Case Quality Metrics

Annual Interconnection-Wide Model Assessment

October 2020

RELIABILITY | RESILIENCE | SECURITY

3353 Peachtree Road NE
Suite 600, North Tower
Atlanta, GA 30326
404-446-2560 | www.nerc.com

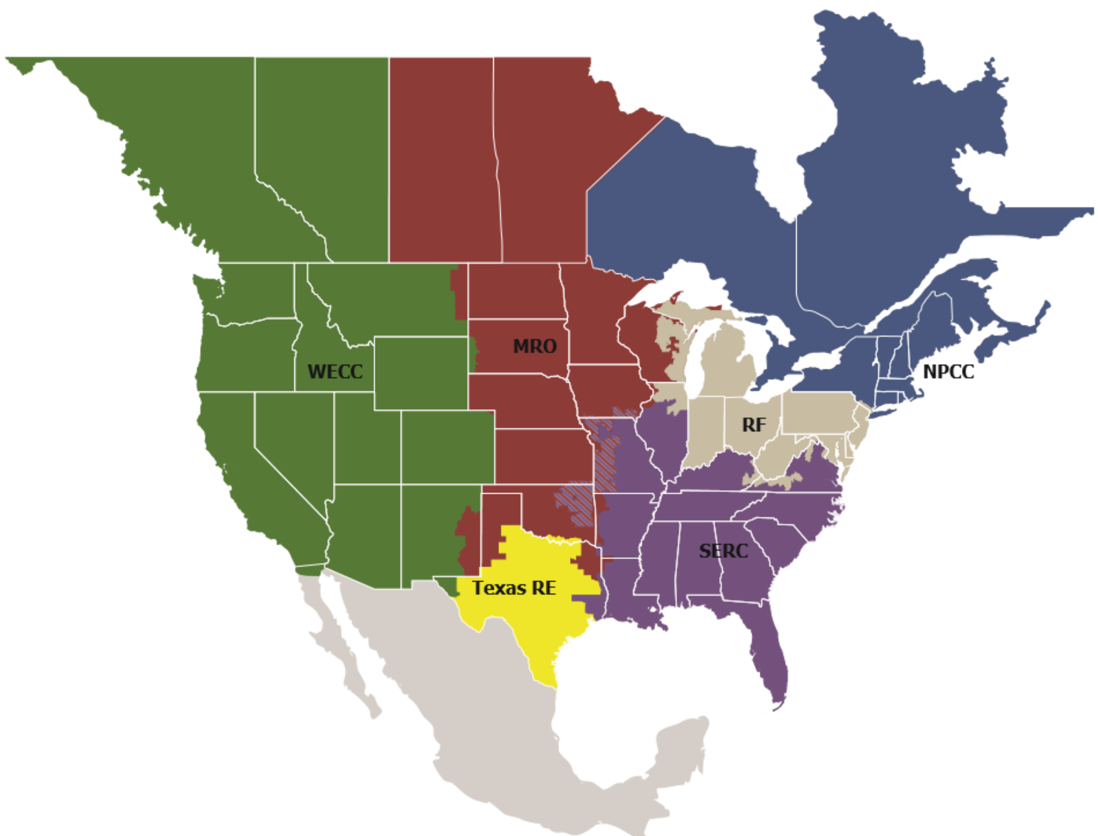
Table of Contents

Preface

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

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

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



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

Executive Summary

Powerflow and dynamics cases are the foundation of virtually all power system studies. Calculations of operating limits, planning studies, and performance analyses for various operating conditions all depend on mathematical representations of transmission topology, generation, and load. Case quality refers to the reasonableness of the data in the individual equipment models that comprise the base case for the characteristics and operating states desired for study. A reasonable model contains information that is mathematically correct and does not contain suspicious data entries in part, or at a whole. This presumes that sufficient procedures are in place to ensure that the equipment models that have been provided are reasonable representations of the physical equipment the models are meant to represent. This *2020 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 *2020 Case Quality Metrics Assessment*, NERC has made the following observations:

- 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.
- Past nomenclature for the WI Winter case was incorrect in previous assessments and has been corrected in this version of the NERC *2020 Case Quality Metrics Assessment*.
- 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 all Interconnections. The EI, however, is improving this metric on a year-over-year basis and the WI has made significant improvements in this year's assessment. 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. In particular, the saturation factors with severe inaccuracies should be a priority for the WI. 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 and 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. All Interconnections have a consistently high or worsening score for these metrics. These generator models contain bad data.
- A general decline in performance regarding generators above the modeling threshold not having generator models have been observed. The TI is an exception to this general trend for this year. Generators flagged are indicative of a case setup issue in addition to being a suspect condition for such generators.
- A noticeable historic 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%. This is especially evident in the summer peak cases in those Interconnections.

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

- In the unacceptable or not recommended model metrics, all Interconnections demonstrate either a consistently high performance or improving score with most instances being improving.[2] Of special note is the TI and WI that have maintained the unacceptable model score below 5%. The majority of models that are not recommended use the genrou generator model.
- The WI and EI should ensure their generator terminal voltages, when such generators at the modeled powerflow bus regulate other powerflow busses, should remain within the 0.95 to 1.05 boundary. Generators outside those boundaries signify a poor dispatch based on discussions with the NERC Power Plant Modeling and Verification Task Force (PPMVTF).
- The TI had a large increase of Generator Reactive Limit Power Factor metric for their 2022 Summer Peak Case.
- The WI had an increase of performance for the Generator Reactive at Limits, Generator Terminal Voltage, Natural Gas Generator, and Reactive Capability Curve metrics. All of these metric are related to case dispatch or suspect data involving reactive capability of generators. Additionally, the WI's natural gas generation in the case does not reflect the ambient thermal impact related to changes in steady-state active power limits for natural gas generators based on such ambient temperature changes between the seasonal cases; such data is suspect.

Table ES.1 gives a "scorecard" for performance based on the overall assessment of cases for each Interconnection. One of NERC's 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 zero percent 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 zero percent. The scorecard colors represent those trends.

Table ES. 1: Interconnection Scorecard

Interconnection	Metrics	Evaluation
Eastern	Powerflow	Most metrics below 5% 3 metric consistent high score or improving
	Dynamics	Most metrics below 5% 3 metrics consistent high score 1 metric generally improving or consistent score above 5% 1 metric improving
Texas	Powerflow	Most metrics below 5% 1 metric worsening by significant bounds in one base case 2 metrics worsening or consistent high score
	Dynamics	Most metrics below 5% 1 metrics worsening 2 metric has consistent performance 2 metrics improving performance
Western	Powerflow	Most metrics below 5% 3 metrics worsening or consistent high score 1 metric consistent high score to past performance

[2] WECC and NERC have jointly been reviewing this issue for the WI, and all generators without acceptable models have been identified in 2020. Corrections to this initial list are still ongoing.

Table ES. 1: Interconnection Scorecard		
Interconnection	**Metrics**	**Evaluation**
	Dynamics	Most metrics below 5% Many metrics below 5% trending higher Many metrics have a consistently high score 1 metric worsening

Based on the observations listed above, 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.

Introduction

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

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

Base case quality has two principal aspects:

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

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

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

Chapter 1: Case Quality Metrics

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

Steady-State Powerflow Metrics

The following list describes the steady-state powerflow metrics found 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.

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

---

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

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

[6] Wind machines and units with Pgen <= 0 will be omitted from this check.

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

[8] Opposite direction of positive sequence current flow

11. Individual aggregate loads greater than 2 MVA[9] and with positive active and reactive power consumption[10] should have a power factor with absolute value greater than 0.5 pf.
12. The ratio of generator R_{source}: X_{source} should be less than 1.0.[11]
13. Generator terminal bus voltages should be between 0.95 and 1.05 when regulating a non-terminal bus.[12]
14. For all generator capability curves provided, no part of the piecewise function can limit a box defined by the Pmax, Pmin, Qmax, Qmin 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.

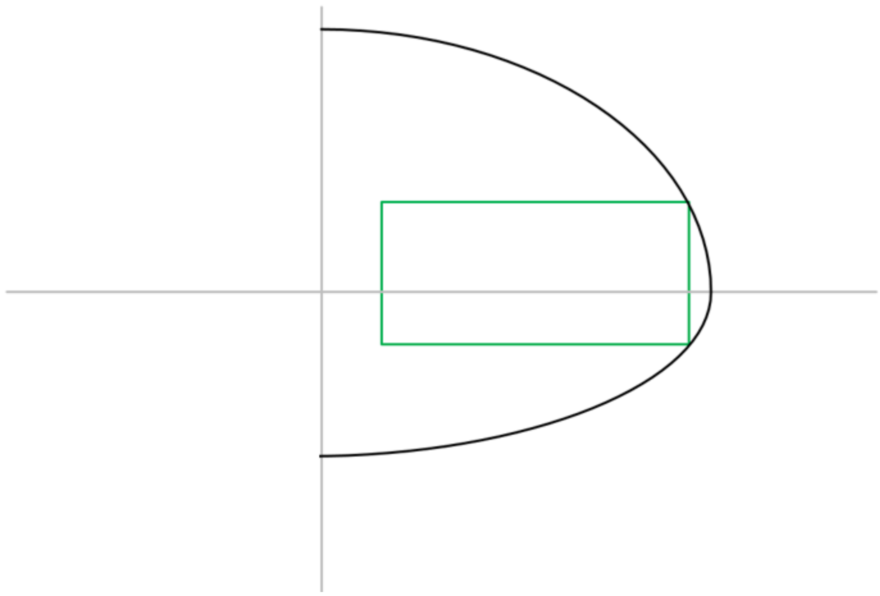


Figure 1.1: Generator Reactive Capability Box Overview

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 Pmax values should be less than the winter Pmax values.

Transient Dynamics Metrics

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

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

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

1. Generating units larger than the criteria threshold established for each Interconnection[13] should have a generator model included in their dynamics record; units without a generator model are flagged as not meeting this modeling criteria.
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[14] 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 $T''_{q0} \leq T'_{q0}$ [15] and $T'_{q0} \leq T'_{d0}$ [16].
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[17].
9. Saturation factors S (1.0) and S (1.2) should be reasonable[18].
    a. $0.03 \leq S(1.0) \leq 0.18$
    b. $0.2 \leq \mathrm{S}(1.2) \leq 0.85$
    c. S(1.2) should be within 2 to 8 times S(1.0).
    d. Severe saturation factor check:
        i. S(1.0) and S(1.2) should be greater than zero.
        ii. S(1.0) and S(1.2) should be less than 1.0.

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

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

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.[19]
13. Turbine power development fractions should add up to 1.0[20]. An example of these fractions in the block diagrams for a turbine governor model is in **Figure 1.2**.

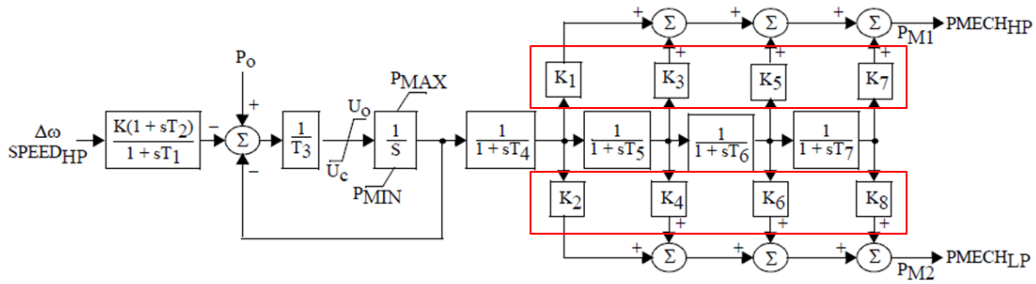


Figure 1.2: IEEEG1 Model Block Diagram (Source: Siemens PTI)

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

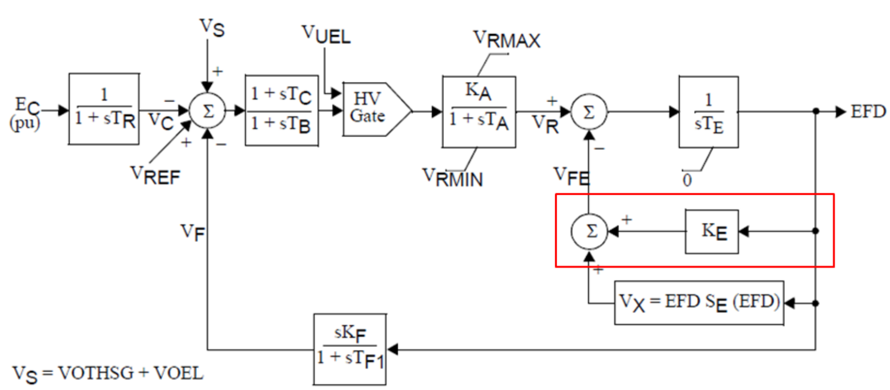


Figure 1.3: ESDC1A Model Block Diagram (Source: Siemens PTI)

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

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

17. Models should not be listed as unacceptable or not recommended on the NERC Acceptable Model List.[22]
    a. Unacceptable models are tallied for all generator, exciter, stabilizer, and turbine-governor models.
    b. Not recommended models are tallied for all generator, exciter, stabilizer, and turbine-governor models.

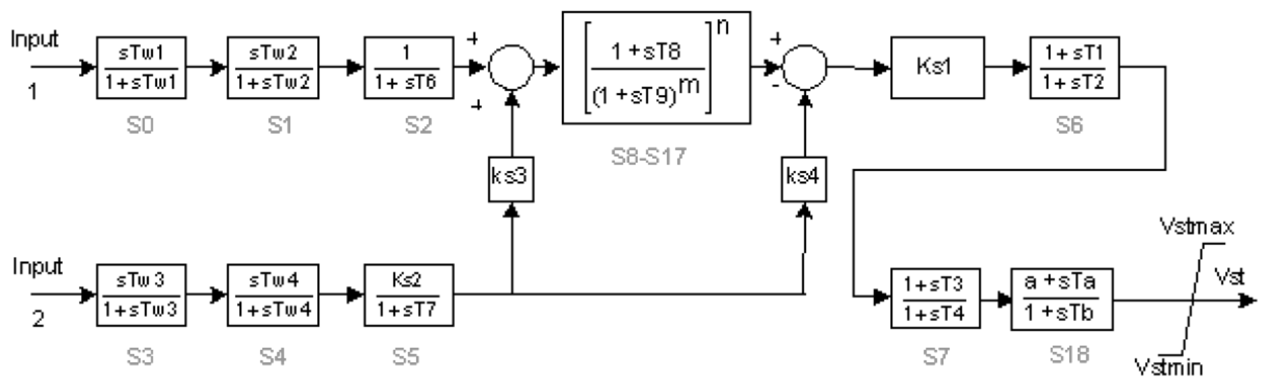


Figure 1.4: PSS2A Block Diagram [Source: GE PSLF

Metric Categorization

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

Table 1.1: Bad and Suspect Data Metrics			
Steady-State Metrics			
Metric	**Bad Data**	**Suspect Data**	**Case Setup Issue**
P_{max} Exceedances			X
P_{min} Exceedances			X
Scheduled Interchange Sum			X
Voltage Schedule Conflicts			X
Tap Step Conflicts		X	
Tap Step Conflicts (Severe)		X	

[22] All disclosures regarding 'acceptability' are documented on the Systems Analysis and Modeling Subcommittee website. If not listed on the spreadsheet, models are considered "acceptable."

Table 1.1: Bad and Suspect Data Metrics			
Steady-State Metrics			
Metric	**Bad Data**	**Suspect Data**	**Case Setup Issue**
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	
Pos Seq 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	
Gas Generator Pmax	X	X	
Dynamics Metrics			
Metric	**Bad Data**	**Suspect Data**	**Case Setup Issue**
Gens without Models		X	X
Netted Gens with Models		X	X
Netted Generators		X	
Gens with Classical Models		X	
Unacceptable Models	X		
Not Recommended Models		X	
User-Written Models[23]		(X)	
Inconsistent Reactances	X		
Inconsistent Time Constants	X		
Unreasonable Inertia Constants		X	
Unreasonable Saturation Factors		X	
Severe Saturation Factors	X		
PSS but no Excitation		X	
Inconsistent Speed Damping	X		
Inconsistent Lead-Lag Time Const	X		
Erroneous Power Dev Fractions	X		
DC Exciter Self-Excitation Errors	X		
Inconsistent Type III Wind Speeds	X		
Suspect PSS2A/2B parameters		X	
Incorrect DER_A Tripping Parameters		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

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

the corresponding criteria is applicable in the case. Each metric is reported as a count and performance is expressed as a percentage of all data issues identified[24] as a percentage of all applicable models.

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

Dynamics Cases

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

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

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

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

Chapter 2: Software Differences and Considerations

Software Differences

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

- PSS®E stores voltage set point for generators and static VAR systems with the device data record whereas PSLF stores voltage set point for these devices with the bus data record. In PSLF, it is not possible to have voltage schedule conflicts for multiple generators and static VAR systems that are regulating a common location. However, transformer data records in PSLF have their own voltage regulation data.
- PSLF has a turbine type flag in the generator data to indicate if a generating unit is a wind unit.[25] However, this flag is not completely populated in WI base cases. Therefore, to eliminate wind units from the reactive limits check (Q_{gen} at Q_{max} or Q_{min}), the dynamics data file has to be loaded and the corresponding dynamic models have to be checked. The units with the any of the following wind generator models were eliminated from the check: genwri, gewtg, gewtgx, regc_a, regc_c, wt1g, wt2g, wt3g, and wt4g. It is recommended that the turbine type flag be utilized to improve the code's speed and complexity in identifying unit fuels.
- The names of the dc exciter models differ between PSS®E and PSLF. Hence, for the check on parameter KE in dc exciters, the following models were checked in PSLF: esdc1a, esdc2a, esdc3a, esdc4b, exdc1, exdc2, exdc2a, exdc4, ieeet1, and rexs.
- PSLF has the generator MVA base specified in both the powerflow and dynamics data files. All dynamic data is then taken on the per-unit MVA base specified in the dynamics data file. In PSS®E, one value of MVA base is specified and located in the powerflow file. In evaluating generator inertia constants for the WI base cases (using PSLF), the inertia constant has been evaluated on the MVA base specified in the powerflow file unless the specified powerflow base was the default 100 MVA. This calculated constant is an MVA base transfer between the dynamic and powerflow MVAs if the powerflow MVA is not 100 MVA.
- Fuel types are not capable of being accessed in PSS®E. As such, for this current year's metrics, a N/A score is produced for the natural gas Pmax 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 Pgen and Qgen 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 Pmax and Qmax are the maximum real and reactive output limits of the unit in the powerflow data
- MBASE value unless value is 100.0 MVA (default value) in which case this parameter is ignored

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

Chapter 3: Case Quality Metric Assessment

The goal of the case quality metrics assessment is to promote good modeling practices and to strive to reduce data errors in Interconnection-wide base cases. Since the performance score is the percentage of elements that have data errors, the goal translates into attempting to drive performance scores towards zero. However, it is not expected that all performance scores reach zero. There are legitimate modeling reasons why some of the generic metrics developed by NERC in this *2020 Case Quality Metrics Assessment* could be violated (e.g., equivalencing or back-to-back dc ties between Interconnections).

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

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**.

Eastern Interconnection Case Quality Metrics Assessment

The performance and score, evaluated as a percentage, for all of the Eastern Interconnection cases are tabulated in **Table 3.1** to **Table 3.9**. **Table 3.1** to **Table 3.3**are for the 2020SUM base case; **Table 3.4** to **Table 3.6**are for the 2020WIN base case; **Table 3.7** to **Table 3.9** are for the 2020SPR base case.

2020 Summer Peak Case: 2020SUM

Table 3.1: Steady-State Metrics		
Metric	**Performance**	**Score (%)**
P_{max} Exceedances	3/6,642	0.05
P_{min} Exceedances	1/6,642	0.02
Scheduled Interchange Sum	0	-
Voltage Schedule Conflicts	29	-
Tap Step Conflicts	33/21,017	0.16
Tap Step Conflicts (Severe)	19/21,017	0.09
Low Emergency Rating	17/95,247	0.02
High Emergency Rating	1/95,247	0.00
Thermal Overloads	127/95,247	0.13
Thermal Overloads (Severe)	106/98,247	0.11
Generator Reactive at Limits	762/4,613	**16.52**
Generator Reactive Limit Power Factor	564/5,477	**10.30**
Pos Seq TX Circulating Current	0/2,704	0.00
Poor Load Power Factor	145/47,834	0.30
Generator R_{source}:X_{source} Ratio	4/6,642	0.06
Generator Terminal Voltage	160/2,894	**5.53**
Generator Reactive Capability Curve	0/0	0.00
X/R Ratio Check	221/89,041	0.25
Natural Gas Generator Pmax	N/A	N/A

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

Table 3.1: Steady-State Metrics

Metric	Performance	Score (%)
Natural Gas Generator Pmax (Severe)	N/A	N/A

Table 3.2: Dynamics Metrics

Metric	Performance	Score (%)	Pmax (MW)	Qmax (MVAR)
Generators without Models	151/6,674	2.26	4,299	1,349
Netted Generators with Models	23/4,880	0.47	955	641
Netted Generators	136/4,880	2.79	4,184	1,433
Generators with Classical Models	14/5,023	0.28	6,450	3,774
Unacceptable Models (total)	2071/17,529	**11.81**	-	-
Not Recommended Models (total)	3697/17,529	**21.09**	-	-
User-Written Models[27]	968/25,914	-	-	-
Inconsistent Reactances	36/4,417	0.82	2,970	1,500
Inconsistent Time Constants	6/4,654	0.13	1,923	1,044
Unreasonable Inertia Constants	459/5,693	**8.06**	30,516	18,469
Unreasonable Saturation Factors	512/4,654	**11.00**	55,312.7	28,623
Severe Saturation Factors	42/4,654	0.90	5911	3,069
PSS but no Excitation	7/6,674	0.10	264	375
Inconsistent Speed Damping	122/5,492	2.22	8,153	3,755
Inconsistent Lead-Lag Time Const	36/1,982	1.82	10,446	4,343.8
Erroneous Power Dev Fractions	7/581	1.20	1,336	725
DC Exciter Self-Excitation Errors	132/1,029	**12.83**	4,242	2,736
Inconsistent Type III Wind Speeds	0/252	0.00	0	0
Suspect PSS2A/2B parameters	311/1,828	**17.01**	61,861	35,510
Incorrect DER_A Tripping Parameters	0/0	0.00	0	0

Table 3.3: Unacceptable and Not Recommended Model Breakdown

Category	Subcategory	Performance	Score (%)
Unacceptable Models	Generator	1,342/6,523	**20.57**
	Exciter	488/6,188	**7.89**
	Stabilizer	241/2,409	**10.00**
	Turbine Governor	0/2,409	0.00
Not Recommended Models	Generator	3,697/6,523	**56.68**
	Exciter	0/6,188	0.00
	Stabilizer	0/2,409	0.00
	Turbine Governor	0/2,409	0.00
User Written Models	Generator	63/8,489	1.74
	Exciter	104/7,845	1.33
	Stabilizer	141/3,501	4.02
	Turbine Governor	575/6,079	**9.46**

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

2020–2021 Winter Peak Case: 2020WIN

Table 3.4: Steady-State Metrics		
Metric	**Performance**	**Score (%)**
P_{max} Exceedances	1/5,632	0.02
P_{min} Exceedances	1/5,632	0.02
Scheduled Interchange Sum	0	-
Voltage Schedule Conflicts	36	-
Tap Step Conflicts	33/21,143	0.16
Tap Step Conflicts (Severe)	19/21,143	0.09
Low Emergency Rating	24/95,605	0.03
High Emergency Rating	2/95,605	0.00
Thermal Overloads	148/95,605	0.15
Thermal Overloads (Severe)	112/95,605	0.12
Generator Reactive at Limits	567/3,916	**14.48**
Generator Reactive Limit Power Factor	399/4,673	**8.54**
Pos Seq TX Circulating Current	0/2,729	0.00
Poor Load Power Factor	116/46,182	0.25
Generator R_{source}:X_{source} Ratio	3/5,632	0.05
Generator Terminal Voltage	113/2,513	4.50
Generator Reactive Capability Curve	0/0	0.00
X/R Ratio Check	217/89,366	0.24
Natural Gas Generator Pmax	N/A	N/A
Natural Gas Generator Pmax (Severe)	N/A	N/A

Table 3.5: Dynamics Metrics				
Metric	**Performance**	**Score (%)**	**Pmax (MW)**	**Qmax (MVAR)**
Generators without Models	161/6,725	2.39	5,726	1,774
Netted Generators with Models	11/4,192	0.26	782	428
Netted Generators	91/4,192	2.17	2,788	931
Gens with Classical Models	14/5,074	0.28	6,450	3,774
Unacceptable Models (total)	1823/17,640	**10.33**	-	-
Not Recommended Models (total)	3694/17,640	**20.94**	-	-
User-Written Models[28]	971/25,787	-		
Inconsistent Reactances	28/4,403	0.64	2,995	1,321
Inconsistent Time Constants	6/4,640	0.13	1,990	1,048
Unreasonable Inertia Constants	459/5,685	**8.07**	31,103	18,358
Unreasonable Saturation Factors	510/4,640	**10.99**	56,468	28,515
Severe Saturation Factors	42/4,640	0.91	5,993	3,041
PSS but no Excitation	7/6,725	0.10	264	376
Inconsistent Speed Damping	122/5,484	2.22	8,206	3,762
Inconsistent Lead-Lag Time Const	36/1,989	1.81	10,603	4,348
Erroneous Power Dev Fractions	7/581	1.20	1,343	725
DC Exciter Self-Excitation Errors	129/1,025	**12.59**	4,814	2,704
Inconsistent Type III Wind Speeds	0/253	0.00	0	0

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

Table 3.5: Dynamics Metrics				
Metric	**Performance**	**Score (%)**	**Pmax (MW)**	**Qmax (MVAR)**
Suspect PSS2A/2B parameters	319/1,842	**17.32**	63,236	35,407
Incorrect DER_A Tripping Parameters	0/0	0.00	0	0

Table 3.6: Unacceptable and Not Recommended Model Breakdown			
Category	**Subcategory**	**Performance**	**Score (%)**
Unacceptable Models	Generator	1,333/6,564	**20.31**
	Exciter	490/6,222	**7.88**
	Stabilizer	242/2,427	**9.97**
	Turbine Governor	0/2,427	0.00
Not Recommended Models	Generator	3,694/6,564	**56.28**
	Exciter	0/6,222	0.00
	Stabilizer	0/2,427	0.00
	Turbine Governor	0/2,427	0.00
User Written Models	Generator	158/8,476	1.86
	Exciter	109/7,827	1.39
	Stabilizer	137/3,456	3.96
	Turbine Governor	567/6,028	**9.41**

2020 Spring Light Load: 2020SLL

Table 3.7: Steady-State Metrics		
Metric	**Performance**	**Score (%)**
P_{max} Exceedances	6/3,583	0.17
P_{min} Exceedances	4/3,583	0.11
Scheduled Interchange Sum	0.001	-
Voltage Schedule Conflicts	38	-
Tap Step Conflicts	33/20,915	0.16
Tap Step Conflicts (Severe)	19/20,915	0.09
Low Emergency Rating	20/94,932	0.02
High Emergency Rating	1/94,932	0.00
Thermal Overloads	49/94,932	0.05
Thermal Overloads (Severe)	44/94,932	0.05
Generator Reactive at Limits	444/2,261	**19.64**
Generator Reactive Limit Power Factor	273/2,940	**9.29**
Pos Seq TX Circulating Current	0/0	0.00
Poor Load Power Factor	156/44,418	0.35
Generator R_{source}:X_{source} Ratio	3/3,583	0.08
Generator Terminal Voltage	93/1,533	**6.07**
Generator Reactive Capability Curve	0/0	0.00
X/R Ratio Check	216/88,753	0.24
Natural Gas Generator Pmax	N/A	N/A
Natural Gas Generator Pmax (Severe)	N/A	N/A

Table 3.8: Dynamics Metrics

Metric	Performance	Score (%)	Pmax (MW)	Qmax (MVAR)
Generators without Models	157/6,639	2.36	6,057	2,019
Netted Gens with Models	8/2,622	0.31	690	420
Netted Generators	54/2,622	2.06	2,153	801
Generators with Classical Models	14/4,999	0.28	15,449	13,200
Unacceptable Models (total)	2063/17,397	**11.86**	-	-
Not Recommended Models (total)	3679/17,397	**21.15**	-	-
User-Written Models[29]	968/25,779	-	-	-
Inconsistent Reactances	36/4,393	0.82	2,983	1,527
Inconsistent Time Constants	6/4,628	0.13	1,939	1,050
Unreasonable Inertia Constants	454/5,665	**8.01**	39,524	27,618
Unreasonable Saturation Factors	511/4,628	**11.04**	55,002	28,228
Severe Saturation Factors	42/4,628	0.91	5,900	3,054
PSS but no Excitation	7/6,639	0.11	264	376
Inconsistent Speed Damping	122/5,464	2.23	8,161	3,828
Inconsistent Lead-Lag Time Const	36/1,968	1.83	10,446	4,344
Erroneous Power Dev Fractions	7/578	1.21	1,343	725
DC Exciter Self-Excitation Errors	132/1,028	**12.84**	4,246	2,736
Inconsistent Type III Wind Speeds	0/0	0.00	0	0
Suspect PSS2A/2B parameters	327/1,807	**18.09**	63,906	35,733
Incorrect DER_A Tripping Parameters	0/0	0.00	0	0

Table 3.9 Unacceptable and Not Recommended Model Breakdown

Category	Subcategory	Performance	Score (%)
Unacceptable Models	Generator	1,334/6,482	**20.58**
	Exciter	488/6,147	7.94
	Stabilizer	241/2,384	**10.11**
	Turbine Governor	0/2,384	0.00
Not Recommended Models	Generator	3,679/6,482	**56.76**
	Exciter	0/6,147	0.00
	Stabilizer	0/2,384	0.00
	Turbine Governor	0/2,384	0.00
User Written Models	Generator	148/8,465	1.75
	Exciter	104/7,808	1.33
	Stabilizer	141/3,472	4.06
	Turbine Governor	575/6,034	**9.53**

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

Texas Interconnection Case Quality Metrics Assessment

The performance and score, evaluated as a percentage, for all of the Texas Interconnection cases are tabulated in **Table 3.10** to **Table 3.18**. **Table 3.10** to **Table 3.12** are for the 2022_SP_Final_NonCnv base case; **Table 3.13**to**Table 3.15** are for the 2023_HWLL_Final_NonCnv base case; **Table 3.16** to **Table 3.18** are for the 2026_SP_Final_NonCnv base case.

2022 Summer Peak Case: 2022_SP_Final_NonCnv

Table 3.10: Steady-State Metrics

Metric	Performance	Score (%)
P_{max} Exceedances	0/846	0.00
P_{min} Exceedances	0/846	0.00
Scheduled Interchange Sum	0	-
Voltage Schedule Conflicts	47	-
Tap Step Conflicts	20/1,501	1.33
Tap Step Conflicts (Severe)	0/1,501	0.00
Low Emergency Rating	0/10,063	0.00
High Emergency Rating	0/10,063	0.00
Thermal Overloads	10/10,063	0.10
Thermal Overloads (Severe)	4/10,063	0.04
Generator Reactive at Limits	46/678	**6.78**
Generator Reactive Limit Power Factor	261/820	**31.83**
Pos Seq TX Circulating Current	0/50	0.00
Poor Load Power Factor	3/4,922	0.06
Generator R_{source}:X_{source} Ratio	0/846	0.00
Generator Terminal Voltage	2/665	0.30
Generator Reactive Capability Curve	0/0	0.00
X/R Ratio Check	38/8,598	0.44
Natural Gas Generator Pmax	N/A	N/A
Natural Gas Generator Pmax (Severe)	N/A	N/A

Table 3.11: Dynamics Metrics

Metric	Performance	Score (%)	Pmax (MW)	Qmax (MVAR)
Generators without Models	23/913	2.52	7,653*	4,349*
Netted Generators with Models	0/824	0.00	0	0
Netted Generators	0/824	0.00	0	0
Generators with Classical Models	0/763	0.00	4,833*	4,492*
Unacceptable Models (total)	48/2,283	2.10	-	-
Not Recommended Models (total)	497/2,283	**21.77**	-	-
User-Written Models[30]	917/36,459	-	-	-
Inconsistent Reactances	5/467	1.07	267	185
Inconsistent Time Constants	4/507	0.79	94	79
Unreasonable Inertia Constants	83/542	**15.31**	3,173	2,311
Unreasonable Saturation Factors	65/507	**12.82**	8,286	5,124
Severe Saturation Factors	6/507	1.18	573	380

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

Table 3.11: Dynamics Metrics

Metric	Performance	Score (%)	Pmax (MW)	Qmax (MVAR)
PSS but no Excitation	0/871	0.00	0	0
Inconsistent Speed Damping	15/531	2.82	611	377
Inconsistent Lead-Lag Time Const	0/202	0.00	0	0
Erroneous Power Dev Fractions	0/33	0.00	0	0
DC Exciter Self-Excitation Errors	7/52	**13.46**	537	371
Inconsistent Type III Wind Speeds	0/0	0.00	0	0
Suspect PSS2A/2B parameters	38/270	**14.07**	2,687	1,751
Incorrect DER_A Tripping Parameters	0/0	0.00	0	0

* 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 3.12: Unacceptable and Not Recommended Model Breakdown

Category	Subcategory	Performance	Score (%)
Unacceptable Models	Generator	30/876	3.42
	Exciter	18/753	2.39
	Stabilizer	0/327	0.00
	Turbine Governor	0/327	0.00
Not Recommended Models	Generator	469/876	**53.54**
	Exciter	28/753	3.72
	Stabilizer	0/327	0.00
	Turbine Governor	0/327	0.00
User Written Models	Generator	364/9351	3.89
	Exciter	229/9,217	2.48
	Stabilizer	30/8,792	0.34
	Turbine Governor	294/9,099	3.23

2023 Light Load Case: 2023_HWLL_Final_NonCnv

Table 3.13: Steady-State Metrics		
Metric	**Performance**	**Score (%)**
P_{max} Exceedances	0/546	0.00
P_{min} Exceedances	2/546	0.37
Scheduled Interchange Sum	0	-
Voltage Schedule Conflicts	62	-
Tap Step Conflicts	24/1,503	1.60
Tap Step Conflicts (Severe)	0/1,503	0.00
Low Emergency Rating	0/10,101	0.00
High Emergency Rating	0/10,101	0.00
Thermal Overloads	3/10,101	0.03
Thermal Overloads (Severe)	1/10,101	0.01
Generator Reactive at Limits	58/414	**14.01**
Generator Reactive Limit Power Factor	41/523	**7.84**
Pos Seq TX Circulating Current	0/50	0.00
Poor Load Power Factor	¾,878	0.06
Generator R_{source}:X_{source} Ratio	0/546	0.00
Generator Terminal Voltage	0/396	0.00
Generator Reactive Capability Curve	0/0	0.00
X/R Ratio Check	37/8,627	0.43
Natural Gas Generator Pmax	N/A	N/A
Natural Gas Generator Pmax (Severe)	N/A	N/A

Table 3.14: Dynamics Metrics				
Metric	**Performance**	**Score (%)**	**Pmax (MW)**	**Qmax (MVAR)**
Generators without Models	27/922	2.93	93,440*	4,855*
Netted Generators with Models	2/527	0.38	419	105
Netted Generators	2/527	0.38	419	105
Generatirs with Classical Models	0/768	0.00	4,833*	4,492*
Unacceptable Models (total)	48/2,280	2.11	-	-
Not Recommended Models (total)	494/2,280	**21.67**	-	-
User-Written Models[31]	914/36,420	-	-	-
Inconsistent Reactances	5/467	1.07	269	96
Inconsistent Time Constants	4/506	0.79	94	56
Unreasonable Inertia Constants	83/542	**15.31**	3,320	1,936
Unreasonable Saturation Factors	65/506	**12.85**	8,890	4,015
Severe Saturation Factors	6/506	1.19	852	288
PSS but no Excitation	0/879	0.00	0	0
Inconsistent Speed Damping	15/531	2.82	620	330
Inconsistent Lead-Lag Time Const	0/202	0.00	0	0
Erroneous Power Dev Fractions	0/33	0.00	0	0
DC Exciter Self-Excitation Errors	7/52	**13.46**	543	305
Inconsistent Type III Wind Speeds	0/0	0.00	0	0

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

Table 3.14: Dynamics Metrics				
Metric	Performance	Score (%)	Pmax (MW)	Qmax (MVAR)
Suspect PSS2A/2B Parameters	38/270	**14.07**	2,828	1,558
Incorrect DER_A Tripping Parameters	0/0	0.00	0	0

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

Table 3.15: Unacceptable and Not Recommended Model Breakdown			
Category	Subcategory	Performance	Score (%)
Unacceptable Models	Generator	30/876	3.42
	Exciter	18/750	2.40
	Stabilizer	0/327	0.00
	Turbine Governor	0/327	0.00
Not Recommended Models	Generator	469/876	**53.54**
	Exciter	25/750	3.33
	Stabilizer	0/327	0.00
	Turbine Governor	0/327	0.00
User Written Models	Generator	364/9,342	3.90
	Exciter	226/9,205	2.46
	Stabilizer	30/8,783	0.34
	Turbine Governor	294/9,090	3.23

2026 Summer Peak Case: 2026_SP_Final_NonCnv

Table 3.16: Steady-State Metrics		
Metric	Performance	Score (%)
P_{max} Exceedances	0/860	0.00
P_{min} Exceedances	0/860	0.00
Scheduled Interchange Sum	0	-
Voltage Schedule Conflicts	37	-
Tap Step Conflicts	21/1,504	1.40
Tap Step Conflicts (Severe)	0/1,504	0.00
Low Emergency Rating	0/10,160	0.00
High Emergency Rating	0/10,160	0.00
Thermal Overloads	5/10,160	0.05
Thermal Overloads (Severe)	4/10,160	0.04
Generator Reactive at Limits	111/682	**16.28**
Generator Reactive Limit Power Factor	105/834	**12.59**
Pos Seq TX Circulating Current	0/52	0.00
Poor Load Power Factor	2/4,982	0.04
Generator R_{source}:X_{source} Ratio	0/860	0.00
Generator Terminal Voltage	2/669	0.30
Generator Reactive Capability Curve	0/0	0.00
X/R Ratio Check	38/8,663	0.44
Natural Gas Generator Pmax	N/A	N/A
Natural Gas Generator Pmax (Severe)	N/A	N/A

Table 3.17: Dynamics Metrics				
Metric	**Performance**	**Score (%)**	**Pmax (MW)**	**Qmax (MVAR)**
Generators without Models	31/925	3.35	10,931*	5,365*
Netted Generators with Models	2/838	0.24	419	124
Netted Generators	2/838	0.24	419	124
Generators with Classical Models	0/772	0.00	4,833*	4,492*
Unacceptable Models (total)	48/2,284	2.10	-	-
Not Recommended Models (total)	497/2,284	**21.76**	-	-
User-Written Models[32]	919/36,409	-	-	-
Inconsistent Reactances	5/467	1.07	267	96
Inconsistent Time Constants	4/506	0.79	94	56
Unreasonable Inertia Constants	83/542	**15.31**	3,173	1,936
Unreasonable Saturation Factors	65/506	**12.85**	8,286	3,963
Severe Saturation Factors	6/506	1.19	573	288
PSS but no Excitation	0/882	0.00	0	0
Inconsistent Speed Damping	15/531	2.82	611	330
Inconsistent Lead-Lag Time Const	0/202	0.00	0	0
Erroneous Power Dev Fractions	0/33	0.00	0	0
DC Exciter Self-Excitation Errors	7/52	**13.46**	537	305
Inconsistent Type III Wind Speeds	0/0	0.00	0	0
Suspect PSS2A/2B Parameters	38/270	**14.07**	2687	1,495
Incorrect DER_A Tripping Parameters	0/0	0.00	0	0

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

Table 3.18: Unacceptable and Not Recommended Model Breakdown			
Category	**Subcategory**	**Performance**	**Score (%)**
Unacceptable Models	Generator	30/876	3.42
	Exciter	18/754	2.39
	Stabilizer	0/327	0.00
	Turbine Governor	0/327	0.00
Not Recommended Models	Generator	469/876	**53.54**
	Exciter	28/754	3.71
	Stabilizer	0/327	0.00
	Turbine Governor	0/327	0.00
User Written Models	Generator	364/9,338	3.90
	Exciter	230/9,205	2.50
	Stabilizer	30/8,779	0.34
	Turbine Governor	295/9,087	3.25

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

Western Interconnection Case Quality Metrics Assessment

The performance and score, evaluated as a percentage, for all of the Western Interconnection cases are tabulated in Table 3.19 to Table 3.27. Table 3.19 to Table 3.21 are for the 20HS3a base case; Table 3.22 to Table 3.24 are for the 21HW2a base case; Table 3.25 to Table 3.27 are for the 20LS1a base case.

2020 Summer Peak Case: 20HS3a

Table 3.19: Steady-State Metrics

Metric	Performance	Score (%)
P_{max} Exceedances	7/3,100	0.23
P_{min} Exceedances	10/3,100	0.32
Scheduled Interchange Sum	-0.0	-
Voltage Schedule Conflicts	55	-
Tap Step Conflicts	55/8,878	0.62
Tap Step Conflicts (Severe)	4/8,878	0.05
Low Emergency Rating	99/26,657	0.37
High Emergency Rating	2/26,657	0.01
Thermal Overloads	14/28,314	0.05
Thermal Overloads (Severe)	10/28,314	0.04
Generator Reactive at Limits	126/2,291	**5.50**
Generator Reactive Limit Power Factor	344/3,419	**10.06**
Pos Seq TX Circulating Current	0/1,814	0.00
Poor Load Power Factor	4/7,348	0.05
Generator R_{source}:X_{source} Ratio	2/4,312	0.05
Generator Terminal Voltage	85/1,409	**6.03**
Generator Reactive Capability Curve	20/577	3.47
X/R Ratio Check	97/51,069	0.19
Natural Gas Generator Pmax	599/712	**84.13**
Natural Gas Generator Pmax (Severe)	31/712	4.35

Table 3.20: Dynamics Metrics

Metric	Performance	Score (%)	Pmax (MW)	Qmax (MVAR)
Generators without Models	229/3,422	**6.69**	15,306	7,734
Netted Generators with Models	4/3,503	0.16	90	49
Netted Generators	81/2,516	3.22	3,731	708
Generators with Classical Models	0/4,312	0.00	0	0
Unacceptable Models (total)	474/12,698	3.73	-	-
Not Recommended Models (total)	1382/12,698	**10.88**	-	-
User-Written Models[33]	0/26,378	-	-	-
Inconsistent Reactances	106/3,274	3.24	2,748	1,408
Inconsistent Time Constants	188/3,274	**5.74**	3,166	1,571
Unreasonable Inertia Constants	390/3,274	**11.91**	17,392*	10,844*
Unreasonable Saturation Factors	637/3,274	**19.46**	29,672*	14,407*
Severe Saturation Factors	210/3,274	**6.41**	6,628*	3,160*
PSS but no Excitation	13/1,811	0.72	1,015	343

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

Table 3.20: Dynamics Metrics				
Metric	**Performance**	**Score (%)**	**Pmax (MW)**	**Qmax (MVAR)**
Inconsistent Speed Damping	237/3,274	**7.24**	6,698	2,861
Inconsistent Lead-Lag Time Const	34/1,373	2.48	3,043	1,929
Erroneous Power Dev Fractions	5/186	2.69	552	220
DC Exciter Self-Excitation Errors	30/562	**5.34**	1,277	601
Inconsistent Type III Wind Speeds	1/76	1.32	46	23
Suspect PSS2A/2B Parameters	50/1,582	3.16	33,056	14,449
Incorrect DER_A Tripping Parameters	0/0	0.00	0	0

* 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	146/4,312	3.39
	Exciter	141/4,047	3.48
	Stabilizer	65/1,892	3.44
	Turbine Governor	122/2,447	**4.99**
Not Recommended Models	Generator	1029/4,312	**23.86**
	Exciter	288/4,047	**7.12**
	Stabilizer	0/1,892	0.00
	Turbine Governor	65/2,447	2.66
User Written Models	Generator	0/4,312	0.00
	Exciter	0/4,047	0.00
	Stabilizer	0/1,892	0.00
	Turbine Governor	0/2,447	0.00

2020–2021 Winter Peak Case: 21HW2a

Table 3.22: Steady-State Metrics

Metric	Performance	Score (%)
P_{max} Exceedances	14/2,547	0.55
P_{min} Exceedances	15/2,547	0.59
Scheduled Interchange Sum	-0.0	-
Voltage Schedule Conflicts	54	-
Tap Step Conflicts	51/8,987	0.57
Tap Step Conflicts (Severe)	5/8,987	0.06
Low Emergency Rating	93/26,917	0.35
High Emergency Rating	7/26,917	0.03
Thermal Overloads	7/28,588	0.02
Thermal Overloads (Severe)	7/28,588	0.02
Generator Reactive at Limits	86/1,834	4.69
Generator Reactive Limit Power Factor	362/3,520	10.28
Pos Seq TX Circulating Current	0/1,856	0.00
Poor Load Power Factor	9/6,873	0.13
Generator R_{source}:X_{source} Ratio	5/4,426	0.11
Generator Terminal Voltage	119/1,925	6.18
Generator Reactive Capability Curve	15/445	3.37
X/R Ratio Check	101/52,102	0.19
Natural Gas Generator Pmax	N/A	N/A
Natural Gas Generator Pmax (Severe)	N/A	N/A

Table 3.23: Dynamics Metrics

Metric	Performance	Score (%)	Pmax (MW)	Qmax (MVAR)
Generators without Models	290/3,510	8.26	37,646	8,436
Netted Generators with Models	4/3,570	0.20	151	84
Netted Generators	60/2,050	2.93	4,059	593
Generators with Classical Models	0/4,426	0.00	0	0
Unacceptable Models (total)	432/12,785	3.38	-	-
Not Recommended Models (total)	1302/12,785	10.18	-	-
User-Written Models[34]	0/25,378	-	-	-
Inconsistent Reactances	115/3,269	3.52	3,092	1,616
Inconsistent Time Constants	201/3,269	6.15	3,431	1,672
Unreasonable Inertia Constants	389/3,269	11.90	16,732*	10,535*
Unreasonable Saturation Factors	621/3,269	19.00	26,704*	13,002*
Severe Saturation Factors	200/3,269	6.12	5,404*	2,596*
PSS but no Excitation	12/1,816	0.66	1,069	662
Inconsistent Speed Damping	235/3,269	7.19	5,913	2,549
Inconsistent Lead-Lag Time Const	32/1,338	2.39	2,753	1,728
Erroneous Power Dev Fractions	6/184	3.26	553	220
DC Exciter Self-Excitation Errors	32/544	5.88	1,495	643
Inconsistent Type III Wind Speeds	1/66	1.52	46	23

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

Table 3.23: Dynamics Metrics				
Metric	Performance	Score (%)	Pmax (MW)	Qmax (MVAR)
Suspect PSS2A/2B Parameters	65/1,604	4.05	34,269	15,173
Incorrect DER_A Tripping Parameters	0/0	0.00	0	0

* 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	136/4,426	3.07
	Exciter	128/4,049	3.16
	Stabilizer	57/1,887	3.02
	Turbine Governor	111/2,423	**4.58**
Not Recommended Models	Generator	963/4,426	**21.76**
	Exciter	273/4,049	**6.74**
	Stabilizer	0/1,887	0.00
	Turbine Governor	66/2,423	2.72
User Written Models	Generator	0/4,426	0.00
	Exciter	0/4,049	0.00
	Stabilizer	0/1,887	0.00
	Turbine Governor	0/2,423	0.00

2020 Summer Light Load Case: 20LS1a

Table 3.25: Steady-State Metrics		
Metric	Performance	Score (%)
P_{max} Exceedances	3/2,174	0.14
P_{min} Exceedances	19/2,174	0.87
Scheduled Interchange Sum	-0.0	-
Voltage Schedule Conflicts	56	-
Tap Step Conflicts	53/8,877	0.60
Tap Step Conflicts (Severe)	6/8,877	0.07
Low Emergency Rating	99/26,660	0.37
High Emergency Rating	2/26,660	0.01
Thermal Overloads	4/28,312	0.01
Thermal Overloads (Severe)	2/28,312	0.01
Generator Reactive at Limits	88/1,551	**5.67**
Generator Reactive Limit Power Factor	362/3,416	**10.60**
Pos Seq TX Circulating Current	0/1,816	0.00
Poor Load Power Factor	5/6,467	0.08
Generator R_{source}:X_{source} Ratio	2/4,315	0.05
Generator Terminal Voltage	93/1,961	4.74
Generator Reactive Capability Curve	8/367	2.18
X/R Ratio Check	97/51,623	0.19
Natural Gas Generator Pmax	N/A	N/A
Natural Gas Generator Pmax (Severe)	N/A	N/A

Table 3.26: Dynamics Metrics				
Metric	**Performance**	**Score (%)**	**Pmax (MW)**	**Qmax (MVAR)**
Generators without Models	235/3,438	**6.84**	16,044	8,052
Netted Generators with Models	5/3,489	0.29	-248	113
Netted Generators	48/1,696	2.83	2,279	466
Generators with Classical Models	0/0	0.00	0	0
Unacceptable Models (total)	482/12,705	3.79	-	-
Not Recommended Models (total)	1375/12,705	**10.82**	-	-
User-Written Models[35]	0/25,032	-	-	-
Inconsistent Reactances	106/3,275	3.24	-	-
Inconsistent Time Constants	188/3,275	**5.74**	3,166	1,584
Unreasonable Inertia Constants	393/3,275	**12.00**	17,381*	10,843*
Unreasonable Saturation Factors	635/3,275	**19.39**	29,679*	14,604*
Severe Saturation Factors	208/3,275	**6.35**	6,628*	3,240*
PSS but no Excitation	10/1,808	0.55	565	306
Inconsistent Speed Damping	237/3,275	**7.24**	6,629	2,864
Inconsistent Lead-Lag Time Const	34/1,374	2.47	3,041	1,895
Erroneous Power Dev Fractions	6/187	3.21	553	220
DC Exciter Self-Excitation Errors	31/561	**5.53**	1,306	580
Inconsistent Type III Wind Speeds	1/79	1.27	46	23
Suspect PSS2A/2B Parameters	50/1,579	3.17	3,2973	14,416
Incorrect DER_A Tripping Parameters	0/0	0.00	0	0

* 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	146/4,315	3.38
	Exciter	144/4,051	3.55
	Stabilizer	66/1,890	3.49
	Turbine Governor	126/2,449	**5.14**
Not Recommended Models	Generator	1028/4,315	**23.82**
	Exciter	282/4,051	**6.96**
	Stabilizer	0/1,890	0.00
	Turbine Governor	65/2,449	2.65
User Written Models	Generator	0/4,315	0.00
	Exciter	0/4,051	0.00
	Stabilizer	0/1,890	0.00
	Turbine Governor	0/2,449	0.00

[35] 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.
- Past nomenclature for the WI Winter case was incorrect in previous assessments and has been corrected in this version of the NERC *2020 Case Quality Metrics Assessment*.
- 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 all Interconnections. The EI, however, is improving this metric on a year-over-year basis and the WI has made significant improvements in this year's assessment. 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. In particular, the saturation factors with severe inaccuracies should be a priority for the WI. 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 and 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. All Interconnections have a consistently high or worsening score for these metrics. These generator models contain bad data.
- A general decline in performance regarding generators above the modeling threshold not having generator models have been observed. The TI is an exception to this general trend for this year. Generators flagged are indicative of a case setup issue in addition to being a suspect condition for such generators.
- A noticeable historic 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%. This is especially evident in the summer peak cases in those Interconnections.

- In the unacceptable or not recommended model metrics, all Interconnections demonstrate either a consistently high performance or improving score with most instances being improving.[36] Of special note is the TI and WI that have maintained the unacceptable model score below 5%. The majority of models that are not recommended use the genrou generator model.
- The WI and EI should ensure their generator terminal voltages, when such generators at the modeled powerflow bus regulate other powerflow busses, should remain within the 0.95 to 1.05 boundary. Generators outside those boundaries signify a poor dispatch based on discussions with the NERC Power Plant Modeling and Verification Task Force (PPMVTF).
- The TI had a large increase of Generator Reactive Limit Power Factor metric for their 2022 Summer Peak Case.
- The WI had an increase of performance for the Generator Reactive at Limits, Generator Terminal Voltage, Natural Gas Generator, and Reactive Capability Curve metrics. All of these metric are related to case dispatch or suspect data involving reactive capability of generators. Additionally, the WI's natural gas generation in the case does not reflect the ambient thermal impact related to changes in steady-state active power limits for natural gas generators based on such ambient temperature changes between the seasonal cases; such data is suspect.

The WI had an increase of performance for the Generator Reactive at Limits, Generator Terminal Voltage, Natural Gas Generator, and Reactive Capability Curve metrics. All of these metric are related to case dispatch or suspect data involving reactive capability of generators. Additionally, the WI's natural gas generation in the case does not reflect the ambient thermal impact related to changes in steady-state active power limits for natural gas generators based on such ambient temperature changes between the seasonal cases; such data is suspect.
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% 3 metric consistent high score or improving
	Dynamics	Most metrics below 5% 3 metrics consistent high score 1 metric generally improving or consistent score above 5% 1 metric improving
Texas	Powerflow	Most metrics below 5% 1 metric worsening by significant bounds in one base case 2 metrics worsening or consistent high score
	Dynamics	Most metrics below 5% 2 metric has consistent performance 2 metrics improving performance
Western	Powerflow	Most metrics below 5% 3 metrics worsening or consistent high score 1 metric consistent high score to past performance 1 metric major improvement

[36] WECC and NERC have jointly been reviewing this issue for the WI, and all generators without acceptable models have been identified in 2020. Corrections to this initial list are still ongoing.

Table 4 2: Interconnection Scorecard		
Interconnection	**Metrics**	**Evaluation**
	Dynamics	Most metrics below 5% Many metrics below 5% trending higher Many metrics have a consistently high score 1 metric 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.
- NERC should work with the MOD-032 designees to improve the process for excluding verified data for “Suspect Data” metrics so that such data does not get counted in the performance score.
- The MOD-032 designees for the EI and TI should focus on verifying the saturation factor curves and provide exceptions for verified generator parameters via a whitelist. The WI should focus on the severe saturation factor generators as a priority. Each MOD-032 designee should review the listed units with unreasonable saturation factors and work with their respective Generator Owners (GOs) to review model validation test reports to ensure accuracy.
- Generators above the modeling threshold for each Interconnection should have a model, one that conforms to the MOD-032 designees modeling practices (and all models should adhere to the NERC Acceptable Model List). In the TI, a general improvement warrants lesser attention; however, the MOD-032 designees should review their model building process and enforce their modeling thresholds. The large majority of not recommended models is the generator model GENROU. MOD-032 designees are encouraged to read the *Modeling Notification: Use of GENTPJ Generator Model*[37] for recommended models to better represent the effect of stator current on saturation.
- The MOD-032 designees for each Interconnection should review the generators identified in the Generator Reactive Limit Power Factor to determine if the power factor is correct and provide verified exceptions via a whitelist.
- The MOD-032 designee for the WI should actively work with its GOs to correct units with inconsistent time constants. The metric is flagging generator model parameters that are not physically realistic.
- The MOD-032 designee for the WI should work with its respective GOs to correct the use of speed damping coefficients on units that are not modeled as classical machines. These values should be zero for generation units flagged.
- Each MOD-032 designee should work with their respective GOs to correct issues associated with the dc exciter self-excitation errors. This report provides some information in the description of the metric on how to correct these issues.
- The MOD-032 designee for the EI and TI should implement consistent usage of the WMOD flag in PSS®E to ensure the wind generators that get exceptions to the metrics are not falsely counted against their respective performance.
- The MOD-032 designees for the WI should review the additional units that were identified as netted that fall above the netting threshold in WECC and fix those units by getting a verified and representative model.
- The MOD-032 designees for the WI and EI should monitor the generator terminal bus voltages when dispatching their Interconnection-wide base case and ensure such voltages remain in the 0.95 to 1.05 range. Generators outside those boundaries signify a poor dispatch based on discussions with the NERC PPMVTF, and as such signify a suspect dispatch in the Interconnection-wide base case.

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

- 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 flagged in those metrics to begin targeting efforts for model improvement and replacement.
- The MOD-032 designee for the TI should review the increase of flagged models in the Generator Reactive Limit Power Factor metric in the 2022 Summer peak case and address the modeling concern of having suspiciously high reactive capability (in both negative and positive range) for that particular case and ensure the anomaly is not repeatable.
- The MOD-032 designee for the WI should review their case dispatch procedure and ensure that generator reactive capability curves are entered properly, that generator bus voltages stay within 0.95 and 1.05 p.u., and that generators are not dispatched to their reactive maximum capability.

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

Eastern Interconnection

Table A.1: Heavy Summer Cases							
Type of Metric	Metric	2016 Score (%)	2017 Score (%)	2018 Score (%)	2019 Score (%)	2020 Score (%)	Performance
Powerflow	P_{max} Exceedances	0.1	0.06	0.15	0.10	0.05	
	P_{min} Exceedances	0.02	0.03	0.10	0.1	0.02	
	Scheduled Interchange Sum	0.001	-0.001	0	0.01	0	
	Voltage Schedule Conflicts	25	22	27	14	29	
	Tap Step Conflicts	0.04	0.07	0.07	0.07	0.16	
	Tap Step Conflicts (Severe)	0.02	0.03	0.03	0.01	0.09	
	Low Emergency Rating	0.01	0	0.00	0.00	0.02	
	High Emergency Rating	0.1	0.1	0.03	0.00	0.00	
	Thermal Overloads	0.17	0.1	0.17	0.19	0.13	
	Thermal Overloads (Severe)	0.11	0.07	0.13	0.15	0.11	
	Generator Reactive at Limits	**24.68**	**25.34**	**18.82**	**18.88**	**16.52**	
	Generator Reactive Limit Power Factor	**13.33**	**13.63**	**13.16**	**12.14**	**10.30**	
	Pos Seq TX Circulating Current	0.00	0.00	0.00	0.00	0.00	
	Poor Load Power Factor	0.27	0.32	0.35	0.29	0.30	
	Generator R_{source}:X_{source} Ratio	0.00	0.00	0.00	0.00	0.06	
	Generator Terminal Voltage	N/A	N/A	N/A	**6.33**	**5.53**	
	Generator Reactive Capability Curve	N/A	N/A	N/A	0.00	0.00	
	X/R Ratio Check	N/A	N/A	N/A	0.25	0.25	
	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	0.97	1.31	1.62	1.96	2.26	
	Netted Generators with Models	0.46	0.36	0.26	0.64	0.47	
	Netted Generators	1.21	1.5	3.58	2.65	2.79	
	Generators with Classical Models	0.39	0.32	0.26	0.25	0.28	
	Unacceptable Models	N/A	N/A	N/A	**11.83**	**11.81**	
	Not Recommended Models	N/A	N/A	N/A	**23.56**	**21.09**	
	User-Written Models[38]	N/A	N/A	N/A	N/A	-	
	Inconsistent Reactances	0.38	0.21	0.23	0.24	0.82	
	Inconsistent Time Constants	0.04	0.11	0.11	0.11	0.13	
	Unreasonable Inertia Constants	**10.83**	**10.14**	**8.04**	**8.44**	**8.06**	
	Unreasonable Saturation Factors	**44.44**	**21.92**	**22.22**	**10.76**	**11.00**	
	Severe Saturation Factors	1.13	0.94	0.94	0.81	0.90	
	PSS but no Excitation	0.22	0.14	0.11	0.06	0.10	
	Inconsistent Speed Damping	**6.41**	4.06	3.33	3.13	2.22	
	Inconsistent Lead-Lag Time Const	1.98	2.01	1.64	2.06	1.82	
	Erroneous Power Dev Fractions	**58.04**	1.00	1.02	1.27	1.20	

[38] Performance not tracked

Table A.1: Heavy Summer Cases							
Type of Metric	Metric	2016 Score (%)	2017 Score (%)	2018 Score (%)	2019 Score (%)	2020 Score (%)	Performance
	DC Exciter Self-Excitation Errors	**11.38**	**11.35**	**10.34**	**10.58**	**12.83**	
	Inconsistent Type III Wind Speeds	0.27	0.25	0.00	0.00	0.00	
	Suspect PSS2A/2B parameters	N/A	N/A	**16.41**	**16.69**	**17.01**	
	Incorrect DER_A Tripping Parameters	N/A	N/A	N/A	0.00	0.00	

Table A.2 Heavy Winter Cases							
Type of Metric	Metric	2016 Score (%)	2017 Score (%)	2018 Score (%)	2019 Score (%)	2020 Score (%)	Performance
Powerflow	P_{max} Exceedances	0.34	0.18	0.31	0.10	0.02	
	P_{min} Exceedances	0.04	0.07	0.08	0.16	0.02	
	Scheduled Interchange Sum	-0.001	-0.001	0	0	0	
	Voltage Schedule Conflicts	36	22	31	16	36	
	Tap Step Conflicts	0.04	0.06	0.07	0.07	0.16	
	Tap Step Conflicts (Severe)	0.02	0.01	0.02	0.00	0.09	
	Low Emergency Rating	0.02	0.00	0.00	0.00	0.03	
	High Emergency Rating	0.11	0.09	0.03	0.00	0.00	
	Thermal Overloads	0.15	0.09	0.13	0.18	0.15	
	Thermal Overloads (Severe)	0.12	0.06	0.11	0.14	0.12	
	Generator Reactive at Limits	**22.55**	**23.20**	**18.35**	**17.99**	**14.48**	
	Generator Reactive Limit Power Factor	**25.53**	**12.11**	**11.28**	**11.14**	**8.54**	
	Pos Seq TX Circulating Current	0.00	0.00	0.00	0.00	0.00	
	Poor Load Power Factor	0.24	0.25	0.27	0.24	0.25	
	Generator R_{source}:X_{source} Ratio	0.00	0.00	0.00	0.00	0.05	
	Generator Terminal Voltage	N/A	N/A	N/A	**7.75**	4.50	
	Generator Reactive Capability Curve	N/A	N/A	N/A	0.00	0.00	
	X/R Ratio Check	N/A	N/A	N/A	0.26	0.24	
	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	1.15	1.38	1.72	2.07	2.39	
	Netted Generators with Models	0.56	0.29	0.23	0.71	0.26	
	Netted Generators	1.58	1.16	4.07	2.45	2.17	
	Gens with Classical Models	0.38	0.32	0.25	0.27	0.28	
	Unacceptable Models	N/A	N/A	N/A	**13.87**	**10.33**	
	Not Recommended Models	N/A	N/A	N/A	**23.48**	**20.94**	
	User-Written Models[39]	N/A	N/A	N/A	N/A	-	
	Inconsistent Reactances	0.38	0.21	0.23	0.27	0.64	
	Inconsistent Time Constants	0.04	0.11	0.11	0.11	0.13	

[39] Performance not tracked

Table A.2 Heavy Winter Cases							
Type of Metric	Metric	2016 Score (%)	2017 Score (%)	2018 Score (%)	2019 Score (%)	2020 Score (%)	Performance
	Unreasonable Inertia Constants	**10.88**	**10.19**	**8.11**	**8.49**	**8.07**	
	Unreasonable Saturation Factors	**44.29**	**21.87**	**22.19**	**10.75**	**10.99**	
	Severe Saturation Factors	1.17	0.97	0.94	0.81	0.91	
	PSS but no Excitation	0.22	0.16	0.11	0.06	0.10	
	Inconsistent Speed Damping	**6.43**	4.05	3.33	3.12	2.22	
	Inconsistent Lead-Lag Time Const	1.97	1.99	1.63	2.16	1.81	
	Erroneous Power Dev Fractions	**57.95**	1.00	1.36	1.27	1.20	
	DC Exciter Self-Excitation Errors	**11.37**	**11.40**	**10.54**	**10.77**	**12.59**	
	Inconsistent Type III Wind Speeds	0.26	0.25	0.00	0.00	0.00	
	Suspect PSS2A/2B parameters	N/A	N/A	**16.51**	**16.67**	**17.32**	
	Incorrect DER_A Tripping Parameters	N/A	N/A	N/A	0.00	0.00	

Table A.3: Light Spring Cases							
Type of Metric	Metric	2016 Score (%)	2017 Score (%)	2018 Score (%)	2019 Score (%)	2020 Score (%)	Performance
Powerflow	P_{max} Exceedances	0.03	0.03	0.11	0.06	0.17	
	P_{min} Exceedances	0.08	0.03	0.06	0.21	0.11	
	Scheduled Interchange Sum	0.0	-0.3	0	0	0.001	
	Voltage Schedule Conflicts	35	21	32	13	38	
	Tap Step Conflicts	0.09	0.07	0.06	0.06	0.16	
	Tap Step Conflicts (Severe)	0.02	0.03	0.02	0.00	0.09	
	Low Emergency Rating	0.02	0.00	0.00	0.00	0.02	
	High Emergency Rating	0.11	0.1	0.03	0.00	0.00	
	Thermal Overloads	0.08	0.04	0.06	0.07	0.05	
	Thermal Overloads (Severe)	0.05	0.03	0.05	0.06	0.05	
	Generator Reactive at Limits	**33.74**	**30.03**	**23.62**	**20.87**	**19.64**	
	Generator Reactive Limit Power Factor	**14.21**	**13.99**	**13.65**	**13.65**	**9.29**	
	Pos Seq TX Circulating Current	0.00	0.00	0.00	0.00	0.00	
	Poor Load Power Factor	0.40	0.31	0.38	0.38	0.35	
	Generator R_{source}:X_{source} Ratio	0.00	0.00	0.00	0.00	0.08	
	Generator Terminal Voltage	N/A	N/A	N/A	**13.51**	**6.07**	
	Generator Reactive Capability Curve	N/A	N/A	N/A	0.00	0.00	
	X/R Ratio Check	N/A	N/A	N/A	0.25	0.24	
	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	0.94	1.25	1.68	1.81	2.36	
	Netted Gens with Models	0.71	0.40	0.24	1.05	0.31	
	Netted Generators	1.82	1.29	**5.40**	2.75	2.06	
	Generators with Classical Models	0.39	0.32	0.26	0.23	0.28	

Table A.3: Light Spring Cases							
Type of Metric	Metric	2016 Score (%)	2017 Score (%)	2018 Score (%)	2019 Score (%)	2020 Score (%)	Performance
	Unacceptable Models	N/A	N/A	N/A	**13.95**	**11.86**	
	Not Recommended Models	N/A	N/A	N/A	**23.79**	**21.15**	
	User-Written Models[40]	N/A	N/A	N/A	N/A	-	
	Inconsistent Reactances	0.36	0.21	0.24	0.25	0.82	
	Inconsistent Time Constants	0.04	0.11	0.11	0.11	0.13	
	Unreasonable Inertia Constants	**10.61**	**10.15**	**8.01**	**8.32**	**8.01**	
	Unreasonable Saturation Factors	**44.43**	**21.83**	**22.12**	**10.78**	**11.04**	
	Severe Saturation Factors	1.13	0.90	0.94	0.81	0.91	
	PSS but no Excitation	0.22	0.14	0.11	0.06	0.11	
	Inconsistent Speed Damping	**6.23**	4.07	3.35	3.12	2.23	
	Inconsistent Lead-Lag Time Const	1.99	2.01	1.64	2.08	1.83	
	Erroneous Power Dev Fractions	**58.07**	1.00	1.02	1.09	1.21	
	DC Exciter Self-Excitation Errors	**11.34**	**11.27**	**10.27**	**10.58**	**12.84**	
	Inconsistent Type III Wind Speeds	0.27	0.25	0.00	0.00	0.00	
	Suspect PSS2A/2B parameters	N/A	N/A	**17.85**	**17.73**	**18.09**	
	Incorrect DER_A Tripping Parameters	N/A	N/A	N/A	0.00	0.00	

Texas Interconnection

Table A.4: Heavy Summer Peak Cases							
Type of Metric	Metric	2016 Score (%)	2017 Score (%)	2018 Score (%)	2019 Score (%)	2020 Score (%)	Performance
Powerflow	P_{max} Exceedances	**24.50**	0.00	0.00	0.00	0.00	
	P_{min} Exceedances	2.60	0.00	0.00	0.00	0.00	
	Scheduled Interchange Sum	0.0	0.0	0	0	0	
	Voltage Schedule Conflicts	4	3	0	5	47	
	Tap Step Conflicts	3.92	3.33	3.21	0.07	1.33	
	Tap Step Conflicts (Severe)	0.17	0.08	0.00	0.00	0.00	
	Low Emergency Rating	0.01	0.00	0.00	0.00	0.00	
	High Emergency Rating	0.08	0.01	0.02	0.03	0.00	
	Thermal Overloads	0.16	0.22	0.13	0.06	0.10	
	Thermal Overloads (Severe)	0.14	0.17	0.10	0.04	0.04	
	Generator Reactive at Limits	**23.44**	**20.24**	**14.11**	**6.37**	**6.78**	
	Generator Reactive Limit Power Factor	**10.56**	**11.33**	**11.11**	**13.73**	**31.83**	
	Pos Seq TX Circulating Current	0.00	0.00	0.00	0.00	0.00	
	Poor Load Power Factor	**22.39**	**19.71**	0.11	0.13	0.06	
	Generator R_{source}:X_{source} Ratio	0.00	0.00	0.00	0.13	0.00	
	Generator Terminal Voltage	N/A	N/A	N/A	1.92	0.30	

[40] Performance not tracked

Table A.4: Heavy Summer Peak Cases							
Type of Metric	**Metric**	**2016 Score (%)**	**2017 Score (%)**	**2018 Score (%)**	**2019 Score (%)**	**2020 Score (%)**	**Performance**
	Generator Reactive Capability Curve	N/A	N/A	N/A	0.00	0.00	
	X/R Ratio Check	N/A	N/A	N/A	0.43	0.44	
	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	4.38	3.07	4.07	**5.20**	2.52	
	Netted Gens with Models	0.76	1.26	0.00	0.00	0.00	
	Netted Generators	2.27	2.16	0.14	0.00	0.00	
	Generators with Classical Models	0.71	0.31	1.55	2.15	0.00	
	Unacceptable Models	N/A	N/A	N/A	2.96	2.10	
	Not Recommended Models	N/A	N/A	N/A	**24.37**	**21.77**	
	User-Written Models[41]	N/A	N/A	N/A	N/A	-	
	Inconsistent Reactances	2.16	1.50	1.25	0.62	1.07	
	Inconsistent Time Constants	0.00	0.40	0.42	0.40	0.79	
	Unreasonable Inertia Constants	**13.17**	**15.33**	**11.30**	**14.01**	**15.31**	
	Unreasonable Saturation Factors	**43.01**	**20.08**	**20.12**	**13.17**	**12.82**	
	Severe Saturation Factors	2.12	2.21	1.45	1.20	1.18	
	PSS but no Excitation	0.16	0.00	0.00	0.00	0.00	
	Inconsistent Speed Damping	**9.04**	**11.01**	3.78	3.10	2.82	
	Inconsistent Lead-Lag Time Const	0.00	0.00	0.00	0.00	0.00	
	Erroneous Power Dev Fractions	**24.00**	0.00	0.00	0.00	0.00	
	DC Exciter Self-Excitation Errors	**10.81**	**9.86**	**11.67**	**12.50**	**13.46**	
	Inconsistent Type III Wind Speeds	0.00	0.00	0.00	0.00	0.00	
	Suspect PSS2A/2B parameters	N/A	N/A	**12.5**	**16.92**	**14.07**	
	Incorrect DER_A Tripping Parameters	N/A	N/A	N/A	0.00	0.00	

Table A.5: Heavy Wind Light Load Cases							
Type of Metric	**Metric**	**2016 Score (%)**	**2017 Score (%)**	**2018 Score (%)**	**2019 Score (%)**	**2020 Score (%)**	**Performance**
Powerflow	P_{max} Exceedances	3.32	0.00	0.00	0.00	0.00	
	P_{min} Exceedances	**16.83**	0.00	0.00	0.00	0.37	
	Scheduled Interchange Sum	0.0	0.0	0	0	0	
	Voltage Schedule Conflicts	6	6	0	12	62	
	Tap Step Conflicts	3.50	3.34	3.21	0.00	1.60	
	Tap Step Conflicts (Severe)	0.00	0.00	0.00	0.00	0.00	
	Low Emergency Rating	0.01	0.00	0.00	0.00	0.00	
	High Emergency Rating	0.08	0.01	0.02	0.03	0.00	
	Thermal Overloads	0.27	0.19	0.25	0.05	0.03	
	Thermal Overloads (Severe)	0.21	0.15	0.18	0.04	0.01	

[41] Performance not tracked

Table A.5: Heavy Wind Light Load Cases

Type of Metric	Metric	2016 Score (%)	2017 Score (%)	2018 Score (%)	2019 Score (%)	2020 Score (%)	Performance
	Generator Reactive at Limits	**30.11**	**29.31**	**17.34**	**12.59**	**14.01**	
	Generator Reactive Limit Power Factor	**11.89**	**10.66**	**12.39**	**7.82**	**7.84**	
	Pos Seq TX Circulating Current	0.00	0.00	0.00	0.00	0.00	
	Poor Load Power Factor	**17.04**	**16.07**	0.20	0.19	0.06	
	Generator R_{source}:X_{source} Ratio	0.00	0.00	0.00	0.21	0.00	
	Generator Terminal Voltage	N/A	N/A	N/A	0.00	0.00	
	Generator Reactive Capability Curve	N/A	N/A	N/A	0.00	0.00	
	X/R Ratio Check	N/A	N/A	N/A	0.43	0.43	
	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	**5.01**	3.18	**6.62**	**8.55**	2.93	
	Netted Gens with Models	1.17	2.00	0.00	0.00	0.38	
	Netted Generators	3.28	3.00	0.22	0.00	0.38	
	Generators with Classical Models	0.69	0.31	1.55	1.43	0.00	
	Unacceptable Models	N/A	N/A	N/A	2.79	2.11	
	Not Recommended Models	N/A	N/A	N/A	**24.68**	**21.67**	
	User-Written Models[42]	N/A	N/A	N/A	N/A	-	
	Inconsistent Reactances	2.10	1.50	1.25	1.23	1.07	
	Inconsistent Time Constants	0.00	0.40	0.41	0.39	0.79	
	Unreasonable Inertia Constants	**15.08**	**15.32**	**11.30**	**13.98**	**15.31**	
	Unreasonable Saturation Factors	**42.27**	**20.08**	**20.12**	**13.19**	**12.85**	
	Severe Saturation Factors	2.06	2.21	1.45	1.18	1.19	
	PSS but no Excitation	0.15	0.00	0.00	0.00	0.00	
	Inconsistent Speed Damping	**11.07**	**11.01**	3.78	3.07	2.82	
	Inconsistent Lead-Lag Time Const	0.00	0.00	0.00	0.00	0.00	
	Erroneous Power Dev Fractions	**32.00**	0.00	0.00	0.00	0.00	
	DC Exciter Self-Excitation Errors	**10.81**	**9.86**	**11.67**	**12.5**	**13.46**	
	Inconsistent Type III Wind Speeds	0.00	0.00	0.00	0.00	0.00	
	Suspect PSS2A/2B parameters	N/A	N/A	**12.5**	**16.92**	**14.07**	
	Incorrect DER_A Tripping Parameters	N/A	N/A	N/A	0.00	0.00	

Table A.6: Second Summer Peak Cases

Type of Metric	Metric	2016 Score (%)	2017 Score (%)	2018 Score (%)	2019 Score (%)	2020 Score (%)	Performance
Powerflow	P_{max} Exceedances	**17.26**	0.00	0.00	0.00	0.00	
	P_{min} Exceedances	2.31	0.00	0.00	0.00	0.00	
	Scheduled Interchange Sum	0.0	0.0	0	0	0	
	Voltage Schedule Conflicts	1	5	0	23	37	

[42] Performance not tracked

Table A.6: Second Summer Peak Cases							
Type of Metric	Metric	2016 Score (%)	2017 Score (%)	2018 Score (%)	2019 Score (%)	2020 Score (%)	Performance
	Tap Step Conflicts	3.89	3.45	3.35	0.94	1.40	
	Tap Step Conflicts (Severe)	0.17	0.00	0.00	0.80	0.00	
	Low Emergency Rating	0.00	0.00	0.00	0.00	0.00	
	High Emergency Rating	0.13	0.01	0.02	0.03	0.00	
	Thermal Overloads	0.22	0.24	0.22	0.04	0.05	
	Thermal Overloads (Severe)	0.16	0.22	0.15	0.04	0.04	
	Generator Reactive at Limits	**21.67**	**25.37**	**16.24**	**9.14**	**16.28**	
	Generator Reactive Limit Power Factor	**9.84**	**11.64**	**10.97**	**13.35**	**12.59**	
	Pos Seq TX Circulating Current	0.00	0.00	0.00	0.00	0.00	
	Poor Load Power Factor	**19.78**	**20.10**	0.11	0.13	0.04	
	Generator R_{source}:X_{source} Ratio	0.00	0.00	0.00	0.13	0.00	
	Generator Terminal Voltage	N/A	N/A	N/A	0.00	0.30	
	Generator Reactive Capability Curve	N/A	N/A	N/A	0.00	0.00	
	X/R Ratio Check	N/A	N/A	N/A	0.43	0.44	
	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	**5.75**	3.07	3.94	**5.19**	3.35	
	Netted Gens with Models	0.75	1.24	0.00	0.00	0.24	
	Netted Generators	4.02	2.13	0.14	0.00	0.24	
	Gens with Classical Models	0.70	0.46	1.55	1.43	0.00	
	Unacceptable Models	N/A	N/A	N/A	2.72	2.10	
	Not Recommended Models	N/A	N/A	N/A	**24.57**	**21.76**	
	User-Written Models[43]	N/A	N/A	N/A	N/A	-	
	Inconsistent Reactances	2.94	1.50	1.25	1.23	1.07	
	Inconsistent Time Constants	0.00	0.40	0.41	0.39	0.79	
	Unreasonable Inertia Constants	**13.17**	**15.30**	**11.30**	**13.98**	**15.31**	
	Unreasonable Saturation Factors	**42.80**	**20.08**	**20.12**	**13.21**	**12.85**	
	Severe Saturation Factors	2.12	2.21	1.45	1.18	1.19	
	PSS but no Excitation	0.15	0.00	0.00	0.00	0.00	
	Inconsistent Speed Damping	**9.04**	**11.01**	3.78	3.07	2.82	
	Inconsistent Lead-Lag Time Const	0.00	0.00	0.00	0.00	0.00	
	Erroneous Power Dev Fractions	**25.00**	0.00	0.00	0.00	0.00	
	DC Exciter Self-Excitation Errors	**12.16**	**9.86**	**11.67**	**12.50**	**13.46**	
	Inconsistent Type III Wind Speeds	0.00	0.00	0.00	0.00	0.00	
	Suspect PSS2A/2B parameters	N/A	N/A	**12.5**	**16.92**	**14.07**	
	Incorrect DER_A Tripping Parameters	N/A	N/A	N/A	0.00	0.00	

[43] Performance not tracked

Western Interconnection

Table A. 7: Heavy Summer Cases							
Type of Metric	Metric	2016 Score (%)	2017 Score (%)	2018 Score (%)	2019 Score (%)	2020 Score (%)	Performance
Powerflow	P_{max} Exceedances	0.36	0.00	0.03	0.00	0.23	
	P_{min} Exceedances	0.36	0.30	0.03	0.03	0.32	
	Scheduled Interchange Sum	0.0	0.0	0	0.0	-0.0	
	Voltage Schedule Conflicts	159	78	80	63	55	
	Tap Step Conflicts	4.51	0.62	0.66	0.72	0.62	
	Tap Step Conflicts (Severe)	0.13	0.07	0.10	0.45	0.05	
	Low Emergency Rating	0.15	0.14	0.13	0.40	0.37	
	High Emergency Rating	0.02	0.01	0.02	0.01	0.01	
	Thermal Overloads	0.03	0.00	0.01	0.01	0.05	
	Thermal Overloads (Severe)	0.01	0.00	0.00	0.00	0.04	
	Generator Reactive at Limits	**23.59**	**22.47**	**6.53**	4.84	**5.50**	
	Generator Reactive Limit Power Factor	**13.77**	**14.43**	**25.11**	**28.35**	**10.06**	
	Pos Seq TX Circulating Current	0.00	0.00	0.00	0.00	0.00	
	Poor Load Power Factor	0.12	0.14	0.04	0.07	0.05	
	Generator R_{source}:X_{source} Ratio	0.10	0.17	0.21	0.05	0.05	
	Generator Terminal Voltage	N/A	N/A	N/A	3.90	**6.03**	
	Generator Reactive Capability Curve	N/A	N/A	N/A	0.00	3.47	
	X/R Ratio Check	N/A	N/A	N/A	0.18	0.19	
	Natural Gas Generator Pmax	N/A	N/A	N/A	**72.30**	**84.13**	
	Natural Gas Generator Pmax (Severe)	N/A	N/A	N/A	**5.94**	4.35	
Dynamics	Generators without Models	4.17	4.66	4.73	4.89	**6.69**	
	Netted Gens with Models	0.11	0.04	0.20	1.07	0.16	
	Netted Generators	0.46	2.01	2.01	3.57	3.22	
	Generators with Classical Models	0.07	0.07	0.00	0.00	0.00	
	Unacceptable Models	N/A	N/A	N/A	4.19	3.73	
	Not Recommended Models	N/A	N/A	N/A	**11.93**	**10.88**	
	User-Written Models[44]	N/A	N/A	N/A	N/A	-	
	Inconsistent Reactances	3.28	3.23	3.34	3.54	3.24	
	Inconsistent Time Constants	**6.36**	**6.07**	**5.96**	**5.87**	**5.74**	
	Unreasonable Inertia Constants	**18.55**	**18.99**	**13.03**	**13.06**	**11.90**	
	Unreasonable Saturation Factors	**55.77**	**26.83**	**27.08**	**19.74**	**19.00**	
	Severe Saturation Factors	**7.25**	**6.81**	**6.86**	**6.65**	**6.12**	
	PSS but no Excitation	1.04	0.73	0.39	0.00	0.72	
	Inconsistent Speed Damping	**9.34**	**8.44**	**8.23**	**7.22**	**7.24**	
	Inconsistent Lead-Lag Time Const	1.66	1.81	1.86	2.49	2.48	
	Erroneous Power Dev Fractions	**9.38**	3.18	3.74	2.91	2.69	
	DC Exciter Self-Excitation Errors	**7.82**	**7.04**	**5.78**	4.98	**5.34**	

[44] Performance not tracked

Table A. 7: Heavy Summer Cases							
Type of Metric	Metric	2016 Score (%)	2017 Score (%)	2018 Score (%)	2019 Score (%)	2020 Score (%)	Performance
	Inconsistent Type III Wind Speeds	0.98	0.00	0.00	1.27	1.32	
	Suspect PSS2A/2B parameters	N/A	N/A	4.19	3.52	3.16	
	Incorrect DER_A Tripping Parameters	N/A	N/A	N/A	0.00	0.00	

Table A.8: Heavy Winter Cases							
Type of Metric	Metric	2016 Score (%)	2017 Score (%)	2018 Score (%)	2019 Score (%)	2020 Score (%)	Performance
Powerflow	P_{max} Exceedances	0.47	0.24	0.08	0.08	0.55	
	P_{min} Exceedances	0.63	0.48	0.35	0.41	0.59	
	Scheduled Interchange Sum	0.0	0.0	0.0	0	-0.0	
	Voltage Schedule Conflicts	142	82	77	63	54	
	Tap Step Conflicts	1.91	0.98	0.62	0.61	0.57	
	Tap Step Conflicts (Severe)	0.12	0.07	0.06	0.06	0.06	
	Low Emergency Rating	0.18	0.14	0.27	0.14	0.35	
	High Emergency Rating	0.02	0.02	0.04	0.02	0.03	
	Thermal Overloads	0.12	0.09	0.00	0.01	0.02	
	Thermal Overloads (Severe)	0.07	0.06	0.00	0.00	0.02	
	Generator Reactive at Limits	**24.28**	**24.99**	**5.82**	3.81	4.69	
	Generator Reactive Limit Power Factor	**14.25**	**13.87**	**12.31**	**27.41**	**10.28**	
	Pos Seq TX Circulating Current	0.00	0.00	0.00	0.00	0.00	
	Poor Load Power Factor	0.19	0.25	0.06	0.06	0.13	
	Generator R_{source}:X_{source} Ratio	0.12	0.15	0.28	0.16	0.11	
	Generator Terminal Voltage	N/A	N/A	N/A	3.90	**6.18**	
	Generator Reactive Capability Curve	N/A	N/A	N/A	0.00	3.37	
	X/R Ratio Check	N/A	N/A	N/A	0.18	0.19	
	Natural Gas Generator Pmax	N/A	N/A	N/A	N/A	N/A	
	Natural Gas Generator Pmax (Severe)	N/A	N/A	N/A	N/A	N/A	
Dynamics	Gens without Models	**5.65**	4.36	**5.15**	4.38	**8.26**	
	Netted Gens with Models	0.65	0.14	0.20	0.40	0.20	
	Netted Generators	1.02	1.86	1.43	2.00	2.93	
	Generators with Classical Models	0.08	0.07	0.00	0.00	0.00	
	Unacceptable Models	N/A	N/A	N/A	4.66	3.38	
	Not Recommended Models	N/A	N/A	N/A	**12.36**	**10.18**	
	User-Written Models[45]	N/A	N/A	N/A	N/A	-	
	Inconsistent Reactances	3.66	3.24	3.35	3.32	3.52	
	Inconsistent Time Constants	**6.46**	**6.16**	**5.84**	**6.02**	**6.15**	

[45] Performance not tracked

Table A.8: Heavy Winter Cases							
Type of Metric	Metric	2016 Score (%)	2017 Score (%)	2018 Score (%)	2019 Score (%)	2020 Score (%)	Performance
	Unreasonable Inertia Constants	**18.50**	**19.05**	**13.10**	**13.32**	**12.48**	
	Unreasonable Saturation Factors	**56.09**	**26.72**	**27.09**	**19.75**	**19.85**	
	Severe Saturation Factors	**7.59**	**6.93**	**6.97**	**6.70**	**6.39**	
	PSS but no Excitation	1.29	0.29	0.34	0.11	0.66	
	Inconsistent Speed Damping	**10.12**	**8.69**	**8.51**	**7.03**	**7.19**	
	Inconsistent Lead-Lag Time Const	2.34	1.69	1.82	2.59	2.39	
	Erroneous Power Dev Fractions	**8.82**	3.18	3.67	2.86	3.26	
	DC Exciter Self-Excitation Errors	**7.47**	**7.57**	**6.98**	**5.86**	**5.88**	
	Inconsistent Type III Wind Speeds	1.30	0.00	0.00	0.00	1.52	
	Suspect PSS2A/2B parameters	N/A	N/A	4.01	3.95	4.05	
	Incorrect DER_A Tripping Parameters	N/A	N/A	N/A	0.00	0.00	

Table A.9: Light Summer Cases							
Type of Metric	Metric	2016 Score (%)	2017 Score (%)	2018 Score (%)	2019 Score (%)	2020 Score (%)	Performance
Powerflow	P_{max} Exceedances	0.22	0.61	0.00	0.19	0.14	
	P_{min} Exceedances	0.48	0.33	0.00	0.05	0.87	
	Scheduled Interchange Sum	0.0	0.0	0	0.0	-0.0	
	Voltage Schedule Conflicts	244	74	75	62	56	
	Tap Step Conflicts	4.51	0.65	0.61	0.45	0.60	
	Tap Step Conflicts (Severe)	0.13	0.07	0.07	0.06	0.07	
	Low Emergency Rating	0.14	0.14	0.14	0.39	0.37	
	High Emergency Rating	0.01	0.02	0.03	0.02	0.01	
	Thermal Overloads	0.00	0.01	0.01	0.01	0.01	
	Thermal Overloads (Severe)	0.00	0.00	0.00	0.00	0.01	
	Generator Reactive at Limits	**25.99**	**24.94**	**6.76**	**5.99**	**5.67**	
	Generator Reactive Limit Power Factor	**13.75**	**17.48**	**25.24**	**28.43**	**10.60**	
	Pos Seq TX Circulating Current	0.00	0.00	0.00	0.00	0.00	
	Poor Load Power Factor	0.15	0.13	0.03	0.06	0.08	
	Generator R_{source}:X_{source} Ratio	0.10	0.19	0.21	0.05	0.05	
	Generator Terminal Voltage	N/A	N/A	N/A	**7.30**	4.74	
	Generator Reactive Capability Curve	N/A	N/A	N/A	0.00	2.18	
	X/R Ratio Check	N/A	N/A	N/A	0.17	0.19	
	Natural Gas Generator Pmax	N/A	N/A	N/A	N/A	N/A	
	Natural Gas Generator Pmax (Severe)	N/A	N/A	N/A	N/A	N/A	
Dynamics	Generators without Models	4.50	4.85	4.79	4.96	**6.84**	
	Netted Gens with Models	0.11	0.11	0.12	0.40	0.29	
	Netted Generators	0.37	2.07	1.76	2.94	2.83	
	Generators with Classical Models	0.07	0.00	0.00	0.00	0.00	

Table A.9: Light Summer Cases							
Type of Metric	Metric	2016 Score (%)	2017 Score (%)	2018 Score (%)	2019 Score (%)	2020 Score (%)	Performance
	Unacceptable Models	N/A	N/A	N/A	4.17	3.79	
	Not Recommended Models	N/A	N/A	N/A	**11.85**	**10.82**	
	User-Written Models[46]	N/A	N/A	N/A	N/A	-	
	Inconsistent Reactances	3.29	3.10	3.33	3.55	3.24	
	Inconsistent Time Constants	**6.37**	**5.94**	**5.95**	**5.88**	**5.74**	
	Unreasonable Inertia Constants	**18.51**	**19.10**	**13.16**	**13.01**	**12.00**	
	Unreasonable Saturation Factors	**55.63**	**26.96**	**27.15**	**19.72**	**19.39**	
	Severe Saturation Factors	**7.27**	**6.89**	**6.85**	**6.68**	**6.35**	
	PSS but no Excitation	0.70	0.45	0.45	0.28	0.55	
	Inconsistent Speed Damping	**9.34**	**8.42**	**8.22**	**7.19**	**7.24**	
	Inconsistent Lead-Lag Time Const	1.68	1.82	1.85	2.48	2.47	
	Erroneous Power Dev Fractions	**9.38**	4.02	3.74	2.90	3.21	
	DC Exciter Self-Excitation Errors	**7.85**	**7.08**	**5.83**	**5.22**	**5.53**	
	Inconsistent Type III Wind Speeds	0.97	0.00	0.00	1.28	1.27	
	Suspect PSS2A/2B parameters	N/A	N/A	4.19	3.76	3.17	
	Incorrect DER_A Tripping Parameters	N/A	N/A	N/A	0.00	0.00	

[46] Performance not tracked