 Score (%)**	**2019 Score (%)**	**2020 Score (%)**	**2021 Score (%)**	**2022 Score (%)**	**Performance**
	Unreasonable Saturation Factors	**20.12**	**13.19**	**12.85**	**13.55**	**13.12**	
	Severe Saturation Factors	1.45	1.18	1.19	1.65	1.55	
	PSS but no Excitation	0.00	0.00	0.00	0.00	0.00	
	Inconsistent Speed Damping	3.78	3.07	2.82	2.91	2.92	
	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	2.44	**7.84**	
	DC Exciter Self-Excitation Errors	**11.67**	**12.5**	**13.46**	**11.32**	**10.52**	
	Inconsistent Type III Wind Speeds	0.00	0.00	0.00	0.00	0.00	
	Suspect PSS2A/2B parameters	**12.5**	**16.92**	**14.07**	**16.21**	**17.87**	
	Incorrect DER_A Tripping Parameters	N/A	0.00	0.00	0.00	0.00	
	Second Generation Renewable Model Parameterization	N/A	N/A	N/A	0.00	0.00	

Table A.6: TI Second Summer Peak Cases							
Type of Metric	**Metric**	**2018 Score (%)**	**2019 Score (%)**	**2020 Score (%)**	**2021 Score (%)**	**2022 Score (%)**	**Performance**
Powerflow	P_{max} Exceedances	0.00	0.00	0.00	0.11	0.00	
	P_{min} Exceedances	0.00	0.00	0.00	0.00	0.00	
	Scheduled Interchange Sum	0	0	0	0	0	
	Thermal Overloads	0.22	0.04	0.05	0.29	0.25	
	Thermal Overloads (Severe)	0.15	0.04	0.04	0.25	0.23	
	Low Emergency Rating	0.00	0.00	0.00	0.00	0.00	
	High Emergency Rating	0.02	0.03	0.00	0.02	0.02	
	Voltage Schedule Conflicts	0	23	37	39	37	
	Tap Step Conflicts	3.35	0.94	1.40	3.60	3.45	
	Tap Step Conflicts (Severe)	0.00	0.80	0.00	0.00	0.00	
	Generator Reactive at Limits	**16.24**	**9.14**	**16.28**	**13.37**	**20.91**	
	Generator Reactive Limit Power Factor	**10.97**	**13.35**	**12.59**	**9.15**	**9.30**	
	Positive Sequence TX Circulating Current	0.00	0.00	0.00	0.00	0.00	
	Poor Load Power Factor	0.11	0.13	0.04	0.02	0.05	

Table A.6: TI Second Summer Peak Cases							
Type of Metric	Metric	2018 Score (%)	2019 Score (%)	2020 Score (%)	2021 Score (%)	2022 Score (%)	Performance
	Generator R_{source}:X_{source} Ratio	0.00	0.13	0.00	0.43	0.61	
	X/R Ratio Check	N/A	0.43	0.44	0.34	0.42	
	Generator Terminal Voltage	N/A	0.00	0.30	0.29	0.67	
	Generator Reactive Capability Curve	N/A	0.00	0.00	0.00	0.00	
	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	3.94	**5.19**	3.35	3.26	1.79	
	Gens with Classical Models	1.55	1.43	0.00	1.21	1.09	
	Netted Gens with Models	0.00	0.00	0.24	0.00	0.29	
	Netted Generators	0.14	0.00	0.24	0.00	0.29	
	Inconsistent Reactances	1.25	1.23	1.07	1.31	1.15	
	Unacceptable Models	N/A	2.72	2.10	1.85	1.42	
	Not Recommended Models	N/A	**24.57**	**21.76**	**20.09**	**16.79**	
	User-Written Models[44]	N/A	N/A	-	-	-	
	Inconsistent Time Constants	0.41	0.39	0.79	0.73	0.69	
	Unreasonable Inertia Constants	**11.30**	**13.98**	**15.31**	**16.40**	**18.86**	
	Unreasonable Saturation Factors	**20.12**	**13.21**	**12.85**	**13.55**	**13.13**	
	Severe Saturation Factors	1.45	1.18	1.19	1.65	1.55	
	PSS but no Excitation	0.00	0.00	0.00	0.00	0.00	
	Inconsistent Speed Damping	3.78	3.07	2.82	2.91	2.92	
	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	2.44	**6.78**	
	DC Exciter Self-Excitation Errors	**11.67**	**12.50**	**13.46**	**11.32**	**10.52**	
	Inconsistent Type III Wind Speeds	0.00	0.00	0.00	0.00	0.00	
	Suspect PSS2A/2B parameters	**12.5**	**16.92**	**14.07**	**16.21**	**20.38**	
	Incorrect DER_A Tripping Parameters	N/A	0.00	0.00	0.00	0.00	

[44] Performance not tracked.

Table A.6: TI Second Summer Peak Cases							
Type of Metric	Metric	2018 Score (%)	2019 Score (%)	2020 Score (%)	2021 Score (%)	2022 Score (%)	Performance
	Second Generation Renewable Model Parameterization	N/A	N/A	N/A	0.00	0.00	

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Table A.7: WI Heavy Summer Cases							
Type of Metric	Metric	2018 Score (%)	2019 Score (%)	2020 Score (%)	2021 Score (%)	2022 Score (%)	Performance
Powerflow	P_{max} Exceedances	0.03	0.00	0.23	0.28	0.37	
	P_{min} Exceedances	0.03	0.03	0.32	0.21	0.26	
	Scheduled Interchange Sum	0	0.0	-0.0	0.0	0.0	
	Voltage Schedule Conflicts	80	63	55	58	64	
	Tap Step Conflicts	0.66	0.72	0.62	0.54	0.26	
	Tap Step Conflicts (Severe)	0.10	0.45	0.05	0.07	0.06	
	Low Emergency Rating	0.13	0.40	0.37	0.03	0.02	
	High Emergency Rating	0.02	0.01	0.01	0.01	0.00	
	Thermal Overloads	0.01	0.01	0.05	0.07	0.06	
	Thermal Overloads (Severe)	0.00	0.00	0.04	0.05	0.04	
	Generator Reactive at Limits	**6.53**	4.84	**5.50**	**5.19**	**6.65**	
	Generator Reactive Limit Power Factor	**25.11**	**28.35**	**10.06**	**9.78**	**8.78**	
	Positive Sequence TX Circulating Current	0.00	0.00	0.00	0.00	0.00	
	Poor Load Power Factor	0.04	0.07	0.05	0.05	0.04	
	Generator R_{source}:X_{source} Ratio	0.21	0.05	0.05	0.09	0.17	
	Generator Terminal Voltage	N/A	3.90	**6.03**	**7.24**	4.01	
	Generator Reactive Capability Curve	N/A	0.00	3.47	0.00	**5.03**	
	X/R Ratio Check	N/A	0.18	0.19	0.19	0.20	
	Natural Gas Generator Pmax	N/A	**72.30**	**84.13**	**79.67**	**75.74**	
	Natural Gas Generator Pmax (Severe)	N/A	**5.94**	4.35	**6.41**	3.89	
Dynamics	Generators without Models	4.73	4.89	**6.69**	**7.16**	**8.06**	
	Netted Gens with Models	0.20	1.07	0.16	0.34	0.18	
	Netted Generators	2.01	3.57	3.22	3.98	**5.03**	

Table A.7: WI Heavy Summer Cases

Type of Metric	Metric	2018 Score (%)	2019 Score (%)	2020 Score (%)	2021 Score (%)	2022 Score (%)	Performance
	Generators with Classical Models	0.00	0.00	0.00	0.00	0.00	
	Unacceptable Models	N/A	4.19	3.73	3.23	7.78	
	Not Recommended Models	N/A	**11.93**	**10.88**	**9.13**	5.95	
	User-Written Models[45]	N/A	N/A	-	-	-	
	Inconsistent Reactances	3.34	3.54	3.24	3.35	3.45	
	Inconsistent Time Constants	**5.96**	**5.87**	**5.74**	**6.16**	**6.33**	
	Unreasonable Inertia Constants	**13.03**	**13.06**	**11.90**	**11.69**	**10.25**	
	Unreasonable Saturation Factors	**27.08**	**19.74**	**19.00**	**19.14**	**16.92**	
	Severe Saturation Factors	**6.86**	**6.65**	**6.12**	**5.91**	**5.45**	
	PSS but no Excitation	0.39	0.00	0.72	0.76	1.89	
	Inconsistent Speed Damping	**8.23**	**7.22**	**7.24**	**7.04**	**6.74**	
	Inconsistent Lead-Lag Time Constant	1.86	2.49	2.48	3.11	**5.39**	
	Erroneous Power Dev Fractions	3.74	2.91	2.69	2.73	1.89	
	DC Exciter Self-Excitation Errors	**5.78**	4.98	**5.34**	**5.75**	**5.76**	
	Inconsistent Type III Wind Speeds	0.00	1.27	1.32	0.00	**0**	
	Suspect PSS2A/2B parameters	4.19	3.52	3.16	3.74	3.15	
	Incorrect DER_A Tripping Parameters	N/A	0.00	0.00	0.00	0.0	
	Second Generation Renewable Model Parameterization	N/A	N/A	N/A	**31.13**	**36.35**	

Table A.8: WI Heavy Winter Cases

Type of Metric	Metric	2018 Score (%)	2019 Score (%)	2020 Score (%)	2021 Score (%)	2022 Score (%)	Performance
Powerflow	P_{max} Exceedances	0.08	0.08	0.55	0.44	0.44	
	P_{min} Exceedances	0.35	0.41	0.59	0.33	0.33	
	Scheduled Interchange Sum	0.0	0	-0.0	0.0	0.0	
	Voltage Schedule Conflicts	77	63	54	64	64	
	Tap Step Conflicts	0.62	0.61	0.57	0.34	-0.34	

[45] Performance not tracked.

Table A.8: WI Heavy Winter Cases							
Type of Metric	**Metric**	**2018 Score (%)**	**2019 Score (%)**	**2020 Score (%)**	**2021 Score (%)**	**2022 Score (%)**	**Performance**
	Tap Step Conflicts (Severe)	0.06	0.06	0.06	0.08	-0.08	
	Low Emergency Rating	0.27	0.14	0.35	0.35	-0.35	
	High Emergency Rating	0.04	0.02	0.03	0.02	-0.02	
	Thermal Overloads	0.00	0.01	0.02	0.04	-0.04	
	Thermal Overloads (Severe)	0.00	0.00	0.02	0.01	-0.01	
	Generator Reactive at Limits	**5.82**	3.81	4.69	**5.06**	**6.97**	
	Generator Reactive Limit Power Factor	**12.31**	**27.41**	**10.28**	**9.58**	**8.78**	
	Positive Sequence TX Circulating Current	0.00	0.00	0.00	0.00	0.00	
	Poor Load Power Factor	0.06	0.06	0.13	0.04	0.04	
	Generator R_{source}:X_{source} Ratio	0.28	0.16	0.11	0.20	0.20	
	Generator Terminal Voltage	N/A	3.90	**6.18**	**10.15**	**10.15**	
	Generator Reactive Capability Curve	N/A	0.00	3.37	0.00	0.00	
	X/R Ratio Check	N/A	0.18	0.19	0.20	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	**5.15**	4.38	**8.26**	**7.87**	**7.87**	
	Netted Gens with Models	0.20	0.40	0.20	0.23	0.23	
	Netted Generators	1.43	2.00	2.93	3.30	3.30	
	Generators with Classical Models	0.00	0.00	0.00	0.00	0.00	
	Unacceptable Models	N/A	4.66	3.38	2.48	2.62	
	Not Recommended Models	N/A	**12.36**	**10.18**	**6.59**	**6.33**	
	User-Written Models[46]	N/A	N/A	-	-	0.30	
	Inconsistent Reactances	3.35	3.32	3.52	3.45	0	
	Inconsistent Time Constants	**5.84**	**6.02**	**6.15**	**6.49**	**7.87**	
	Unreasonable Inertia Constants	**13.10**	**13.32**	**12.48**	**11.86**	**9.88**	
	Unreasonable Saturation Factors	**27.09**	**19.75**	**19.85**	**19.13**	**16.66**	
	Severe Saturation Factors	**6.97**	**6.70**	**6.39**	**5.83**	**5.61**	
	PSS but no Excitation	0.34	0.11	0.66	0.98	2.62	

46 Performance not tracked.

Table A.8: WI Heavy Winter Cases							
Type of Metric	Metric	2018 Score (%)	2019 Score (%)	2020 Score (%)	2021 Score (%)	2022 Score (%)	Performance
	Inconsistent Speed Damping	**8.51**	**7.03**	**7.19**	**6.87**	**6.87**	
	Inconsistent Lead-Lag Time Constant	1.82	2.59	2.39	3.27	3.27	
	Erroneous Power Dev Fractions	3.67	2.86	3.26	2.69	2.69	
	DC Exciter Self-Excitation Errors	**6.98**	**5.86**	**5.88**	**5.08**	**5.80**	
	Inconsistent Type III Wind Speeds	0.00	0.00	1.52	0.00	0.00	
	Suspect PSS2A/2B parameters	4.01	3.95	4.05	3.71	3.71	
	Incorrect DER_A Tripping Parameters	N/A	0.00	0.00	0.00	0.00	
	Second Generation Renewable Model Parameterization	N/A	N/A	N/A	**34.66**	**34.62**	

Table A.9: WI Light Summer Cases							
Type of Metric	Metric	2018 Score (%)	2019 Score (%)	2020 Score (%)	2021 Score (%)	2022 Score (%)	Performance
Powerflow	P_{max} Exceedances	0.00	0.19	0.14	0.08	0.42	
	P_{min} Exceedances	0.00	0.05	0.87	0.25	1.34	
	Scheduled Interchange Sum	0	0.0	-0.0	0.0	0.0	
	Voltage Schedule Conflicts	75	62	56	58	61	
	Tap Step Conflicts	0.61	0.45	0.60	0.53	0.33	
	Tap Step Conflicts (Severe)	0.07	0.06	0.07	0.07	0.07	
	Low Emergency Rating	0.14	0.39	0.37	0.03	0.12	
	High Emergency Rating	0.03	0.02	0.01	0.01	0.01	
	Thermal Overloads	0.01	0.01	0.01	0.04	0.05	
	Thermal Overloads (Severe)	0.00	0.00	0.01	0.01	0.01	
	Generator Reactive at Limits	**6.76**	**5.99**	**5.67**	**5.43**	**6.90**	
	Generator Reactive Limit Power Factor	**25.24**	**28.43**	**10.60**	**9.94**	**9.15**	
	Positive Sequence TX Circulating Current	0.00	0.00	0.00	0.00	0.00	
	Poor Load Power Factor	0.03	0.06	0.08	0.08	0.06	
	Generator R_{source}:X_{source} Ratio	0.21	0.05	0.05	0.09	0.22	

Table A.9: WI Light Summer Cases							
Type of Metric	Metric	2018 Score (%)	2019 Score (%)	2020 Score (%)	2021 Score (%)	2022 Score (%)	Performance
	Generator Terminal Voltage	N/A	**7.30**	4.74	**5.20**	**6.77**	
	Generator Reactive Capability Curve	N/A	0.00	2.18	0.00	3.76	
	X/R Ratio Check	N/A	0.17	0.19	0.19	0.21	
	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	4.79	4.96	**6.84**	**7.30**	**8.46**	
	Netted Gens with Models	0.12	0.40	0.29	0.32	0.74	
	Netted Generators	1.76	2.94	2.83	3.46	**6.08**	
	Generators with Classical Models	0.00	0.00	0.00	0.00	0.00	
	Unacceptable Models	N/A	4.17	3.79	3.41	2.77	
	Not Recommended Models	N/A	**11.85**	**10.82**	**9.11**	**7.64**	
	User-Written Models[47]	N/A	N/A	-	-	-	
	Inconsistent Reactances	3.33	3.55	3.24	3.44	3.37	
	Inconsistent Time Constants	**5.95**	**5.88**	**5.74**	2.86	**6.33**	
	Unreasonable Inertia Constants	**13.16**	**13.01**	**12.00**	**10.95**	**9.84**	
	Unreasonable Saturation Factors	**27.15**	**19.72**	**19.39**	**13.57**	**16.80**	
	Severe Saturation Factors	**6.85**	**6.68**	**6.35**	1.67	**5.61**	
	PSS but no Excitation	0.45	0.28	0.55	0.00	1.98	
	Inconsistent Speed Damping	**8.22**	**7.19**	**7.24**	**10.12**	**6.74**	
	Inconsistent Lead-Lag Time Constant	1.85	2.48	2.47	3.55	3.47	
	Erroneous Power Dev Fractions	3.74	2.90	3.21	1.49	1.89	
	DC Exciter Self-Excitation Errors	**5.83**	**5.22**	**5.53**	**7.08**	**5.76**	
	Inconsistent Type III Wind Speeds	0.00	1.28	1.27	0.00	0.00	
	Suspect PSS2A/2B parameters	4.19	3.76	3.17	3.75	3.26	
	Incorrect DER_A Tripping Parameters	N/A	0.00	0.00	0.00	0.00	

[47] Performance not tracked.

Table A.9: WI Light Summer Cases							
Type of Metric	**Metric**	**2018 Score (%)**	**2019 Score (%)**	**2020 Score (%)**	**2021 Score (%)**	**2022 Score (%)**	**Performance**
	Second Generation Renewable Model Parameterization	N/A	N/A	N/A	**30.72**	**35.49**	