Balancing Authority FRS Form 1 Background and Instructions

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B. FRS Form 1 Instructions

This document includes the purpose and description of the Frequency Response Survey (FRS) Form 1, including specific instructions to complete the survey form.

A. Frequency Response Characteristics and their Measurement

Disturbances can cause frequency to either increase from loss of load or decrease from loss of generation; Frequency Response characteristics should be evaluated for both types of events.

Accurate measurement of Frequency Response for an Interconnection or for individual Balancing Authorities is difficult unless the frequency deviation resulting from a system disturbance is significant. Therefore, it is better to analyze response only when significant frequency deviations occur.

1. Frequency Response — For any change in generation/load balance in the Interconnection, a frequency change occurs. Each Balancing Authority in the Interconnection will respond to this frequency change through:

- A load change resulting from the load's Frequency Response[1] that acts to arrest frequency changes, and varies with frequency in a continuous and inverse relationship,
- A generation change resulting from governor action that acts to arrest frequency changes, and varies with frequency in a continuous and inverse relationship, and
- A change in energy consumption or production from other devices resulting from the device's control system that acts to arrest frequency changes, and varies with frequency in a continuous and inverse relationship.

[1]Rotating (motor) and inductive loads are the dominant load response factors; resistive loads do not change with changing frequency.

Frequency responsive resources (generation, load, and other devices as above described) produce these responses. The net effect of these actions is the Balancing Authority's response to the frequency change, that is, its Frequency Response. The combined response of all Balancing Authorities in the Interconnection will cause the Interconnection frequency to settle at some value different from the pre-disturbance value and maintain it there. Frequency will remain different until the Balancing Authority with the generation/load imbalance (referred to as the "contingent Balancing Authority") corrects that imbalance, thus returning the Interconnection frequency to its pre-disturbance value.

2. **Response to Internal and External Generation/Load Imbalances —** Most of a Balancing Authority's Frequency Response will be reflected in a change in its actual net interchange. By monitoring frequency error (the difference between actual and scheduled frequency) and the change in actual interchange in response to the frequency deviation, a Balancing Authority's automatic generation control (AGC) can determine whether the imbalance in load and generation is internal or external to its system. If internal, the Balancing Authority's AGC and/or deployment of Contingency Reserve should gradually correct the imbalance. If external, the Balancing Authority's AGC should allow its frequency responsive resources to continue responding (as allowed by its Frequency Bias Setting contribution in its ACE equation) until the contingent Balancing Authority corrects its imbalance, which should return frequency to its pre-disturbance value.

3. **Frequency Response versus Frequency Bias Setting—** If the Balancing Authority's Frequency Bias Setting matches its Frequency Response in its AGC ACE equation, the Balancing Authority's Frequency Bias Setting allowance term would exactly offset the change in tie line flow included in the ACE that results from frequency responsive resource action countering a frequency deviation on the Interconnection . The following sections discuss effects of Frequency Bias Settings on control action. The discussion explains control action by all Balancing Authorities external to the contingent Balancing Authority (the Balancing Authority that experienced the sudden generation/load imbalance) and by the contingent Balancing Authority itself.

While this discussion deals with loss of generation, it applies equally to loss of load, or any sudden contingency resulting in a generation/load mismatch. Each Balancing Authority's Frequency Response will vary with each disturbance because generation and load characteristics change continuously. This discussion also assumes that frequency error from 60 Hz was zero (all ACE values were zero) just prior to the sudden generation/load imbalance.

For further explanation of the ACE equation, refer to the *Area Interchange Error Training Document*.

4. **Effects of a Disturbance on all Balancing Authorities External to the Contingent Balancing Authority —** When a loss of generation occurs, Interconnection frequency declines because machine speed must decrease to supply a portion of the energy shortfall from rotating kinetic energy. Initially, rotating kinetic energy from all rotating machines with direct mechanical–to-electrical coupling addresses the entire shortfall by lowering machine speed, and hence frequency, of the Interconnection[2]. Over time, Balancing Authorities' frequency responsive

[2]An amount of kinetic energy proportional to the power (generation) lost will be withdrawn from the stored energy in rotating machines with direct mechanical-to-electrical coupling throughout the Interconnection. As the mechanical speeds are reduced, Interconnection frequency decreases proportionally.

resources should respond to frequency error and change energy to stabilize frequency accordingly. This will cause a change in the Balancing Authorities' actual net interchange. In other words, the Actual Net Interchange (NI_A) generally should be greater than its value before the contingency for all but the contingent Balancing Authority, and the result should be an increase in flow out of non-contingent Balancing Authorities (or a decrease in flow into non-contingent Balancing Authorities). The resulting tie flow error ($NI_A - NI_S$) will be counted as Inadvertent Interchange.

If Balancing Authorities were using only tie line flow error (i.e., flat tie control ignoring the frequency error), this non-zero ACE would cause their AGC to reduce generation until NI_A was equal to NI_S; returning their ACE to zero. However, doing this would not help arrest Interconnection frequency decline because the Balancing Authorities would not be helping to temporarily replace some of the generation deficiency in the Interconnection. With the tie-line bias method, the Balancing Authorities' AGC should allow their frequency responsive resources to continue responding to the frequency deviation until the contingent Balancing Authority replaces the generation it has lost.

For the AGC to allow frequency responsive resource action to continue to support frequency, a frequency bias contribution term is added to the ACE equation to offset the tie flow error. This bias contribution term is equal in magnitude and opposite in direction to the frequency responsive resource action and should ideally be equal to each Balancing Authority's Frequency Response measured in MW/0.1 Hz. Then, when multiplied by the frequency error, ideally the Frequency Bias Setting should exactly be offset by the tie flow error portion of the ACE calculation, allowing continued support of frequency responsive resource action to support system frequency while maintaining ACE at zero.

The ACE equation is then:

$$ACE = (Ni_A - Ni_S) - 10B(f_A - f_S) - I_{ME}$$

Where:

- The factor 10 converts the Frequency Bias Setting (B) from MW/0.1 Hz to MW/Hz.
- I_{ME} is a meter error correction estimate; this term should normally be very small or zero.

NOTE: Frequency Response and Frequency Bias Settings are often referred to as positive values (such as "our bias is 50 MW/0.1 Hz"). Frequency Response and Frequency Bias Settings are actually negative values.

If the Frequency Bias Setting is greater (as an absolute value) than the Balancing Authority's actual Frequency Response, then its AGC will increase generation beyond the primary frequency responsive resource response in order to achieve ACE = 0, which further helps arrest the frequency decline, but increases Inadvertent Interchange. Likewise, if the Frequency Bias Setting contribution term is less (as an absolute value) than actual Frequency Response, its AGC will reduce generation in order to achieve ACE = 0, thereby reducing the Balancing Authority's contribution to arresting frequency change.

5. **Effects of a Disturbance on the Contingent Balancing Authority —** In the contingent Balancing Authority where the generation deficiency occurred, most of the replacement power comes from the Interconnection over its tie lines from Frequency Response contributions by other Balancing Authorities in the Interconnection, as allowed by Frequency Bias Settings. A small portion will be made up internally from the contingent Balancing Authority's own frequency responsive resource response. In this case, the change in NI_A for the contingent Balancing Authority is much greater than its Frequency Bias Setting component. Its ACE will be negative (if the loss is generation), and its AGC will begin to increase generation.

   NI_A — drops by the total generation lost less the contingent Balancing Authority's own frequency responsive resource response
   NI_S — does not change

   The energy supplied from the Interconnection appears in the contingent Balancing Authority's inadvertent balance.

6. **Effects of a Disturbance on the Contingent Balancing Authority with a Jointly-Owned Unit[3] —** When a generation deficiency occurs within a Balancing Authority on a jointly-owned unit (with dynamically scheduled shares being exported), the effects on the tie line component (NI_A – NI_S) of their ACE equation are more complicated. The NI_A drops by the total amount of the generator lost, while the NI_S is reduced only by the dynamic reduction in the shares being exported.

   NI_A — drops by the total generation lost less the contingent Balancing Authority's own frequency responsive resource response
   NI_S — decreases by the reduction in dynamic shares being exported

   The net effect is that the tie line bias component reflects only the response by the contingent Balancing Authority for its share of the lost generation. Most of the replacement power comes from the Interconnection over its tie lines from Frequency Response contributions by other Balancing Authorities in the Interconnection.

7. **Effects of a Disturbance on a Balancing Authority with a Contingent Jointly-Owned Unit[4] Geographically-Located in an External Balancing Authority —** In a Balancing Authority whose generation deficiency occurred on a jointly-owned unit in another Balancing Authority (with dynamically scheduled shares being exported from the other BA), the effects on the tie line component (NI_A – NI_S) of their ACE equations are also complicated. The NI_A increases by the Balancing Authority's own Frequency Response, while the NI_S is reduced only by the dynamic reduction in the share the BA is importing from the unit.

   NI_A — increases by the Balancing Authority's own frequency responsive resource response
   NI_S — decreases by the BA's dynamic share of the jointly-owned unit.

   The net effect is that the tie line bias component reflects only the response by the contingent Balancing Authority for its share of the lost generation. Most of the replacement power comes from the Interconnection over its tie lines from Frequency Response contributions of other Balancing Authorities in the Interconnection.

3 This example assumes dynamic scheduling, not the use of pseudo-ties.
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B. BAL-003 - FRS Form 1 Instructions

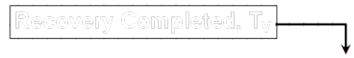

Figure 1 — Classic Frequency Excursion and Recovery

A sample frequency chart is shown in Figure 1 with points A, B, and C labeled. Point A represents the interconnected system frequency immediately before the disturbance. Point B represents the interconnected system frequency at the point immediately after frequency stabilizes due to Frequency Response but before the contingent Balancing Authority takes corrective AGC action. Point C represents the interconnected system frequency at its maximum deviation. All dynamic adjustments as cited bulleted items 4 through 6 needs to be made to NI_A.

Line-by-line instructions for the survey form follow:

FRS Form 1 *Date/Time*		*Point "A" Information*		*Point "B" Information*		*SEFRD*	*Internal*	
Column A (XXXX Prevailing)	**Column B DelFreq**	**Column C Load**	**Column D NAI**	**Column E Load**	**Column F NAI**	**Column G (MW/0.1Hz)**	**Column I Contingency**	Column J **Unit**
12/20/2008 2:12	-0.058	2869.1	-117.0	2861.2	-93.8	-40.2	N	
12/27/2008 4:18	-0.066	2553.6	-138.5	2576.9	-110.8	-41.9	N	
1/5/2009 9:26	-0.040	2838.7	-99.2	2857.8	-88.5	-26.5	N	
1/27/2009 0:39	-0.053	2524.7	-94.4	2522.3	-13.8	-153.6	N	

Point A values are averages over the period from -16 seconds to 0 seconds before initial frequency decline.

Point B values are averages over the period from 18 seconds to 52 seconds after the first scan indicating an initial frequency decline

Data Values

The times of events are approximate; your local observations may vary in time due to the proximity to the loss of generation and SCADA scan rates. The time skew of your observations may be several seconds and your data should be reported accordingly.

Similarly, Delta Frequency values are approximate.

Note: The following table shows the data cells for a Generation Only Balancing Authority

Modified Heading for Generation only BA

A	B	C	D	E	F	G	I
		Point "A" Information		**Point "B" Information**			
Date/Time (xxxx Prevailing)	**Del Freq**	**Load**	**Generation**	**Load**	**Generation**	**SEFRD (MW/0.1Hz)**	**Internal Contingency Unit**

Point A values are averages over the period from -16 seconds to 0 seconds before initial frequency decline.

Point B values are averages over the period from 18 seconds to 52 seconds after the first scan indicating an initial frequency decline

Notes: Add any necessary notes to the response. Please note that Excel allows a maximum of 256 characters for a cell.

All other data on the survey form is calculated.