NERC
NORTH AMERICAN ELECTRIC
RELIABILITY CORPORATION

DER Modeling Study

Investigating Modeling Thresholds

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RELIABILITY | RESILIENCE | SECURITY




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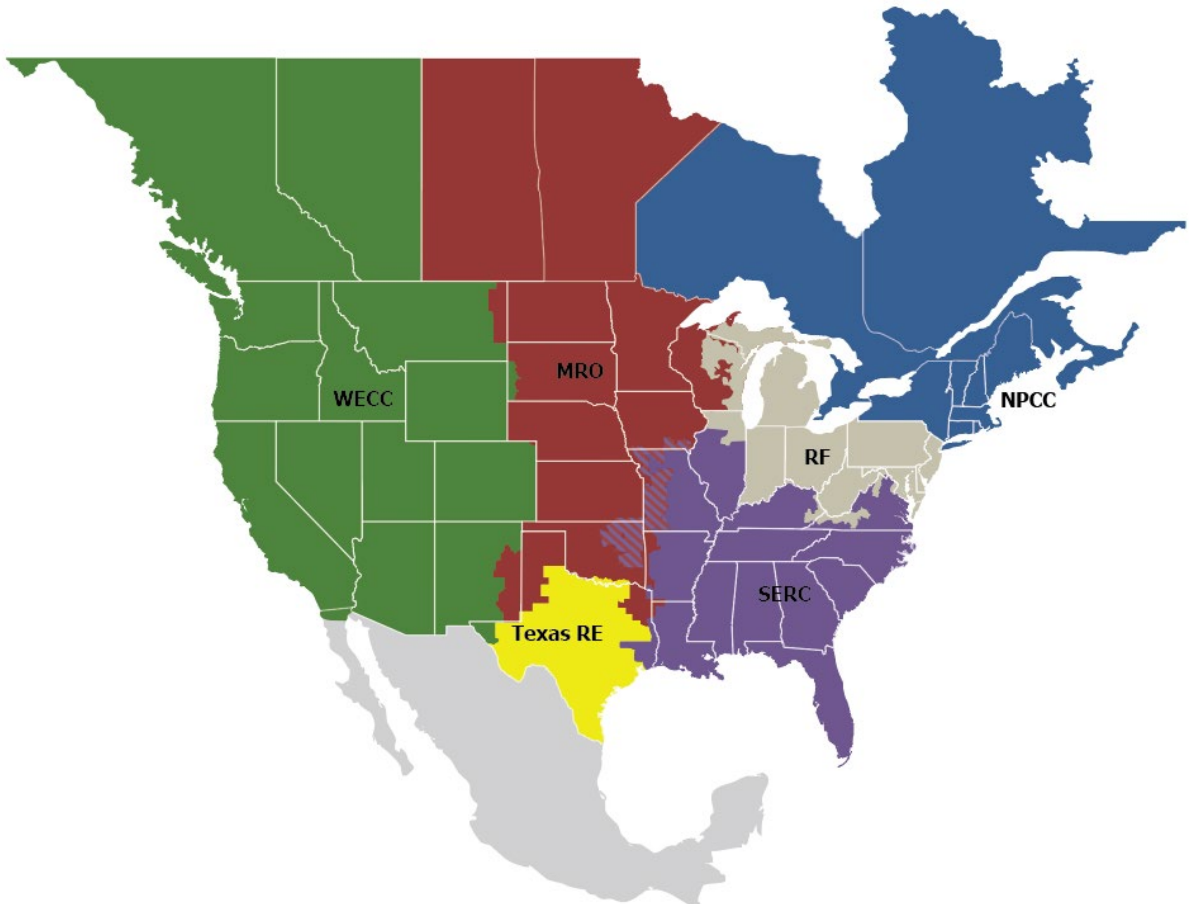
Table of Contents

Preface

Electricity is a key component of the fabric of modern society and the Electric Reliability Organization (ERO) Enterprise serves to strengthen that fabric. The vision for the ERO Enterprise, which is comprised of the North American Electric Reliability Corporation (NERC) and the six Regional Entities, 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 Regional Entity boundaries as shown in the map and corresponding table below. The multicolored area denotes overlap as some load-serving entities participate in one Regional Entity while associated Transmission Owners (TOs)/Operators (TOPs) 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

Preamble

NERC studies information from a variety of sources available to the ERO Enterprise to evaluate potential risks to reliability of the BPS. NERC completes these studies as part of executing its mission to ensure reliability of the BPS and in fulfilment of its responsibilities under section 215 of the Federal Power Act. Such assessments and studies do not seek to plan or propose fully realized solutions for the topic studied, rather they provide stakeholders with engineering analysis on potential risks to reliability. Such studies provide key findings, guidance, and information on specific issues to promote and maintain a reliable, resilient, and secure BPS.

Each entity registered in the NERC compliance registry is responsible and accountable for maintaining reliability and compliance with applicable mandatory Reliability Standards. NERC's studies are not binding norms or parameters nor are they Reliability Standards; however, NERC encourages entities to review, validate, adjust, and/or develop a program with the information supplied in this study.

Entities should review this study in detail and in conjunction with their evaluation of internal processes and procedures. Review of this study and such internal processes and procedures could highlight appropriate changes that should be made with consideration of system design, configuration, and business practices.

Executive Summary

NERC performed a study on the impacts of modeling thresholds for generation on the distribution system, also known as distributed energy resources (DER). In the study, the team found that a non-zero bright line threshold for providing data to input into models negatively affected the quality of the transmission case simulations. The study found that one of the seven cases had similar performance to the base case; however, such a result was only available while modeling all of the DERs on the system. This result supports the System Planning Impacts from Distributed Energy Resources Working Group's (SPIDERWG) contention and emphasis that all DERs must be modeled for accurate simulations of study future-year conditions. If all DERs are not modeled, the results are inaccurate and the reliable operation of the BPS could be impacted.

Key Finding
Non-zero bright line thresholds for gathering of DER information negatively affect the quality of transmission study cases.

Key Recommendation
A zero MVA threshold should be used to gather DER information.

SPIDERWG has published various white papers, reliability guidelines, and technical reference materials that underscored the need for developing models that represented DERs[1] in transmission planning studies. The SPIDERWG work products emphasize that a 0 MVA threshold (all DERs) is required for gathering of data to populate system models.[2] Some in the industry have argued for a non-zero threshold for establishing data submittal requirements for TPs and PCs. This study explores non-zero thresholds, the impact these thresholds can have on simulation results, and attempts to prove by contradiction that a bright line non-zero modeling threshold would have no impact on simulation studies.

The study uses a Western Interconnection (WI) base case that represents a heavy load condition for spring of 2023 to demonstrate that a predetermined modeling threshold cannot be established without knowing the total capacity of DERs in the system. The study team explored seven study case representations that ignored DERs[3] that were 75 MVA or lower, 20 MVA or lower, 5 MVA or lower, less than 10% of the load, less than 25% of the load, less than 50% of the load, and less than 100% of the load (i.e., back-feeding onto the modeled transmission grid). Further work is highlighted in this study that can explore the differences between explicit representation and "netting" of load;[4] however, these cases compare gross load modeling with DER model assumptions.

In each case except for the 10% study case, the modeling threshold impacted the simulated study results. In particular, the frequency nadir of resource loss contingencies was altered. This evidence contradicts the notion that a pre-determined modeling threshold has no impact on the simulation output of the Interconnection-wide cases. In the 10% study case, the amount of ignored DERs was minimal, so it matched well with the base case. This conclusion, however, was only available because the study team knew the capacity of all DERs in the base case. Because all DER information was available (i.e., a 0 MVA gathering threshold), this is another piece of evidence that contradicts the assertion that a non-zero bright line threshold would not alter the results of simulations. Thus, establishing a non-zero value for obtaining DER information negatively affects the quality of the base cases and eventually can cause concern on actions taken from studies that do not adequately represent DERs in their system.

[1] SPIDERWG terms and definitions, particularly on DER, are available here: https://www.nerc.com/comm/RSTC/SPIDERWG/SPIDERWG%20Terms%20and%20Definitions%20Working%20Document.pdf

[2] This is to say that all information should be available to the TP and PC for their joint modeling practices.

[3] Ignoring DER is effectively the same as establishing a modeling threshold for explicit representation of DER in the system. Interconnection-wide cases represent "aggregate demand" as part of MOD-032 (https://www.nerc.com/pa/Stand/Reliability%20Standards/MOD-032-1.pdf). The study team did not assume that the modeler would alter the demand to "net" the generation with load in this process. Furthermore, SPIDERWG recommends the separation of generation (i.e., DER) from load. The ignored DER was replaced by local bulk generation as outlined in the study setup section.

[4] This is sometimes referred to "masking" load. A study exploring this would require knowledge of DER capacity as well as the capacity of load that was netted and their difference in dynamic performance. Ideas for work in this area are included in the chapters.

Introduction

Background

The Distributed Energy Resource Task Force (DERTF), Load Modeling Working Group (LMWG), and SPIDERWG have all identified DERs as having a potential impact on planning the BPS as they mask the impact of gross load on the system. Planners require accurate identification of load and resources to perform their annual planning assessments. The work the DERTF, LMWG, and SPIDERWG have done demonstrates that modeling DERs is the first step by which to begin study of the impact from such equipment. Models require information, so SPIDERWG has developed a set of reliability guidelines[5] to provide the type of information to gather when populating DER models.

The ERO has published a position paper that has the term DER defined as "any source of electric power located on the distribution system," which is in alignment with efforts in IEEE and SPIDERWG. This study will use the currently available software tools that can aggregate the impact of these distribution-connected resources into a simulation useful to Transmission Planners. The study follows the guidance provided by SPIDERWG and, in particular, the impact modeling thresholds have on Interconnection-wide simulation results. SPIDERWG has recommended previously that a 0 MVA threshold be established to account for all the DERs in the study case. This study aims to explore other non-zero bright line thresholds and their impact on bulk system simulation results. For more information, the following reliability guidelines explain the DER_A transient dynamic model and the ability to gather DER information for modeling purposes:

- *Parameterization of the DER_A Model*[6]
- *DER Data Collection for Modeling in Transmission Planning Studies*[7]

The above reliability guidelines identify the modeling framework that will be used in this study as well as the separation of DER into two useful modeling distinctions: utility-scale DER (U-DER) and retail-scale DER (R-DER). The threshold for modeling is the value where an explicit representation of DER information is placed into the set of models. This can be based on collected capacity, location, or other supplemental information a TP or PC can use to build steady-state, transient dynamic, and short-circuit models of their system. This study explores the modeling thresholds for representation in the Interconnection-wide base cases.

Study Purpose

NERC is studying the differences found in the results of analysis that include DERs and comparisons with the same base case without including the impact of DERs defined below a percentage threshold as well as a numeric threshold. In many publically posted comment periods for reliability guidelines relating to DERs,[8] some commenters request a bright line for when to begin modeling practice development or to begin to gather data for development of DER models into their planning cases. NERC is studying the concept of a bright line threshold for modeling DERs as a way to respond to the comments and in support of NERC's overall DER strategy.[9] Furthermore, the ERO RISC report has identified DERs to be a potential risk in its Grid Transformation category, and DER modeling is required in order to study DER's impacts on the bulk system.

[5] https://www.nerc.com/comm/Pages/Reliability-and-Security-Guidelines.aspx

[6] https://www.nerc.com/comm/RSTC_Reliability_Guidelines/Reliability_Guideline_DER_A_Parameterization.pdf

[7] https://www.nerc.com/comm/RSTC_Reliability_Guidelines/Reliability_Guideline_DER_Data_Collection_for_Modeling.pdf

[8] Primarily from SPIDERWG authored reliability guidelines on modeling and gathering of modeling information for DER. This study started as a way to respond to similar comments on current and revised guidance in this area.

[9] DER Strategy document available: https://www.nerc.com/comm/RSTC/Documents/NERC_DER%20Strategy_2022.pdf

Chapter 1: Study Structure

The study structure and setup is described in this chapter in detail. The study uses a single Interconnection-wide base case and makes modifications to the DER penetration to explore DER impacts. For this study, the altered information relates to the removal of DER generation and rebalancing to be able to solve the case mathematically.

Study Method

Each study required models that have populated information reflective of installed facilities and equipment. Some equipment has a direct representation of its parameters; others are represented by an electrical equivalent, typically done at the connecting edges of Interconnections. For example, the set of transmission models do not typically model the sub-transmission or distribution system in their area in detail but rather summarize the electrical quantities at the nearest BPS bus (e.g., 115 kV bus). Far more often, the sub-transmission is modeled rather than a distribution system—primarily with electrical equivalents to capture well-known and understood phenomena—e.g., the collector system of a solar photovoltaic (PV) plant. With DERs being distribution-connected, the latest guidance for representation in transmission studies uses an aggregate model to expand the load record into a few electrical equivalents to capture the behavior of the distribution-connected resources. The modeling framework as proposed by SPIDERWG is in **Figure 1.1**, and it describes the modifications to a "load hanging off the bulk system bus" to represent DERs.

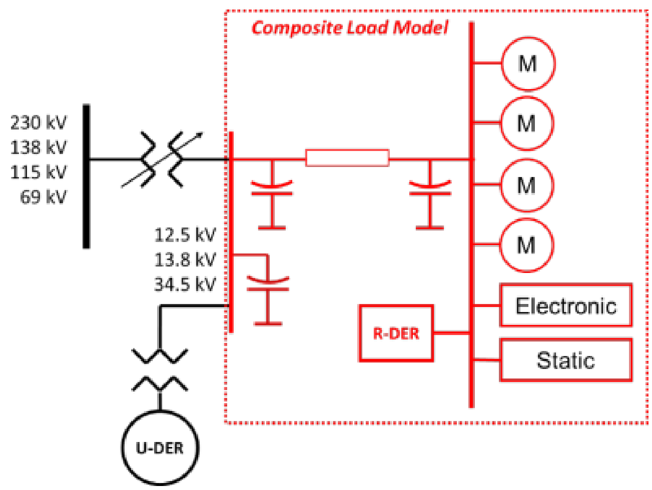


Figure 1.1 Recommended DER Modeling Framework

The load record is first expanded into a transmission to distribution (T–D) transformer with a low side bus, equivalent feeder representation, and a load bus at the end of the feeder equivalent. Typically, the composite load model is used to produce the equivalent feeder and expands the representation for the engineer on initialization of the composite load model. Notice that a DER can be located in two locations: at the equivalent feeder head for U-DER or at the load bus for R-DER. This study uses this representation of a DER for dynamic modeling purposes and captures the total amount of a DER in a study. Each load record that represents these T–D interfaces has an input for distribution connected generation that is used for the steady-state analysis. For this study, the team used the GE Positive Sequence Load Flow (PSLF) software version 22.0.4 for both the load flow and transient stability simulations. Simulation results data was exported from the PSLF simulations into an Excel workbook for charts and figures in the report.

The study will perform a frequency stability analysis of the bulk system with a disturbance of two large generation facilities loss in the Interconnection (titled Conventional Resource Loss) as well as a loss of the major high-voltage direct current (HVDC) intertie connecting California and the Pacific Northwest (titled HVDC Contingency with Generation Loss) to investigate the changes in system response performance from including distribution-connected generation in the transmission study. The frequency analysis is anticipated to show the impact of DERs when reviewing loss of generation studies.

Also, since the dominate technology for DERs is solar PV, the dynamic response of the system is investigated with a transmission fault study. Voltage ride-through for solar PV inverters is highly dependent on the voltage at the inverter terminals. Under specific faults, there is a possibility that the DER in the study could experience low voltage for long durations, especially under delayed-clearing faults. The transmission fault is expected to show the potential stability risks posed by possible tripping of DERs during these faults. The faults studied in this case are:

- A single phase delayed clearing line fault on a 230 kV line
- A three phase normally cleared bus fault on a 500 kV substation
- A three phase delayed clearing bus fault on a 500 kV substation
- A three phase delayed clearing bus fault on a 500 kV substation electrically far away from the DER cluster

For each of the types of studies, the following monitored values will be recorded for comparison:

- Frequency of buses in each area of the Interconnection-wide case
- Voltage of the same buses
- Angle of generators
- Large HVDC line flows
- DER power generated

Study Setup

In this study, the study group selected a single base case that represented the WI for study and also reviewed the available base cases[10] as well as compared a few of them to find how much current DER is dispatched in the study. The comparison is summarized in **Table 1.1**. Based on the high-level comparison, the chosen base case for study is the heavy spring case that has a significant percentage of the load served by DERs as populated in the models.

Table 1.1: Base Case Comparison

Case name	Case Description	Total DER Pgen	Total Gross Load[11]	Load Served by DER
26HS2a1	2026 Heavy Summer	3,094 MW	193,120 MW	1.60 %
23HSP1a1	2023 Heavy Spring	12,719 MW	151,198 MW	8.41 %
27HW2a1	2026–2027 Heavy Winter	20 MW	158,038 MW	0.01 %
24LSP1Sa1	2024 Light Spring	34 MW	94,345 MW	0.04 %

[10] WECC cases are available to those with the prerequisite access to their information here: https://www.wecc.org/SystemStabilityPlanning/Pages/BaseCases.aspx

[11] Summation of all Pload in the PSLF load table in the software. May count offline load records

The 2023 heavy spring case allows the study team to have a higher DER penetration case to begin the analysis on impacts on the BPS should such DERs be excluded from models in the case. The base case was adjusted to correct any data quality issues (e.g., bus voltages set to outside their schedule with a nearby reactive device off-line) The study cases used throughout the report are built based on the following logic:

- Study the lack of modeled DERs by performing studies of the reduction of modeled DER:
  - Based on a MW modeling threshold for each load record
  - Based on a percentage threshold on local load for each load record
  - By only including load records where DER generation exceeds feeder load or total T–D interface load for each load record
- Addition of local bulk generation to replace DER generation[12]
- Solve the load flow, rebalance area to area scheduled interchange within reason to ensure area slack generators are balanced with the change in losses
- Ensure a 20-second no fault flat start for each study case

For more details on the study setup, including the response of the flat start, see **Appendix A**.

[12] The study team dispatched generation that was modeled as offline in the case with the highest Pgen first for each area that had DER reduced. This is equivalent to filtering the generator table for a zero status and sorted by highest Pgen for each area. This minimized the number of "extra" generators added to the case. Each study case built off the same generator records, so if a generator was dispatched in the 5 MVA threshold, it was also added to the 20 MVA threshold.

Chapter 2: Study Results

The study results are summarized in this chapter. Table 2.1 describes the total DER adjustments and additional bulk generation increases in order to balance any alteration from a decrease or increase of DERs in the case. The study cases' names and brief description of the changes are also included.

Table 2.1: Case Name and Generation Changes

Case name	Case Name Shorthand	Case Description	Total DER Generation Change	Percent of Base Case DER Generation[13]
Base Case	"Base"	Base case used for the study.	0 MW	100 %
75 MVA DER threshold	"75 MVA"	Same as base case but ignores Pdgen records and generator records with a der_a dynamic model with less than 75 MVA.	8,237 MW	35.24 %
20 MVA DER threshold	"20 MVA"	Similar to the above, but the defined threshold to include is 20 MVA	6,343 MW	50.13 %
5 MVA DER threshold	"5 MVA"	Similar to the above, but the defined threshold is 5 MVA	1,850 MW	85.45 %
10% of load threshold	"10%"	Similar to the above, but the threshold to ignore DER is only 10% of the load record. All explicit generator records remain	390 MW	96.93 %
25% of load threshold	"25%"	Similar to the percent load case above, but the threshold is 25% of the load record	3,535 MW	72.21 %
50% of load threshold	"50%"	Similar to the percent load case above, but the threshold is 50% of the load record	7,628 MW	40.03 %
Only model backfeeding	"Backfeed"	Same as the base case, but only include explicitly modeled generator records and DER whose Pdgen is greater than the Pload of a load record	11,549 MW	9.20 %

In building the study cases, the study team enabled some voltage controlling devices to ensure the controlled bus voltage stayed within its schedule in the simulation. These do impact the voltage stability in specific areas of the simulation; however, the changes are a reasonable redispatch assumption as an N-0 case since operators maintained their scheduled voltage fairly tightly in various reconfigurations of the system.

[13] Calculated by the ratio of the study case's DER generation to the base case DER generation (12,719 MW)

Interconnection-wide Frequency Response

The study team subjected all cases to two different resource loss simulations. The first was a conventional two large generator loss and the other a generator loss after the outage of a large HVDC line, respectively named "Conventional Resource Loss" and "HVDC Contingency with Generation Loss" in this report. **Figure 2.1** demonstrates the response of all cases from the conventional generator loss, and **Figure 2.2** plots the outage of the HVDC line and resulting generation drop.

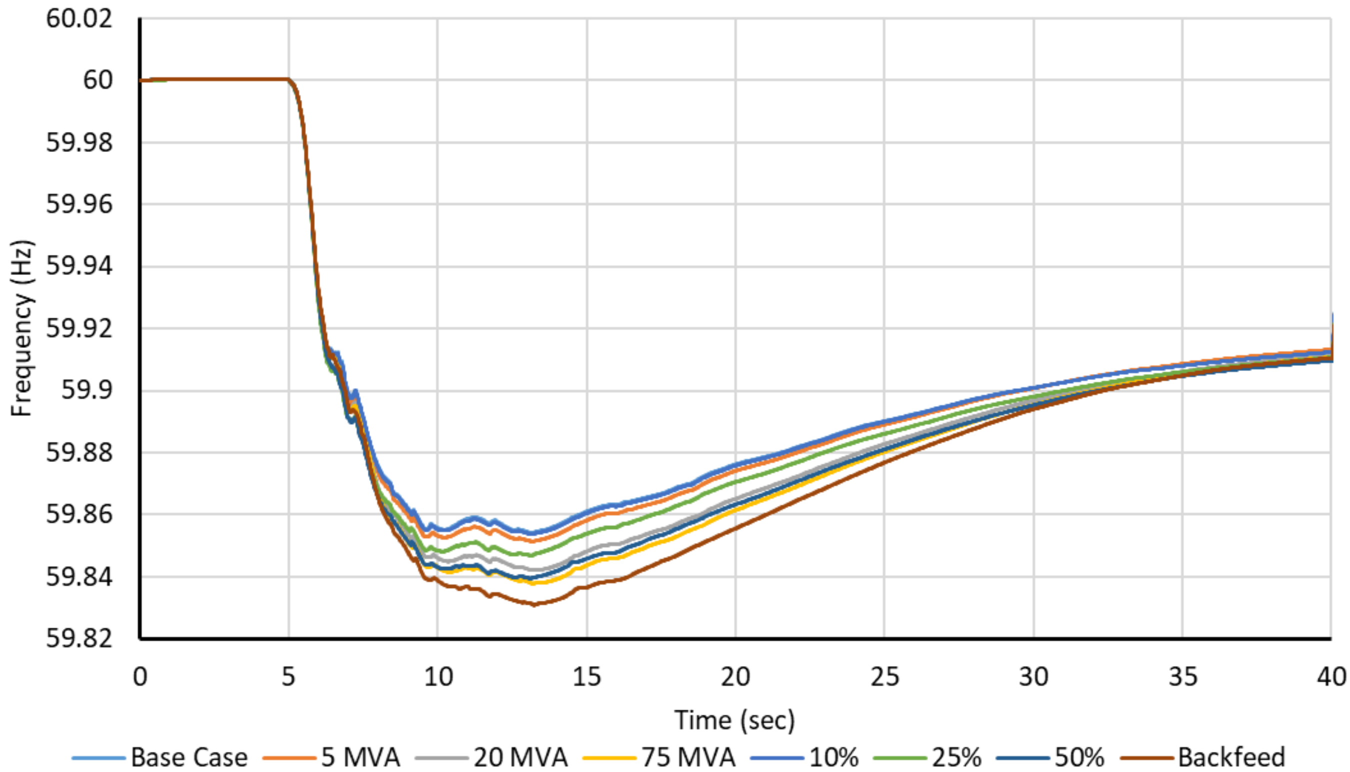


Figure 2.1: Median Frequency during Conventional Resource Loss

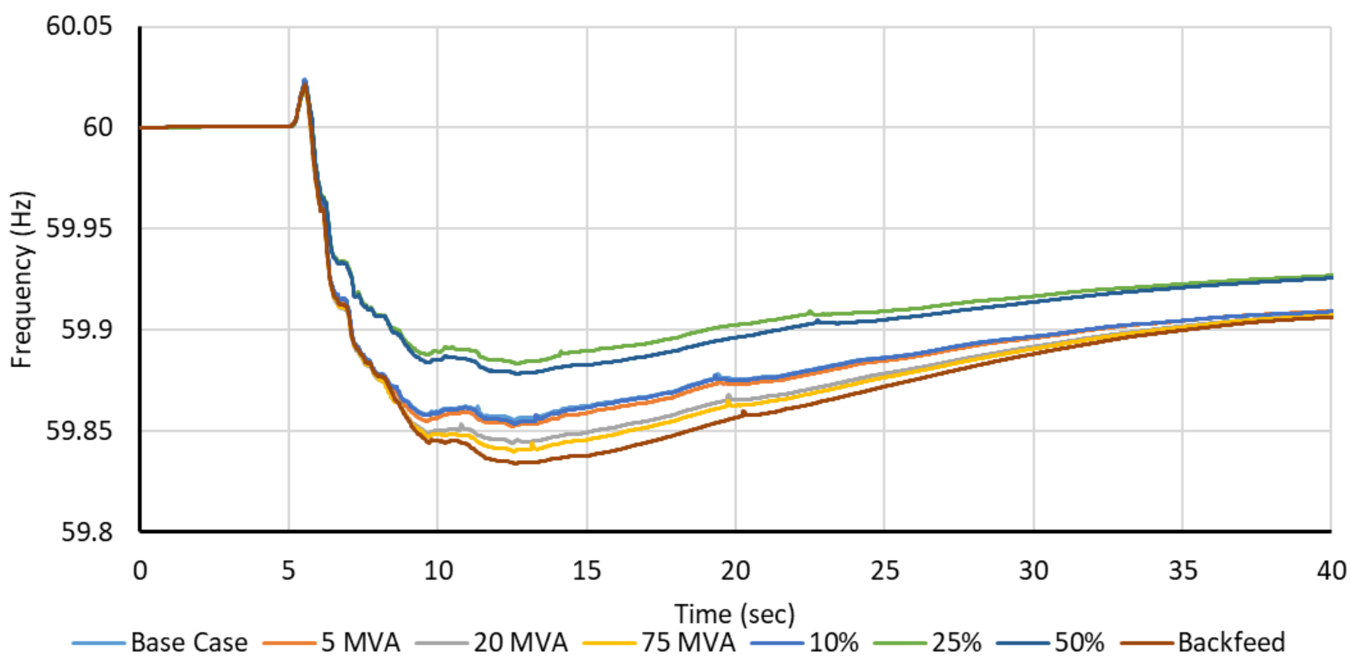


Figure 2.2: Median Frequency during HVDC Contingency with Generation Loss

Key Finding
Impact to the system can be both positive and negative for a DER. Not modeling DERs in specific resource loss events made for both more optimistic and pessimistic results,

Based on the response to the conventional resource loss, the study team found that both the base case line and the 10% study case were nearly overlapping and had the same nadir. The other study cases all had lower and lower nadirs, indicating that (due to the modeling threshold) the median frequency across the interconnection was nearer underfrequency conditions as the DER generation was ignored. This was also seen in the HVDC outage condition in **Figure 2.2**. However, unique to the HVDC outage was a higher nadir for the 25% and 50% study cases not seen in the base or other study cases. These nadir raises were attributed to the variety of flows that allowed the relative percentage of modeled DERs to be less than that of the other cases. That is, there was a lesser difference between pre-disturbance and post-disturbance MW output of all modeled DERs as seen in the active power output in those cases (See **Figure 2.6**). While the 25% and 50% cases contained a large reduction of DERs from the base case, the output was still significant enough to assist in riding through the frequency excursion.[14] This difference can be seen in **Figure 2.3,** which shows the DER output for the conventional resource loss and in **Figure 2.4**, which depicts the DER output during the HVDC outage.

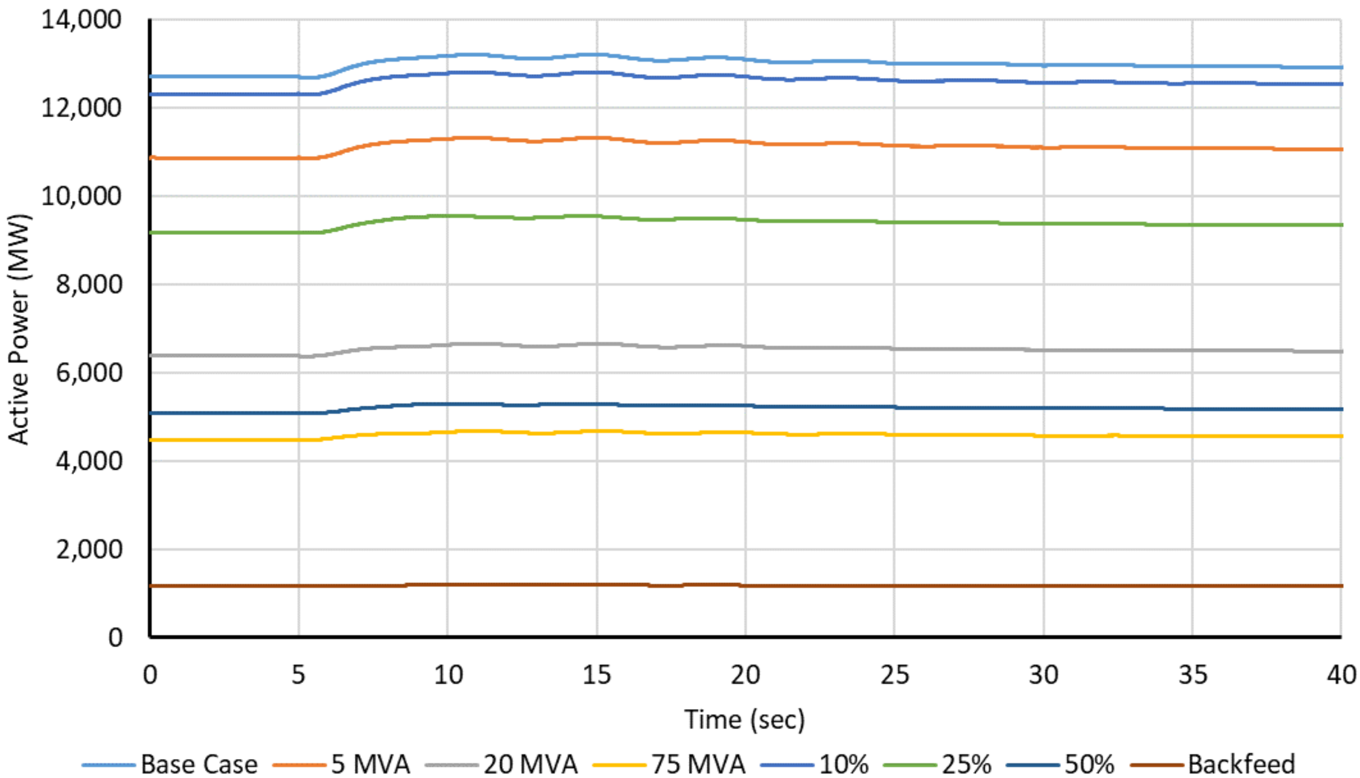


Figure 2.3: DER Output during Conventional Resource Loss

[14] This confirms that generation serving local load during frequency excursions will assist in Interconnection performance due to the lower losses during the event. While important in determining overall reliability impact (or in this case benefit) of DERs, it serves in this study to emphasize that unmodeled DER contribution during Interconnection frequency response has an impact depending on the threshold as in the "Key Finding" boxes throughout this section.

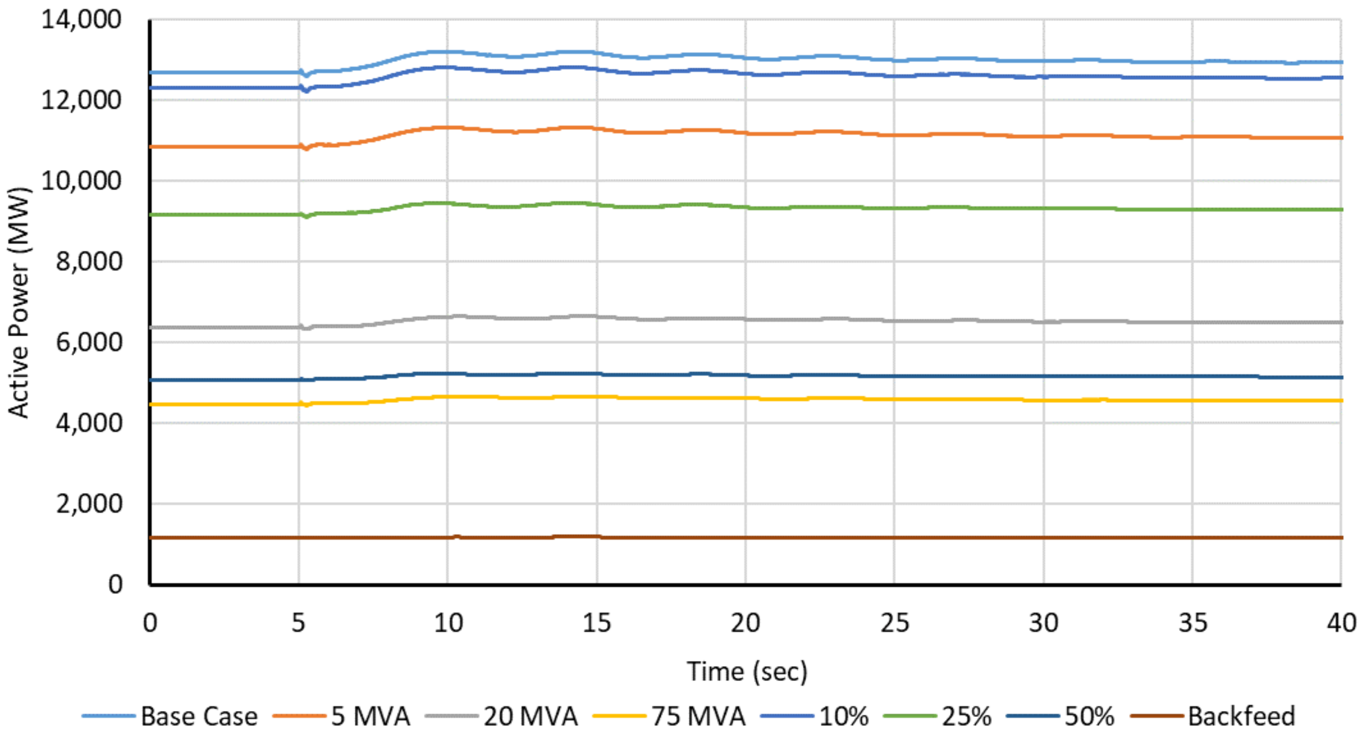


Figure 2.4: DER Output during HVDC Contingency with Generation Loss

As seen in the above figures, the DER output did not reduce or trip off-line, but the modeling threshold did affect the amount of distribution-connected generation in the case supporting the frequency drop. As the modeled DERs had a frequency response enabled,[15] they responded to the frequency excursion, and the median frequency was improved in these resource loss events when those resources were modeled.[16]

Key Finding
Modeled DER thresholds influenced the frequency nadir in a positive and negative direction for the median frequency of the system for resource loss events.

This is more readily visualized in comparing the change of active power of the DERs in the simulation for each study case. **Figure 2.5** shows the comparison for the conventional resource loss, and **Figure 2.6** shows the comparison for the HVDC contingency. The same type of curve can be seen for the base case and the scenario cases. The backfeed scenario case demonstrates that the modeling threshold has an impact to the output of the DER generation. As the active power output of generation in the case affects the nadir frequency of a resource loss event, thus the modeling thresholds are influenced by the amount of DERs modeled in the case.[17] Of note is the 25% and 50% study cases in **Figure 2.6** having a lower active power response than the other study cases except for the backfeed case.

[15] This is true for 1547-2018 compliant inverters that have headroom. The goal of this study was not to relate to frequency support from these devices but rather to take what was already modeled and compare to see if thresholds were insignificant to Interconnection performance. Solar PV DER typically does not have headroom to provide frequency response; however, the models in the base case had the function enabled and was not changed for the study cases.

[16] This in part was true due to how the generation was replaced in the transmission system. While not intended, the majority of the generation replaced (sorted by off-line highest Pgen in each area) typically had a baseload flag of 2, meaning that generator would not respond to frequency excursions.

[17] This is true due to the capabilities and modeled behavior of the base case settings which has a frqflag enabled for the modeled DERs. The study team did not alter the capabilities or the parameters of the response for modeled DERs, but only adjusted modeling thresholds.

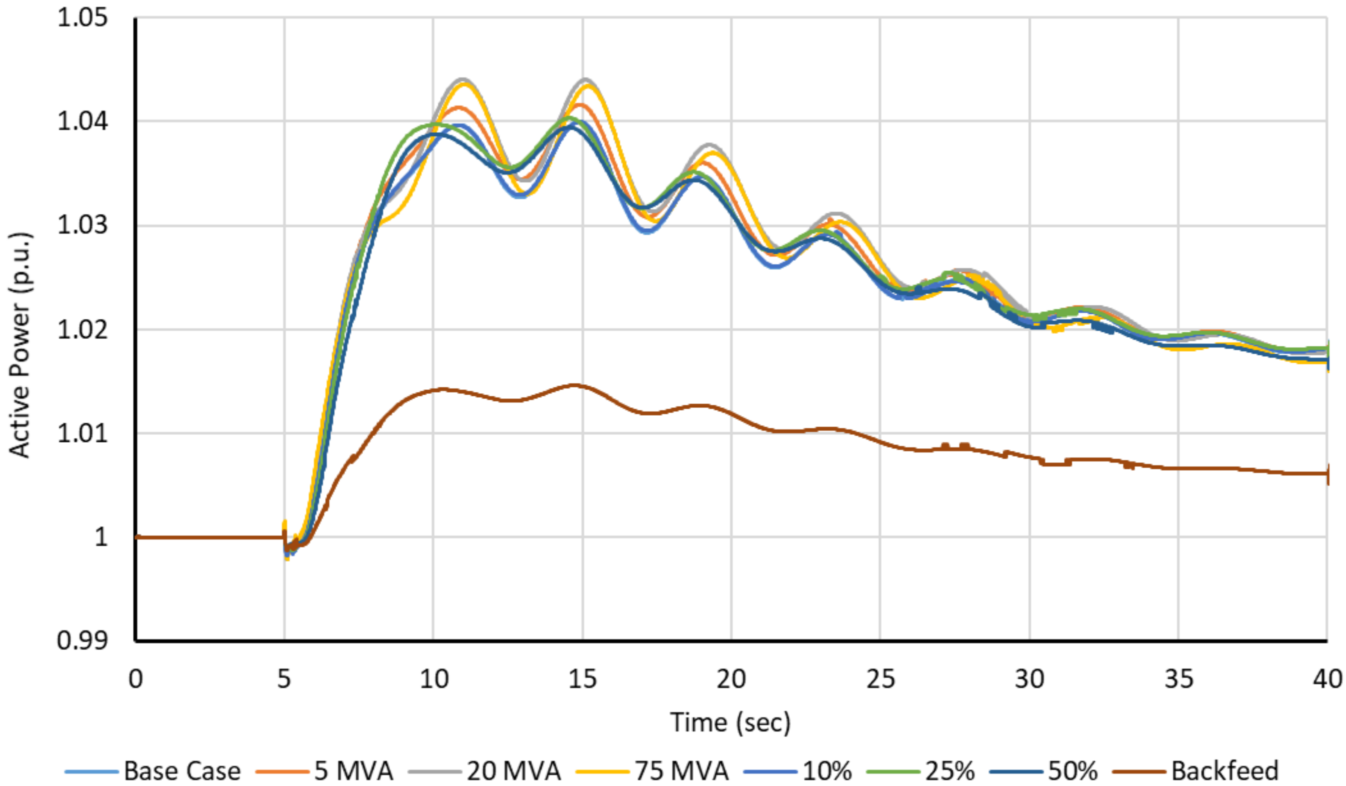


Figure 2.5: Relative DER Output during Conventional Resource Loss

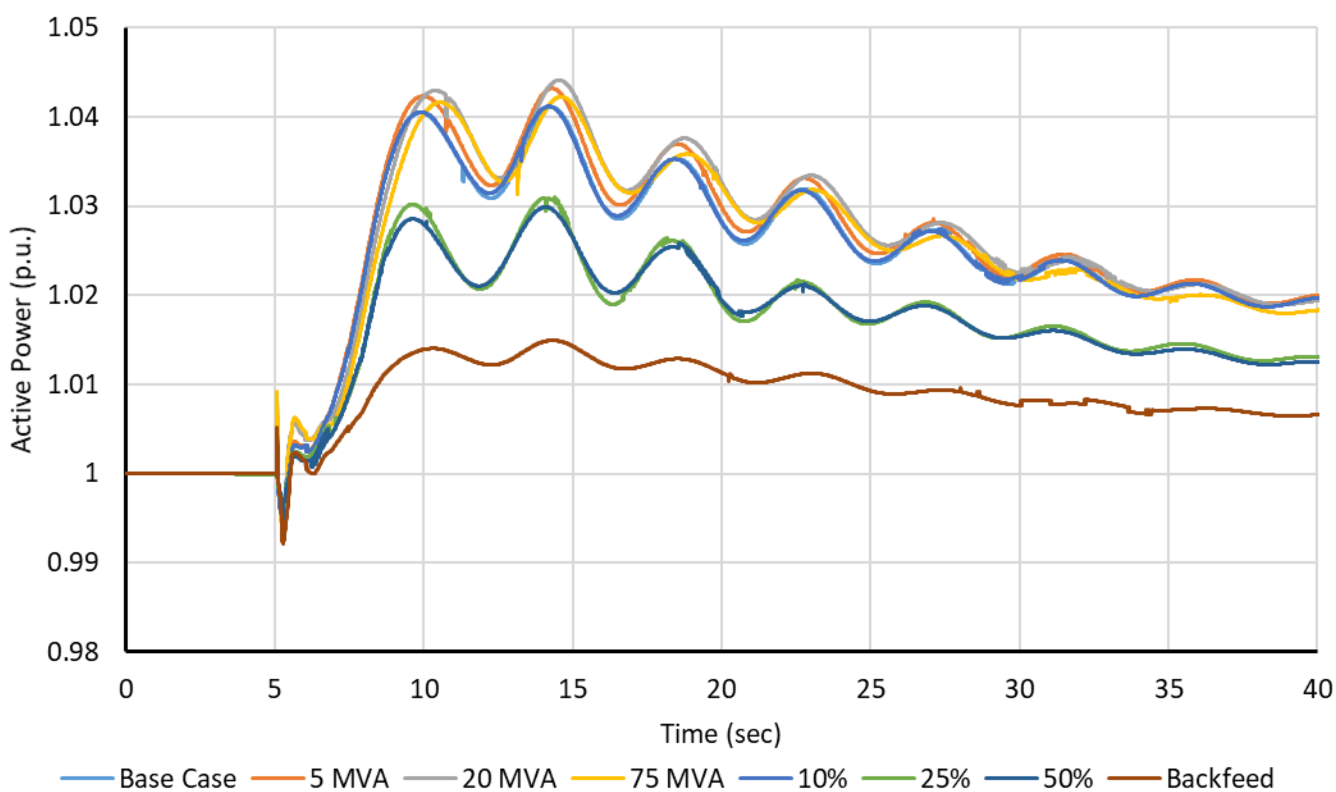


Figure 2.6: Relative DER Output during HVDC Contingency with Generation Loss

To translate the resource loss into a "missed" spinning reserve, the study team took the Interconnection frequency response obligation (IFRO) for the WI and translated the nadir differences into MWs of frequency response, labeled as "Delta Spinning." The results are in **Table 2.2**. The IFRO of the WI used for this study was 858 MW/0.1 Hz, and the "Delta Spinning" column is calculated using the WI IFRO and multiplying by the Hz difference between the frequency nadirs of the study cases to the base case. Notably, the 10% study case had the same nadir for the conventional resource loss contingency and only a very slightly different nadir for the HVDC contingency. A positive value for "Delta Spinning" in **Table 2.2** indicates that the Interconnection lost that value of frequency responsive reserves, and a negative value indicates that the system gained that amount of frequency reserves.

Table 2.2: Spinning Reserve Differences from Conventional Resource Loss and HVDC Contingency

Case name	Nadir (Hz)	Delta to Nadir (Hz)	Delta Spinning (MW)
Conventional Resource Loss			
Base Case	59.854	0	0
5 MVA	59.851	0.003	25.74
20 MVA	59.842	0.012	102.96
75 MVA	59.838	0.016	137.28
10%	59.854	0	0
25%	59.847	0.007	60.06
50%	59.839	0.015	128.7
Backfeed	59.831	0.023	197.34
HVDC Contingency With Generation Loss			
Base Case	59.855	0	0
5 MVA	59.852	0.003	25.74
20 MVA	59.844	0.011	94.38
75 MVA	59.840	0.015	128.7
10%	59.854	0.001	8.58
25%	59.883	-0.028	-240.24
50%	59.878	-0.023	-197.34
Backfeed	59.834	0.021	180.18

Fault Contingencies

The study team also subjected the cases to a variety of fault contingencies to study the impact of DER tripping settings as they are voltage sensitive equipment. The study team found that most of the DERs were clustered in three areas of the system with two of those areas being electrically close to the other and contained numerous ac ties to each other across many voltage levels. The study team subjected this cluster to a single-line to ground (SLG) fault at a 230 kV line, a 500 kV normally cleared bus fault, and a 500 kV delayed clearing bus fault. Investigating the performance of the SLG fault found that most DERs did not trip during the disturbance due to the modeled inverter point-of-interconnection not dropping below the tripping threshold.[18] The team then compared the normally cleared bus fault to the delayed clearing bus fault to see if the modeling threshold affected the recovery of the system post-disturbance. The normally cleared bus fault had a 4-cycle clearing time while the delayed clearing bus fault was 10 cycles. This equated to the delayed clearing bus fault being much longer than the lowest trip timer for IEEE 1547-2018 Category 2 or Category 3 inverters (0.16 second timer versus 0.1667 fault) to test both the voltage value and duration of fault. **Figure 2.7** is the system load response to a normally cleared bus fault near the DER cluster. The system settles within a few seconds after the fault and shows similar but slightly different recovery patterns depending on the DER modeling threshold. This is highlighted in **Figure 2.8** that compares the DER tripping during the normally cleared fault. Most of the DERs fully recovered post fault, but some of the modeling thresholds had the MW output of the DERs vary widely immediately following the fault. Notably, the 20 MVA study case had a momentary increase of power immediately post-disturbance than compared to pre-disturbance output.

Key Finding

The modeling threshold of DER influences post-fault recovery in the system for transmission level faults. There is a direct relationship between threshold and study results, contradicting the assumption that a pre-determined threshold can be provided.

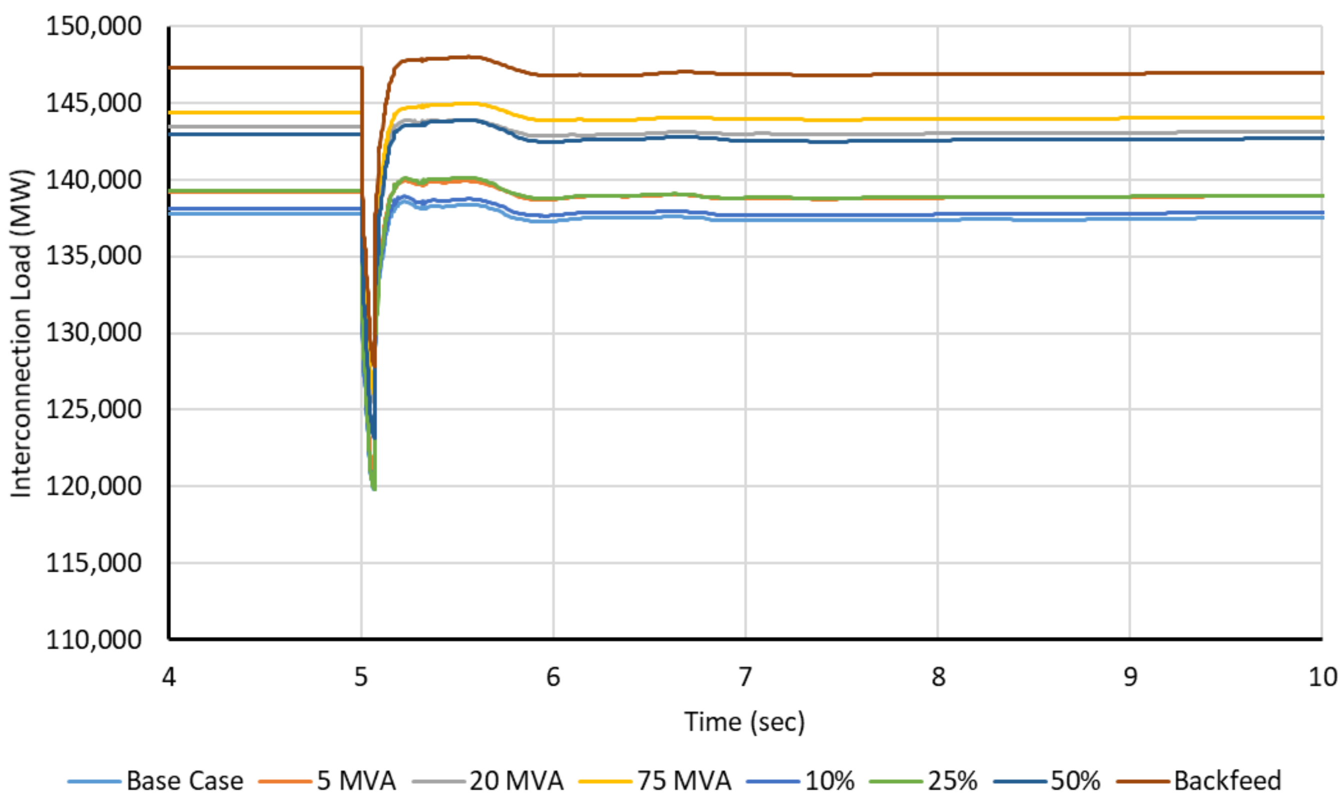


Figure 2.7: System Net Load during Normally Cleared Bus Fault

[18] Tripping threshold for the DER were 0.44 p.u. and the lowest load bus voltage in the SLG fault case was 0.66 p.u.

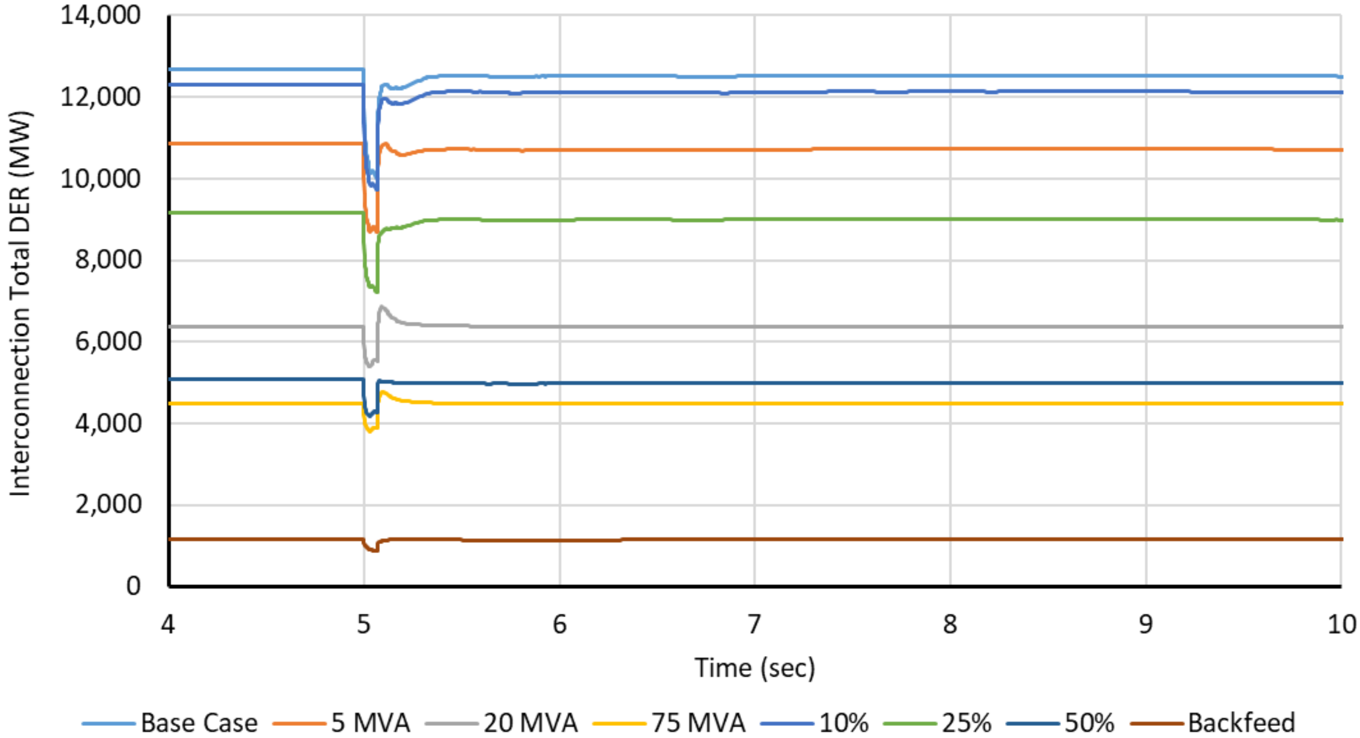


Figure 2.8: Total DER Output during Normally Cleared Bus Fault.

Comparing **Figure 2.7** to the delayed clearing bus fault system load (**Figure 2.9**), the system again has slightly different recovery patters as a whole from pre-disturbance to post-disturbance. Again, no system instabilities were found for these cases, but the recovery trajectory depended on the modeling threshold of the DERs. This is notably seen in comparing the backfeed, 75 MVA, and 50% study cases to the base case where the system load dampened slower to its post-disturbance point. Looking into the DER output during the delayed clearing bus fault (**Figure 2.10**), the reason becomes evident. The amount of DER tripping during each of these cases varies for the study cases that contained a significant reduction of DERs. However, the 10% study case and the base case had very similar performance, and the study team concluded it was reasonable to conclude the Interconnection impact was minimal to negligible. There was a slight difference immediately post-disturbance, which should be investigated locally, but did not warrant an Interconnection-level finding.

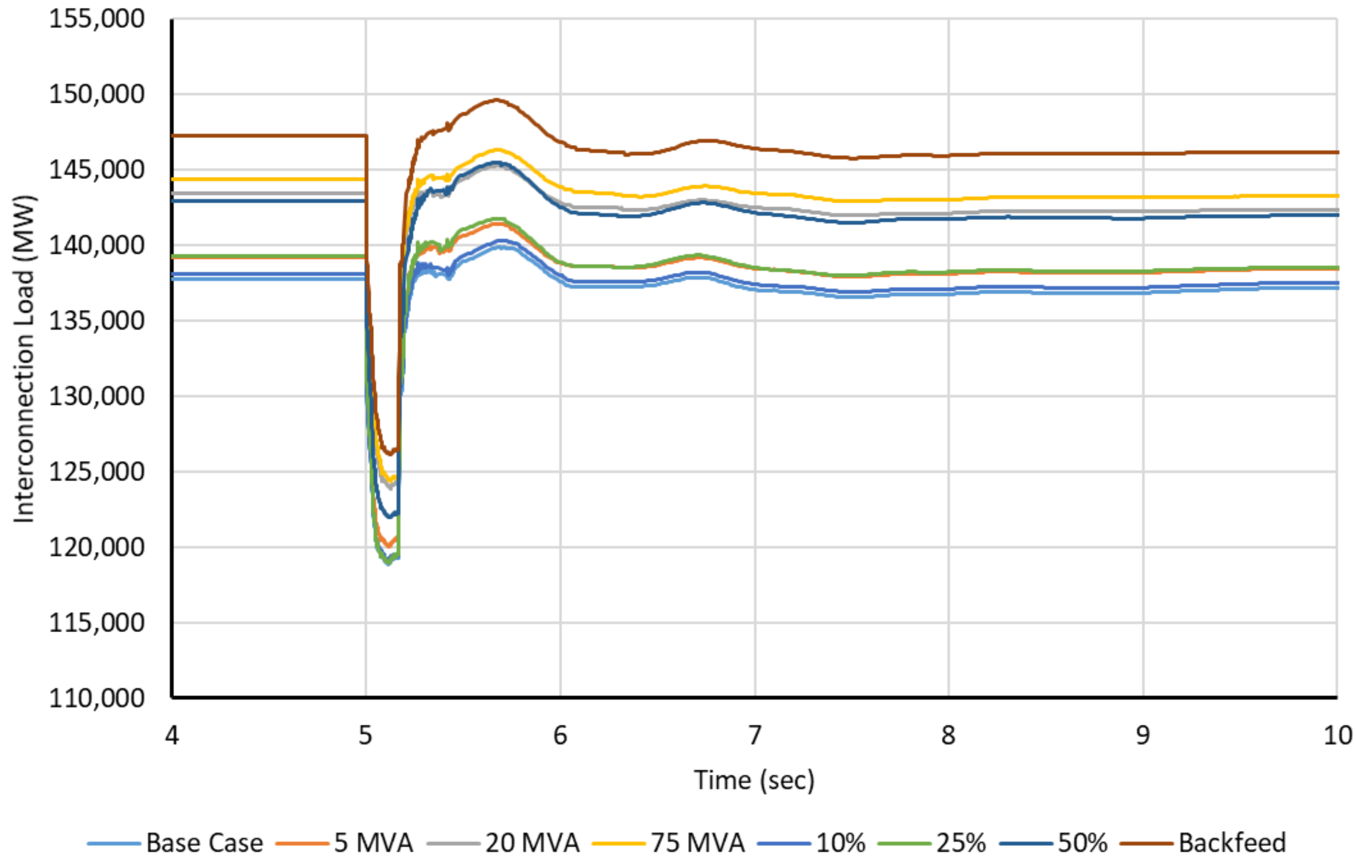


Figure 2.9: System Net Load during Delayed Clearing Bus Fault

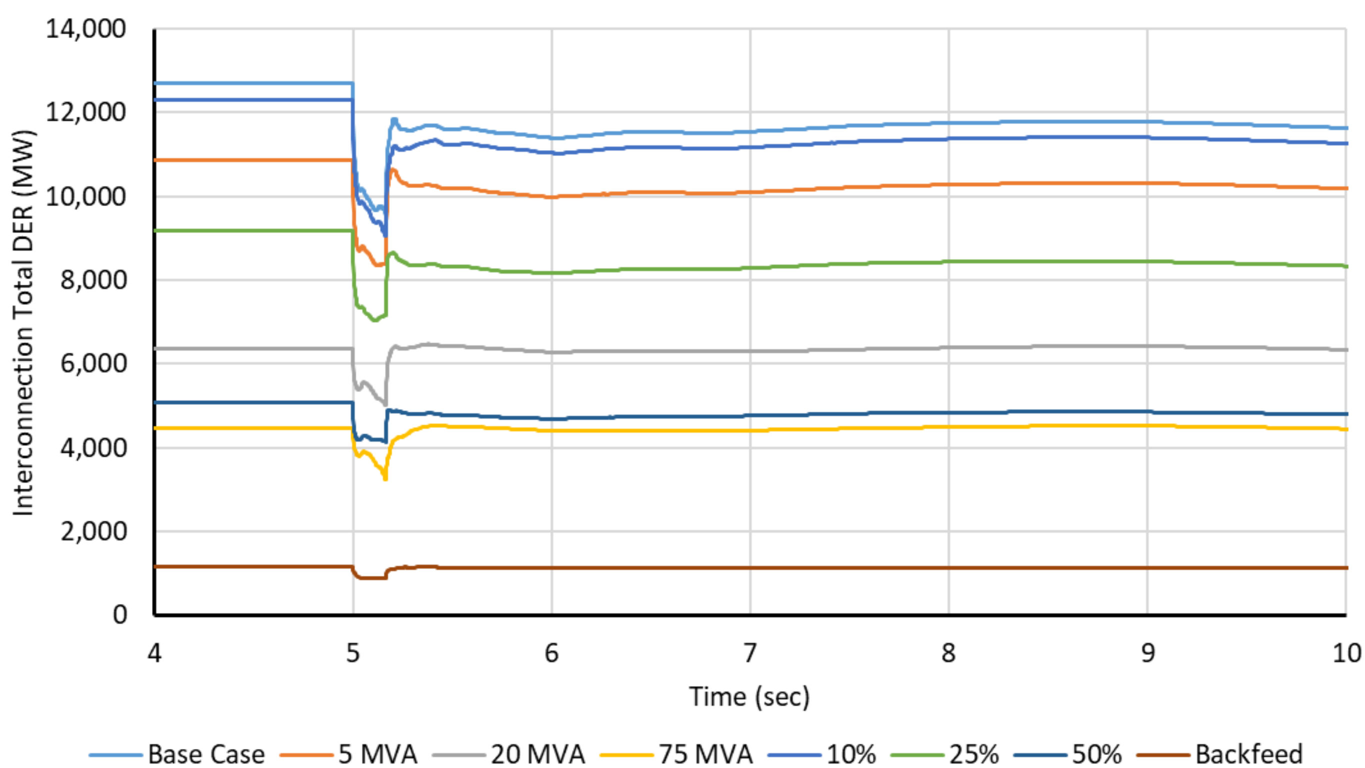


Figure 2.10: Total DER Output during Delayed Clearing Bus Fault

To test the delayed clearing bus fault even further, the study team subjected the system to a delayed clearing fault, but this time at a bus electrically further than before. The study team found that the system level load (in **Figure 2.11**) was still affected by the DER tripping behavior (shown in **Figure 2.12**); however, the major trajectory differences were not as significant. **Figure 2.12** highlights this dependency as the DER output has roughly the same shape but a different magnitude for all cases. The study team concluded that the DER tripping behavior to bulk system bus faults was dependent on the modeling threshold for system faults in areas with large DER clusters. These areas can be large spans of lands, for example the state of Arizona, the Northern California, or the front range of Colorado.

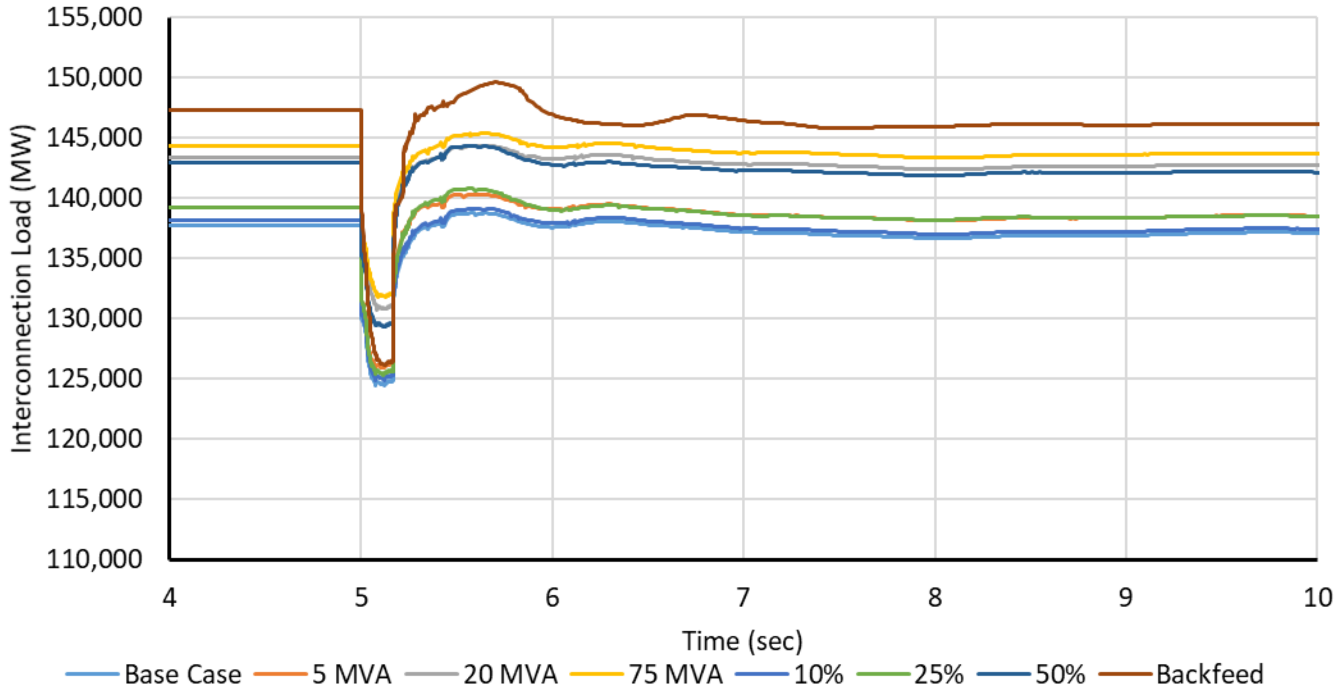


Figure 2.11: System Net Load during a Far Away Delayed Clearing Fault

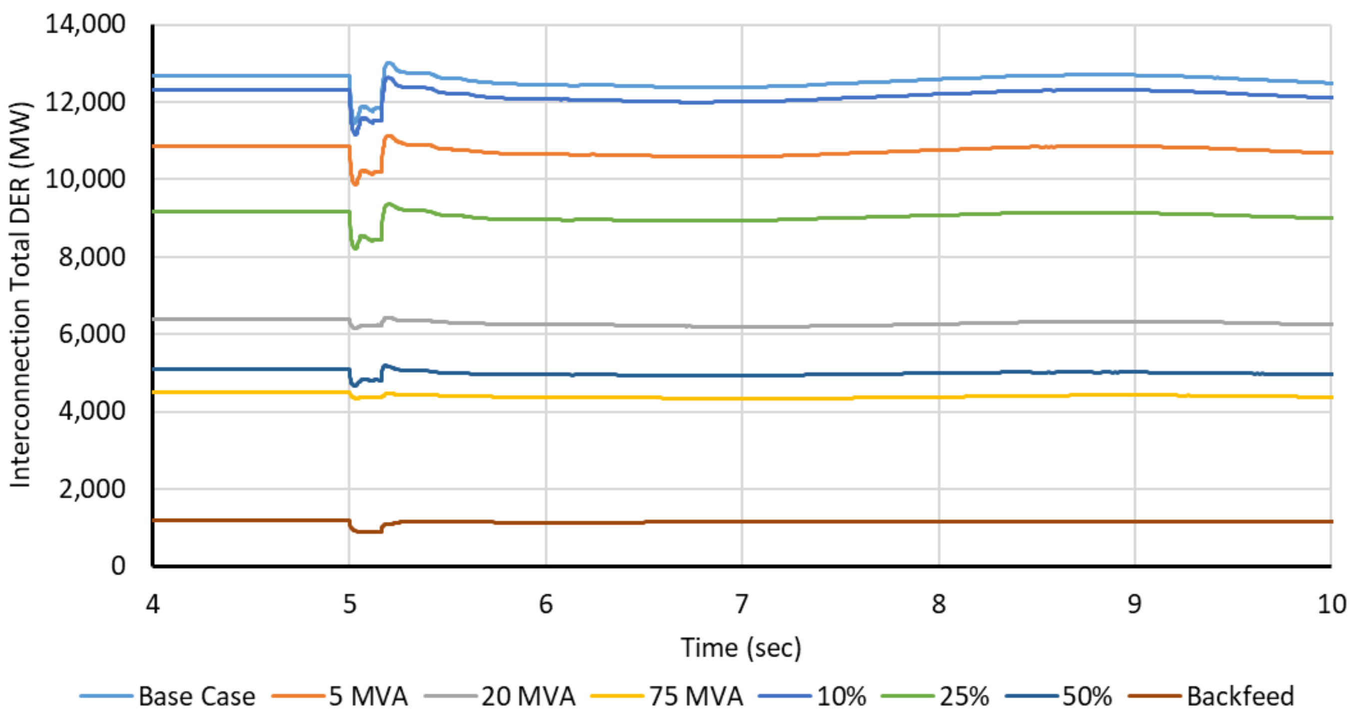


Figure 2.12: Total DER Output during a Far Away Delayed Clearing Fault

Pre-Determined Modeling Threshold Requires Study

Based on the above study findings, the study team concluded that for this case, the 10% study case was an adequate modeling threshold, but the study team concluded this was adequate due to a few qualifiers. Namely, the study team found that the 10% study case ignored 391 records in the load table with an average DER MW generation of 0.998 MW per load record. However, the top five load records had a MW value of 48.38, 32.14, 22.84, 13.99, and 4.34 MW in order from largest to smallest. As those are outliers for the entire set, the study team excluded those to find that the majority of the DERs ignored by the 10% case followed these parameters:

- Average DERs ignored was 0.696 MW
- Total DERs ignored was 268.78 MW
- None of the DERs was above 5 MVA

Key Finding
Modeling thresholds can only be determined insignificant through study of the Interconnection-wide impacts, and with full knowledge of the total amount of DERs on the system. This requires some level of detail on capacity and control of all DERs in the system.

This, however, isn't entirely showing the whole picture. In order to have determined that this modeling threshold was insignificant, the study team needed to have a total amount of DERs to begin with and to compare the reduction of DERs to the modeling threshold. The difference of DERs from the base case to the 10% case was 390 MW (see **Table 2.1**). Framed a different way, 96.93% of all DERs were modeled in the case. The study results show that while the impact on the Interconnection performance wasn't significant, all other modeling thresholds reduced the DERs by greater than 10% from the base case causing Interconnection-wide differences in the system response. Overall, this is a testament to having proper data collection and data verification procedures in place. The data collection does not need to gather all of the information (in this study, ~95% of capacity and control) as the data verification can fine tune capacity and control parameters to ensure accurate study results over time. The study team has found that the important information to gather is the following:

- The T–D interface where the DER is located, electrically (geographical location can supplement)
- Active and reactive power capacity and control[19]
- Vintage of IEEE 1547 of the equipment[20]

[19] The control logic to dictate the active and reactive power control and other dynamic information is desirable as well. More details are available here: https://www.nerc.com/comm/RSTC_Reliability_Guidelines/Reliability_Guideline_DER_Data_Collection_for_Modeling.pdf
[20] Although the Interconnection date can serve as a proxy for this piece of information.

Chapter 3: Additional Supportive Analysis and Findings

After documenting the major study findings, the study team explored one interesting result in the median frequency of the system post-fault and demonstrated why the findings in **Chapter 2** are supported with fundamental power system calculations.

Frequency Post-Fault Dependence

The study team plotted the median frequency during the electrically closer delayed bus fault to investigate the impact of the MW drop from the fault-induced DER tripping. The median frequency plot can be found in **Figure 3.1** and it shows that the modeling threshold impacted the post-fault system level frequency in a fairly significant way. With the DERs being frequency enabled, the active power containing the frequency excursion from going higher post fault as the motor loads that tripped also were prevalent in this contingency. While the deviation of frequency isn't as great as during a resource loss, this is further proving that modeling thresholds impact the recovery post-fault. Again, noting that the 10% and base cases overlapped in this system level measure; this was not seen in the other faults displayed in **Figure 3.2**.

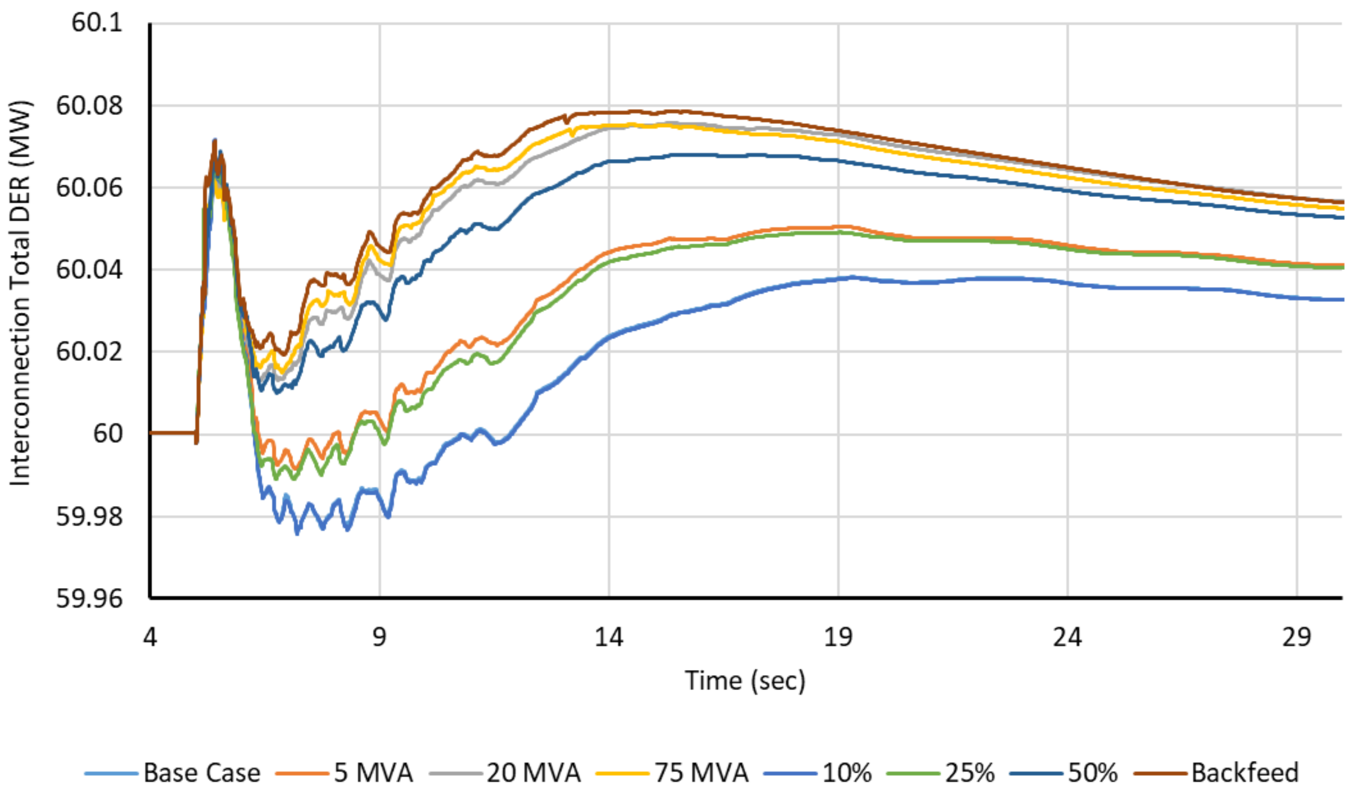


Figure 3.1: Median Frequency during Delayed Clearing Bus Fault

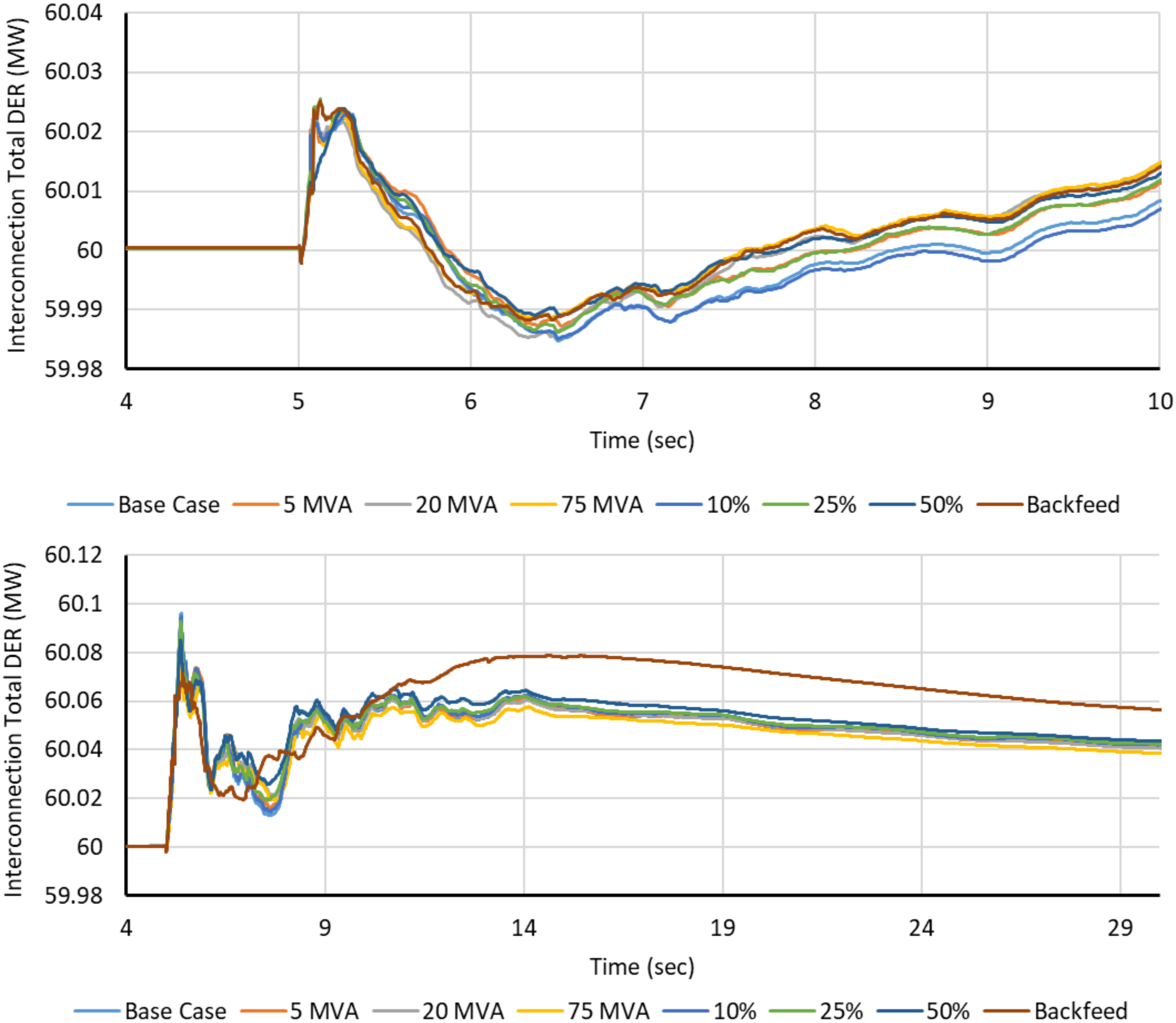


Figure 3.2: Median Frequency during Normally Cleared (Top) and Far Away Delayed Cleared (Bottom) Faults

The modeled DERs did not trip extensively during the normally cleared fault, and as such, there is not a great spread in how the median frequency of the system altered depending on the modeled threshold (about a 10 mHz difference). The study team also found that the far away delayed clearing bus fault did not impact the system recovery as much except for the backfeed study case that had a shift in the recovery post-fault. Since frequency typically isn't a concern for post-fault recovery of the system unless a high instantaneous penetration of IBRs is present, these findings did not rise to a separate takeaway but rather supported the conclusion that the modeling threshold of voltage sensitive equipment is not negligible from other findings.

Outage Distribution Factor Explanation

One way to visualize the impact of ignoring the distribution-connected generation is by calculating the impact of the flow redistribution after taking the generation out of service and still needing to serve the gross load. This is the fundamental problem statement of ignoring generation connected to the distribution system while studying the gross load of the system. In many power system applications, the distribution factors of the system can calculate the alteration of flows as a portion of a pre-outage condition for all lines in a system. Primarily, using a power transfer distribution factor; however, for PSLF the distribution factor calculator provided only contains outage transfer distribution factors (OTDFs) as provided in **Figure 3.3**.

$$\text{OTDF}\{(i,j)(k,l)\} = \frac{\text{Change in MW flow on influenced branch,k-l}}{\text{Pre-outage MW flow on outaged branch,i-j}}$$

Figure 3.3: Outage Transfer Distribution Factors [Source: PSLF]

Extending the load record into a jumper line to a fictitious bus for the generation component allows for the study team to calculate the resulting impact of the flow change with this tool, trying to mimic the power transfer distribution factor tool in other software. The summary report output is summarized in **Table 3.1** with the MW columns for the pre-outage and post-outage flows for each record highlighted. The study team's tool output each line[21] influenced above a magnitude 0.05 OTDF. In the PSLF output, each line number, name, and kV are included; however, they are masked in this table with "*" to include in this report. The OTDF calculation requires the lines to exist in software and be unique in the identifiers. As demonstrated in **Table 3.1**, some of the flows altered significantly, and as a result they have a higher OTDF than others. A negative OTDF or change indicates that the flow direction (or reduction) occurred in the direction of the To Bus to the From Bus in the planning model, rather than the indication of the From Bus to the To Bus. For the DER Pdgen of 142.7 MW (one of the larger sizes in this study), the OTDFs can reach higher than 0.25, indicating a 25% change of flow from pre-outage conditions.

Table 3.1: OTDF Output Summary Report Sample

Line From	Line To	OTDF	Flow Previous [MW]	Per Unit Change [p.u. MVA]	Flow After [MW]
Outage of Line with -142.7 MW Loading					
*	*	-0.0667	137.4772	0.0953	127.9506
*	*	0.3478	90.8139	-0.4964	140.4565
*	*	0.0766	-309.7940	-0.1093	-298.8599
*	*	0.2661	-361.3925	-0.3798	-323.4168

[21] Line From and Line To are included in this table to show that the OTDF report is provided for each line in the monitored area. However, the from bus number and to bus number here are marked with a * to indicate this information is redacted in the report.

Chapter 4: Recommendations and Next Steps

Throughout this study, the team sought to answer if the modeling threshold had insignificant impact on the Interconnection-wide study results from various types of contingencies. The team tested the assumption that a pre-determined modeling threshold can clearly show that ignoring generation below such a threshold in transmission studies is safe due to the impact being insignificant. The study team demonstrated that the various modeling thresholds did have a significant difference in simulated system level performance. This evidence is in contradiction with the assumption that a pre-determined bright line threshold can be used for an entire Interconnection's footprint. There should be no intentional limitation on the information flow from the distribution system. A good corollary to examine is the list of loads in those simulations. The lowest non-zero positive load in the case is 0.01 MVA, which can represent motor load of 10 kW. With such granularity[22] on load connected to the distribution system, the same effort should be placed to gathering the generation side (i.e., DER) in order to adequately represent the interaction between the transmission and distribution systems in transmission studies.

The study team has the following key recommendations and next steps:

- Each PC and TP should use available data gathering techniques to gather the total DER capacity[23] for their footprint.
- Each PC and TP should ensure that their load composition improvements are also including DER control performance, especially when exploring system level response to faults.
- Each PC and TP should determine modeling thresholds as appropriate for their local system.[24]
- WECC and NERC should work together to improve the quality of the Interconnection-wide base cases to reflect best available engineering judgement, particularly around the documented troubleshooting in this study in **Appendix A**.
- Current and future standards projects relating to the gathering of Interconnection-wide modeling data (e.g., MOD-032) should incorporate the findings of this study when adding language to such standards for DERs. Note that a zero MVA threshold is recommended for such standards activities that relate to the supply of DER data to TPs and PCs.

Future Work and Further Exploration

In coordination with the NERC SPIDERWG, the study team found that this study could be further enhanced by performing sensitivity and other studies that target different aspects of simulated DER output, but the identified work did not fall into the study's purpose of identifying modeling thresholds. These studies can be performed for each TP and PC to help inform the joint TP and PC modeling practices. **Table 4.1** shows the future work identified, the relationship to this study, and any anticipated findings or improvements to the study results should the future work be performed.

[22] With such granularity on the representation of load in the transmission case, it calls to question the reluctance of obtaining similar granularity for the generation as they both are on the distribution system.

[23] From review of these findings, ERO Enterprise engineers have identified the above information as typically provided during an interconnection process, and typically would not be available after signing of an interconnection agreement or energization of the facility.

[24] This does not mean to impose a threshold on data gathering, but rather for populating of transmission level models. This threshold should be clear in their joint modeling procedures.

Table 4.1: Potential Future Work		
Future Work	**Relation to this Study**	**Anticipated Improvements**
Instead of dispatching bulk generation, simply net the DERs with load (performed on an Interconnection[25] level).	This study used the assumption that the gross load was identifiable from the generation component in a load record.	• Test the modeling representation that if the DER was ignored, it would instead be netted with load opposed to providing a gross load number. • Reinforce the SPIDERWG recommended guidance on explicit representation of the DERs from load. • Bolster the findings from this study that a knowledge of the total DERs on the system is needed prior to even determining what exactly goes into the transmission models.
Instead of using the base case DER settings, alter to assume IEEE 1547-2003 or more restrictive settings	This study assumed that the base case had sufficient DER data gathering techniques to assign the proper capacity and control behavior.	• The future work tests that assumption as this study had relatively higher "grid friendly" options in the parameterization, particularly disabling frequency response and tripping the entirety of the aggregation (rather than only half) when voltage returns to pre-fault conditions. • The future work explores the setting and parameter differenced depending on the control behavior of the DER. • The study team anticipates settings that are more restrictive could result in larger differences of system results as DER penetrations rise. The future work would provide clarity on this.
Keep the same settings of DER, but ensure no head room and add DER capacity until 100% penetration reached or if instability, uncontrolled separation, or cascading occur.	This study stopped at the base case level of DER penetration[26] to compare study results.	• The study team anticipates that the modeling threshold study can be augmented by such a penetration study to determine system specific reinforcements required to move from current penetrations to higher penetrations. • The study team anticipates that this work will explore the "confidence" a planner may have in modeling DERs at a future date given a growing uncertain "net load" at each T–D interface.
Add another scenario case that looks at only ignoring DER less than 5% of the load.	This study stopped at 10% of the load, but if the 5% of the load differs even a little bit from the 10% load case, there are further findings that can be concluded.	• If the 5% scenario performs worse or better than the 10% scenario, the idea that all DERs need to be accounted for is reinforced. • This can maybe further expand on why the 25% and 50% levels performed better from a frequency standpoint.

[25] Certain areas in an Interconnection are likely separating DER from load in their submission to Interconnection-wide model building. However, some areas are likely still masking their gross load with DER in these cases. This study should be for the entire Interconnection rather than focusing on areas with DER already supplied separate from load.

[26] That is, the study team did not add to the DER penetration level or see what penetration of DER would the system experience either 100% penetration or one of instability, uncontrolled separation, or cascading.

Appendix A: Study Case Details

This appendix serves to explain the study case statistics and flat start figures for the study.

Detailed Study Statistics

Each study case is used to compare the performance of the portion of the study to the base case to answer the question of what impacts are lost with the DER not modeled in the system due to a threshold. Should there be a change in bulk system electrical quantities[27], the need to model DER is established through a proof by contradiction.[28] The study team used reasonable engineering assumptions to increase DER by identifying states that have distribution-connected generation targets as well as areas that have shown growth of such generation in recent years. The team studied a total of eight cases (summarized in **Table A.1**) that detail case-wide statistics for the base and study cases.

Table A.1: Comparison of Case Parameters for each Case in This Study

Case Parameter	Base	5 MVA	20 MVA	75 MVA	10%	25%	50%	Backfeed
Total Case Online Load	148,319 MW	148,319 MW	148,319 MW	148,319 MW	148,319 MW	148,319 MW	148,319 MW	148,319 MW
Total Online Generation Table Pgen	141,485 MW	143,364 MW	147,866 MW	149,793 MW	141,889 MW	144,957 MW	149,166 MW	153,260 MW
Bulk-connected IBR penetration (Wind + Solar)	30,540 MW (21.59 %)	31,051 MW (21.66 %)	31,846 MW (21.54 %)	31,846 MW (21.26 %)	30,684 MW (21.63 %)	31,051 MW (21.42 %)	31,703 MW (21.25 %)	32,706 MW (21.34 %)
Penetration of Steam Turbine (Nuclear + Coal)	18,198 MW (12.86 %)	18,248 MW (10.64 %)	18,261 MW (12.35 %)	19,004 MW (12.69 %)	18,217 MW (12.84 %)	19,161 MW (13.22 %)	19,179 MW (12.86 %)	19,197 MW (12.53 %)
Penetration of Hydro	47,493 MW (33.57 %)	47,484 MW (33.12 %)	47,487 MW (32.11 %)	47,485 MW (31.70 %)	47,493 MW (33.47 %)	46,777 MW (32.27 %)	46,822 MW (31.39 %)	47,599 MW (31.06 %)
Penetration of Natural Gases	29,409 MW (20.78 %)	30,783 MW (21.47 %)	33,271 MW (22.50 %)	33,606 MW (22.43 %)	29,530 MW (20.81 %)	30,239 MW (20.86 %)	32,693 MW (21.92 %)	34,171 MW (22.30 %)
Major Transfer Path[29] Net Flows	TOT 1A: 316 MW TOT 2A: 278 MW TOT 2C: 369 MW TOT 3: 1,009 MW TOT 4B: -99 MW	TOT 1A: 326 MW TOT 2A: 256 MW TOT 2C: 375 MW TOT 3: 1,029 MW TOT 4B: -100 MW	TOT 1A: 325 MW TOT 2A: 256 MW TOT 2C: 375 MW TOT 3: 1,036 MW TOT 4B: -100 MW	TOT 1A: 325 MW TOT 2A: 258 MW TOT 2C: 379 MW TOT 3: 1,038 MW TOT 4B: -101 MW	TOT 1A: 316 MW TOT 2A: 276 MW TOT 2C: 368 MW TOT 3: 1,018 MW TOT 4B: -99 MW	TOT 1A: 342 MW TOT 2A: 230 MW TOT 2C: 375 MW TOT 3: 999 MW TOT 4B: -101 MW	TOT 1A: 344 MW TOT 2A: 229 MW TOT 2C: 372 MW TOT 3: 1,009 MW TOT 4B: -104 MW	TOT 1A: 329 MW TOT 2A: 249 MW TOT 2C: 378 MW TOT 3: 1,029 MW TOT 4B: -100 MW

[27] e.g., Root-Mean-Square frequency or positive sequence transmission bus voltage.

[28] A proof by contradiction is one where the opposite of a claim is assumed and if a contradiction arises, then the original claim is considered proven. In this study, the claim is "There does not exist a bright line threshold for modeling DER such that below the threshold the impacts can be ignored."

[29] WECC defines the lines that total the flows in this dispatch. The paths are net flows from various transmission lines and can have a negative value as the interface is directional. A 2013 report describing the lines involved in each of the paths is available at the following link: https://www.wecc.org/Reliability/TAS_PathReports_Combined_FINAL.pdf

Table A.1: Comparison of Case Parameters for each Case in This Study								
Case Parameter	**Base**	**5 MVA**	**20 MVA**	**75 MVA**	**10%**	**25%**	**50%**	**Backfeed**
	TOT 5: 374 MW TOT 7: 310 MW TOT 2B1: -125 MW TOT 2B2: 66 MW TOTBEAST: 1,897 MW PDCI: 2,711 MW COI: 4,084 MW	TOT 5: 375 MW TOT 7: 313 MW TOT 2B1: -104 MW TOT 2B2: 56 MW TOTBEAST: 1,818 MW PDCI: 2,711 MW COI: 4,159 MW	TOT 5: 374 MW TOT 7: 314 MW TOT 2B1: -106 MW TOT 2B2: 57 MW TOTBEAST: 1,823 MW PDCI: 2,711 MW COI: 4,165 MW	TOT 5: 374 MW TOT 7: 314 MW TOT 2B1: -108 MW TOT 2B2: 57 MW TOTBEAST: 1,829 MW PDCI: 2,711 MW COI: 4,147 MW	TOT 5: 372 MW TOT 7: 311 MW TOT 2B1: -126 MW TOT 2B2: 66 MW TOTBEAST: 1,897 MW PDCI: 2,711 MW COI: 4,083 MW	TOT 5: 378 MW TOT 7: 307 MW TOT 2B1: -70 MW TOT 2B2: 39 MW TOTBEAST: 1,705 MW PDCI: 2,711 MW COI: 3,656 MW	TOT 5: 379 MW TOT 7: 310 MW TOT 2B1: -67 MW TOT 2B2: 38 MW TOTBEAST: 1,685 MW PDCI: 2,711 MW COI: 3,707 MW	TOT 5: 375 MW TOT 7: 313 MW TOT 2B1: -98 MW TOT 2B2: 52 MW TOTBEAST: 1,801 MW PDCI: 2,711 MW COI: 4,276 MW
Total DER Pgen[30]	12,719 MW (8.98%)	10,869 MW (7.58 %)	6,375 MW (4.31 %)	4,482 MW (2.99 %)	12,328 MW (8.69 %)	9,783 MW (6.34 %)	5,090 MW (3.41 %)	1,170 MW (0.76 %)

Each case was simulated for 35 seconds to ensure a flat start at all generation mixes at the bulk level. **Figure A.1** to **Figure A.2** demonstrate the voltage deviations at a bulk system bus and the median frequency movement, respectively, to establish a flat start for all cases. **Figure A.3** shows the relative voltage movement to the starting value in order to reframe the information in **Figure A.1** as the change in flows across study cases slightly altered the initial setting of the voltage. The study team found these graphs to indicate a flat start capable for each case and can perform the contingencies and disturbances to compare across the cases. It was further noted that the following were observed for each case:

- The largest MW deviation in each case was less than 1 MW
- The largest MVAR deviation in each case was less than 1 MVAR
- The largest speed deviation (spd) in each case was less than 0.0005
- The largest voltage deviation of all transmission buses was less than 0.0003 p.u. and settled to below 0.0002 p.u.
- The median frequency deviation at 35 seconds was 0.00001 p.u. frequency

As all of the above values are very small and no growing oscillation was observed in the no-disturbance flat runs, the study team concluded its testing on the base and study cases and determined them suitable for study.

[30] Notes that this percentage is based off the total generation online in the case and not the load. Due to losses, these percentages will be different.

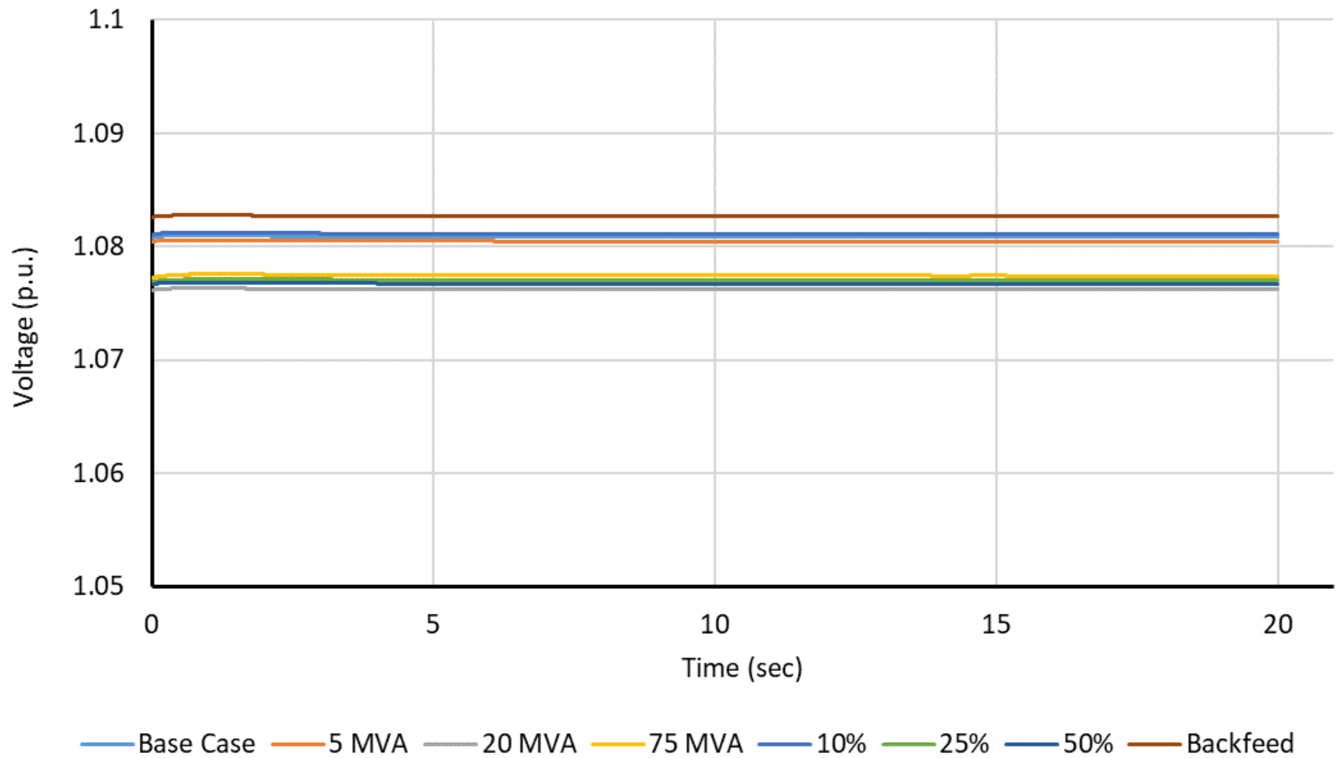


Figure A.1: No Fault Simulation Voltage Plots

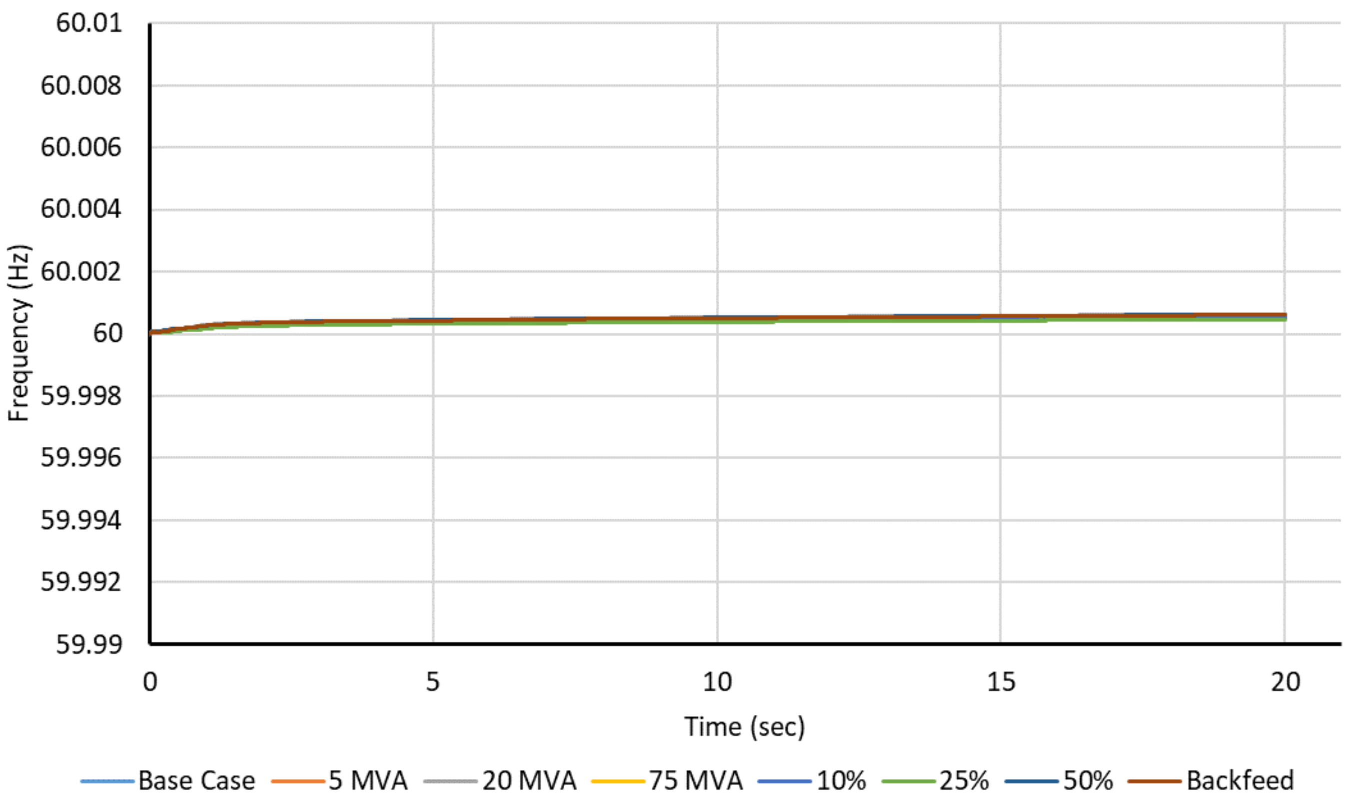


Figure A.2: No Fault Simulation Frequency Plots

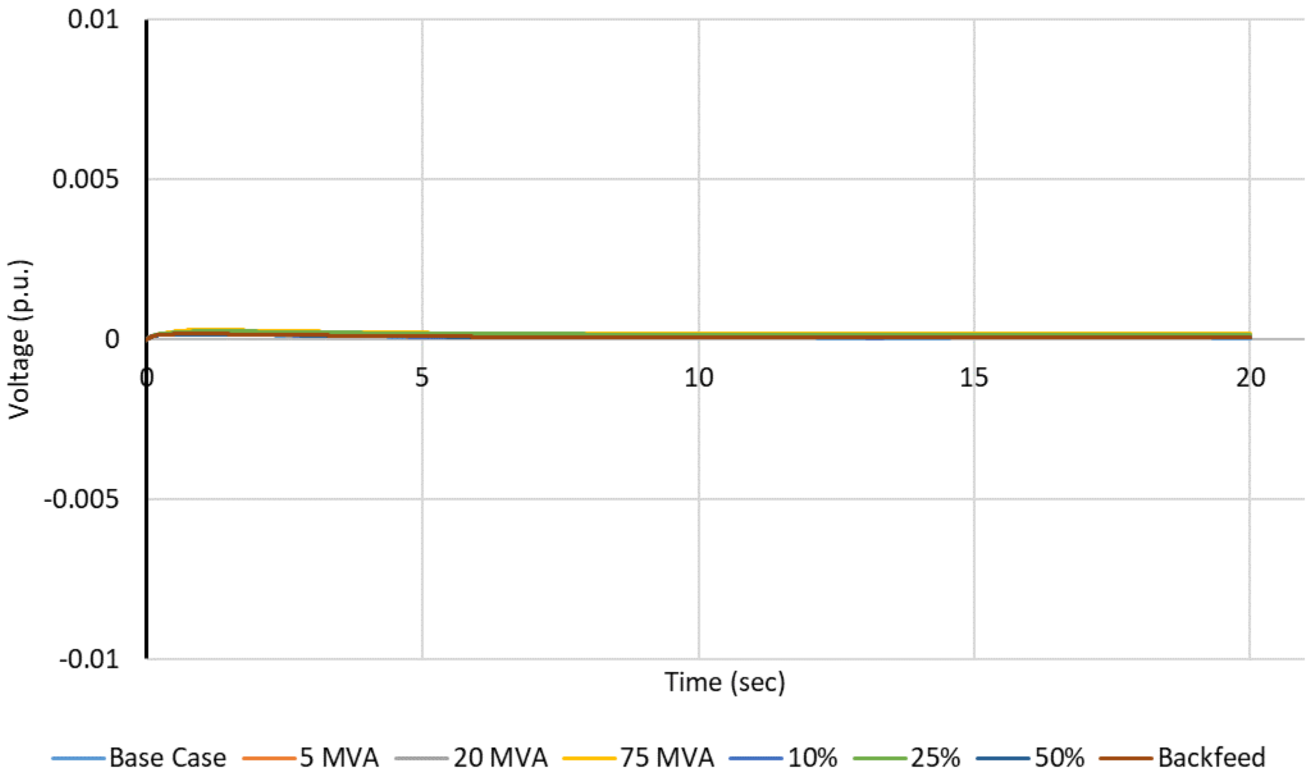


Figure A.3: Voltage Deviation Relative to Flat Start

Relevant DER Model Parameters

In the study, the DER dynamic model used was the PSLF "der_a" model integrated into the composite load model. The relevant DER settings for this study were the frequency response and voltage ride-through settings for these models. For all of the DERs in the study, the relevant parameters are listed in Table A.2

Table A.2: Relevant DER Parameters		
Case Parameter	**Description**	**Value**
Vl0	Voltage break-point for low voltage cut-out of the inverter, p.u.	0.49
Vl1	Voltage break-point for low voltage cut-out of the inverter, p.u.	0.54
Vh0	Voltage break-point for high voltage cut-out of the inverter, p.u.	1.2
Vh1	Voltage break-point for high voltage cut-out of the inverter, p.u.	1.15
Vrfrac	Fraction of device(s) that recover after voltage returns between *vl1* and *vh1*	0.5
Tvl0	Low voltage cut-out timer, sec.	0.16
Tvl1	Lowe voltage cut-out timer, sec.	1.5
Tvh0	High-voltage cut-out timer, sec.	0.16
Tvh1	High-voltage cut-out timer, sec.	1.5

Table A.2: Relevant DER Parameters		
Case Parameter	**Description**	**Value**
Fltrp	Low frequency threshold for cut-out of the inverter, Hz.	58.5
Fhtrp	High frequency threshold for cut-out of the inverter, Hz.	61.2
Tfl	Low frequency cut-out timer, sec.	300.0
Tfh	High frequency cut-out timer, sec.	300.0
Fdbd1	Lower frequency control deadband, p.u.	-0.0006
Fdbd2	Upper frequency control deadband, p.u.	0.0006
Ddn	Frequency control droop gain (down side)	20.0
Dup	Frequency control droop gain (upper side)	20.0
Frqflg	Frequency control enable/disable flag	1
Pmax	Maximum power, p.u.	1.0
Pmin	Minimum power, p.u.	0.0

Documented Troubleshooting and Workarounds for this Study

While performing the study setup and creating the various cases for this report, the following issues and workarounds were performed due to software or data limitations; recommendations for improvements are also included as follows:

- **Issue:** The powerflow records associated with turbine_type and fuel_type were not completely filled nor where consistent in an area for what was filled out and what data was missing. The study team used engineering judgement to sort categories of generation facilities in order to fill out the summary statistics tables.

  Recommendation: WECC should ensure that their generator data requirements are fulfilled for generator records such that both mathematically required (e.g., generator capabilities) and ancillary (e.g., fuel types, owner, area) information is supplied to users of the base cases.

- **Issue:** When running contingencies, the study team found a few motors and first generation renewable models that were not small signal stable and had a growing oscillatory behavior after the system began to recover from the contingency. The study team observed this in both the resource loss and bus voltage fault contingencies and was attributed to the model rather than system performance. Units were netted to resolve and it was noted the renewable plant modeled was using an "unacceptable" designated model per the WECC Model Validation Subcommittee.

  Recommendation: WECC should ensure their model validation process rigorously tests the stability of models for credible disturbances to their system at various dispatch levels of the models and ensure that their Interconnection-wide models conform to their set of approved models.

- **Issue:** There were a few instances of generator records being tied to a DER_A record with no way of indicating in the powerflow data that the generator was a distribution-connected equipment as some voltages on the records were bulk connected buses (above 100 kv) as well as typical bulk-connected IBR collector system voltages (below 1 kV) in the case. In order to track what type of DER (both U-DER and R-DER), the study team used an open value in the turbine_type field to indicate “DER compliant to 1547-2018 versus 1547-2014 or 1547-2003.”

Recommendation: WECC should ensure that U-DER and R-DER values in their powerflow model are readily identifiable so that their PCs and TPs can identify the type of generation in the record. This is important to ensure that neighboring PCs and TPs can understand the generation mix in the Interconnection and ensure any required changes to the generation based on the type of study are accurately performed in their own and neighboring systems. For example, DER voltage control settings when performing contingency analysis of an inter-area tie line.

Recommendation: The study team assumed that all parameterized DERs in the model were correct, which is confirmed by comparing the capacity found in **Figure A.4** with the DER penetration in the case. The WI case’s distributed generation fields in the load records are primarily in the California state, and are a good basis for percentage values to apply for those load records as such. Furthermore, as this assumption is applied on all cases, no bias is introduced; however, the DER model should be accurate to its T–D interface, as explored in **Chapter 2**.

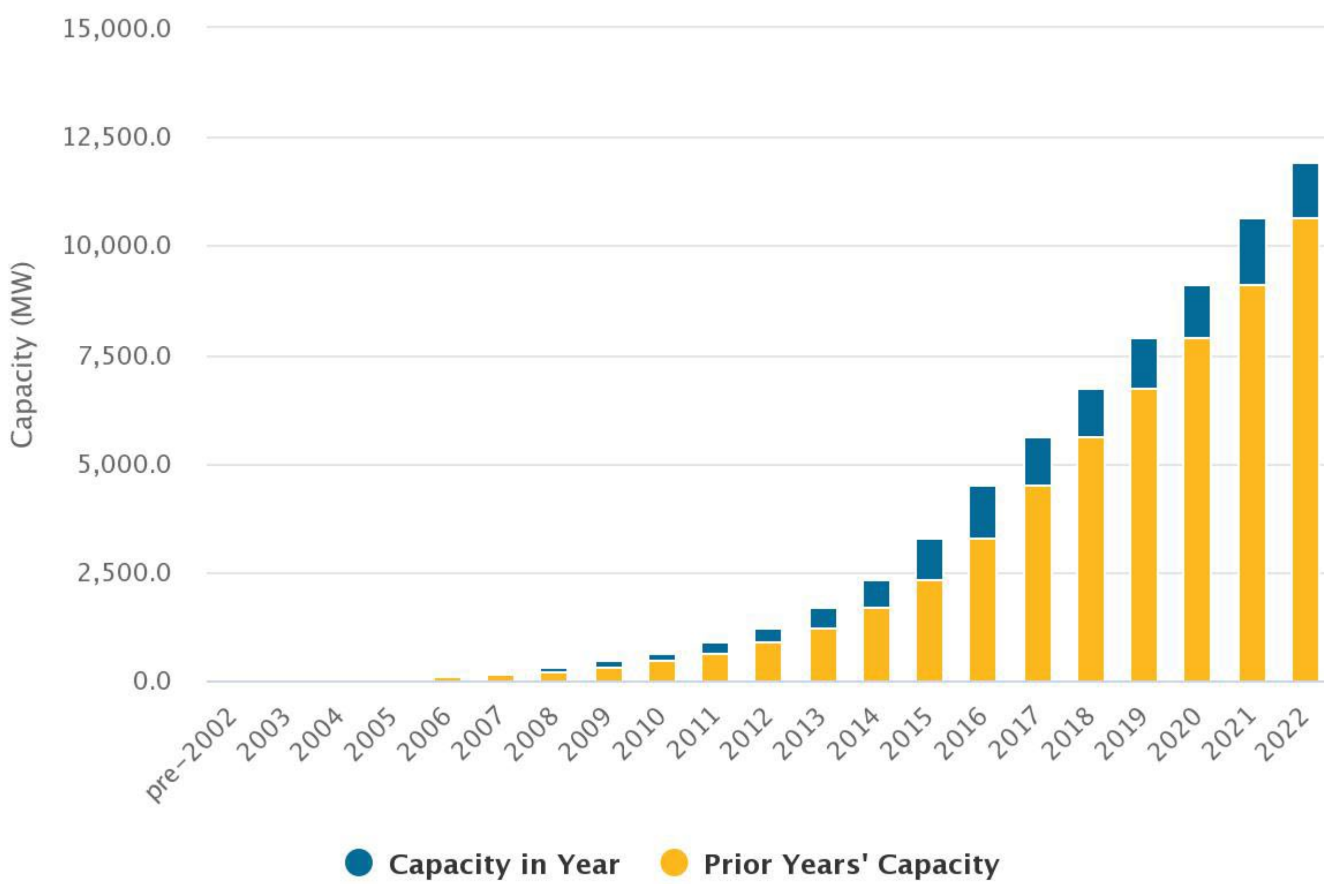


Figure A.4: California Area Cumulative Capacity by Year

[Source: https://www.californiadgstats.ca.gov/charts/]

Appendix B: Study Team

NERC would like to acknowledge the following people who contributed to the study and its report. The study team would like to also thank the NERC SPIDERWG for feedback from a presentation by this study team to the SPIDERWG to enhance the findings and identify areas of future work related to the study.

Table A.1: Study Team	
Name	**Company**
John Paul "JP" Skeath	North American Electric Reliability Corporation
Ryan Quint	North American Electric Reliability Corporation
Olushola Lutalo	North American Electric Reliability Corporation
Hongtao Ma	North American Electric Reliability Corporation
David Till	North American Electric Reliability Corporation