

**NERC**

NORTH AMERICAN ELECTRIC  
RELIABILITY CORPORATION

# Frequency Response Standard Background Document

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**RELIABILITY | ACCOUNTABILITY**



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# Introduction

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This document provides background on the development, testing and implementation of BAL-003-1 - Frequency Response Standard (FRS). The intent is to explain the rationale and considerations for the Requirements and their associated compliance information. The document also provides good practices and tips for Balancing Authorities with regard to Frequency Response.

In Order No. 693, the FERC directed additional changes to BAL-003-0.1b. This document explains how those directives are met by BAL-003-1.

The original Standards Authorization Request (SAR), finalized on June 30, 2007, ~~assumed~~, assumed the Frequency Response currently available to be adequate in all the North American Interconnections. The goal of the SAR was to update the Standard to make the measurement process more objective and to provide this objective data to Planners and Operators for improved modeling. The improved models will improve understanding of the trends in Frequency Response to determine if reliability limits were being approached. The Standard would also lay the process groundwork for a transition to a performance-based Standard if reliability limits were approached.

This document will be periodically updated by the FRS Drafting Team until the Standard is approved (expected to occur during Spring of 2012). Once approved, this document will then be maintained and updated by the ERO and the NERC Resources Subcommittee.

## Background and Rationale by Requirement

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### Requirement 1

*R1. Each Balancing Authority (BA) or Reserve Sharing Group (RSG) shall achieve an annual Frequency Response Measure (FRM) (as detailed in Attachment A and calculated on FRS Form 1) that is equal to or more negative than its Frequency Response Obligation (FRO) to ensure that sufficient Frequency Response is provided by each BA or RSG to maintain an adequate level of Frequency Response in the Interconnection.*

#### *Background and Rationale*

R1 is intended to meet the following primary objectives:

- Determine whether a Balancing Authority (BA) has sufficient Frequency Response for reliable operations.
- Provide the feeder information needed to calculate CPS limits and Frequency Bias Settings.

With regard to the first objective, FRS Form 1 and the process in Attachment A provide the method for determining the Interconnections' necessary amount of Frequency Response and allocating it to the Balancing Authorities. The field trial for BAL-003-1 is testing an allocation methodology based on the amount of load and generation in the BA. This is to accommodate the wide spectrum of BAs from generation-only all the way to load-only.

The basic Frequency Response Obligation is based on non-coincident peak load and generation data reported in FERC Form 714 for the previous full calendar year. The basic allocation formula used by NERC is:

$$FRO_{BA} = FRO_{Int} \times \frac{\text{Peak Gen}_{BA} + \text{Peak Load}_{BA}}{\text{Peak Gen}_{Int} + \text{Peak Load}_{Int}}$$

Where:

- Peak Gen<sub>BA</sub> is the average of monthly “Output of Generating Plants”, FERC Form 714, column f of Part II - Schedule 3.
- Peak Load<sub>BA</sub> is the average of “Monthly Peak Demand (MW)”, FERC Form 714, column j of Part II - Schedule 3.
- Peak Gen<sub>Int</sub> is the sum of all BAs’ in that interconnection reported average monthly peak generation.
- Peak Load<sub>Int</sub> is the sum of all BAs in that interconnection reported average monthly peak demand.

Balancing Authorities can approximate their FRO by multiplying their Interconnection’s FRO by their share of Interconnection bias.

Balancing Authorities that merge or that transfer load or generation need to notify the ERO of the change in footprint and corresponding changes in allocation such that the net obligation for the Interconnection remains the same.

Note: The methodology for determining the Interconnection’s Frequency Response Obligation and allocating it to BAs may change on the basis of field trial results. The drafting team is evaluating a risk-based approach for basing the Interconnection Frequency Response Obligation on an historic probability density of frequency error, and for allocating the obligation on the basis of the Balancing Authority’s average annual ACE share of frequency error.

Attachment A proposes the following Interconnection event criteria as a basis to determine an Interconnection’s Frequency Response Obligation:

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

Given the fact that the Interconnections currently have sufficient Frequency Response, few BAs should encounter problems meeting R1, particularly with the options the Standard provides with regard to obtaining Frequency Response.

With regard to the second objective above (determining Frequency Bias Settings and CPS limits), Balancing Authorities have been asked to perform annual reviews of their Frequency Bias Settings by measuring their Frequency Response, dating back to Policy 1. This obligation

was carried forward into BAL-003-01.b. While the associated training document provided useful information, it left many of the details to the judgment of the person doing the analysis. The FRS Form 1 and FRS Form 2 provide a consistent, objective process for calculating Frequency Response to develop an annual measure, the FRM.

The FRM will be computed from Single Event Frequency Response Data (SEFRD), defined as: “the data from an individual event from a Balancing Authority that is used to calculate its Frequency Response, expressed in MW/0.1Hz”. The SEFRD for a typical Balancing Authority in an Interconnection with more than one Balancing Authority is basically the change its Net Actual Interchange on its tie lines with its adjacent Balancing Authorities divided by the change in Interconnection frequency. (Some Balancing Authorities may choose to apply corrections to their Net Actual Interchange values to account for factors such as nonconforming loads. FRS Form 1 shows the types of adjustments that are allowed.)

A standardized sampling interval of 20 to 52 seconds will be used in the computation of SEFRD values. Microsoft Excel® spreadsheet interfaces for EMS scan rates of 2 through 6 seconds will be provided to support the computation. During the field trial, other sampling intervals will be evaluated as well to determine if another sampling interval is more appropriate.

In an attempt to balance the workload of Balancing Authorities with the need for accuracy in the FRM, the field trial will require at least 25 samples selected during the course of the year to compute the FRM. Research conducted by the Frequency Responsive Reserve Standard Drafting Team (FRSDDT) indicated that a Balancing Authority’s FRM will converge to a reasonably stable value with 20 to 25 samples. The FRSDDT will re-evaluate the required number of samples during the field trial.

The FRSDDT also evaluated different approaches for “averaging” individual event observations to compute a technically sound estimate of Frequency Response Measure (FRM). The MW contribution for a single BA in a multi-BA Interconnection is small compared to the minute to minute changes in load, interchange and generation. For example, a 3000 MW BA in the east may only be called on to contribute 10MW for the loss of a 1000MW. The 10 MW of governor and load response may easily be masked by a coincident change in load. Because of this large “noise to signal” ratio, the mean did not prove to be an appropriate measure of true typical performance.

In general, statisticians use the median as the best measure of central tendency when a population has outliers. Two independent reviews by the FRSDDT has shown the Median to be less influenced by noise in the measurement process and the team has chosen the median as the initial metric for calculating the BAs’ Frequency Response Measure.

In addition, The FRSDDT is evaluating the linear regression as a means to estimate the BA’s typical frequency response. This calculation is embedded in FRS Form 1 and will be evaluated during the field trial. Initial review implies that the linear regression tends to skew calculated FRM due to the influence of outliers. The outliers are being evaluated by the FRSDDT as they may point to needed improvements in the measurement process or training issues for the BA in question.

In order to support field trial evaluations of sample size, sampling intervals, and aggregation techniques, the FRSDT will be retrieving scan rate data from the Balancing Authorities for each SEFRD. Additional frequency events may also be requested for research purposes, though they will not be included in the FRM computation.

FERC Order No. 693 directed the ERO to define the number of Frequency Response surveys that were conducted each year and to define a necessary amount of Frequency Response. R1 addresses both of these directives:

- There is a single annual survey of at least 25-30 events each year.
- The FRM calculated on FRS Form 1 is compared by the ERO against the FRO determined 12 months earlier (when the last FRS Form 1 was submitted) to verify the Balancing Authority provided its share of Interconnection Frequency Response.

FERC Order No. 693 also directed that the Standard should identify methods for Balancing Authorities to obtain Frequency Response. Requirement R1 allows Balancing Authorities to participate in Reserve Sharing Groups (RSGs) to provide or obtain Frequency Response. These may be the same RSGs that cooperate for BAL-002-0 or may be RSGs that form for the purposes of BAL-003-1.

If BAs participate as an RSG for BAL-003-1, compliance is based on the sum of the participants' performance.

Two other ways that BAs could obtain Frequency Response are through Supplemental Service or Overlap Regulation Service:

- No special action is needed if a BA provides or receives supplemental regulation. If the regulation occurs via Pseudo Tie, the transfer occurs automatically as part of Net Actual Interchange (NIA) and in response to information transferred from recipient to provider.
- If a BA provides overlap regulation, its FRS Form 1 will include the Frequency Bias setting as well as peak load and generation of the combined Balancing Authority Areas. The FRM event data will be calculated on the sum of the provider's and recipient's performance.

In the Violation Severity Levels for Requirement R1, the impact of a BA not having enough frequency response depends on two factors:

- Does the Interconnection have sufficient response?
- How short is the BA in providing its FRO?

The VSL takes these factors into account.

## Requirement 2

*R2. Each Balancing Authority not participating in Overlap Regulation Service shall implement the Frequency Bias Setting (fixed or variable) validated by the ERO, into its Area Control Error*

*(ACE) calculation beginning on the date specified by the ERO to ensure effectively coordinated Tie Line Bias control.*

#### *Background and Rationale*

Attachment A of the Standard discusses the process the ERO will follow to validate the BA's FRS Form 1 data and publish the official Frequency Bias Settings. Historically, it has taken multiple rounds of validation and outreach to confirm each BA's data due to transcription errors, misunderstanding of instructions, and other issues. While BAs historically submit Bias Setting data by January 1, it often takes one or more months to complete the process.

The target is to have BAs submit their data by January 10. The BAs are given 30 days to assemble their data since the BAs are dependent on the ERO to provide ~~them with~~them with FRS Form 1, and there may be process delays in distributing the forms since they rely on identification of frequency events through November 30 of the preceding year.

Frequency Bias Settings generally change little from year to year. Given the fact that BAs can encounter staffing or EMS change issues coincident with the date the ERO sets for new Frequency Bias Setting implementation, the standard provides a 24 hour window on each side of the target date.

To recap the annual process:

1. The ERO posts the official list of frequency events to be used for this Standard in early December. The FRS Form 1 for each Interconnection will be posted shortly thereafter.
2. The Balancing Authority submits its revised annual Frequency Bias Setting value to NERC by January 10.
3. The ERO and the Resources Subcommittee validate Frequency Bias Setting values, perform error checking, and calculate, validate, and update CPS2 L10 values. This data collection and validation process can take as long as two months.
4. Once the L10 and Frequency Bias Setting values are validated, The ERO posts the values for the upcoming year and also informs the Balancing Authorities of the date on which to implement revised Frequency Bias Setting values. Implementation typically would be on or about March 1<sup>st</sup> of each year.

#### Requirement 3

*R3. Each Balancing Authority not receiving Overlap Regulation Service shall operate its Automatic Generation Control (AGC) in Tie Line Bias mode to ensure effectively coordinated control, unless such operation would have an Adverse Reliability Impact on the Balancing Authority's Area.*

#### *Background and Rationale*

This requirement serves several functions. The primary reason for operating in Tie Line Bias is so ACE is calculated properly for performance purposes. Even if a BA temporarily operated in manual mode, as long as CPS is properly calculated and the BA met CPS, it is operating reliably.

There are legitimate reasons for taking AGC out of Tie Line Bias or operating manually including:

- Telemetry problems that lead the operator to believe ACE is significantly in error.
- The frequency input to AGC is not reflective of the BA's true frequency (such as if the control center were operating a local generator and disconnected from the Interconnection).
- During restoration (where one BA might be controlling frequency while another to which it is connected is managing interchange between them).
- For training purposes.
- Many AGC systems will automatically switch to an alternate mode if the EMS determines Tie Line Bias control could lead to problems.
- For single BA Interconnections, Flat Frequency and Tie Line Bias are equivalent.

Because it is rare that temporary operation out of Tie Line Bias can lead to reliability problems, the VSLs for this requirement are structured accordingly.

#### Requirement 4

*R4. Each Balancing Authority that is performing Overlap Regulation Service shall modify its Frequency Bias Setting in its ACE calculation to be equivalent to the sum of the Frequency Bias Settings of the participating Balancing Authorities as validated by the ERO or calculate the Frequency Bias Setting based on the entire area being combined and thereby represent the Frequency Response for the combined area being controlled.*

#### *Background and Rationale*

This requirement reflects the operating principles first established by NERC Policy 1 and is similar to Requirement R6 of the approved BAL-003-0.1b standard. Overlap Regulation Service is a method of providing regulation service in which the Balancing Authority providing the regulation service incorporates another Balancing Authority's actual interchange, frequency response, and schedules into the providing Balancing Authority's AGC/ACE equation.

As noted earlier, a BA that is providing Overlap Regulation will report the sum of the Bias Settings in its FRS Form 1. Balancing Authorities receiving Overlap Regulation Service have an ACE and Frequency Bias Setting equal to zero (0).

#### Requirement 5

*R5. In order to ensure adequate control response each Balancing Authority shall use a monthly average Frequency Bias Setting whose absolute value is at least equal to one of the following:*

- *The minimum percentage of the Balancing Authority Area's estimated yearly Peak Demand within its metered boundary per 0.1 Hz change as specified by the ERO in accordance with Attachment B.*

- *The minimum percentage of the Balancing Authority Area's estimated yearly peak generation for a generation- only BA, per 0.1 Hz change as specified by the ERO in accordance with Attachment B.*

### *Background and Rationale*

BAL-003-0.1b standard requires a minimum Frequency Bias Setting equal in absolute value to one percent of the Balancing Authority's estimated yearly peak demand (or maximum generation level if native load is not served). For most Balancing Authorities this calculated amount of Frequency Bias is significantly greater in absolute value than their actual Frequency Response characteristic (which represents an over-bias condition) resulting in over-control since a larger magnitude response is realized. This is especially true in the Eastern Interconnection where this condition requires excessive secondary frequency control response which degrades overall system performance and increases operating cost as compared to requiring an appropriate balance of primary and secondary frequency control response.

Balancing Authorities were given a minimum Frequency Bias Setting obligation because there had never been a mandatory Frequency Response Obligation. This historic "one percent of peak per 0.1Hz" obligation, dating back to NERC's predecessor, NAPSIC, was intended to ensure all BAs provide some support to Interconnection frequency.

The ideal system control state exists when the Frequency Bias Setting of the Balancing Authority exactly matches the actual Frequency Response characteristic of the Balancing Authority. If this is not achievable, over-bias is significantly better from a control perspective than under-bias with the caveat that Frequency Bias is set relatively close in magnitude to the Balancing Authority actual Frequency Response characteristic. Setting the Frequency Bias to better approximate the Balancing Authority natural Frequency Response characteristic will improve the quality and accuracy of ACE control, CPS & DCS and general AGC System control response. This is the technical basis for recommending an adjustment to the long standing "1% of peak/0.1Hz" Frequency Bias Setting. Attachment B is intended to bring the Balancing Authorities' Frequency Bias Setting closer to their natural Frequency Response. Attachment B balances the following objectives:

- Bring the Frequency Bias Setting and Frequency Response closer together.
- Ensure there is no negative impact on other Standards (CPS, BAAL and to a lesser extent DCS) by adjustments in the minimum Frequency Bias Setting, by accommodating only minor adjustments.
- Do not allow the Frequency Bias Setting minimum to drop below natural Frequency Response, because under-biasing could affect an Interconnection adversely.

Finally, for BAs using variable bias, FRS Form 1 has a data entry location for the previous year's average monthly bias. The Balancing Authority and the ERO can compare this value to the previous year's Frequency Bias Setting minimum to ensure R5 has been met.

# How this Standard Meets the FERC Order 693 Directives

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## FERC Directive

The following is the relevant paragraph of Order No. 693.

*Accordingly, the Commission approves Reliability Standard BAL-003-0 as mandatory and enforceable. In addition, the Commission directs the ERO to develop a modification to BAL-003-0 through the Reliability Standards development process that: (1) includes Levels of Non-Compliance; (2) determines the appropriate periodicity of frequency response surveys necessary to ensure that Requirement R2 and other requirements of the Reliability Standard are being met, and to modify Measure M1 based on that determination and (3) defines the necessary amount of Frequency Response needed for Reliable Operation for each balancing authority with methods of obtaining and measuring that the frequency response is achieved.*

### 1. Levels of Non-Compliance

VRFs and VSLs are an equally effective way of assigning compliance elements to the standard.

### 2. Determine the appropriate periodicity of frequency response surveys necessary to ensure that Requirement R2 and other Requirements of the Reliability Standard are met

BAL-003 V0 R2 (the basis of Order No. 693) deals with the calculation of Frequency Bias Setting such that it reflects natural Frequency Response.

The drafting team has determined that a sample size on the order of at least 25-30 events is necessary to have a high confidence in the estimate of a BA's Frequency Response. Selection of the frequency excursion events used for analysis will be done via a method outlined in Attachment A to the Standard.

On average, these events will represent the largest 2-3 "clean" frequency excursions occurring each month.

Since Frequency Bias Setting is an annual obligation, the survey of the at least 25-30 frequency excursion events will occur once each year.

### 3. Define the necessary amount of Frequency Response needed for Reliable Operation for each Balancing Authority with methods of obtaining and measuring that the frequency response is achieved

#### *Necessary Amount of Frequency Response*

The drafting team has proposed the following approach to defining the necessary amount of frequency response. In general, the goal is to avoid triggering the first step of under-frequency load shedding (UFLS) in the given Interconnection for reasonable contingencies expected. The

methodology for determining each Interconnection's and Balancing Authority's obligation is outlined in Attachment A to the Standard.

It should be noted that the standard cannot guarantee that there will never be a triggering of UFLS as the magnitude of "point C" differs throughout an interconnection during a disturbance and there are local areas that see much wider swings in frequency.

The contingency protection criterion is the largest reasonably expected contingency in the Interconnection. This can be based on the largest observed credible contingency in the previous 10 years or the largest Category C event for the Interconnection.

The Safety Margin included addresses the difference between Points B and C and accounts for variables.

For multiple BA interconnections, the Frequency Response Obligation is allocated to BAs based on size. This allocation will be based on the following calculation:

$$FRO_{BA} = FRO_{Int} \times \frac{\text{Peak Gen}_{BA} + \text{Peak Load}_{BA}}{\text{Peak Gen}_{Int} + \text{Peak Load}_{Int}}$$

#### *Methods of Obtaining Frequency Response*

The drafting team believes the following are valid methods of obtaining Frequency Response:

- Supplemental regulation.
- Overlap regulation.
- Contractual service (The drafting team has developed an approach to obtain a contractual share of Frequency Response from Adjacent Balancing Authorities. See FRS Form 1). While the final rules with regard to contractual services are being defined, the current expectation is that the ERO and the associated Region(s) should be notified beforehand and that the service be at least 6 months in duration.
- Through a tariff (e.g. Frequency Response and regulation service).
- From generators through an interconnection agreement.
- Contract with an internal resource or loads (The drafting team encourages the development of a NAESB business practice for Frequency Response service for linear (droop) and stepped (e.g. LaaR in Texas) response).

#### *Measuring that the Frequency Response is Achieved*

FRS Form 1 and the underlying data retained by the BA will be used for measuring whether Frequency Response was provided. FRS Form 1 will provide the guidance on how to account for and measure Frequency Response.

## Going Beyond the Directive

Based on the combined operating experience of the SDT, the drafting team believes each Interconnection has sufficient Frequency Response. If margins decline, there may be a need for additional standards or tools. The drafting team and the Resources Subcommittee are working with the ERO on its Frequency Response Initiative to develop processes and good practices so the Interconnections are prepared. These good practices and tools are described in the following section.

The drafting team is also evaluating a risk-based approach for basing the Interconnection Frequency Response Obligation on an historic probability density of frequency error, and for allocating the obligation on the basis of the Balancing Authority's average annual ACE share of frequency error. This allocation method uses the inverse of the rationale for allocating the CPS1 epsilon requirement by Bias share.



### Good Practices

Knowing the quantity and depth of frequency responsive reserves in real time is a possible next step to being better prepared for the next event. The challenge in achieving this is having the knowledge of the capabilities of all sources of frequency response. Presently the primary source of frequency response remains with the generation resources in our fleets.

Understanding how each of these sources performs to changes in system frequency and knowing their limitations would improve the BA's ability to measure frequency responsive reserves. Presently there are only guidelines, criteria and protocols in some regions of the industry that identify specific settings and performance expectations of primary frequency response of resources. One method of gaining better understanding of performance is to measure performance during actual events that occur on the system. This approach would only provide feedback for performance during that specific event and would not provide insight into depth of response or other limitations. Repeated measurements will increase confidence in expected performance. NERC modeling standards are in process to be revised that will improve the BA's insight into predicting available frequency responsive reserves. However, knowing how resources are operated, what modes of operation provide sustained primary frequency response and knowing the operating range of this response would give the BA the knowledge to accurately predict frequency response and the amount of frequency responsive reserves available in real time.

Some benefits on several interconnections have been realized by communicating to generation resources (GO) the importance of operating in modes that allow primary frequency response to be sustained by the control systems of the resource. Other improvements in implementation of primary frequency response have been achieved through improved settings on turbine governors through the elimination of "step" frequency response with the simultaneous reduction in governor dead-band settings. Improvements in the full AGC control loop of the

generating resource, which accounts for the expected primary frequency response, have improved the delivery of quality primary frequency response while minimizing secondary control actions of generators. Some of these actions can provide quick improvement in delivery of primary frequency response.

Once primary frequency response sources are known the BA could calculate available reserves that are frequency responsive. Planning for these reserves during normal and emergency operations could be developed and added to the normal planning process.

#### Tools

Single generating resource primary frequency response performance evaluation tools for steam turbine, combustion turbine (simple cycle or combined cycle) and for intermittent resources are available at the following link.

[http://texasre.org/standards\\_rules/standardsdev/rsc/sar003/Pages/Default.aspx](http://texasre.org/standards_rules/standardsdev/rsc/sar003/Pages/Default.aspx).

These tools and the regional standard associated with them are in their final stages of development in the Texas region.

These tools will be posted on the [NERC website](#).

## Field Trial

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This section is a summary of the Field Trial activities that have been or will be conducted by the ERO, the Resources Subcommittee and the FRS Drafting Team.

1. The NERC BA recommendation (alert) and observations.√
2. The NERC governor recommendation (alert) and observations.√
3. The 2011 bias calculation √
  1. Evaluate measurement methodology√
  2. Serve as initial training for BAs√
  3. Evaluate median, mean, regression and possibly other measures√
  4. Evaluate sample size (to address the directive of frequency of surveys) √
  5. Evaluate impact of inclusion/exclusion of internal contingencies √
  6. Improve FRS Form 1√
4. Create supporting process for FRS Form 1 √
  1. For Interconnection benchmarking (proving adequacy of frequency response)
  2. Evaluating trend
  3. Test process for developing candidate list for FRS Form 1
5. 2012 bias calculation
  1. Further refinement of items in 2011 bias calculation
  2. Test the FRO allocation methodology
  3. Test approach for handling variable bias
  4. Evaluate 12 month vs. 24 month rolling average approach to performance
6. Evaluate reduction in bias setting floor below 1% (initially 0.8% in 2012) to evaluate impact on frequency and calculated CPS and BAAL performance.
7. Evaluate effectiveness of administrative process to support the standard.
8. Evaluate a risk-based approach for basing the Interconnection Frequency Response Obligation on an historic probability density of frequency error, and for allocating the obligation on the basis of the Balancing Authority's average annual ACE share of frequency error.

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