

NERC

NORTH AMERICAN ELECTRIC
RELIABILITY CORPORATION

2019 Generator Operator Survey Summary Report

Final

NERC Resource Subcommittee

Approved November 25, 2020

RELIABILITY | RESILIENCE | SECURITY



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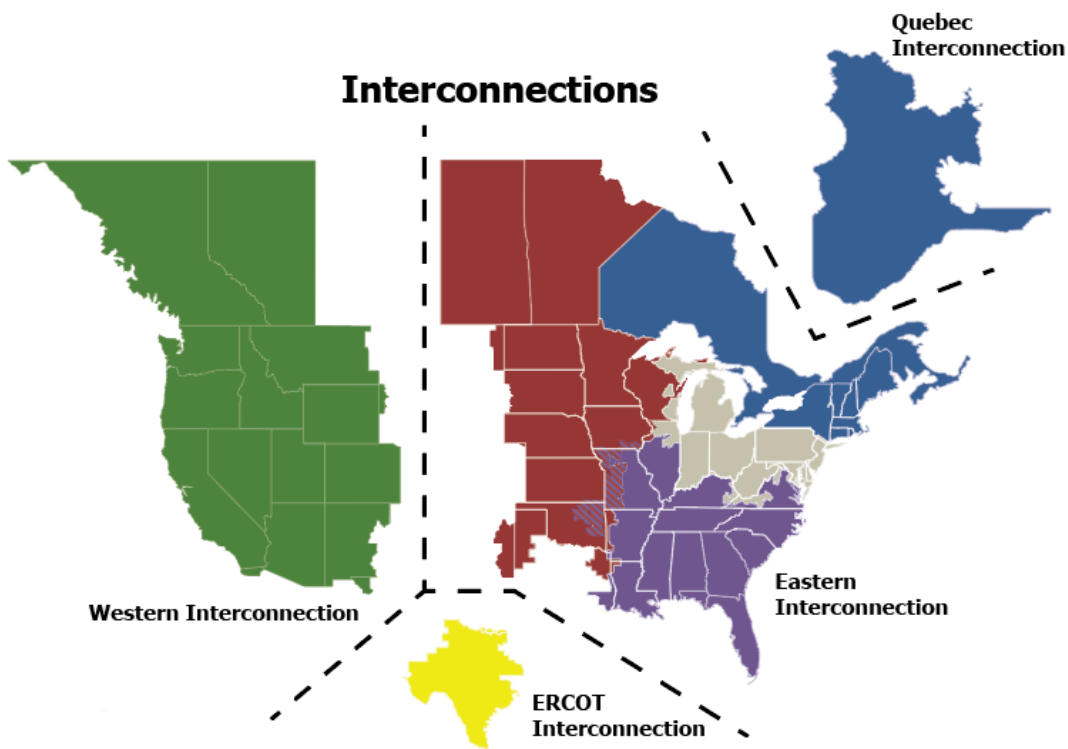
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Preface

Electricity is a key component of the fabric of modern society and the Electric Reliability Organization (ERO) Enterprise serves to strengthen that fabric. The vision for the ERO Enterprise, which is comprised of 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	Western Electricity Coordinating Council

Introduction

In December 2016, the NERC Operating Committee approved a multi-year generator survey to support the education of the industry in regards to the aspects of primary frequency response and to encourage Generator Owner (GOs) and Generator Operators (GOPs) to voluntarily modify settings and coordinate outer loop control to allow the generators to respond to frequency deviations for system reliability. The multi-year effort would be led by the NERC Resources Subcommittee (RS) and the North America Generator Forum (NAGF).

In 2017, the RS and NAGF conducted voluntary generator surveys in three of the four North American Interconnections: Quebec, Western, and Eastern. ERCOT/TRE had implemented requirements and compliance measures for its generators to provide and sustain primary frequency response several years earlier, so they were excluded from the surveys. ERCOT lessons learned, technical expertise, and resources were instrumental in conducting the 2017 Generator Survey and 2019 Generator Survey.

The 2017 GOP Survey was successful with voluntary participation in all three Interconnections. Deadband settings, outer loop control, and lack of knowledge by the industry related to primary frequency response were the three leading causes of generators in ability to provide or sustain primary frequency response to maintain system reliability. The survey notification and related documents were sent out via the NERC email compliance lists, NERC regional contact lists, and the NAGF member list. GOs and GOPs were asked to submit their responses to NERC via email. A single low-frequency event was selected by each Interconnection to evaluate primary frequency response of each Bulk Electric System generator.

Many lessons were learned in the areas of notifications to GOs and GOPs of the 2017 GOP Survey, the selection of a single event, and the data submittal process.

As a result of the lessons learned the 2019 GOP Survey the following items were modified for the Eastern and Western Interconnection:

- To improve in communications for the 2019 GOP Survey, the RS with the NAGF hosted multiple WebEx meetings¹ (communicated in NERC regional meetings), a RS regional representative contacted Balancing Authorities, extracted email addresses from the 2017 NERC GOP Survey submittals, and used the latest email lists submitted by the registered entities.
- Multiple frequency low events were provided to allow several opportunities for GOPs to evaluate their response. GOPs were asked to provide only one response to a single selected event of their choice.
- The data collection process was modified to request Balance Authorities to collect and summarize the data from its generators and to submit to NERC through existing processes.
- An additional Excel summary spreadsheet was developed to aid Balancing Authorities to import and provide a consistent summary of individual GOP evaluations.

Primary frequency control is the first active response of resources to arrest the locally measured or sensed changes in speed/frequency. Governors are continuously active, automatic (not driven by a centralized system), and respond instantaneously to frequency deviations exceeding its governor deadband limits. Governor action is delivered proportionally on the droop curve for excursions of frequency beyond the governor deadband limits. For the purpose of 2019 GOP Survey, primary and sustained primary response is measured as follows:

¹ [WebEx meetings](#)

- **Primary Response:** Generator performance is measured as a percent of expected MW response during the period 20 to 52 seconds after the start of the event.
- **Sustained Primary Response:** Generator performance is measured as a percent of expected MW response at 46 seconds after the start of event as compared to the max MW change during the period 46 to 60 seconds after the start of the event.

Generators that provide at least 75% of their expected response with their governors set in accordance with the NERC *Reliability Guideline Primary Frequency Control*² in the proper direction and sustain it for the lesser of the event duration or for one minute received a satisfactory/ passing score.

² [NERC Reliability Guideline: Primary Frequency Control](#)

Executive Summary

The 2019 GOP Survey was initiated in August 2019. The support of Balancing Authorities led to a successful survey with increased participation in the Eastern and Western Interconnections (see [Table E.1](#)).

Table E.1: Interconnection Submittals

Interconnection	2017 Submittals	2017 Submittal Percent	2019 Submittals	2019 Submittals Percent	Percent Increase
Eastern	752	25.8%	1,833	48%	143.8%
Western	213	23.3%	427	29%	100.5%
Quebec	337	100%	340	100%	0.9%

The generator survey evaluated individual generator performance based on data submitted by the Generator Operator (GOP). Metrics were established to evaluate primary and sustained frequency response. 2019 submittals include the total of evaluated units, off-line units, and units that were at Pmax. The 2019 Evaluated Units column only includes units that have adequate headroom to increase output during the low frequency event. All units were requested to submit data for at least one of the events identified even if off-line or at Pmax (see [Table E.2](#)).

Table E.2: Interconnection GADS Submittals

Interconnection	Number of GADS Units (August 2019)	2019 Submittals	2019 Evaluated Units	Units with Desired Primary and Sustained Performance
Eastern	3,834	1,833	648	273
Western	1,472	427	184	80
Quebec	340	340	117	12

Primary response was evaluated if a GOP provided at least 75% of the expected calculated response. Sustained response was identified if the generator provided frequency support for at least one minute or the lesser of the duration of the event. Generators were identified as performing well if they provided both primary and sustained frequency response (see [Table E.3](#) and [Table E4](#)). The same evaluation metrics were used in the 2017 GOP Survey.

Table E.3: Interconnection Generator Numbers

Interconnection	Eastern Number of Generators	Eastern Percent of Generation	Western Number of Generators	Western Percent of Generation	Quebec Number of Generators	Quebec Percent of Generation
Primary ($\geq .75$)	293	45%	87	43%	12	10%
Sustain ($\geq .75$)	322	50%	95	47%	56	48%
Primary and Sustained	273	42%	80	40%	12	10%
Total Evaluation	648		184		117	

Table E.4: Interconnection GADS Metrics

Interconnection	2019 Percent of GADS Units Submitted	2019 Percent of Submitted Units Evaluated	2019 Percent of GADS Units Evaluated	2019 Percent of Units with Desired Primary and Sustained Performance (Submitted/GADS)
Eastern	48%	35%	17%	42%/7%
Western	29%	43%	13%	40%/5%
Quebec	100%	62%	34%	10%/4%

Based on collected and analyzed data, the NERC Resources Subcommittee (RS) concludes outer loop control and coordination issues within plant or unit governor controls, such as the plant digital control system, continues to be one of the primary prevailing issues why generators are not responding to deviations of frequency outside of the desired deadband setting when head room is available. In addition, many generator deadband and droop settings exceed the advised and recommended setting provided for in the *NERC Reliability Guideline Primary Frequency Control*.³

Given the vast majority of units in the Eastern and Western interconnection have the correct droop and deadband settings and yet only 42% and 40% provided at least 75% of Desired Primary and Sustained Response provides evidence that outer loop control is prohibiting response. GOPs are encouraged to coordinate outer loop control with their governors and modify governor controls to the recommended settings.

Additional data was gathered on generator type for the 2019 GOP Survey. Additional graphs and details are provided per Interconnection in the following sections of this report.

³ [NERC Reliability Guideline: Primary Frequency Control](#)

Section 1: Quebec Interconnection

Summary

The RS approved one low frequency event (April 16, 2019, at 20:02:10 UTC with Point C of 59.00 Hz) below the recommended deadband of 59.964 Hz for the Quebec Interconnection GOPs to evaluate.

The Quebec Interconnection, represented by the single Balancing Authority, Hydro Quebec (HQ), participated in the 2017 NERC GOP Survey. HQ took the leadership role in 2017 by testing the spreadsheet used later by the Western and Eastern Interconnections (see [Table 1.1](#) and [Table 1.2](#)).

Table 1.1: Quebec Submittals				
Interconnection	2017 Submittals	2017 Submittal Percent	2019 Submittals	Percent Increase
Quebec	337	100%	340	0.9%

Table 1.2: Quebec GADS Submittals				
Interconnection	Number of GADS Units (August 2019)	2019 Submittals	2019 Evaluated Units	Units with Desired Primary and Sustained Performance
Quebec	340	340	117	12

In the 2019 NERC GOP Survey, 10% of generators submitted for evaluation provide primary and sustained frequency response as illustrated in [Figure 1.1](#). This is best explained by all the generation evaluated to be hydro. By the nature of hydro power generation, time constants can range between 5–60 seconds to account for gate operation and water travel time to the turbine.

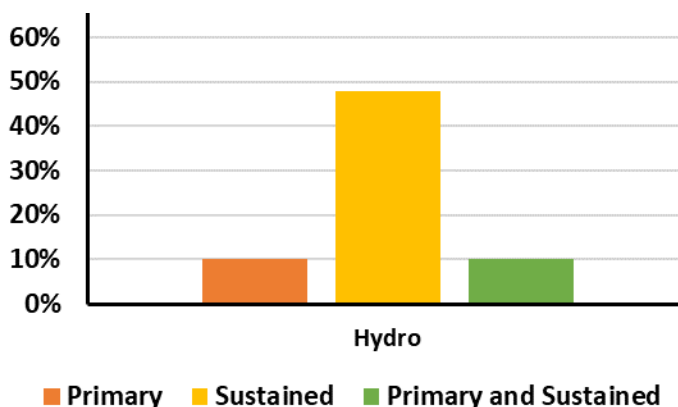


Figure 1.1: Quebec Primary Frequency Response

The 2019 NERC GOP Survey requested additional data from the GOP regarding generator type. As illustrated by [Figure 1.2](#), the Quebec Interconnection generation evaluated in the survey was all Hydro.

Note: Units that were not evaluated due to being at or near Pmax were excluded from the analysis.

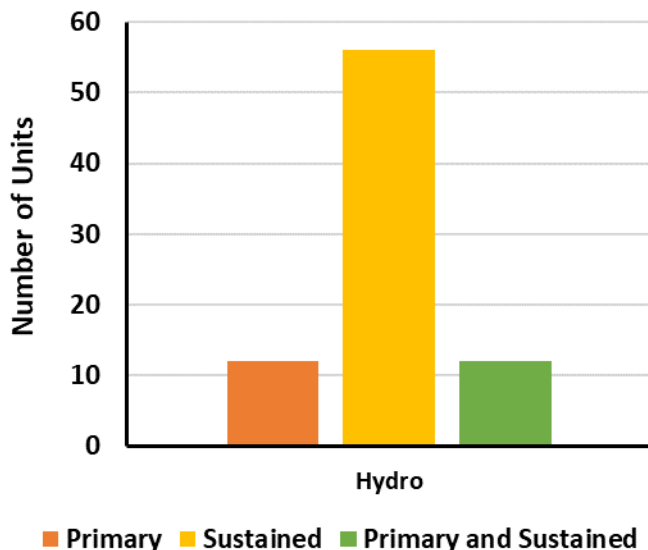


Figure 1.2: Quebec Performance by Generator Type

Generator Droop

The definition of droop is the amount of speed (or frequency) change that is necessary to cause the main prime mover control mechanism to move from fully closed to fully open. In general, the percent movement of the main prime mover control mechanism can be calculated as the speed change (in percent) divided by the per unit droop.

The *NERC Reliability Guideline Primary Frequency Control*⁴ recommends droop setting not to exceed 5%. [Figure 1.3](#) compares by percentage the generators that are set and in accordance and percentage of units that exceed the recommended setting of the guideline. The RS recommends that all generators that exceed the droop setting to comply with the guideline.

Note: The RS recognizes there may be some environmental reasons to exceed the recommend droop setting on some hydro plants.

⁴ [NERC Reliability Guideline: Primary Frequency Control](#)

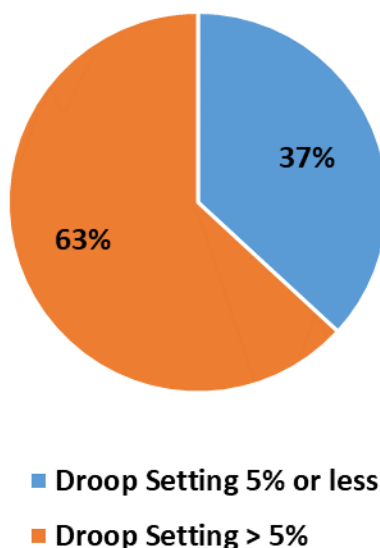


Figure 1.3: Quebec Droop Setting

Generator Deadband

Deadband is the value subtracted from or added to reference frequency of 60 Hz when the governor should begin to respond if headroom or footroom is available due to an interconnection frequency deviation. The *NERC Reliability Guideline Primary Frequency Control*⁵ states for the Quebec Interconnection that “There shall be no intentional governor deadband set on generators within the Quebec Interconnection by local requirement.” For the hydro units evaluated, all units were set in accordance with the guideline.

⁵ [NERC Reliability Guideline: Primary Frequency Control](#)

Section 2: Western Interconnection

Summary

The RS approved three low frequency events (July 26, 2019, at 07:12:13 UTC with Point C of 59.9058 Hz, August 16, 2019, at 15:21:06 UTC with Point C of 59.8857 Hz and August 23, 2019, at 17:43:01 UTC with Point C of 59.8555 Hz) below the recommended deadband of 59.964 Hz for the Western Interconnection GOPs to evaluate.

As stated previously, the participation from the Western Interconnection GOPs increased from 2017 GOP Survey. The increased participation in the 2019 GOP Survey is attributed to the RS request for Balancing Authorities to take an active role (see [Table 2.1](#) and [Table 2.2](#)).

Table 2.1: Western Submittals

Interconnection	2017 Submittals	2017 Submittal Percent	2019 Submittals	2019 Submittal Percent	Percent Increase
Western	213	23.3%	427	29%	100.5%

Note: The number of GADS Bulk Electric System Generators for the Western Interconnection in August 2019 was determined to be 1,472.

Table 2.2: Western GADS Submittals

Interconnection	Number of GADS Units (August 2019)	2019 Submittals	2019 Evaluated Units	Units with Desired Primary and Sustained Performance
Western	1,472	427	184	80

In this 2019 NERC GOP Survey, 40% of generators submitted for evaluation provide primary and sustained frequency response as illustrated in [Figure 2.1](#).

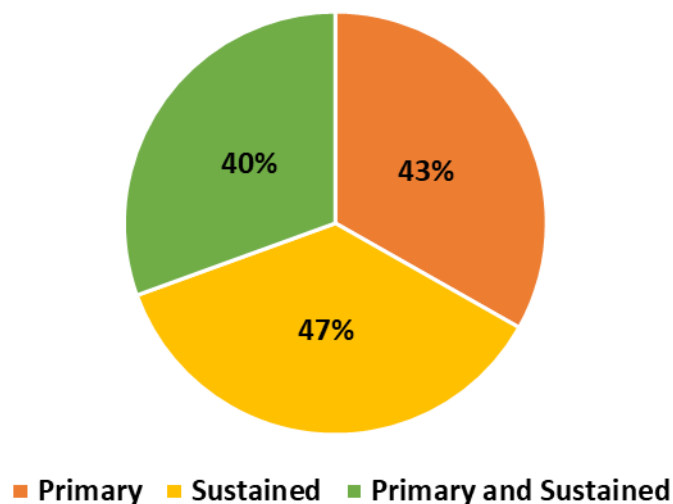


Figure 2.1: Western Primary Frequency Response

This 2019 NERC GOP Survey requested additional data from the GOPs regarding generator type. As illustrated by [Figure 2.2](#), the majority of units that met or exceeded the metric of providing primary and sustained frequency response were Hydro, Combustion Turbine - Combined Cycle, and Steam Turbine - Coal Fired.

Note: Units that were not evaluated due to being at or near Pmax was excluded from the analysis.

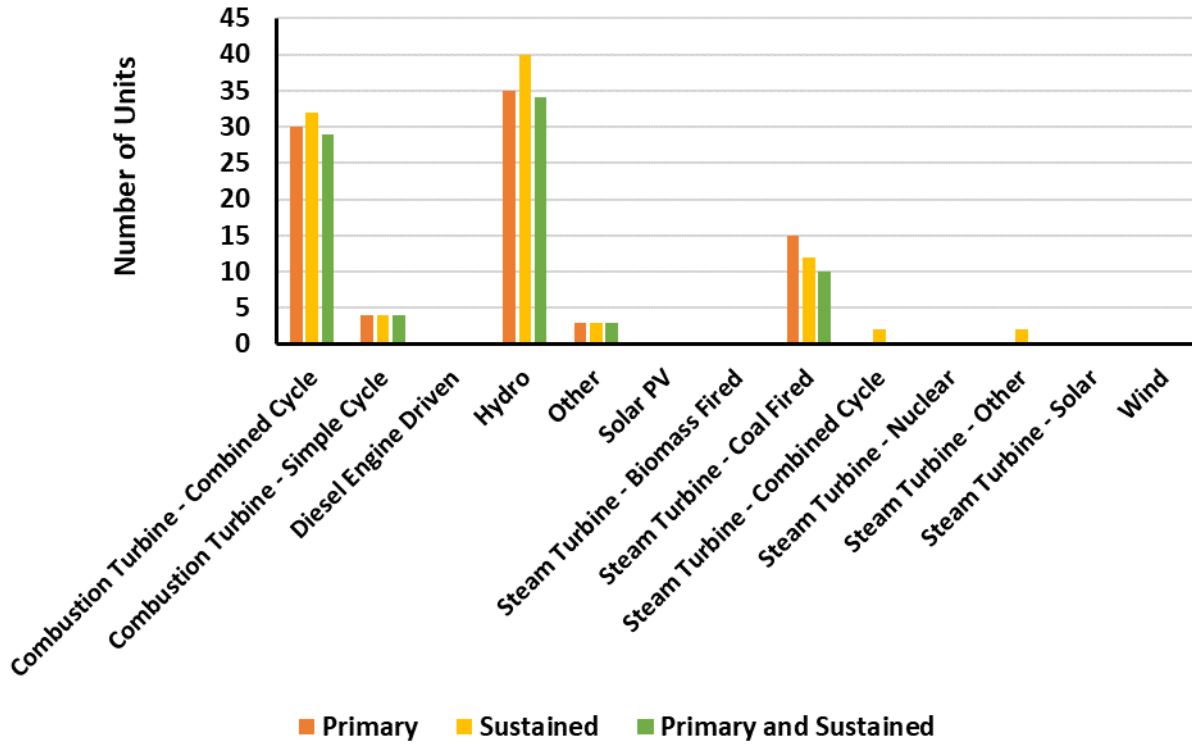


Figure 2.2: Western Primary Frequency Response by Type and Number of Units

Generator Type Comparison

A comparison can be made relative to the total submittals by generator type and comparing the number of units that met or exceed the metric versus those that did not. In [Figure 2.3](#), more than 75% of all other units and more than 60% of all hydro units that responded to the survey met or exceeded the metric of providing primary and sustained frequency response. Comparatively, more than 50% of Combustion Turbine - Simple Cycle units followed more than 40% of Combustion Turbine - Combine Cycle units met or exceeded the metric of providing primary and sustained frequency response.

Note: Units that were not evaluated due to being at or near Pmax was excluded from the analysis.

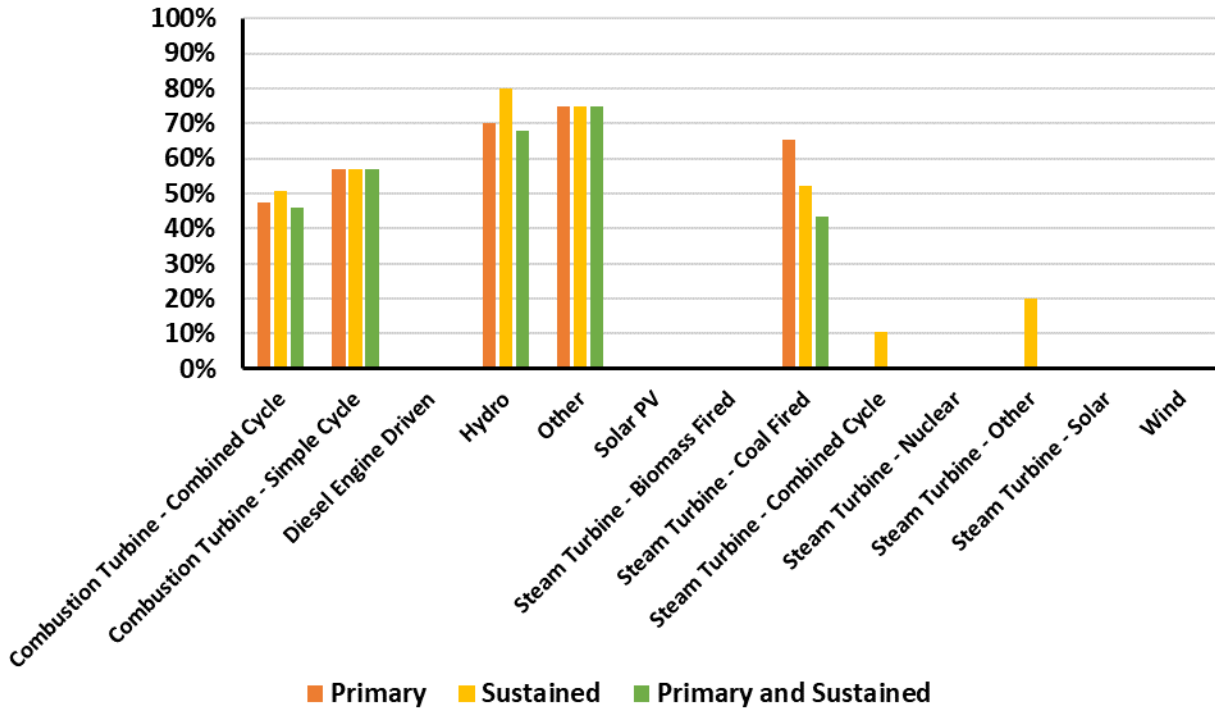


Figure 2.3: Western Primary Frequency Response by Type and Percent of Units

Generator Droop

The definition of droop is the amount of speed (or frequency) change that is necessary to cause the main prime mover control mechanism to move from fully closed to fully open. In general, the percent movement of the main prime mover control mechanism can be calculated as the speed change (in percent) divided by the per unit droop.

The NERC *Reliability Guideline Primary Frequency Control*⁶ recommends droop settings not exceed 5%. For the Western Interconnection, 97% of the units submitted had droop setting that met or exceeded the recommended setting. **Figure 2.4** illustrates the percentage of units in accordance with the guideline by generator type. The RS encourages all generators that exceed the droop setting to comply with the guideline.

Note: The RS recognizes that it may be preferred in some cases to exceed the recommended droop setting in a limited number of boiler and steam turbine configurations. An issue for smaller boilers is that the low steam pressure may exceed reliable operating limits that result from providing frequency response. In addition, there may be some environmental reasons to exceed the recommend droop setting on some hydro plants and other units; in these cases, some frequency response is better than none.

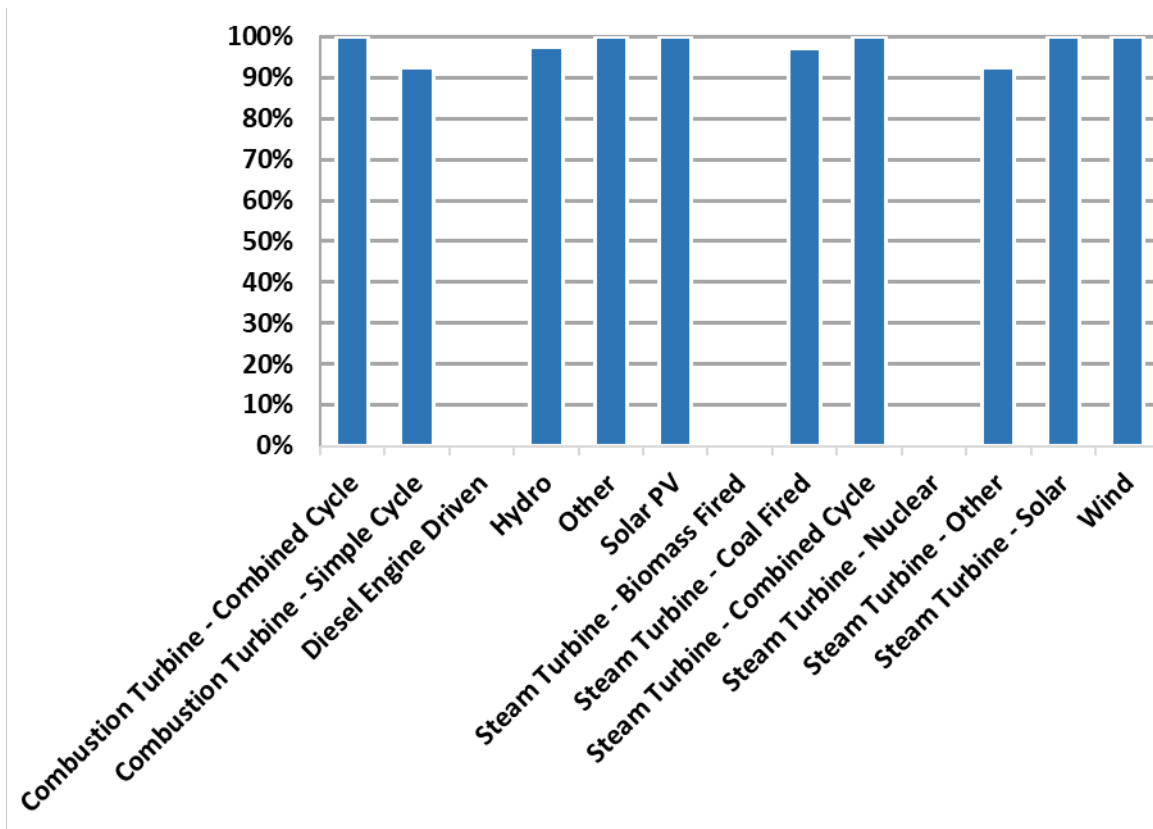


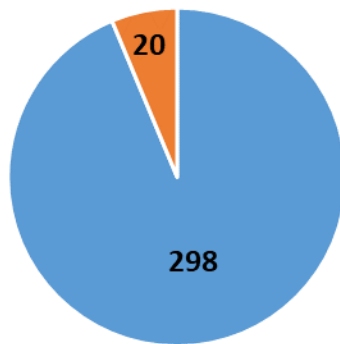
Figure 2.4: Western Droop Setting by Generation Type \leq 5%

⁶ [NERC Reliability Guideline: Primary Frequency Control](#)

Generator Deadband

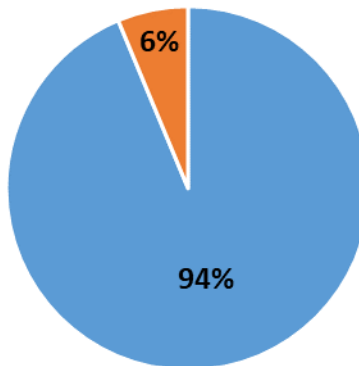
Deadband is the value subtracted or added from reference frequency of 60 Hz when the governor should begin to respond if head room or foot room is available due to an interconnection frequency deviation. *NERC Reliability Guideline Primary Frequency Control*⁷ recommends deadband settings not to exceed +/- 0.036 Hz. The setting is intended to be greater than normal power system frequency changes. [Figure 2.5](#) and [Figure 2.6](#) illustrate the total submittals and deadband values that were provided, the number of units correctly set versus the units that exceeds the recommended settings. The RS recommends all governor deadband settings not exceed +/- 0.036 Hz.

Note: The RS recognizes that there may be a necessity to exceed the recommended deadband settings in a limited number of configurations in some cases. Such issues could be limited to operational reliability, environmental, safety, and regulatory. In these cases, GOPs are encouraged to provide some frequency response to protect the reliability of the Interconnection.



■ Deadband .036 or less ■ Deadband Setting >.036

Figure 2.5: Western Deadband Settings



■ Deadband .036 or less ■ Deadband Setting >.036

Figure 2.6: Western Deadband Settings Percent

⁷ [NERC Reliability Guideline: Primary Frequency Control](#)

Figure 2.7 illustrates the deadband settings by generator type in accordance with the recommended setting. The largest percentage by generator type that exceeds the recommended setting is Other followed by Combustion Turbine-Combined Cycle and Combustion Turbine-Simple Cycle.

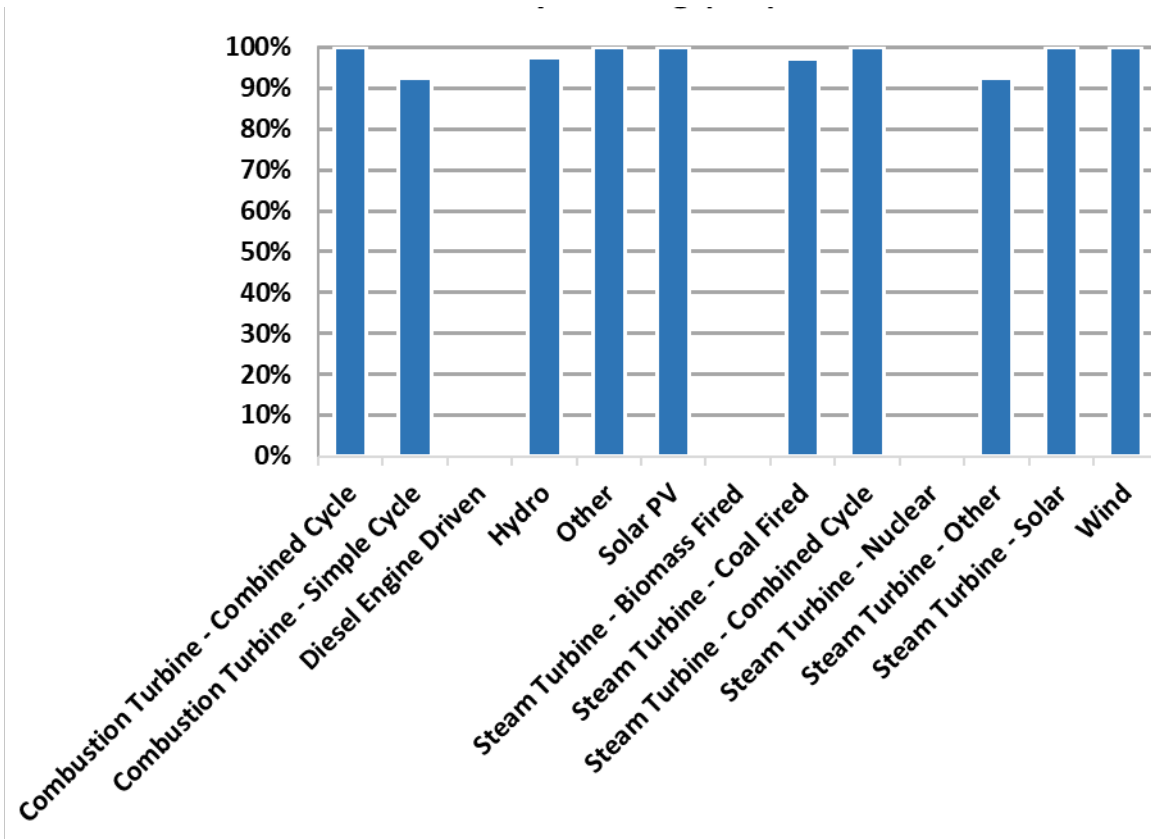


Figure 2.7 Western Deadband Settings $\leq .036$ by Generator Type

Section 3: Eastern Interconnection

Summary

The RS approved five low frequency events (May 3, 2019 at 19:54:08 UTC with Point C of 59.9488 Hz, May 9, 2019 at 08:48:12 UTC with Point C of 59.9466 Hz, July 12, 2019 at 00:45:14 UTC with Point C of 59.9437 Hz, July 26, 2019 at 22:11:05 UTC with Point C of 59.9434 Hz and September 03, 2019 at 13:35:29 UTC with Point C of 59.9401 Hz) below the recommended deadband of 59.964 Hz for the Eastern Interconnection GOPs to evaluate.

As stated previously, the participation from the Eastern Interconnection GOPs increased from 2017 GOP Survey. The increased participation in the 2019 GOP Survey is attributed to the RS request for Balancing Authorities to take an active role (see [Table 3.1](#) and [Table 3.2](#)).

Table 3.1: Eastern Submittals

Interconnection	2017 Submittals	2017 Submittal Percent	2019 Submittals	2019 Submittal Percent	Percent Increase
Eastern	752	25.8%	1,833	48%	143.8%

Note: The number of GADS Bulk Electric System Generators for the Eastern Interconnection in August 2019 was determined to be 3,834.

Table 3.2: Eastern GADS Submittals

Interconnection	Number of GADS Units (August 2019)	2019 Submittals	2019 Evaluated Units	Units with Desired Primary and Sustained Performance
Eastern	3,384	1,833	648	273

In 2019 NERC GOP Survey, 42% of generators submitted for evaluation provide primary and sustained frequency response as illustrated in [Figure 3.1](#).

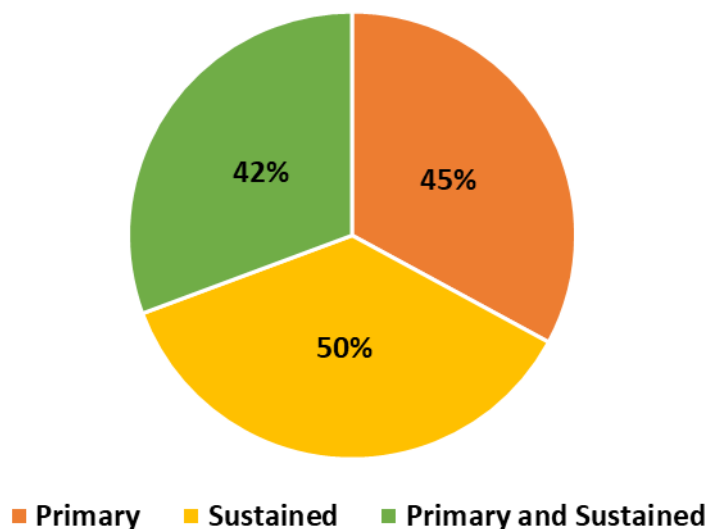


Figure 3.1: Eastern Primary Frequency Response

Generator Type Comparison

The 2019 NERC GOP Survey requested additional data from the GOP regarding generator type. As illustrated by [Figure 3.2](#), the majority of units that met or exceeded the metric of providing primary and sustained frequency response was the generator type Combustion Turbine-Combined Cycle, followed by Steam Turbine-Coal Fired and Hydro units.

Note: Units that were not evaluated due to being at or near Pmax was excluded from the analysis.

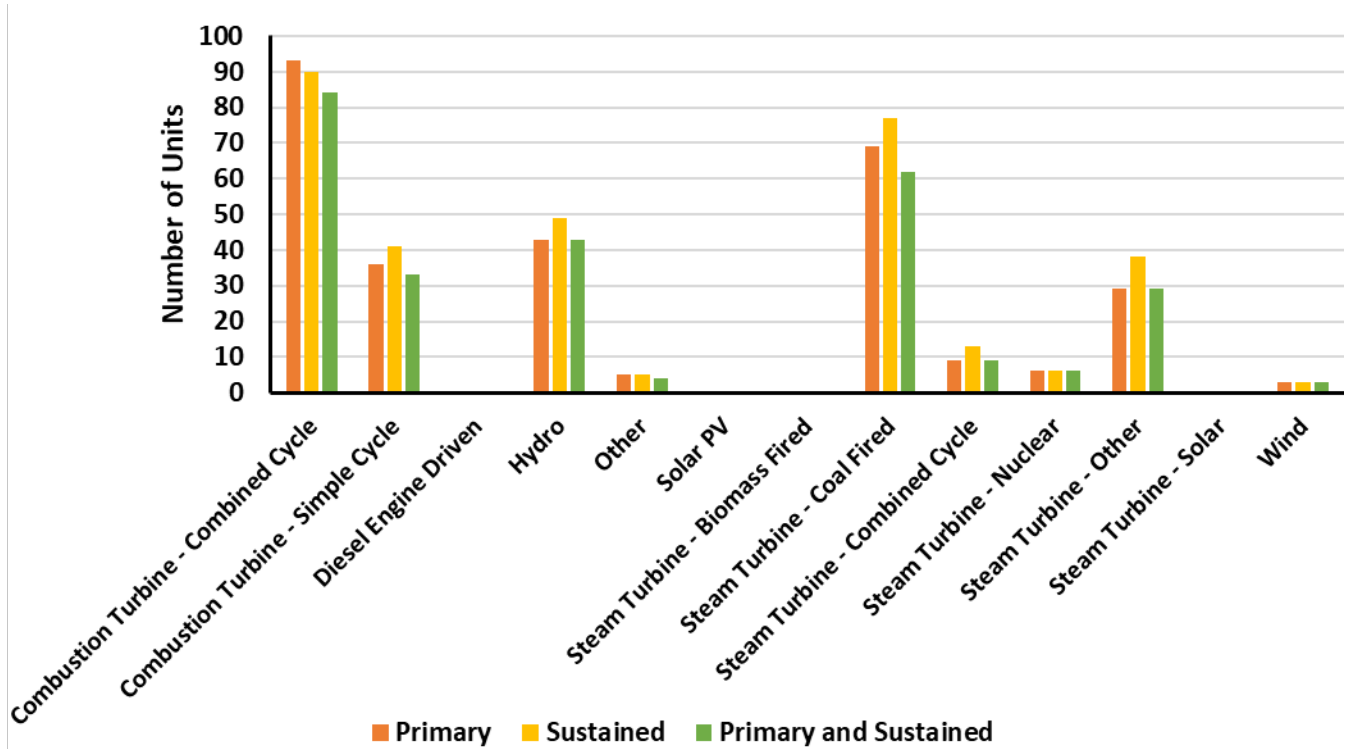


Figure 3.2: Eastern Primary Frequency Response by Type and Number of Units

Generator Droop

A comparison can be made relative to the total submittals by generator type and comparing the number of units that met or exceeded the metric vs those that did not. In [Figure 3.3](#), slightly more than 60% of all hydro units that responded to the survey met or exceeded the metric of providing primary and sustained frequency response. Comparatively, more than 50% of Combustion Turbine – Combined Cycle units followed more than 40% of Steam Turbines – Coal met or exceeded the metric of providing primary and sustained frequency response.

Note: Units that were not evaluated due to being at or near Pmax was excluded from the analysis.

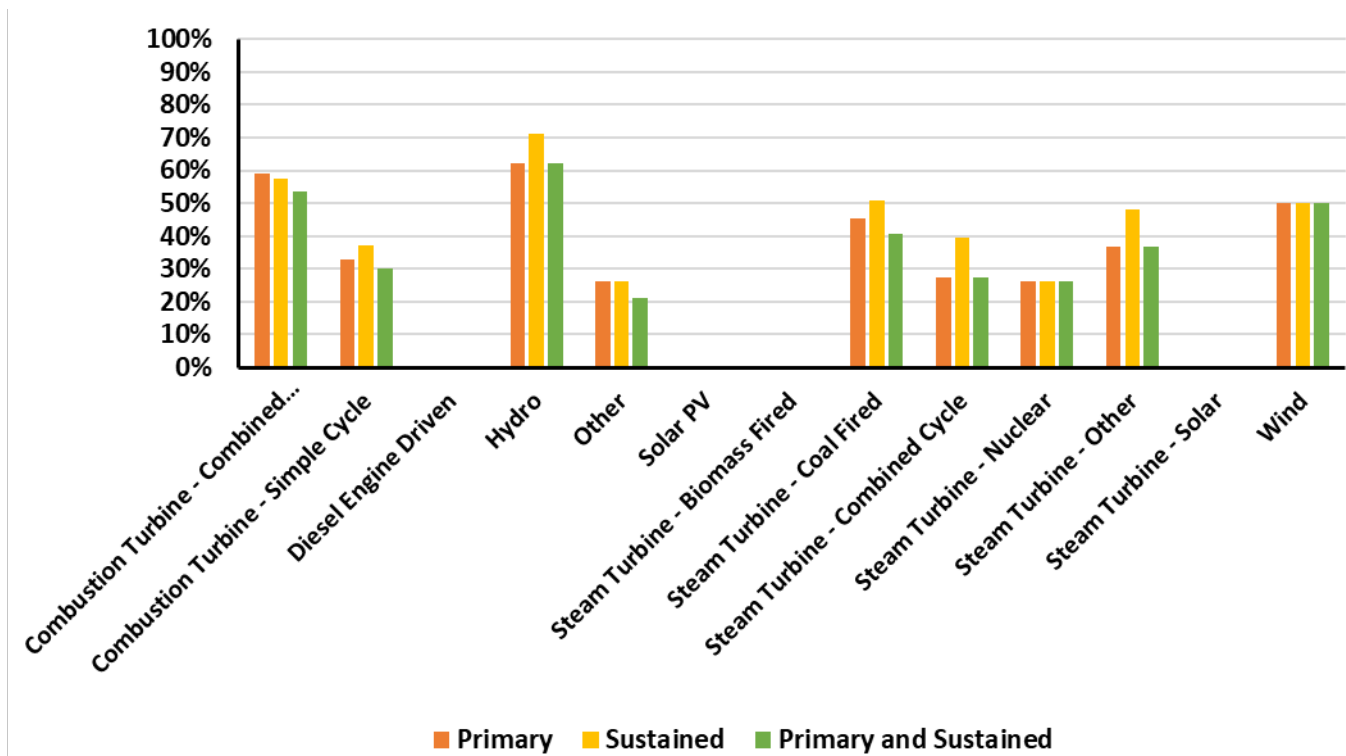


Figure 3.3: Eastern Primary Frequency Response by Type and Percent of Units

The definition of droop is the amount of speed (or frequency) change that is necessary to cause the main prime mover control mechanism to move from fully closed to fully open. In general, the percent movement of the main prime mover control mechanism can be calculated as the speed change (in percent) divided by the per unit droop.

NERC Reliability Guideline Primary Frequency Control⁸ recommends that the droop settings not exceed 5%. For the Eastern Interconnection, 93% of the units submitted had droop setting that met or exceeded the recommended setting. Figure 3.4 illustrates the percentage of units in accordance with the guideline by generator type. The RS encourages all generators that exceed the droop setting to comply with the guideline.

Note: The RS recognizes that it may be preferred in some cases to exceed the recommended droop setting in a limited number of boiler and steam turbine configurations. An issue for smaller boilers is that the low steam pressure may exceed reliable operating limits that result from providing frequency response. In addition, there may be some environmental reasons to exceed the recommend droop setting on some hydro plants and other units. In these cases, some frequency response is better than none.

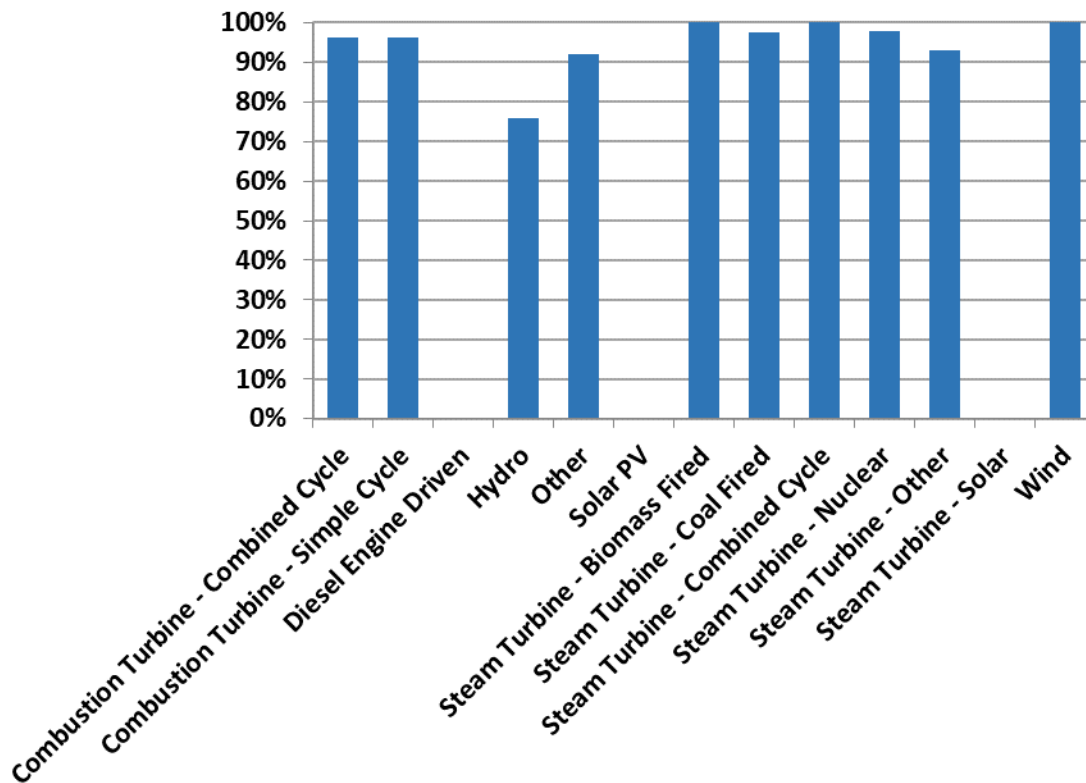


Figure 3.4: Eastern Droop Setting by Generator Type $\leq 5\%$

⁸ [NERC Reliability Guideline: Primary Frequency Control](#)

Generator Deadband

Deadband is the value subtracted from or added to the reference frequency of 60 Hz when the governor should begin to respond if headroom or footroom is available due to an interconnection frequency deviation. *NERC Reliability Guideline Primary Frequency Control*⁹ recommends that deadband settings not exceed +/- 0.036 Hz. The setting is intended to be greater than normal power system frequency changes. Figure 3.5 and Figure 3.6 illustrate the total submittals and deadband values that were provided, the number of units correctly set versus the units that exceeds the recommended settings. The RS recommends that all governor deadband settings not exceed +/- 0.036 Hz.

Note: The RS recognizes that there may be a necessity in some cases to exceed the recommended deadband settings in a limited number of configurations. Such issues could be limited to operational reliability, environmental, safety, and regulatory. In these cases, GOPs are encouraged to provide some frequency response to protect the reliability of the Interconnection.

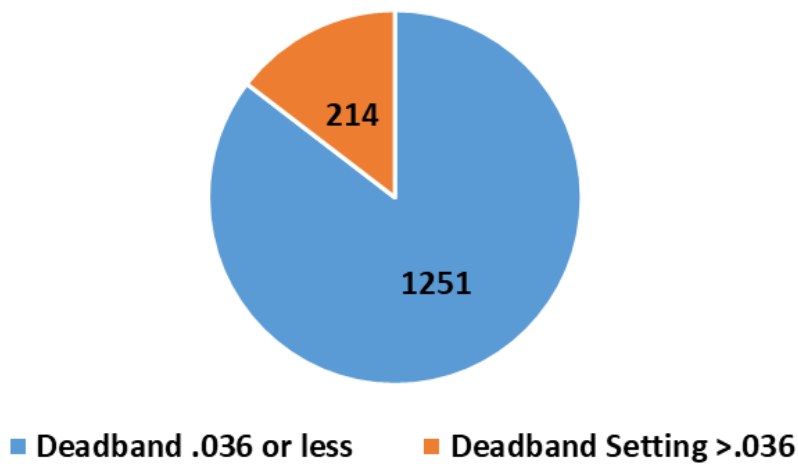


Figure 3.5: Eastern Deadband Settings

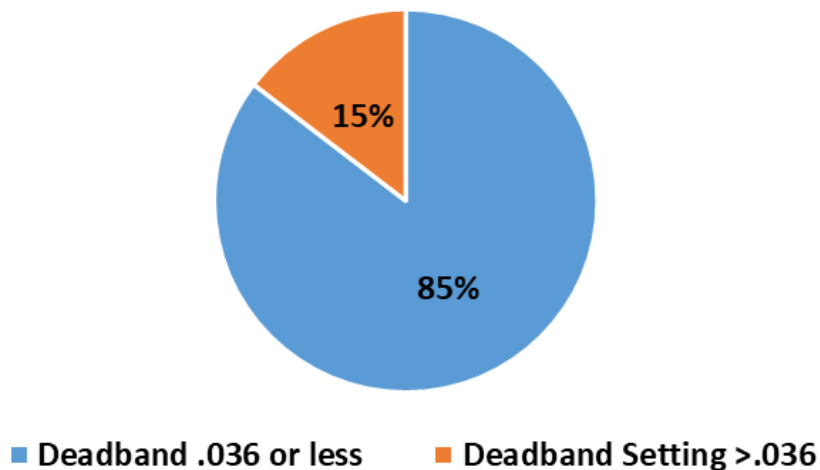


Figure 3.6: Eastern Deadband Settings Percent

⁹ [NERC Reliability Guidelin Primary Frequency Control](#)

Figure 3.7 illustrates by generator type the deadband settings in accordance with the recommended setting. The largest percentage by generator type that exceeds the recommended setting is the Steam Turbines – Nuclear and Steam Turbine - Other.

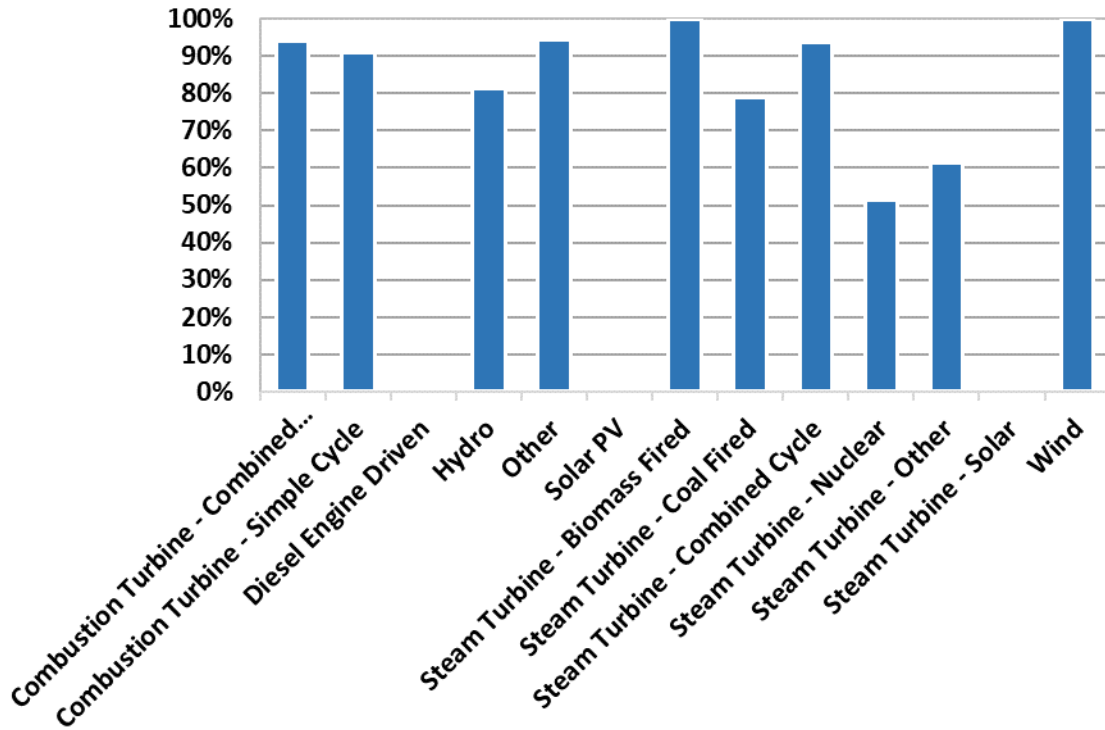


Figure 3.7: Eastern Deadband Settings $\leq .036$ by Generator Type

Section 4: Conclusion

The RS and NAGF recognize and appreciate the GOPs that have enabled their generators to provide primary frequency response. This cooperative support demonstrates the ability for the industry to address reliability issues without the addition of mandatory standards to date. The RS wishes to thank the GOPs and Balancing Authorities that supported the 2019 NERC GOP Survey. A special thanks to the NERC staff for its support in collecting the data from the submittals. The RS finally wishes to thank Southern Company employees who modified and supported the excel summary tool used by Balancing Authorities to import the individual GOP forms. In addition, Southern Company employees, assisted compiling and organizing the data and creation of charts and graphs used in this document and various presentations.

The tremendous effort that has been provided to conduct the 2017 and 2019 GOP Survey has been designed to provide industry education and awareness of reliability issues that have been created with the implementation of electronic governors and control systems installed on or provided to existing generation in the past 20 years. This education and awareness has helped to correct reliability issues without the introduction of mandatory NERC standards.

Note: The generators that did not provide at least 75% of the desired primary frequency response and sustain it for the lesser of the event duration or for one minute are asked to take the opportunity over upcoming plant outages to address issues. The RS has many resources to support and aid GOPs. Balancing Authorities are encouraged to assist it generators in being capable of provide primary frequency response. The RS offers to all GOPs the evaluation spreadsheets provided in the surveys that can be used to evaluate their generator frequency response independent of a NERC survey request.

Modern generating resource control systems generally incorporate a form of plant or unit load control. These load control systems can be applied within the turbine control system, the plant or unit control system, or remotely from a central dispatch center. Regardless of their location or method of implementation, the design of secondary controls must be coordinated with that of the governor to ensure that primary frequency response can be sustained.

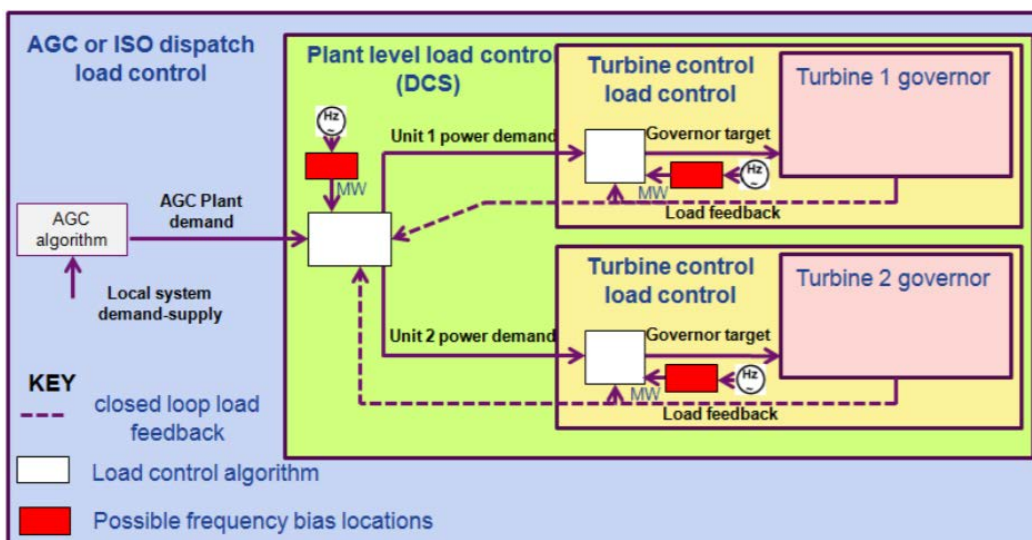


Figure 4.1: Typical High Level Generating Resources Control System

Additional information provided in the data submittals highlighted that some generators recorded that interconnection frequency either did not change or actually exceeded 60 Hz at the time of the event. The RS encourages these generators to look at the equipment they are using to measure system frequency and/or look at

parameters to measure and record frequency inside the historian. The RS also suggests that the generator’s Balancing Authority can provide data for system frequency to compare. To illustrate, **Figure 4.2** below depicts a recent eastern frequency event and the recorded measurements from Maine to Key West, FL, to Raleigh, NC, to Kansas and many points in between. If a generator is local to the frequency event, it will record a lower frequency.

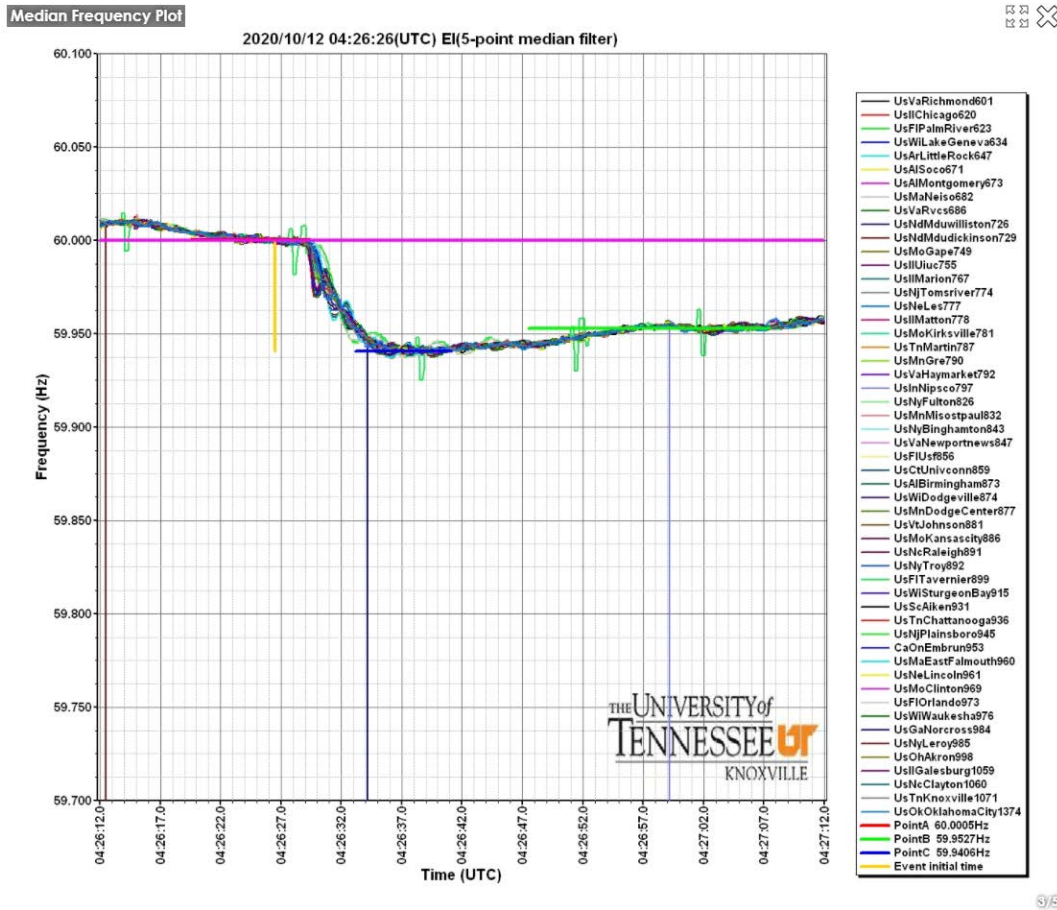


Figure 4.2: Example of Eastern Interconnection Frequency

As stated earlier, the 2019 NERC GOP Survey requested that GOPs provide their generator type. The RS provided 13 generator types. An oversight in the Excel Spreadsheet also allowed Generator Type to be free typed, so the Eastern Interconnection generators created an additional 18 types, and the Western Interconnection provided an additional 4 generator types. The RS will need to address this issue in future generator surveys.

The 2019 NERC GOP Survey was a tremendous success and is an excellent example of what the industry can do to address reliability issues. GOPs who did not participate in the 2019 NERC GOP Survey are encouraged to participate in future surveys. The NERC 2019 Survey participation is an excellent example of how the industry can lead an effort to correct reliability issues without the addition of mandatory standards. The more generators that are capable of providing frequency response, the less each individual generator will need to provide to arrest the frequency decline.