Calculating and Using Reporting ACE in a Tie Line Bias Control Program

Introduction:

Tie Line Bias[1] (TLB) control has been used as the preferred control method in North America for 75 years. In the early 1950's the term Area Control Error (ACE) was developed for the specific implementation of coordinated Tie Line Bias control now in use throughout the world. This document provides responsible entities guidelines for using both required specifics and the best practices for calculating and using Reporting ACE[2] in coordination with other measures to provide reliable frequency control. While the incorporation of these best practices is strictly voluntary; reviewing, revising, or developing a process using these practices is highly encouraged to promote and achieve reliability for the Bulk Electric System.

The following definitions are included in the NERC Glossary:

Definition:
Actual Frequency **F_A** **5/11/2015**
The Interconnection frequency measured in Hertz (Hz).

Definition:
Actual Net Interchange **NI_A** **5/11/2015**
The algebraic sum of actual megawatt transfers across all Tie Lines, including Pseudo-Ties, with all Adjacent Balancing Authority areas within the same Interconnection. Actual megawatt transfers on asynchronous DC tie lines directly connected to another Interconnection are excluded from Actual Net Interchange.

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[1] Capitalized terms hold the same definition as in the NERC glossary throughout this document.

[2] The CPS1 measure was among the first of the results based measures developed by NERC. It defined not how to perform control, but instead defined the target control results that were to be achieved, and a method to measure whether or not that defined control target had been met. As a result, when CPS1 was implemented, the ACE Equation used in that measure was also specified within that standard.

Historically, Area Control Error (ACE) has been used to describe many terms involved in TLB Control. Within a BAA's Automatic Generation Control (AGC) algorithm there may be more than one ACE value in use. In some systems, the ACE is filtered prior to determining control actions in order to smooth the control signals; or, there may be additional "feed-forward" terms added to ACE in anticipation of future changes (e.g. anticipated ramps, changes in ambient light at sunrise or sunset). There may be gain terms that modify certain variables such as the Frequency Bias Setting to improve the quality of control for the specific characteristics of that particular BAA.

Some auditors have raised compliance issue related to the use of such modifications to the ACE used within the Load-Frequency Control (LFC) system (also referred to as AGC) and required changes in the AGC system to conform to the definition of ACE in BAL-001. The term "Reporting ACE" was developed and is used in place of the term ACE to provide a consistent performance measurement using Reporting ACE and to remove any unnecessary restrictions on the specification of ACE within the LFC system.

Definition:

Automatic Time Error Correction **I_{ATEC}** **5/11/2015**

The addition of a component to the ACE equation for the Western Interconnection that modifies the control point for the purpose of continuously paying back primary Inadvertent Interchange (PII) to correct accumulated time error. Automatic Time Error Correction is only applicable in the Western Interconnection.

$$I_{ATEC} = \frac{PII_{accum}^{on/off\ peak}}{(1-Y)*H}$$ when operating in Automatic Time Error Correction mode.

The absolute value of **I_{ATEC}** shall not exceed **L_{max}** .

I_{ATEC} shall be zero when operating in any other AGC mode.

- **L_{max}** is the maximum value allowed for **I_{ATEC}** set by each BAA between $0.2*|B_i|$ and L_{10}, $0.2*|B_i| \le L_{max} \le L_{10}$.
- **L_{10}** $= 1.65 * \varepsilon_{10}\sqrt{(-10B_i)(-10B_S)}$.
- **ε_{10}** is a constant derived from the targeted frequency bound. It is the targeted root-mean-square (RMS) value of ten-minute average frequency error based on frequency performance over a given year. The bound, ε_{10}, is the same for every Balancing Authority Area within an Interconnection.
- **Y** = B_i / B_S.
- **H** = Number of hours used to payback primary Inadvertent Interchange energy. The value of H is set to 3.
- **B_i** = Frequency Bias Setting for the Balancing Authority Area (MW / 0.1 Hz).
- **B_S** = Sum of the minimum Frequency Bias Settings for the Interconnection (MW / 0.1 Hz).
- Primary Inadvertent Interchange (**PII_{hourly}**) is (1-Y) ∗ (II_{actual} – B_i ∗ ΔTE/6)
- **II_{actual}** is the hourly Inadvertent Interchange for the last hour.
- **ΔTE** is the hourly change in system Time Error as distributed by the Interconnection time monitor,

  where: $\Delta TE = TE_{end\ hour} - TE_{begin\ hour} - TD_{adj} - (t)*(TE_{offset})$
- **TD_{adj}** is the Reliability Coordinator adjustment for differences with Interconnection time monitor control center clocks.
- **t** is the number of minutes of manual Time Error Correction that occurred during the hour.
- **TE_{offset}** is 0.000 or +0.020 or -0.020.
- **PII_{accum}** is the Balancing Authority Area's accumulated PII_{hourly} in MWh. An On-Peak and Off-Peak accumulation accounting is required,

  where:

$$PII_{accum}^{on/offpeak} = last\ period's\ PII_{accum}^{on/offpeak} + PII_{hourly}$$

Definition:

Frequency Bias Setting **B** **4/1/2015**

A number, either fixed or variable, usually expressed in MW/0.1 Hz, included in a Balancing Authority's Area Control Error equation to account for the Balancing Authority Area's inverse Frequency Response contribution to the Interconnection, and discourage response withdrawal through secondary control systems.

Definition:

Interchange Meter Error **I_{ME}** **5/11/2015**

A term, normally zero, used in the Reporting ACE calculation to compensate for data or equipment errors affecting any other components of the Reporting ACE calculation.

Definition:

Reporting ACE **RACE** **5/11/2015**

The scan rate values of a Balancing Authority Area's (BAA) Area Control Error (ACE) measured in MW includes the difference between the Balancing Authority Area's Actual Net Interchange and its Scheduled Net Interchange, plus its Frequency Bias Setting obligation, plus correction for any known meter error. In the Western Interconnection, Reporting ACE includes Automatic Time Error Correction (ATEC).

Reporting ACE is calculated as follows:

Reporting ACE = $(NI_A - NI_S) - 10B\,(F_A - F_S) - I_{ME}$

Reporting ACE is calculated in the Western Interconnection as follows:

Reporting ACE = $(NI_A - NI_S) - 10B\,(F_A - F_S) - I_{ME} + I_{ATEC}$

Where:

- NI_A = Actual Net Interchange.
- NI_S = Scheduled Net Interchange.
- B = Frequency Bias Setting.
- F_A = Actual Frequency.
- F_S = Scheduled Frequency.
- I_{ME} = Interchange Meter Error.
- I_{ATEC} = Automatic Time Error Correction.

All NERC Interconnections with multiple Balancing Authority Areas operate using the principles of Tie-line Bias (TLB) Control and require the use of an ACE equation similar to the Reporting ACE defined above. Any modification(s) to this specified Reporting ACE equation that is(are) implemented for all BAAs on an Interconnection and is(are) consistent with the following four principles of Tie Line Bias control will provide a valid alternative to this Reporting ACE equation:

1. All portions of the Interconnection are included in exactly one BAA so that the sum of all BAAs' generation, load, and loss is the same as total Interconnection generation, load, and loss;
2. The algebraic sum of all BAAs' Scheduled Net Interchange is equal to zero at all times and the sum of all BAAs' Actual Net Interchange values is equal to zero at all times;
3. The use of a common Scheduled Frequency F_S for all BAAs at all times; and,
4. Excludes metering or computational errors. (The inclusion and use of the I_{ME} term corrects for known metering or computational errors.)

Definition:
Scheduled Frequency F_S **3/16/2007**
60.0 Hz, except during a manual Time Error Correction.

Definition:
Scheduled Net Interchange NI_S **5/11/2015**
The algebraic sum of all scheduled megawatt transfers, including Dynamic Schedules, with all Adjacent Balancing Authority areas within the same Interconnection, including the effect of scheduled ramps. Scheduled megawatt transfers on asynchronous DC tie lines directly connected to another Interconnection are excluded from Scheduled Net Interchange.

Structure:

The effective use of Reporting ACE within a TLB control program should address the following components:

(I) Management Roles and Expectations
(II) Information Technology Roles
(III) System Operator Roles
(IV) Manual Source Data Entry
(V) Automatically Collected Source Data
(VI) Uses of Reporting ACE
(VII) Historic Data Management
(VIII) Special Conditions and Calculations

Each individual component should address processes and procedures, evaluation of any issues or problems along with solutions, testing, training, and communications. These provisions and activities together will be referred to as the Tie Line Bias control program.

Each responsible entity should evaluate all of its uses for Reporting ACE in its operations and its reliability measurement. Reporting ACE is one of the most important single measurements available to indicate the current state of the Responsible Entity's contribution to interconnection reliability.[3] Reporting ACE is also used as an integral part of the measurements used in BAL-001 and BAL-002. Technical requirements associated with the parameters used in the calculation of Reporting ACE are specified in BAL-003 and BAL-005.

I. Management Roles and Expectations

Management plays an important role in maintaining an effective TLB control program. The management role and expectations below provide a high-level overview of the core management responsibilities related to each Tie Line Bias control program. The management of each responsible entity should tailor these roles and expectations to fit within its own structure.

a. Set expectations for safety, reliability, and operational performance.

[3] When configured with a Frequency Bias Setting equal to the actual Frequency Response of the BAA, Reporting ACE will reflect the BAA's obligation to match its actual interchange, less the impact from its current Frequency Response offset, to its scheduled interchange.

b. Assure that a TLB control program exists for each responsible entity and is current.
c. Provide annual training on the TLB control program and its purpose and requirements.
d. Ensure the proper expectation of TLB control program performance.
e. Share insights across industry associations.

II. Information Technology (IT) Roles

a. Participate in appropriate TLB control related training.
b. Ensure the Reporting ACE and source information are always current and correct.
c. Implement the TLB control program in Real-time.
d. Ensure that the EMS supports the manual data entry of all source data required to be entered by IT staff, system operations staff, and System Operators and properly manages that data once entered.
e. Ensure that the EMS supports and manages the automatic collection of all source data that is required to be measured in real-time through telemetry and data exchange including data quality information to indicate data validity.
f. Ensure that the programs that manage data used to calculate components of Reporting ACE, Reporting ACE itself, and subsequent measures based on Reporting ACE are up to date and correct as identified by, but not limited to the following calculations and equations:

1) Actual Net Interchange[4] (NI_A):

All BAAs involved account for the power exchange and associated transmission losses as actual interchange between the BAAs, both in their ACE and Reporting ACE equations and throughout all of their energy accounting processes.

i. Calculate for each scan.[5]
ii. Integrated hourly average calculated for each hour as an integration of the scan rate values.

[4] By definition "Actual megawatt transfers on asynchronous DC tie lines directly connected to another Interconnection are excluded from Actual Net Interchange." Additional information on asynchronously connected DC tie lines connected to another interconnection is provided in "Special Conditions and Calculations" section of this document.

[5] Actual Net Interchange scan-rate values are also used as one of the primary inputs to the calculation of Frequency Response Measure (FRM) on FRS Form 1 and FRS Form 2.

2) Scheduled Net Interchange[6] (NI_S):
   i. Calculate for each scan.
   ii. Integrated hourly average calculated for each hour as an integration of the scan rate values. (This value differs from the block accounting value.)

   Note: Dynamic Schedules are to be accounted for as Interchange Schedules by the source, sink, and contract intermediary BAA(s), both in their respective ACE and Reporting ACE equations, and throughout all of their energy accounting processes.

3) Frequency Error ($\Delta F = (F_A - F_S)$):
   i. Calculate for each scan.
   ii. Calculate clock-minute average from valid samples available within each clock-minute[7] where at least half of the scan-rate samples are valid.

4) Frequency Trigger Limit – Low (FTL_{Low})[8]:

   Calculate the Frequency Trigger Limit – Low for each clock-minute where at least half of the scan rate samples are valid by subtracting three times Epsilon1 from the Scheduled Frequency (F_S).

5) Frequency Trigger Limit – High (FTL_{High})[9]:

   Calculate the Frequency Trigger Limit – High for each clock-minute where at least half of the scan rate samples are valid by adding three times Epsilon1 to the Scheduled Frequency (F_S).

6) Accumulated primary Inadvertent Interchange (PII): Calculated each hour for WECC BAAs only.

$$\boldsymbol{PII_{accum}^{on/offpeak}} = \boldsymbol{last\ period's\ PII_{accum}^{on/offpeak}} + \boldsymbol{PII_{hourly}}$$

7) Automatic Time Error Correction (IATEC): Calculate for each hour for WECC BAAs only for inclusion in the ACE and Reporting ACE Equation for the next hour.

   $\boldsymbol{I_{ATEC}} = \dfrac{\boldsymbol{PII_{accum}^{on/off\ peak}}}{\boldsymbol{(1-Y)*H}}$ when operating in ATEC mode.

   The absolute value of $\mathbf{I_{ATEC}}$ shall not exceed $\mathbf{L_{max}}$ **.**

   $\mathbf{I_{ATEC}}$ shall be zero when operating in any other AGC mode.

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6 By definition "Scheduled megawatt transfers on asynchronous DC tie lines directly connected to another interconnection are excluded from Scheduled Net Interchange." Additional information on asynchronously connected DC tie lines connected to another interconnection is provided in the "Special Conditions and Calculations" section of this document.

7 Clock-minute averages are used for the calculation of ACE and Frequency Error in CPS1 and BAAL to eliminate the transient variations of tie-line flows and frequency error used in the calculation of performance measures. The one-minute period was chosen because it is evenly divisible by all whole-second scan rates less than the maximum specified scan rate of six seconds. This assures greater comparability of performance data among BAs with different scan rates.

8 This variable could be entered manually as long as it is changed every time a manual time error correction is started or stopped. If manual time error correction is eliminated, it could become a constant and entered manually.

8) Reporting ACE:
   i. Calculate for each scan.
   ii. Calculated average for each clock-minute for BAAs using a fixed Frequency Bias Setting when at least half of the values are valid.[9]

9) Compliance Factor[10]:
   i. Calculate for each scan where both Reporting ACE and Frequency Error are valid.
   ii. Calculate for each clock-minute where both the average clock-minute Frequency Error and the average clock-minute Reporting ACE are valid.[11]

10) Clock-hour compliance factor[8]:

    Calculate for each hour by summing the valid clock-minute compliance factors for the hour and dividing by the number of valid clock-minute compliance factors in the hour.

11) Month compliance factor[8]:

    Calculate by summing the valid clock-minute compliance factors in the month and dividing by the number of valid clock-minute compliance factors in the month.

12) 12-month compliance factor[8]:

    Calculate by summing the valid clock-minute compliance factors in the 12-month period and dividing by the number of valid clock-minute compliance factors in the 12-month period.

13) CPS1 compliance factor:

    Calculate the CPS1 compliance factor by dividing the 12-month compliance factor by the square of the $Epsilon_1$ value for the Interconnection.

14) CPS1:
   i. Calculate the CPS1 scan rate performance by dividing the scan rate compliance factor by the square of the Epsilon 1 value for the interconnection and subtracting that value from 2 and multiplying the result by 100 to convert to a percentage performance for each scan with a valid compliance factor.
   ii. Calculate the CPS1 clock-minute performance by dividing the clock-minute compliance factor by the square of the Epsilon 1 value for the interconnection and subtracting that value from 2 and multiplying the result by 100 to convert to a percentage performance for each clock-minute with a valid compliance factor.
   iii. Calculate the CPS1 clock-hour performance by dividing the clock-hour compliance factor by the square of the Epsilon 1 value for the interconnection and subtracting that value from 2

[9] The average of the value of the ratio of the scan rate value of Reporting ACE divided by the scan rate value of -10 times the Frequency Bias Setting for those BAs using a variable Frequency Bias Setting, where at least half of the ratio values are valid.

[10] Used for CPS1.

[11] The compliance factor is calculated when the average of the value of the ratio of the scan rate value of Reporting ACE divided by the scan rate value of -10 times the Frequency Bias Setting for those BAs using a variable Frequency Bias Setting, where at least half of the ratio values are valid and the average clock-minute Frequency Error is valid.

and multiplying the result by 100 to convert to a percentage performance for each clock-minute with a valid compliance factor.

iv. Calculate the CPS1 monthly performance by dividing the month compliance factor by the square of the Epsilon 1 value for the interconnection and subtracting that value from 2 and multiplying the result by 100 to convert to a percentage performance for each clock-minute with a valid compliance factor.

v. Calculate the CPS1 12-month performance by dividing the 12-month compliance factor by the square of the Epsilon 1 value for the interconnection and subtracting that value from 2 and multiplying the result by 100 to convert to a percentage performance for each clock-minute with a valid compliance factor.

15) Balancing Authority ACE Limit - Low ($BAAL_{Low}$):

i. Calculate the scan rate Balancing Authority ACE Limit – Low by multiplying three times Epsilon1 squared for the interconnection by -10 times the Frequency Bias Setting and dividing the result by the Frequency Error.

ii. Calculate the clock-minute Balancing Authority ACE Limit – Low by multiplying three times Epsilon1 squared for the interconnection by -10 times the Frequency Bias Setting and dividing the result by the clock-minute Frequency Error when at least half of the values are valid.

16) Balancing Authority ACE Limit - High ($BAAL_{High}$):

i. Calculate the scan rate Balancing Authority ACE Limit – High by multiplying three times Epsilon1 squared for the interconnection by -10 times the Frequency Bias Setting and dividing the result by the Frequency Error.

ii. Calculate the clock-minute Balancing Authority ACE Limit – High by multiplying three times Epsilon1 squared for the interconnection by -10 times the Frequency Bias Setting and dividing the result by the clock-minute Frequency Error when at least half of the values are valid.

17) Balancing Authority ACE Limit - Low Compliance:

i. Alarm $BAAL_{Low}$ potential non-compliance for each period as determined for operations where the clock-minute Reporting ACE is below the clock-minute $BAAL_{Low}$.

ii. Indicate $BAAL_{Low}$ non-compliance for each period where the clock-minute Reporting ACE is below the clock-minute $BAAL_{Low}$ for more than 30-consecutive clock-minutes.

18) Balancing Authority ACE Limit - High Compliance:

i. Alarm $BAAL_{High}$ potential non-compliance for each period as determined for operations where the clock-minute Reporting ACE is above the clock-minute $BAAL_{High}$.

ii. Indicate $BAAL_{High}$ non-compliance for each period where the clock-minute Reporting ACE is above the clock-minute $BAAL_{High}$ for more than 30 consecutive clock minutes.

g. Ensure that the EMS supports the retention of all historic data including data quality information required to be retained to support continuing operations and audit requirements.

h. Ensure that the EMS supports and manages the presentation of all information required to be available to the System Operator for real-time operations, operations staff for evaluation of operations, and auditors for compliance confirmation.

i. Conduct an evaluation of the effectiveness of the TLB control program and incorporate lessons learned.

III. System Operator and Operations Staff Roles

a. Participate in appropriate TLB control related training.
b. Ensure the Reporting ACE information is always current and correct.
c. Conduct an evaluation of the effectiveness of the TLB control program and incorporate lessons learned.
d. Implement the TLB control program in Real-time.

IV. Manual Source Data Entry

Reporting ACE is calculated in Real-time, at least every six seconds[12], by the Responsible Entity's Energy Management System (EMS), and may be partially based on source data manually entered into that system. The following source data may be entered:

NI_A (Actual Net Interchange): The telemetry values of actual tie flows, including pseudo-ties, between Adjacent Balancing Authority Areas may not be available from an automatic collection source, requiring manual entry of estimated flows. These manual entries should be performed in a manner that reasonably assures equal magnitude and opposite sign values are used by the Adjacent Balancing Authority Areas entering the manual data. If the actual flow estimates are the same for the Adjacent Balancing Authority Areas, the effect of any errors will be confined to the two Adjacent Balancing Authority Areas responsible for the manual entries. Failure to match actual flow estimates will result in errors that affect other BAAs on the Interconnection.

NI_S (Scheduled Net Interchange): The power transfer schedules, including the schedule ramps where applicable, are processed by the EMS. If scheduled flow estimates are equal and have opposite signs for the Adjacent Balancing Authority Areas, the effect of any errors will be confined to the two Adjacent Balancing Authority Areas responsible for the manual entries. Failure to match scheduled flow estimates will result in errors that affect other BAAs on the Interconnection.

B (Frequency Bias Setting): The Frequency Bias Setting, or minimum required value, for the Balancing Authority Area is specified by calculations performed as part of compliance with BAL-003-1 - Frequency Response and Frequency Bias Setting;

R2. Each Balancing Authority Area that is a member of a multiple Balancing Authority Area Interconnection and is not receiving Overlap Regulation Service and uses a fixed Frequency Bias Setting shall implement the Frequency Bias Setting determined in accordance with Attachment A, as validated by the ERO, into its Area Control Error

[12] BAL-005-1 Balancing Authority Control - R2. The Balancing Authority shall use no greater than a six-second scan rate in acquiring data necessary to calculate Reporting ACE.

(ACE) calculation during the implementation period specified by the ERO and shall use this Frequency Bias Setting until directed to change by the ERO.[13]

10 is the factor (10 0.1Hz/Hz) that converts the Frequency Bias Setting units to MW/Hz.

F_S (Scheduled Frequency): Scheduled Frequency, normally 60 Hz, is manually adjusted on a coordinated basis when directed to do so by the Interconnection Time Monitor as specified in BAL-004-0.[14] It is important for all BAAs on an interconnection to make these adjustments on a coordinated basis so that all BAAs are controlling to the same Scheduled Frequency at all times.

I_{ME} (Interchange Meter Error): This term, normally zero, is available for use by the System Operator or operations staff to add a correction term in the Reporting ACE calculation to compensate for data or equipment errors affecting any other components identified by analysis of historic data demonstrating the existence of errors, usually errors between integrated hourly scan-rate data and hourly agreed to accumulated meter data. (See the Special Conditions and Calculations section of this document for additional information)

L_{max} is the maximum value allowed for **I_{ATEC}** set by each BA between $0.2*|B|$ and L_{10}, $0.2*|B| \leq L_{max} \leq L_{10}$.

Y is normally calculated by the ATEC program in the EMS for BAAs on the Western Interconnection.

H is normally set to 3 and used by the ATEC program in the EMS for BAs on the Western Interconnection. It represents the number of hours over which the primary inadvertent interchange is paid back.

B_S is used by the ATEC program in the EMS for BAAs on the Western Interconnection. It represents the sum of the minimum Frequency Bias Settings for all BAAs on the Interconnection.

ΔTE is used by the ATEC program in the EMS for BAAs on the Western Interconnection. In some cases, it may be calculated by the EMS based on the factors in the ΔTE equation. ΔTE is the hourly change in system Time Error as distributed by the Interconnection time monitor.

TD_{adj} is an adjustment for the differences between the local clock in the local time standard and the Interconnection time monitor control center clocks so that the local EMS can calculate the correct ΔTE for the BAAs and used by the ATEC program in the EMS for BAAs on the Western Interconnection.

TE_{offset} is entered as instructed by the Interconnection time monitor.

ε_1 is the RMS Limit for the 1-minute average frequency error for the interconnection.

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[13] As a note of interest, the new procedures put forth with BAL-003-1 will result in the reduction of minimum Frequency Bias Setting values on the multiple BA interconnections to bring them closer to the natural measured Frequency Response of the interconnection. The rule requiring a minimum Frequency Bias Setting of 1% of peak load in the NERC Standards dates back to 1962 when NAPSIC, the precursor to the NERC Operating Committee, codified the recommendations of the Interconnected Systems Group made in 1956 to set a minimum of 50% of the natural measured response which was 2% of peak load at that time. The 1% figure is now more than 200% of the natural measured response for the Eastern Interconnection and in some cases is approaching a value that could result in instability by being too high. The logic justifying a minimum of the natural response is still valid.

[14] This is consistent with condition 3 in the Reporting ACE Definition: “The use of a common Scheduled Frequency F_S for all areas at all times.”

V. Automatically Collected Source Data

Reporting ACE is calculated in Real-time, at least as frequently as every six seconds[15], by the responsible entity's Energy Management System (EMS) predominantly based on source data automatically collected by that system. Also, the data must be updated at least every six seconds for continuous scan telemetry and updated as needed for report-by-exception telemetry.

In addition, data quality information (usually in the form of data quality flags associated with each data value) must be retained and presented in real-time to the System Operators. This data quality information is presented to the System Operator to have situational awareness with respect to the quality of the data inputs and final calculated result. It is later used to determine which data is valid for use in performance calculations such as CPS1, BAAL, DCS, and frequency response obligation (FRM).

NI_A (Actual Net Interchange): The tie-line value representing each tie-line flow and pseudo-tie quantity is collected at the required scan rate of six seconds or less.[16,17,18,19] Data that is of questionable accuracy or timeliness is flagged with an appropriate data quality flag. This information is presented to the System Operator to support situational awareness.[20] The EMS sums the individual flow values on all tie lines and pseudo ties with all adjacent BAAs at the scan rate and includes this value as NI_A in the Reporting ACE equation calculation. The result is a series of NI_A values at the EMS scan rate and associated data quality flags. The associated data quality of the telemetry element is passed to the result of all calculations using that element.

NI_S (Scheduled Net Interchange): Most interchange schedules and some Dynamic Schedules are entered into the EMS in a summary format either as individual schedules, schedule nets with each Adjacent Balancing Authority Area, or a final Scheduled Net Interchange. These schedules are converted into scan-rate schedules by the EMS. The EMS calculates the Scheduled Net Interchange, where applicable, by summing all individual schedule values or nets with each Adjacent Balancing Authority Area for all regular and Dynamic Schedules and includes the result as NI_S in the ACE equation.

F_A (Actual Frequency): Actual frequency is provided by a frequency measuring device at the accuracy specified in BAL-005[21] at the EMS scan rate. If a frequency value is not available, the value for that scan is marked invalid.

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[15] BAL-005-1 Balancing Authority Control – "R2. The Balancing Authority Area shall use no greater than a six-second scan rate in acquiring data necessary to calculate Reporting ACE."

[16] Data transmitted at a rate slower than the scan rate of the remote sensing equipment may require the inclusion of anti-aliasing filtering at the source of the measurement to eliminate the risk of aliasing in the data transmitted to the EMS. See the attached document titled "Anti-aliasing Filtering."

[17] It is acceptable to collect tie-line flow data from RTUs that use report by exception as long as those RTUs can support the scan rate of six seconds or less when data is changing rapidly and both adjacent BAAs are receiving comparable data to keep the measured flows equivalent.

[18] The six-second scan rate not only assures that data collected is close to Real-time, it also limits the latency (time skew) associated with the data collection.

[19] The accuracy of the flow data is set by those using the flow data for transmission flow management. As with all ACE data, as long as both adjoining BAAs are using the same values for tie-line flow, the effects of any error in flow measurement will be confined to the two adjacent BAAs.

[20] Indications of suspect data are usually indicated with color changes and/or alarms.

[21] BAL-005 – Automatic Generation Control specifies an accuracy of ≤0.001 Hz (equivalent to ≤ +/- 0.0005 Hz) for the Digital Frequency Transducer.

II_{actual} (Inadvertent Interchange): This term is only used in the Western Interconnection ACE calculation. Inadvertent Interchange "Actual" for the previous hour is calculated by the EMS from the previous hour's data as the difference between the integrated hourly average Scheduled Net Interchange and the integrated hourly average Actual Net Interchange. (Block schedules are not used for this calculation.)

t (Manual Time Error correction minutes in the hour): The number of minutes of manual Time Error correction in the hour.

VI. Uses of Reporting ACE

a. Reporting ACE is currently used to measure secondary frequency control within TLB control on all of the Interconnections.[22] Consequently, Reporting ACE is one of the primary measurement parameters in many of the NERC Balancing Standards. The following standards require the use of Reporting ACE as part of the performance metrics or set requirements associated with the calculation of Reporting ACE.

   i. BAL-001-1 – Real Power Balancing Control Performance and BAL-001-2 – Real Power Balancing Control Performance.

   ii. BAL-002-1 – Disturbance Control Performance and BAL-002-2 – Disturbance Control Standard – Contingency Reserve from a Balancing Contingency Event (when approved).

   iii. BAL-005-0.2b – Automatic Generation Control and BAL-005-1 – Balancing Authority Control (when approved).

   iv. BAL-006-2 Inadvertent Interchange.

b. The industry may also consider the use of Reporting ACE in the future to evaluate the rules associated with transmission loading.

VII. Historic Data Management

The industry currently requires the retention of data supporting the calculation of Reporting ACE and compliance measurements based in part on Reporting ACE to support the NERC compliance audit process. This data retention must be considered as an integral part of the Reporting ACE and "TLB control program".

VIII. Special Conditions and Calculations

IX. **I_{ME} (Interchange Meter Error):** BAL-005-1 R6 requires, "Each Balancing Authority Area that is within a multiple Balancing Authority Area interconnection shall implement an Operating Process to identify and mitigate errors affecting the scan-rate accuracy of data used in the calculation of Reporting ACE." Ideally, errors identified should be corrected immediately, but this is not always possible. The **I_{ME}** term, normally zero, can be used by the System Operator or operations staff to add a correction term in the Reporting ACE calculation correcting errors affecting the scan-rate accuracy of data, thus mitigating the error in the calculation of Reporting ACE until telemetry errors can be corrected.

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[22] On single BAA Interconnections, the ACE Equation reduces to a single term, **$-10B\ (F_A – F_S)$**, because there are no tie lines or schedules to include in the first term, **$(NI_A – NI_S)$**, and there is no **I_{ME}** term to correct for tie line or dynamic schedule measurement errors in the first term.

The calculation of the $\mathbf{I_{ME}}$ is the one of the results of this required Operating Process. It compensates for data or equipment errors affecting components of Reporting ACE identified by analysis of historic data. These errors are usually between integrated hourly scan-rate data and hourly accumulated meter data but can also occur as differences between the accumulated meter data of two adjacent BAAs. The process used for including adjustments in the $\mathbf{I_{ME}}$ term should be based on good quality control methods.[23]

The goal associated with the use of the $\mathbf{I_{ME}}$ is to encourage the scan-rate values of actual and scheduled interchange between Adjacent Balancing Authorities to be equal in magnitude and have opposite signs.[24] Unfortunately, these values cannot be directly compared with each other because of differences between scan time and differences between scan-rates between BAAs. When initially configured, all BAs used "Digital to Analog" converters and "Analog to Digital" converters to transmit tie-line flows and accumulated MWh values from the common metering point required in the standards to the BA's EMS. These "D to A" and "A to D" converters are subject to error and require frequent calibration, and although, many have been replaced by digital telemetry, they still exist and require oversight. Any difference between the scan-rate values agreed to by Adjacent BAAs that is not included in the error mitigation process will be passed to the interconnection for management and will not be included in the performance measures such as CPS1, BAAL and FRM.

Energy Management Systems are capable of integrating the scan-rate values used for the calculation of Reporting ACE and providing those integrated values for comparison to the accumulated megawatt-hour values for the same meters. If the integrated scan rate values are close to the accumulated megawatt-hour values, then one can conclude that the scan-rate values accurately represent the accumulated values. The final step in this process includes a comparison and agreement on the accumulated megawatt-hour values between the Adjacent BAAs sharing the measurement. If the differences between accumulated values between Adjacent BAAs is not included in this process, any adjustments to the accumulated values made by a BAA to achieve agreement with an adjacent BAA will be excluded from the analysis and will not be mitigated. This information used in conjunction with a similar analysis of the scan rate values for the same measurement by the Adjacent Balancing Authority Area including analysis of any differences between the accumulated values and the agreed to accumulated values. This total process provides reasonable assurance that the scan-rate tie line flows or the dynamic schedules used by Adjacent BAAs are consistent with one another confining control problems within the boundaries of the Adjacent BAAs.

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[23] Adjustments to the $\mathbf{I_{ME}}$ term should follow good quality control methods and exclude tampering as demonstrated by the Deming's Funnel Experiment, http://blog.newsystemsthinking.com/w-edwards-deming-and-the-funnel-experiment/ .

[24] As long as the scan-rate tie line flows and scheduled flows match for Adjacent Balancing Authority Areas, any problems with the measurement of balancing on the interconnection will be confined to within the boundaries of those Adjacent Balancing Authority Areas. Any mismatch will pass the difference to the interconnection and will result in frequency control error that will to be excluded from performance measurement and managed by all BAAs through the frequency bias terms of their Reporting ACE.

These error correction adjustments can be used to correct errors in the $\mathbf{NI_A}$ or $\mathbf{NI_S}$[25] terms for Reporting ACE and other measurements that depend upon an accurate Actual Net Interchange and/or an accurate Scheduled Net Interchange. The same logic and evaluation processes that are valid for inclusion in the $\mathbf{I_{ME}}$ term of the Reporting ACE equation should also be valid as adjustments to the scan rate tie-line flows used for the measurement of Frequency Response as part of the BAL-003-1.

a. **Use of Source-Sink Pairs for Asynchronous DC Tie Lines to Another Interconnection:** One of the primary rules for insuring the validity of the Reporting ACE equation is, "All portions of the Interconnection are included in exactly one BAA so that the sum of all BAAs' generation, load, and loss is the same as total Interconnection generation, load, and loss." This is accomplished by requiring the inclusion in Reporting ACE of all tie lines, pseudo ties, interchange schedules and Dynamic Schedules to Adjacent Balancing Authority Areas and only Adjacent Balancing Authority Areas on the same Interconnection, and requiring the exclusion of all asynchronous DC tie lines and associated scheduled interchange with Balancing Authority Areas on a different Interconnection from Reporting ACE. Following this simple rule insures that all loads, losses and generation are properly included with each Interconnection.

Instead of including the power transfers from an asynchronous DC tie line between two Interconnections as a normal interchange transfer between two BAAs, this form of power transfer should be included as though it is a linked source-sink pair for the purposes of managing frequency control within a tie line bias control program. One terminal of an asynchronous DC tie line will appear to the receiving Interconnection and receiving BAA as an energy resource similar to a generator. This is the source end of the source-sink pair. The other terminal of the same asynchronous DC tie line will appear to the supplying Interconnection and supplying BAA as an energy sink similar to a load. This is the sink end of the source-sink pair.

Interchange transactions linked to either the source or sink from other BAAs on the same Interconnection as the source or sink will schedule those transactions, include those transactions in Reporting ACE, and manage those transactions in a similar manner to any other energy transaction. Only the BAA acting as the source or the sink for the DC tie line will exclude the asynchronous tie line from its Reporting ACE while including all transactions with Adjacent BAAs on the same Interconnection associated with that source or sink power transfer in their Reporting ACE.

[25] Errors in the $\mathbf{NI_S}$ would only occur and only support correction in cases where there is a measurement error associated with a Dynamic Schedule.