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NORTH AMERICAN ELECTRIC RELIABILITY CORPORATION

Interconnection Criteria for Frequency Response Requirements

Determination of Interconnection Frequency Response Obligations (IFRO)

Transmission Issues Subcommittee

August 2011

RELIABILITY | ACCOUNTABILITY

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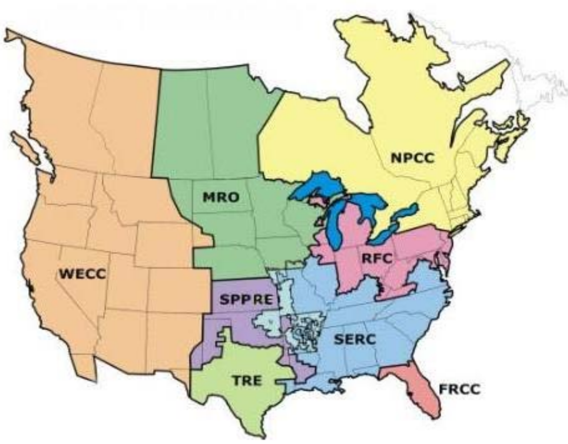
NERC's Mission

The North American Electric Reliability Corporation (NERC) is an international regulatory authority established to evaluate reliability of the bulk power system in North America. NERC develops and enforces Reliability Standards; assesses adequacy annually via a ten-year forecast and winter and summer forecasts; monitors the bulk power system; and educates, trains, and certifies industry personnel. NERC is the electric reliability organization for North America, subject to oversight by the U.S. Federal Energy Regulatory Commission (FERC) and governmental authorities in Canada.[1]

NERC assesses and reports on the reliability and adequacy of the North American bulk power system, which is divided into eight Regional areas, as shown on the map and table below. The users, owners, and operators of the bulk power system within these areas account for virtually all the electricity supplied in the U.S., Canada, and a portion of Baja California Norte, México.



Note: The highlighted area between SPP RE and SERC denotes overlapping Regional area boundaries. For example, some load serving entities participate in one Region and their associated transmission owner/operators in another.

NERC Regional Entities	
FRCC Florida Reliability Coordinating Council	**SERC** SERC Reliability Corporation
MRO Midwest Reliability Organization	**SPP RE** Southwest Power Pool Regional Entity
NPCC Northeast Power Coordinating Council	**TRE** Texas Reliability Entity
RFC ReliabilityFirst Corporation	**WECC** Western Electricity Coordinating Council

[1] As of June 18, 2007, the U.S. Federal Energy Regulatory Commission (FERC) granted NERC the legal authority to enforce Reliability Standards with all U.S. users, owners, and operators of the bulk power system, and made compliance with those standards mandatory and enforceable. In Canada, NERC presently has memorandums of understanding in place with provincial authorities in Ontario, New Brunswick, Nova Scotia, Québec, and Saskatchewan, and with the Canadian National Energy Board. NERC standards are mandatory and enforceable in Ontario and New Brunswick as a matter of provincial law. NERC has an agreement with Manitoba Hydro making reliability standards mandatory for that entity, and Manitoba has recently adopted legislation setting out a framework for standards to become mandatory for users, owners, and operators in the province. In addition, NERC has been designated as the "electric reliability organization" under Alberta's Transportation Regulation, and certain reliability standards have been approved in that jurisdiction; others are pending. NERC and NPCC have been recognized as standards-setting bodies by the Régie de l'énergie of Québec, and Québec has the framework in place for reliability standards to become mandatory. Nova Scotia and British Columbia also have frameworks in place for reliability standards to become mandatory and enforceable. NERC is working with the other governmental authorities in Canada to achieve equivalent recognition.

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Introduction

The NERC Planning Committee tasked the Transmission Issues Subcommittee with what criteria should be used to decide the appropriate level of interconnection-wide frequency response. The TIS started with a body of work already underway by the Resources Subcommittee (RS) and the Frequency Response Working Group (FRWG) of the Operating Committee, and the Frequency Response Standard Drafting Team (FRRSDT). The RS had produced a Position Paper on Frequency Response that was the basis for the method to translate a Resource Contingency Criteria into an Interconnection Frequency Response Obligation (IFRO).

There are various potential ways of assigning the frequency response targets for each interconnection. Initially, the following tenets should be applied:

1. A frequency event should not trip the first stage of regionally approved under-frequency load shedding (UFLS) systems within the interconnection.
2. Local tripping of first-stage UFLS systems for severe frequency excursions, particularly those associated with protracted faults or on system on the edge-of the interconnection, may be unavoidable.
3. Other frequency-sensitive loads or electronically-coupled resources may trip during such frequency events (as is the case for photovoltaic inverters in the Western Interconnection).
4. Other susceptible frequency-sensitivities may have to be considered in the future (electronically coupled load common-mode sensitivities).

UFLS is intended to be a safety net to prevent against system collapse for severe contingencies. Conceptually, that safety net should not be violated for frequency events that happen on a relatively frequent basis. As such, the criteria for resource events for which frequency response should be adequate to avoid violating UFLS settings approved by the Regional Entities.
Several methods of determining the interconnection frequency response targets can be evaluated during the BAL-003 field trial. Fortunately, once the data is collected from a frequency excursion event, multiple Interconnection FROs and allocation methods can be analyzed and compared for each event.

The Frequency Response Standard Drafting Team (FRRSDT) is proposing an administered value approach for the BAL-003 Field Trial. Eventually, one method of determining the Interconnection FRO will be codified either in the Standard itself, or in the ERO Rules of Procedure[2].

[2] http://www.nerc.com/files/NERC_Rules_of_Procedure_EFFECTIVE_20110412.pdf

Interconnection Resource Contingency Protection Criteria

Selection of discrete event protection criteria for each interconnection must be done before the IFRO can be calculated. The protection criteria selected should assure that Point C will not encroach on the first step UFLS. However, the criteria may need to be different from one interconnection to the other due to the differences in size and design characteristics.

The following potential Interconnection event criteria were considered:

- Largest category C loss-of-resource event (N-2)
- Largest total generating plant with common voltage switchyard
- Largest loss of generation in the interconnection in the last 10 years

Largest Category C Event (N-2)

For this approach, each Interconnection will have a target Resource Contingency Protection Criteria based on the largest category C loss-of-resource event (N-2). For both the Texas and Western Interconnections, that would be the loss of the two largest generating units in the interconnection. However, for the Eastern Interconnection, the largest category C loss-of-resource event (N-2) would be the loss of the two Nelson DC bi-pole converters.

Table 1: Largest Category C Event (N-2)

Interconnection	Basis	MW
Eastern	Nelson DC Bi-poles 1 & 2	3,854[3]
Western	2 Palo Verde Units	2,740[4]
Texas	2 South Texas Project Units	2,750[5]

Largest Total Plant with Common Voltage Switchyard

Another approach is to examine the largest complete generating plant outage in each of the interconnections. The reasoning for considering such a protection criteria is that despite popular belief, complete plant outages can and do happen on a regular basis; three complete plant outages occurred in December 2010 alone. The TIS recommends limiting this classification to those generators with a common voltage switchyard.

[3] Nelson Bi-poles 1 & 2 are rated 1,854 MW and 2,000 MW, respectively.

[4] Net winter ratings per Form EIA-860 reporting.

[5] Net rating from ERCOT RARF.

Table 2: Largest Total Plant with Common Voltage Switchyard		
Interconnection	**Basis**	**MW**
Eastern	Bruce B Units 5-8	3,239[6]
Western	3 Palo Verde Units	3,575[7]
Texas	2 South Texas Project Units	2,750[8]

Largest Resource Event in Last 10 Years

A third approach is to examine the largest complete resource loss event in the interconnection over the last 10 years. Although this method yields a reasonable value for the Eastern Interconnection, the values for the other two interconnections would likely not be sustainable without activating some UFLS. It also results in a larger resource contingency for the Western Interconnection than for the Eastern Interconnection.

Table 3: Largest Resource Event in Last 10 Years		
Interconnection	**Basis**	**MW**
Eastern	August 4, 2007 Disturbance	4,500
Western	June 14, 2004 Disturbance	5,000
Texas	May 15, 2003 Disturbance	3,400

TIS-Recommended Criteria

If the philosophy for the criteria is to protect against the largest frequency excursion the interconnection can withstand, the contingency criteria may vary significantly between the interconnections. For example, because of its sheer size and generating capacity, the Eastern Interconnection can withstand a far larger loss of resources.

The TIS recommends that a blending of Resource Contingency Protection Criteria be used in the determination of IFROs for the BAL-003 Field Trial.

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[6] Net winter ratings from the NERC Electricity Supply and Demand.

[7] Net winter ratings per Form EIA-860 reporting.

[8] Net rating from ERCOT RARF.

Table 4: TIS-Recommended Resource Loss Criteria			
Interconnection	**Resource Contingency**	**Basis**	**MW**
Eastern	Largest Resource Event in Last 10 Years	August 4, 2007 Disturbance	4,500
Western	Largest Category C Event (N-2)	2 Palo Verde Units	2,740[9]
Texas	Largest Category C Event (N-2)	2 South Texas Project Units	2,750[10]

Although the size of a resource contingency that can be sustained by an interconnection should be tested through dynamic simulations, that test can currently only be done for the Western and Texas Interconnections.

Therefore, TIS recommends:

1. Dynamic simulation testing of the Western and Texas event protection criteria as soon as possible.
2. Dynamic simulation testing of the Eastern Interconnection event protection criteria when practical.

9 Net winter ratings per Form EIA-860 reporting.

10 Net rating from ERCOT RARF.

Variables in Determination of Interconnection Frequency Response Obligation from Criteria

To make a determination of the appropriate Resource Contingency Protection Criteria to protect for a certain kind of event, the MW target value needs to be translated into an Interconnection Frequency Response Obligation (IFRO) for an appropriate comparison. A number of other variables must be taken into consideration.

Low Frequency Limit

The highest setpoint in the interconnection for regionally approved UFLS systems. The TIS debated whether the highest UFLS setpoint in FRCC or if the prevalent highest setpoint for the Eastern Interconnection (59.5 Hz) should be used to set the IFRO for the Eastern Interconnection. Using the tenet that UFLS should not trip for a frequency event throughout the interconnection, the TIS recommends using the 59.7 Hz value.

Adjustment for the Texas Interconnection

Recent laboratory testing by Southern California Edison of inverters used on residential and commercial scale photovoltaic (PV) systems have revealed a propensity to trip at about 59.4 Hz, which is 200 mHz above the expected 59.3 Hz prescribed in IEEE Standard 1547 for distribution-connected PV rating ≤ 30 kW (57.0Hz for larger installations). This may become pertinent in the Texas Interconnection, which is desireable for PV development. The determination of the IFRO for the Texas Interconnection should be adjusted to prevent tripping of those inverters that are susceptible to a common-mode tripping above the regional UFLS settings. Consequently, the protection set point for the IFRO criteria was adjusted to 59.4 Hz for the Texas Interconnection.

Table 5: Low Frequency Limit

Interconnection	Basis	Frequency
Eastern	Highest Regional UFLS set point	59.7 Hz
Western	Highest Regional UFLS set point	59.5 Hz
Texas	Trip point of distribution-connected PV inverters	59.4 Hz
Quebec	Highest Regional UFLS set point	58.5 Hz

Credit for Load Acting as a Resource (LaaR)

The ERCOT Interconnection depends on contractually interruptible demand that automatically trips at 59.7 Hz to help arrest frequency declines. A 1,150 MW LaaR credit is included against the Resource Contingency for the Texas Interconnection.

Margin

An appropriate margin to account for items such as time error correction, variability of load, variability of interchange, variability of frequency over the course of a normal day, and other uncertainties. Various margins might be applied and they may vary between interconnections if justified.

The TIS examined the variability of measured frequency[11] for each interconnection over a period of 18 months (January 1, 2010 through June 30, 2011) to help determine an appropriate margin to be applied to both positive and negative frequency devations. The margin may differ depending on the direction of the frequency deviation. The measured frequency variations include the effects of all the variables described above.

Each interconnection's data was examined as directional histograms and other statistical parameters. The following are the "frequency deviation duration curves" for the Eastern Interconnection. The full set can be found in Appendix A.

Figure 1: Eastern Interconnection Frequency Deviations Above 60 Hz

[11] This was done using 1-minute frequency readings from the NERC Resource Adequacy tool.

Figure 2: Eastern Interconnection Frequency Deviations Below 60 Hz

Table 6 shows the analysis of the frequency deviations for the 18-month period.

Table 6: Interconnection Frequency Deviation Analysis

Value	Eastern	Western	Texas	Québec
Above 60 Hz				
0.5 % of samples	0.040	0.040	0.054	0.036
1.0 % of samples	0.036	0.036	0.048	0.028
Max. High Freq. Deviation	0.085	0.083	0.170	0.231
1-Day in 10-Years Equivalent	0.053	0.059	0.097	0.070
Below 60 Hz				
0.5 % of samples	-0.042	-0.041	-0.055	-0.054
1.0 % of samples	-0.038	-0.037	-0.048	-0.047
Max. Low Freq. Deviation	-0.096	-0.152	-0.280	-0.268
1-Day in 10-Years Equivalent	-0.058	-0.062	-0.108	-0.085

Since the goal of setting an IFRO is to prevent excursions that would harm reliability, use of a 1-day in 10-years equivalent of the observations was applied. Based on that analysis, the margins were determined through rounding up the absolute value of the deviations to the nearest 10 milihertz. The results are show in Table 7.

Table 7: Interconnection Frequency Margins

Value	Eastern	Western	Texas	Québec
Above 60 Hz	0.060	0.060	0.100	0.070
Below 60 Hz	-0.060	-0.070	-0.110	-0.090

IFRO Alternative Comparison

Each of the proposed Resource Loss criteria alternatives were compared through development of the corresponding IFROs. The following tables show the calculation of an IFRO for each alternative for the Eastern, Western, and Texas Interconnections. The criterion for the Québec Interconnection was not modified for each case.

Largest Category C Event (N-2)

Table 8 shows the determination of IFROs based on a resource loss equivalent to the Largest Category C Event (N-2) in each interconnection.

Table 8: Largest Category C Event (N-2)

	Eastern	Western	Texas	Québec	
Starting Frequency	60.000	60.000	60.000	60.000	Hz
Minimum Frequency Limit	59.700	59.500	59.400	58.500	Hz
Margin	0.060	0.070	0.110	0.090	Hz
Maximum Delta Frequency	0.240	0.430	0.490	1.410	Hz
Target Minimum Frequency	59.760	59.570	59.510	58.590	Hz
Resource Contingency Protection Criteria	3,854	2,740	2,750	1,700	MW
Credit for LaaR			1,150		MW
IFRO	-1,606	-637	-327	-113	MW/0.1Hz
Absolute Value of IFRO	1,606	637	327	113	MW/0.1Hz
IFRO as % of Inter-connection Load[12]	0.266 %	0.428 %	0.512 %	0.550 %	

[12] Interconnection projected Total Internal Demands from the 2010 NERC Long-Term Reliability Assessment: EI = 604,245 MW, WI = 148,895 MW, TI = 63,810 MW, and QI = 20,599 MW.

Largest Total Plant with Common Voltage Switchyard

Table 9 shows the determination of IFROs based on a resource loss equivalent to the Largest Total Plant with Common Voltage Switchyard in each interconnection.

Table 9: Largest Total Plant with Common Voltage Switchyard					
	Eastern	**Western**	**Texas**	**Québec**	
Starting Frequency	60.000	60.000	60.000	60.000	Hz
Minimum Frequency Limit	59.700	59.500	59.400	58.500	Hz
Margin	0.060	0.070	0.110	0.090	Hz
Maximum Delta Frequency	0.240	0.430	0.490	1.410	Hz
Target Minimum Frequency	59.760	59.570	59.510	58.590	Hz
Resource Contingency Protection Criteria	3,239	3,575	2,750	1,700	MW
Credit for LaaR			1,150		MW
IFRO	-1,350	-831	-327	-113	MW/0.1Hz
Absolute Value of IFRO	1,350	831	327	113	MW/0.1Hz
IFRO as % of Inter-connection Load[13]	0.223 %	0.558 %	0.512 %	0.550 %	

[13] Interconnection projected Total Internal Demands from the 2010 NERC Long-Term Reliability Assessment: EI = 604,245 MW, WI = 148,895 MW, TI = 63,810 MW, and QI = 20,599 MW.

Largest Resource Event in Last 10 Years

Table 10 shows the determination of IFROs based on a resource loss equivalent to the Largest Resource Event in Last 10 Years in each interconnection.

Table 10: Largest Resource Event in Last 10 Years

	Eastern	Western	Texas	Québec	
Starting Frequency	60.000	60.000	60.000	60.000	Hz
Minimum Frequency Limit	59.700	59.500	59.400	58.500	Hz
Margin	0.060	0.070	0.110	0.090	Hz
Maximum Delta Frequency	0.240	0.430	0.490	1.410	Hz
Target Minimum Frequency	59.760	59.570	59.510	58.590	Hz
Resource Contingency Protection Criteria	4,500	5,000	3,400	1,700	MW
Credit for LaaR			1,150		MW
IFRO	-1,875	-1,163	-459	-113	MW/0.1Hz
Absolute Value of IFRO	1,875	1,163	459	113	MW/0.1Hz
IFRO as % of Inter-connection Load[14]	0.310 %	0.781 %	0.720 %	0.550 %	

[14] Interconnection projected Total Internal Demands from the 2010 NERC Long-Term Reliability Assessment: EI = 604,245 MW, WI = 148,895 MW, TI = 63,810 MW, and QI = 20,599 MW.

TIS Recommended Criteria

Table 11 shows the determination of IFROs based on a resource loss equivalent to the TIS Recommended Criteria in each interconnection.

Table 11: TIS Recommended Criteria					
	Eastern	**Western**	**Texas**	**Québec**	
Starting Frequency	60.000	60.000	60.000	60.000	Hz
Minimum Frequency Limit	59.700	59.500	59.400	58.500	Hz
Margin	0.060	0.070	0.110	0.090	Hz
Maximum Delta Frequency	0.240	0.430	0.490	1.410	Hz
Target Minimum Frequency	59.760	59.570	59.510	58.590	Hz
Resource Contingency Protection Criteria	4,500	2,740	2,750	1,700	MW
Credit for LaaR			1,150		MW
IFRO	-1,875	-637	-327	-113	MW/0.1Hz
Absolute Value of IFRO	1,875	637	327	113	MW/0.1Hz
IFRO as % of Inter-connection Load[15]	0.310 %	0.428 %	0.512 %	0.550 %	

15 Interconnection projected Total Internal Demands from the 2010 NERC Long-Term Reliability Assessment: EI = 604,245 MW, WI = 148,895 MW, TI = 63,810 MW, and QI = 20,599 MW.

Comparison of IFRO Calculations

Table 12 shows a comparison of the 4 criteria analyzed and compares them to current levels of frequency response performance[16] for the interconnections.

Table 12: IFRO Calculation Comparison					
	Eastern	**Western**	**Texas**	**Québec**	
Current Frequency Response Performance	-2,358	-1,179	-586	N/A	MW/0.1Hz
Largest Category C Event (N-2)					
Resource Loss Criteria	3,854	2,740	2,750	1,700	MW
IFRO	-1,606	-637	-327	-113	MW/0.1Hz
IFRO as % of Interconnection Load[17]	0.266 %	0.428 %	0.512 %	0.550 %	
Largest Total Plant with Common Voltage Switchyard					
Resource Loss Criteria	3,239	3,575	2,750	1,700	MW
IFRO	-1,350	-831	-327	-113	MW/0.1Hz
IFRO as % of Interconnection Load[18]	0.223 %	0.558 %	0.512 %	0.550 %	
Largest Resource Event in Last 10 Years					
Resource Loss Criteria	4,500	5,000	3,400	1,700	MW
IFRO	-1,875	-1,163	-459	-113	MW/0.1Hz
IFRO as % of Interconnection Load[19]	0.310 %	0.781 %	0.720 %	0.550 %	
TIS Recommendation					
Resource Loss Criteria	4,500	2,740	2,750	1,700	MW
IFRO	-1,875	-637	-327	-113	MW/0.1Hz
IFRO as % of Interconnection Load[20]	0.310 %	0.428 %	0.512 %	0.550 %	

[16] Based on the frequency response performance calculated in the daily CERTS-EPG Automated Reliability Reports for 2011 through August 16, 2011.

[17] Interconnection projected Total Internal Demands from the 2010 NERC Long-Term Reliability Assessment: EI = 604,245 MW, WI = 148,895 MW, TI = 63,810 MW, and QI = 20,599 MW.

[18] Ibid.

[19] Ibid.

[20] Interconnection projected Total Internal Demands from the 2010 NERC Long-Term Reliability Assessment: EI = 604,245 MW, WI = 148,895 MW, TI = 63,810 MW, and QI = 20,599 MW.

Appendix A – Interconnection Frequency Deviation Duration Plots

Figure 1: Eastern Interconnection Frequency Deviations Above 60 Hz

Figure 2: Eastern Interconnection Frequency Deviations Below 60 Hz

Figure 3: Western Interconnection Frequency Deviations Above 60 Hz

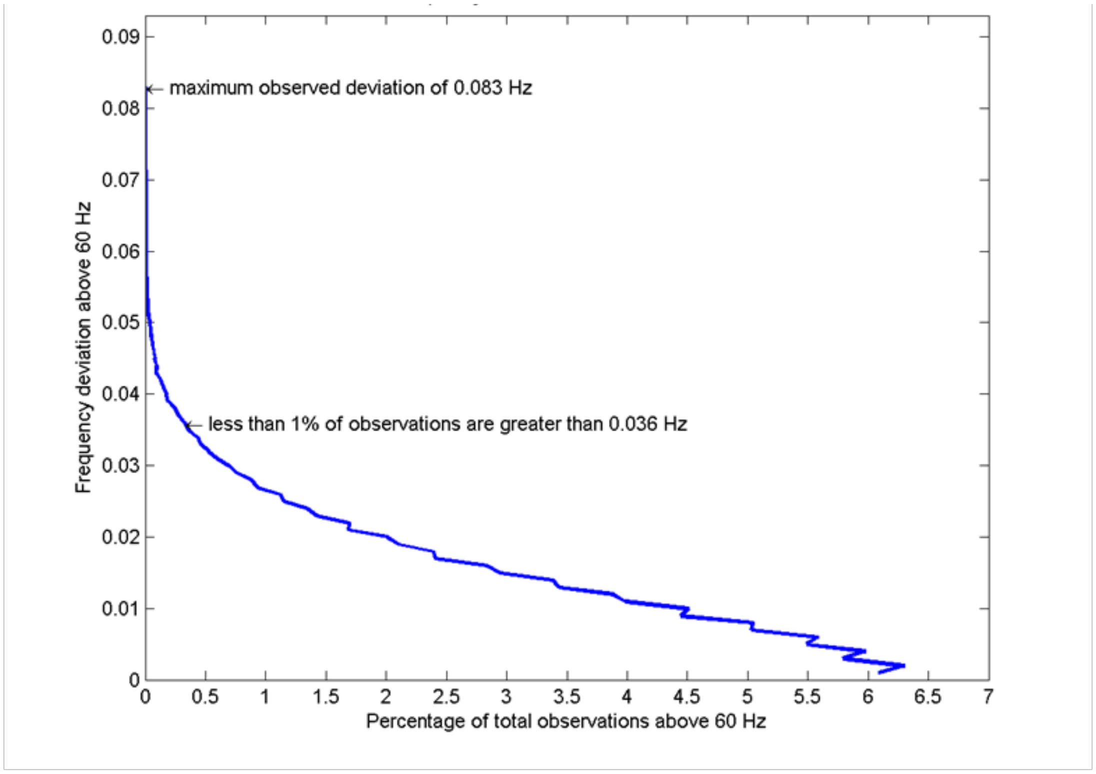

Figure 4: Western Interconnection Frequency Deviations Below 60 Hz

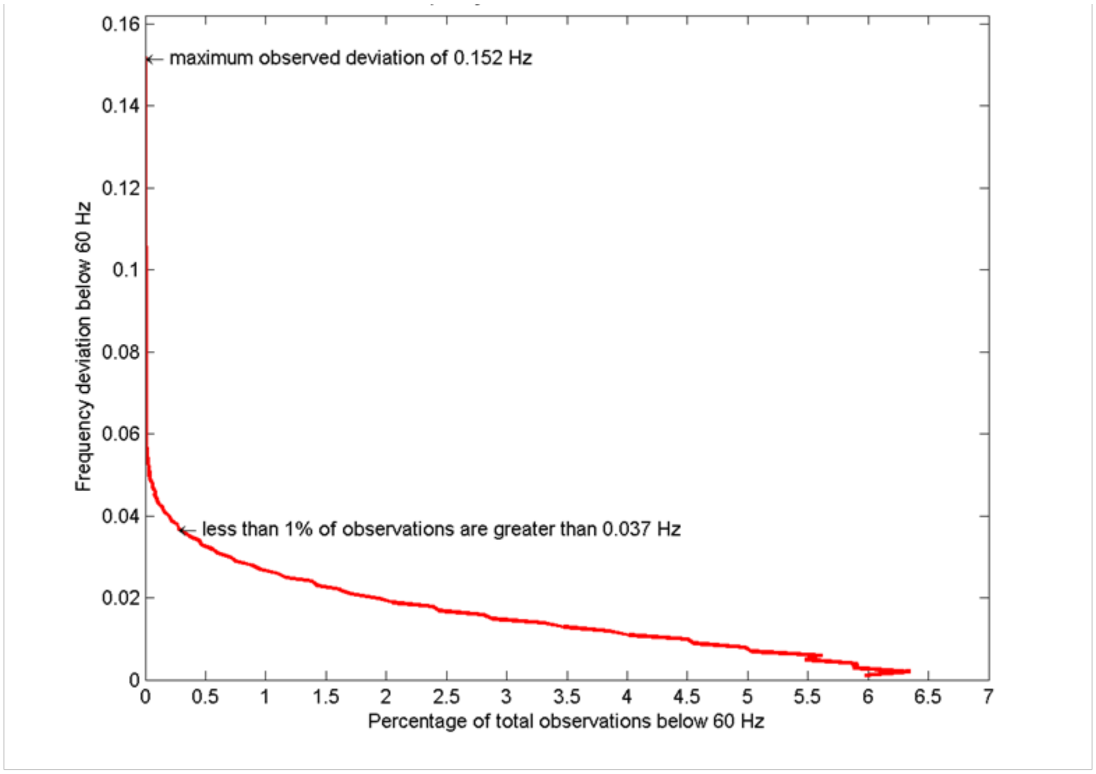

Figure 5: Texas Interconnection Frequency Deviations Above 60 Hz

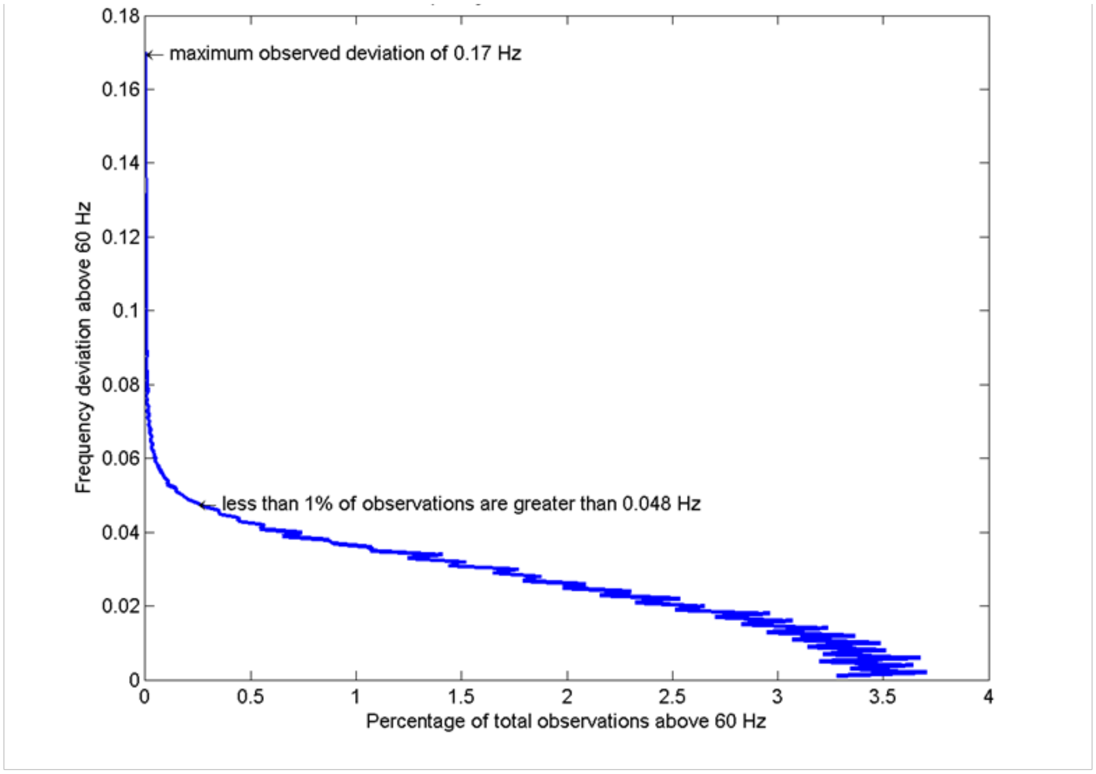

Figure 6: Texas Interconnection Frequency Deviations Below 60 Hz

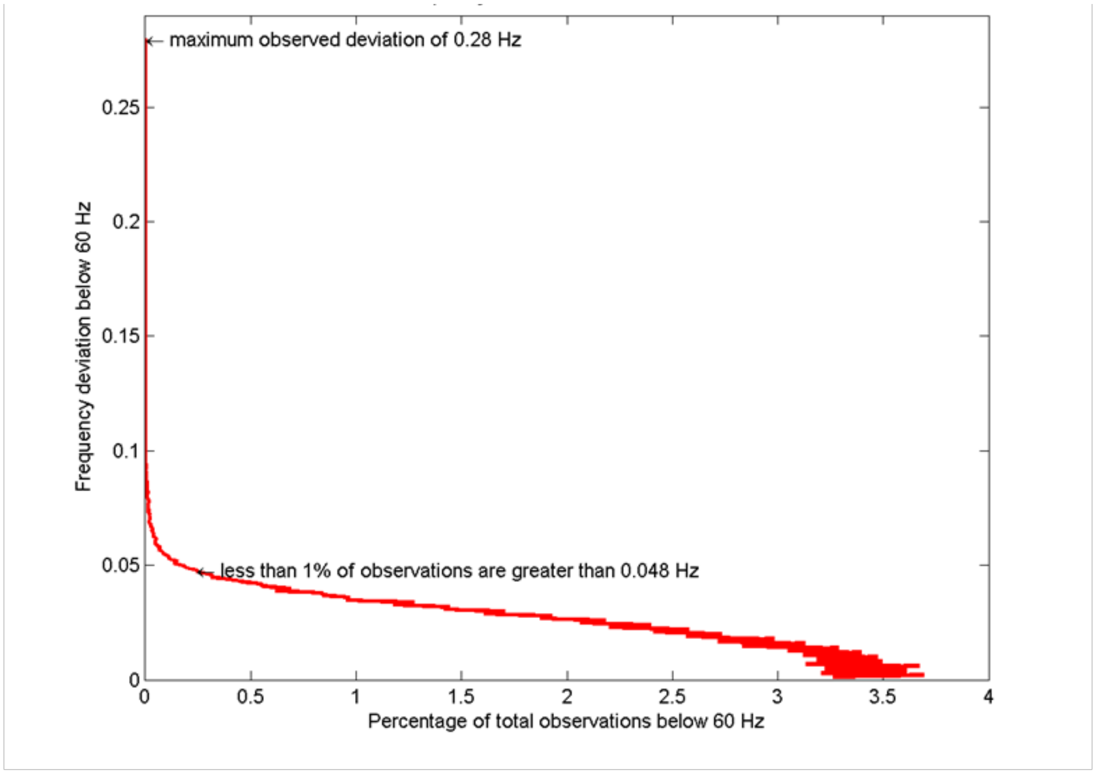

Figure 7: Québec Interconnection Frequency Deviations Above 60 Hz

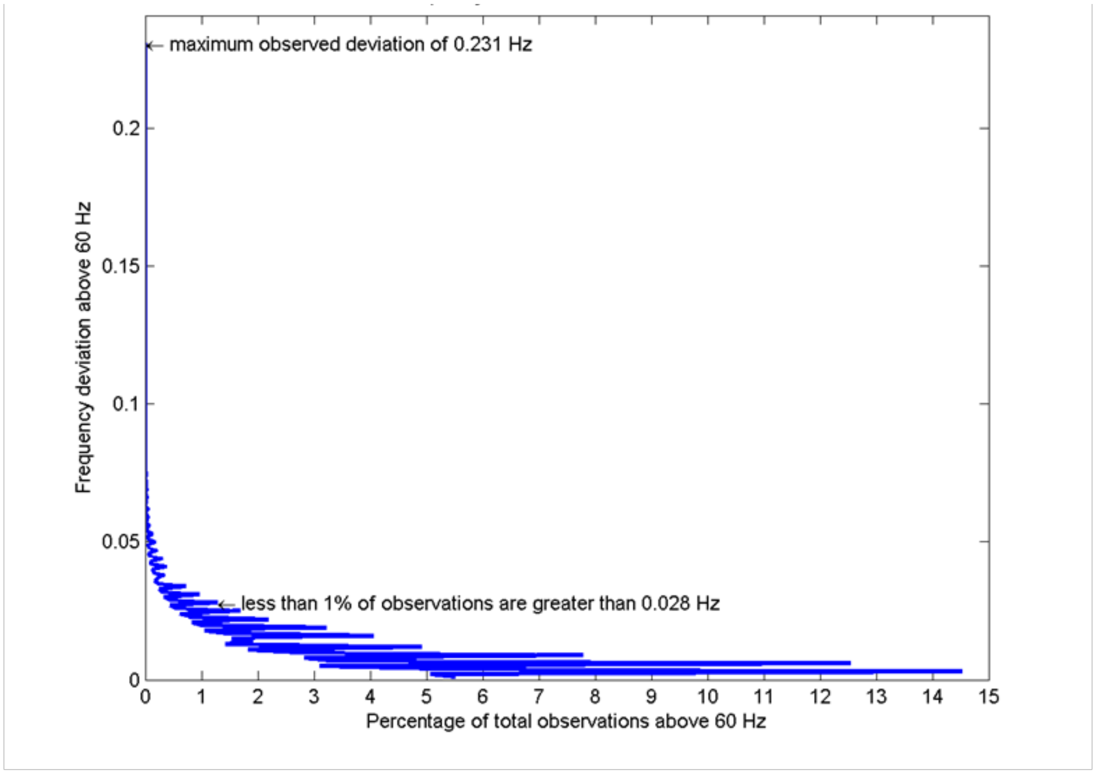

Figure 8: Québec Interconnection Frequency Deviations Below 60 Hz