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2022 WECC Annual Base Case Compilation   
and Data Check Report

WECC Staff

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Executive Summary

WECC conducts the Annual Base Case Compilation and Data Check Program to provide high-quality base cases of the Western Interconnection electric system, as it exists and as is planned over the next 10 years, for WECC member and staff use. This report includes 12 base cases prepared in 2021 and 2022. Seven stability simulations and the Steady-state and Dynamics Dashboard (SADD) were used to evaluate each case. The SADD is a list of potential data issues that the System Review Subcommittee (SRS) has identified as important to track in base cases. The stability simulations are used to find potential data issues and reliability risks. Five of the power flow cases were prepared for conducting operating studies and the other seven modeled various planning cases out to 2033.

This report summarizes the results of the SADD and the disturbance simulations done by WECC staff, overseen by the SRS and the Reliability Assessment Committee (RAC). For the 2022 WECC Base Case Compilation and Data Check Report (2022 Report), disturbances were spread throughout the Western Interconnection in Northern California, Southern California, Colorado, and Idaho. Some of the disturbances have associated Remedial Action Scheme (RAS) action. All disturbances requiring RAS actions were simulated using in-run programs.

The primary objectives of the 2022 Report are to—

* Assess system model performance by simulating disturbances with a potentially high impact on the system; and
* Evaluate the quality of the steady-state data and dynamic transmission system model data that were used to develop WECC base cases.

For the 2022 Report, results of disturbance simulations were checked for undamped oscillations and other deviations from standard behavior. In the 2022 Report, several potential data anomalies found during the stability simulations are shown in Appendix B.

Recommendations

The number of issues found in the SADD is large but decreasing. Data submitters should continue their efforts to resolve these issues. Data submitters should also find a way to update processes to stop recurring errors. Data submitters need to contact WECC staff for models that should be exempt from specific data checks.

Data submitters should prioritize populating turbine type and Balancing Authority Area (BAA) data as well as reducing the amount of load-netted generation.

Data submitters should review the dynamic error logs that WECC staff compiles for each case and in Appendix B for recurring issues and make corrections to prevent the errors from recurring.

Data submitters should ensure that distributed generation and inverter-based resources in their areas are modeled appropriately for the time of day each case is intended to represent.

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# Introduction

Each year, WECC performs a Base Case Compilation and Data Check (BCCDC) to create an ongoing assessment of the electric system model of the Western Interconnection in its existing state and for configurations extending 10 years into the future. Base case performance is gauged by transient simulations of high-impact disturbances and through many data check routines, both of which help WECC staff compiling the cases identify anomalous data. If staff finds anomalies, they are logged for future investigation.

The 2022 BCCDC analyzes the base case model data quality by creating the Steady-state and Dynamics Dashboard (SADD) and running several disturbances on the cases used in the 2022 WECC Annual Base Case Compilation and Data Check Report (2022 Report). The SADD compares the data in the power flow and transient stability data to requirements in the [Data Preparation Manual (DPM)](https://www.wecc.org/Reliability/2023%20Data%20Preparation%20Manual.pdf) and the NERC Case Quality Metrics. The log for each case is shown in Appendix A. The disturbances are run primarily in transient stability simulations but are occasionally evaluated in post-transient power flow simulations, as described in Appendix B. Appendix C explains the base case naming conventions.

The 2022 Report includes lessons learned during the 2022 BCCDC from approved WECC base cases showing system conditions between the winter of 2022 and the summer of 2033. The Results and Recommendations section presents conclusions about the results and recommendations for further action. The General Information section includes information about how the studies were conducted.

To reach the objectives of the 2022 BCCDC, most base cases were compiled to represent system operation under high, but realistic, stress levels. Members of WECC’s System Review Subcommittee (SRS) also requested two specialized base cases be built as part of the 2022 BCCDC. Specialized cases can represent the system under atypical conditions, such as severe weather, major equipment outages, or unusual generation patterns, or they can represent more typical system conditions that are not part of the nine recurring cases staff compiles annually. The nine recurring cases are five operating cases and four general 5- to 10-year cases.

The cases reviewed in this report are:

* 22HS3Sa—2022 Heavy Summer 3 Specialized;
* 33LSP1Sa—2033 Light Spring 1 Specialized;
* 23HW3a—2023 Heavy Winter 3 Operating;
* 23LW1a—2023 Light Winter 1 Operating;
* 23HSP1a—2023 Heavy Spring 1 Operating;
* 28HW2a—2028 Heavy Winter 2 Typical 5-Year Case;
* 28HS2a—2028 Heavy Summer 2 Typical 5-Year Case;
* 23HS4a—2023 Heavy Summer 4 Operating;
* 23LS1a—2023 Light Summer 1 Operating;
* 33HW1a—2033 Heavy Winter 1 Typical 10-Year Case; and
* 33HS1a—2033 Heavy Summer 1 Typical 10-Year Case.

The specialized cases were compiled to study the following:

* 22HS3Sa—To review the 2022 Heavy Summer 2 Operating case and correct SADD errors by at least 50%; and
* 33LSP1Sa—To model light-load conditions due to high impacts of self-generation, along with solar and wind serving a significant but realistic portion of the WECC total load.

# Disturbances Performed

Seven out of eight disturbances were run on each base case created in the 2022 BCCDC. Either the loss of two Palo Verde generating units, or a bi-pole Pacific Direct Current Intertie (PDCI) outage was run on the case, depending on the direction of flow on the California Oregon Intertie (COI).

The 2022 Report included these disturbances:

1. 30-cycle insertion of Chief Joseph braking resistor ("ringdown");
2. Three-phase fault at Comanche and loss of the Daniels Park–Comanche 1 and 2 345-kV lines;
3. Three-phase fault at Colorado River and loss of Colorado River–Red Bluff 1 and 2 500-kV lines;
4. Three-phase fault at Hells Canyon and loss of Brownlee–Hells Canyon 230-kV line;
5. Three-phase fault at Midway and loss of Gates–Midway #1 and Diablo–Midway #2 500-kV lines;
6. Three-phase fault at Imperial Valley and loss of North Gila–Imperial Valley 500-kV lines;
7. Loss of two Palo Verde generating units; and
8. Bi-pole PDCI outage.

Appendix B shows which disturbances were run on each case and the detailed outage information.

# Results and Recommendations

## SADD Totals

The SADD is a list of data issues regarded by the SRS as important to track in base cases. Staff creates two versions of the SADD for each base case. The first is sent out with the initial version of the case for data submitters to review and correct any issues in their data. Data submitters then submit changes for inclusion in the final, approved version of the case. Staff create the second version of the SADD based on the final version of each base case as a way for data submitters to track whether their updates are fixing data issues. The following graphs reflect only the versions of the SADD created for the final version of each case. The cases are listed in chronological order by the original posting date. All cases were built as part of the 2022 WECC [Base Case Compilation Schedule (BCCS).](https://www.wecc.org/Reliability/2022BCCS.pdf)

Figure 1: SADD Totals for 2022 BCCDC

### Recommendation

Overall, SADD numbers in the 2022 BCCDC are down from the 2021 BCCDC across the board. On average, for the 2021 BCCDC, SADD totals averaged 20,339 compared to 11,291 for the 2022 BCCDC. This is encouraging, as it demonstrates a marked improvement in the quality of base cases from the year 2021 to 2022. However, errors nearly doubled from the first case of the year to the second case in the 2022 BCCDC. The first case of the year, the 22HS3Sa, was a specialized case whose purpose was to correct SADD errors by 50%, which was achieved. However, given the increase in SADD errors after the 22HS3Sa, it appears that data submitters did not propagate data fixes throughout the rest of the cases. Staff recommends that data submitters continue to reduce SADD errors but focus on making data fixes propagate through case builds for the 2023 BCCDC. This will ensure that data fixes need only be applied once, as opposed to every case build.

## Scorecard Metrics

WECC’s Board of Directors issued two directives aimed at improving base case quality for the 2022 BCCDC. The first was to hold two workshops focused on modeling improvements. WECC held the first workshop in August 2022 and the second in October. The first workshop was focused on staff members’ process for compiling the cases, data checks they run, errors they look for, and answering stakeholder questions. It also featured stakeholder presentations on their perspectives building cases from a data submitter process. The second workshop was designed as an open-ended forum for staff to share figures related to case quality and answer specific stakeholder questions and to facilitate discussion among stakeholders about best practices.

The second directive from the Board was for staff to work with the SRS to prioritize a list of base case model shortcomings and implement a strategy to reduce them by 10%. The SRS approved staff’s strategy and prioritized list during its June 2022 meeting. The items on the prioritized list are:

1. Reduce the amount of netted generation for units above 10 MVA, or 20 MVA for collector-based generation;
2. Populate generator turbine types;
3. Match generator MVA in power flow and dynamics;
4. Populate generator fuel types; and
5. Regulate generator terminal voltage between 0.95 and 1.05 per unit.

To measure success, staff compared the 23HS4a case compiled in 2022 to the 22HS2a case compiled in 2021. Both are heavy summer operating cases, which tend to be some of the cases most used by WECC members. Staff primarily focused on generator fuel type corrections to achieve the 10% reduction, because most generators were lacking a fuel type. Table 1 summarizes the comparison results.

Table : Scorecard Metric Case Comparison

|  |  |  |
| --- | --- | --- |
| Item | 22HS2a | 23HS4a |
| Netted generation | 143 | 132 |
| Power flow vs. dynamic MVA | 1090 | 854 |
| Blank turbine types | 181 | 411 |
| Blank fuel types | 4564 | 2208 |
| Generator terminal voltages | 203 | 210 |
| Case totals | 6181 | 3815 |

By focusing on fuel types, staff was able to achieve a 38% reduction in prioritized model shortcomings, thus achieving both Board directives. In future years, staff will continue to revise the prioritized list as needed and monitor success at reducing errors.

### Recommendation

Staff and data submitters achieved a remarkable reduction in prioritized model shortcomings. However, staff observed more than a 200% increase in blank turbine types from the previous year’s heavy summer operating case. Figure 2, which is arranged chronologically by the period that the case is intended to model, indicates that operating cases have fewer blank turbine types on average than future-looking cases, which is expected, because 5- and 10-year cases have less certainty about proposed generation. Staff recommends that data submitters review the SADD for each case, because blank turbine type is one of the metrics tracked there. Staff will also take measures to populate blank turbine type data with known data if it is available. Another recommendation is for staff to continue monitoring the prioritized list for items that no longer need to be on it or new items that need to be added.

Figure : Blank Turbine Types in 2022 BCCDC

## NERC Case Quality Metrics

NERC annually publishes a report detailing base case error counts for certain metrics that NERC considers important. The report’s recommendations are directed to each interconnection’s MOD-032 designee, which is WECC for the Western Interconnection. As of the 2022 BCCDC, most NERC case quality metrics have been incorporated directly into the SADD for data submitters to review; however, data submitters should still familiarize themselves with the case quality metrics for those that are not captured in the SADD. Some of the main metrics driving error counts in the Western Interconnection include generators at their reactive power limits, generator terminal voltages outside typical bands, natural gas generator ambient temperature power limits, not recommended generator models, unreasonable saturation factors, non-zero generator speed damping parameters, and the amount of netted generation in cases. The amount of netted generation and generator terminal voltage metrics are both included in the WECC 2022 Corporate Scorecard item prioritized list of power flow model shortcomings as something for staff and data submitters to resolve.

### Recommendation

Staff and data submitters should work together to prioritize reducing NERC case quality metric counts. These case quality metrics should continue to feed into the prioritized list of power flow model shortcomings described in the Scorecard Metrics section. If a data submitter verifies that a value is being flagged as incorrect by the SADD or case quality metrics, but is actually accurate, they should communicate that to staff for inclusion in exemption lists.

## Late Data

Staff maintains a log of late data received for each case in a given year’s BCCS. Late data can make it difficult to assemble a case on time due to complications that arise when attempting to integrate new data into a partially compiled case that staff has already started working on. The DPM contains a process called the Late Data Procedure that allows staff to use the best data available if it determines late data is unusable. The Late Data Procedure is a last resort that staff has not needed to rely on, but the 2022 BCCDC saw an increase in late data compared to the 2021 BCCDC that occasionally caused concerns that a case would not go out on time. Specifically, in the 2021 BCCDC, three case builds out of 22 had late data with a maximum lateness of three days. Note that 22 case builds include the first and final versions for the 11 cases in the 2021 BCCS. In the 2022 BCCDC, 20 out of 22 case builds had late data with a maximum lateness of 13 days. In particular, El Paso Electric (EPE) only submitted data on time eight out of 22 times. These figures do not account for mismatched interchanges, which also require staff intervention to correct.

### Recommendation

Data submitters must strive to submit data on time to staff and give as much advance notice as possible when data will not be submitted on time. EPE must be more punctual with submittals during the 2023 BCCDC. Additionally, staff will be stricter using the Late Data Procedure for late data in the 2023 BCCDC and will not accept data more than three working days after data is due. Finally, data submitters should use the interchange spreadsheets on the SRS team site to coordinate interchanges and resolve mismatches before submitting data to staff. If interchange values need to change, it can cascade into other issues like generators needing to be re-dispatched, dynamic errors, and more.

## Repeated Model Errors

When compiling a case, staff creates a spreadsheet called the Annual Base Case Compilation and Data Check Log, which is included in each case file available on wecc.org. The log tracks issues that staff observed during dynamic simulations but does not include initialization errors. Many dynamic models present the same error throughout multiple case builds each year. The following is a list of some of these recurring issues that staff observed in the 2022 BCCDC, delineated by the bus number of the unit and roughly grouped by similar bus number

* Area 16: TEP
  + 160932: growing reactive power oscillations
* Area 19: WAPA DSW
  + 19985 19981: sometimes shows a sudden real power drop to 0 MW well past a disturbance
* Area 20: CENACE
  + 20188 20190: large real power generation movement with little room on swing machine to adjust
* Area 21: IID
  + 21655 21658 21659 21876: often shows undamped electric field density oscillations
* Area 24: SCE
  + 29415: continuous growth in reactive power generation post disturbance
* Area 30: PG&E
  + 34738: locti model has a nuisance pickup at the start of every simulation
  + 31080: svd model causes large oscillations throughout area 30 in many simulations
  + 365540: large electric field density oscillations
* Area 40: Northwest
  + 44006 44007 44008 44009: large oscillations in all quantities
  + 46732: large electric field density movement above allowable threshold
  + 47995: sometimes trips on low voltage during disturbance
  + 40346: sometimes shows large real power generation oscillations
* Area 50: BC Hydro
  + 51273: sometimes shows speed instability
* Area 54: Alberta
  + 59011: often show speed spreads above allowable threshold
* Area 60: Idaho
  + 60367: speed spread typically begins decreasing largely around 25 seconds in most simulations, which is well past the disturbance
* Area 65: PACE
  + 69732 69773 69778: growing real power oscillations
  + 69748: continuous growth in reactive power generation post disturbance
  + 69013 69017: often cause dynamic simulation to diverge if units are not load netted
* Area 70: PSCo
  + 70739 70742 70736 70775 70733: often show speed spreads above allowable threshold

This list is not comprehensive of all recurring issues.

### Recommendation

Data submitters should review the log that staff prepares for each case as well as the text file staff maintains of all dynamic issues, including initialization errors and the steps staff took to resolve the issues. If data submitters notice a recurring issue, they should try to correct the issue and propagate the fix throughout the case build process so that staff does not have to fix the issue during each case build.

## Inertia

A recommendation from the [2020-21 WECC Study Program](https://www.wecc.org/RAC/Pages/StS.aspx) was for SRS to track the amount of inertia in base cases. Figure 3 shows the inertia in gigawatt-seconds (GW sec) for each case in the 2022 BCCDC in chronological order of the time the case is intended to model. Figure 4 shows the system frequency response to a loss of two Palo Verde generators measured at a 500 kV bus in California. The worst-case frequency response observed is still well above the underfrequency load shedding limit of 59.7 Hz.

Figure : 2022 BCCDC Inertia Totals in GW∙sec

Figure : Frequency Response to Double Palo Verde Outage

### Recommendation

Staff should continue to track inertia in cases. SRS members should consider requesting a specialized case to represent a light spring operating case condition because WECC’S Changes in System Inertia [study](https://www.wecc.org/Reliability/Changes%20in%20System%20Inertia%20(Final).pdf) found that the light spring period put the most strain on the Western Interconnection in terms of inertia and frequency response.

## Inverter-based Resources

As the resource mix continues to change in the Western Interconnection, tracking amounts of distributed generation (DG) as well as inverter-based resources like wind and solar will be essential to ensure those components are being modeled in reasonable amounts in base cases. Figure 5 shows the amount of DG, solar, and wind in gigawatts that is online in each case in the 2022 BCCDC, arranged from nearest to furthest in the future. As expected, the amount of solar and DG online in the cases trends upward the further into the future that the cases model. Wind, on the other hand, seems constant. Note that the 23LW1a and 23LS1a model light load conditions from 3:00 to 5:00 a.m. and 4:00 to 6:00 a.m., respectively, so low amounts of solar should be expected.

Figure 5: Amount of DG, Solar, and Wind in GW

### Recommendation

SRS should continue to track the amount of DG, solar, and wind online in cases. Data submitters should also check the amount in their areas before submitting data to WECC and should check the values to prevent the need to make large adjustments to load or generation after staff has started compiling a case. A common example staff observes when putting together light load cases, or winter cases, is large amounts of solar generation or DG, which typically indicates incorrect dispatches.

## 2021 Report Review

This section will examine the recommendations made in the 2021 Report and progress made toward those recommendations. The first recommendation from the 2021 Report was to continue to reduce SADD errors. Staff and the SRS achieved this goal in 2022 averages compared to 2021, but errors still increased after the first case of the 2022 BCCDC, so continuous improvements are needed.

The 2021 Report also recommended that data submitters reduce the number of load netted units represented in dynamics data. As shown in Table 1, there was essentially no change from the 2021 BCCDC to the 2022 BCCDC. This is one of the top priorities on the scorecard list, so staff and SRS members should seek to improve the amount of generation represented in dynamics data.

The third recommendation in the 2021 Report was to reduce the amount of missing turbine type data. Data submitters achieved this goal comparing 2021 BCCDC averages to 2022, but missing turbine types did start increasing again near the end of the 2022 BCCDC, so data submitters should still prioritize correcting these data errors.

The fourth recommendation in the 2021 Report was for data submitters to reduce the amount of missing climate zone data. Data submitters did achieve this recommendation. In the 2021 BCCDC, the highest recorded amount of missing climate zones was 316. In the 23HS4a, which was part of the 2022 BCCDC, there were 132 missing climate zones for loads that receive a composite load model, i.e., loads of at least 5 MW with a power factor of at least 0.82; the 132 does not include loads with a long ID of PGE\_AEE, which do not receive a populated climate zone. Data submitters should continue to fill out the climate zone field to ensure that composite load models perform correctly during dynamic simulations.

The final recommendation in the 2021 Report was for data submitters to reduce the amount of missing Balancing Authority Area (BAA) data. Data submitters should continue to focus on populating BAA data. In the 2021 BCCDC, missing BAA fields averaged around 11,000. For the last four cases of the 2022 BCCDC, missing BAA fields averaged around 7,600, which shows an improvement but still leaves room for more improvement.

# General Information

For the 2022 Report, disturbances were run on 12 power flow base cases. Stability simulations were run on all cases in the 2022 BCCDC.

1. The power flow, stability, and post-transient simulations for the 2022 BCCDC were conducted on a PC using the Microsoft Windows 10 operating system and Versions 21.0.10.1, 22.0.2, or 22.0.4 of the General Electric (GE) Positive Sequence Load Flow (PSLF) software program.
2. All 2022 Report disturbance simulations were run with the governor response represented in the power flow (base load flag) and dynamic data (governor models) provided.
3. For the 2022 Report disturbance simulations, Phase 2 of the composite load model, which includes single-phase motor stalling, was used. Models were generated using either the climate zone representation, or the load-specific representation.
4. For all the 2022 cases, DG was included in the load data, and DG dynamics data was modeled with the DER\_A model in the composite load model.

As part of the 2022 base case development, data-check routines, along with stability studies, were run to find potential data errors.

# Objectives

The following section addresses each objective developed in the 2022 BCCDC Scope of Work. The objective is stated, followed by the findings and actions related to it.

## Base Case Development

The first objective is the development of steady-state and dynamic base case models.

### Actions and Findings

The 12 power flow base cases and stability data files were created for the 10-year data bank. The 12 cases include five operating cases, three specialized cases, and four typical planning cases. The cases are available to WECC members on wecc.org.

## Model Performance Assessment

The second objective is to annually assess the performance of the transmission system model based on selective disturbances run using the cases.

### Actions and Findings

1. A no-disturbance simulation was done on each case. Data for machines with significant oscillatory behavior were revised. The results for the cases compiled during 2022 for the WECC 10-year power flow and stability data bank showed no significant oscillatory behavior after changes were made.
2. After additions and changes to the master dynamics file, a 35-second simulation of a "ringdown" (30-cycle insertion of Chief Joseph braking resistor) case was done.
3. One standard disturbance was run on each case to tune the dynamic and power flow data. Tripping of two Palo Verde units was simulated as the standard disturbance on cases with north-to-south flows on the COI. For cases with south-to-north flows, loss of the PDCI was simulated. If the standard disturbance results were not stable, changes were made to the base case to correct data problems or flows outside of known operating limits. If the results were still unacceptable, they were shown to the SRS and included in the Annual Base Case Compilation and Data Check Log. None of the 2022 BCCDC standard disturbances had unacceptable results after data problems were corrected and flows were brought within known operating limits.
4. Seven disturbances were run on each case, the results of the stability studies were checked for system data or modeling problems. Any issues found are in Appendix B. WECC urges data submitters to review Appendix B and submit corrections to models shown as being unstable when stressed by these disturbances.
5. Each power flow base case was checked relative to known transfer capabilities and nomograms. Transfers in each of the power flow cases for the 2022 BCCDC were within the estimated transfer capability and nomogram limits at the time they were compiled.

## Disturbance Summary

The Disturbance Summary table shows the stability studies that were conducted and RAS.

| **Fault Location** | **Elements Removed** | **Remedial/Relay Action** |
| --- | --- | --- |
| COMMANCHE 345-kV SUBSTATION | **Time (cycles) Switching**  60 Three-Phase Comanche 345-kV fault  64 Clear the fault after four cycles and open the Comanche–Daniel Park 345-kV Lines 1 and 2  Study terminated at 35 seconds | None |
| COLORADO RIVER 500-kV SUBSTATION | **Time (cycles) Switching**  60 Three-Phase Colorado River 500-kV fault  64 Clear the fault after four cycles and open the Colorado River–Red Bluff 500-kV lines 1 and 2  Study terminated at 35 seconds | None |
| HELLS CANYON 230-kV SUBSTATION | **Time (cycles) Switching**  60 Three-Phase Hells Canyon 230-kV fault  65 Clear the fault after five cycles and open the Hells Canyon–Brownlee 230-kV Line  Study terminated at 35 seconds | Hells Canyon Generator Tripping |
| MIDWAY 500-kV SUBSTATION | **Time (cycles) Switching**  60 Three-Phase Midway 500-kV fault  64 Clear the fault after four cycles and open the Midway–Vincent 500-kV sections 1 and 2 and Midway–Diablo 500-kV line 2  Study terminated at 35 seconds | None |
| IMPERIAL VALLEY 500-kV SUBSTATION | **Time (cycles) Switching**  60 Three-Phase Imperial Valley 500-kV fault  64 Clear the fault after four cycles and open the Imperial Valley–North Gila 500-kV line  Study terminated at 35 seconds | None |
| DOUBLE PALO VERDE UNIT OUTAGE | **Time (cycles) Switching**  60 Trip 2 Palo Verde Generators  Study terminated at 35 seconds | Trip load associated with the loss of 2 Palo Verde units |
| CHIEF JOSEPH RESISTOR INSERTION | **Time (cycles) Switching**  60 Insert Chief Joseph Braking Resistor  90 Clear the Chief Joseph Braking Resistor  Study terminated at 35 seconds | None |
| BI-POLE PACIFIC DC INTERTIE OUTAGE | **Time (cycles) Switching**  60 Open two DC Lines from Sylmar to Celilo  Study terminated at 35 seconds | None |

More details on the results of power flow cases and disturbance simulations are in the appendices. Appendix A includes summary information from the SADD for each power flow case. Appendix B shows anomalies found while running the standard list of disturbances, which is contained in this report. Appendix C explains the base case naming conventions used in this document.

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