NERC
NORTH AMERICAN ELECTRIC RELIABILITY CORPORATION

July 31, 2014

VIA ELECTRONIC FILING

Ms. Kimberly D. Bose
Secretary
Federal Energy Regulatory Commission
888 First Street, NE
Washington, D.C. 20426

Re: Informational Filing, Interim Report on Balancing Authority ACE Limit Field Trial
Docket No. RM14-10-000

Dear Secretary Bose:

The North American Electric Reliability Corporation ("NERC") hereby submits for informational purposes a preliminary field trial report evaluating the effects of revisions to proposed Reliability Standard BAL-001-2. This report is being submitted in accordance with NERC's commitment in the May 9, 2014 Supplemental Filing to the Petition for Approval of Reliability Standard BAL-001-2—Real Power Balancing Control Performance.

The field trial report finds that the results to date demonstrate that the correlation between Requirements R1 and R2 of Reliability Standard BAL-001-2 drive corrective actions to support Interconnection frequency and reliability. The field trial will end for participating entities upon the effective date of Reliability Standard BAL-001-2.

NERC is not requesting any Commission action on the instant filing. NERC respectfully requests that the Commission accept this filing for informational purposes only.

Respectfully submitted,

/s/ Stacey Tyrewala
Stacey Tyrewala

Senior Counsel for North American Electric Reliability Corporation

cc: Official service list in Docket No. RM14-10-000

NERC
NORTH AMERICAN ELECTRIC RELIABILITY CORPORATION

Balancing Authority ACE Limit (BAAL) Preliminary Field Trial Report

July 31, 2014

RELIABILITY | ACCOUNTABILITY




Table of Contents

Introduction

This Interim report on the field trial evaluates the effects of revisions to Requirement R2 of Reliability Standard BAL-001-2. The purpose of Reliability Standard BAL-001-2 is to assure reliability by maintaining Interconnection frequency within predefined frequency limits. This standard defines a new requirement, known as the BAAL (Balancing Authority ACE Limit), which replaces the BAL-001 Requirement R2 currently in effect and known as Control Performance Standard 2 (CPS2).[1] Compliance with the BAAL requires the Balancing Authority (BA) to balance its resources and demand in Real-time so that the clock-minute average of its Reporting Area Control Error (Reporting ACE) does not exceed its clock-minute BAAL for more than 30 consecutive clock-minutes.

As a proof of concept for the BAAL requirement, a BAAL field trial was endorsed by the NERC Operating Committee and subsequently approved by the NERC Standards Committee in June 2005. The purpose of this interim report is to inform the Operating Committee of the status of the BAAL field trial to date and to discuss interim observations and conclusions.

The field trial began in the Eastern Interconnection in July 2005. The Electric Reliability Council of Texas (ERCOT) Interconnection was added to the field trial in December 2009, followed by the Western Interconnection in March 2010, and the Quebec Interconnection in September 2010. Details for each Interconnection can be found later in the report. The field trial will end for participating Balancing Authorities upon the effective date of Reliability Standard BAL-001-2.

As explained below, the field trial results to date demonstrate that the correlation between Requirements R1 and R2 of Reliability Standard BAL-001-2 drive corrective actions to support the Interconnection frequency.

Several tools were developed to facilitate reporting and Real-time operations under the standard, and these tools are available on the project web page.[2] Reliability Coordinators for all Interconnections monitored the performance of those participating BAs and participated in the monthly field trial conference calls. The following sections of the report provide an introduction to the BAAL field trial, the background and history of the development of the BAAL requirement and of the proof-of concept field trial, analysis of the results by Interconnection, and observations and conclusions drawn by the SDT.

---

[1] Unless otherwise designated, all capitalized terms shall have the meaning set forth in the *Glossary of Terms Used in NERC Reliability Standards*, available at http://www.nerc.com/files/Glossary_of_Terms.pdf.

[2] *Available at*: http://www.nerc.com/pa/Stand/Pages/Project-2007-18-Reliability-Based-Control-FieldTrial-Tools-RF.aspx.

Executive Summary

To date, the field trial results demonstrate that Reliability Standard BAL-001-2 supports frequency and improves reliability.

General Policy Conclusions

BAAL provides a short-term measure to compliment the CPS1 long-term measure for interconnection frequency control. The Standard Drafting Team reached the following general conclusions from the field trial:[3]

1. On the Eastern Interconnection, the participants in the field trial observed an increase in system Operator understanding of interconnection frequency control and improved timely response to significant ACE and frequency deviations. Prior to operating to the BAAL, System Operators typically managed just their own ACE. They have since been managing their own ACE in conjunction with system frequency for greater overall system-compatible control. This change in operator understanding and response resulted in a reduction in both the magnitude and duration of large frequency deviations on the Eastern Interconnection resulting in an improvement in frequency control on the Eastern Interconnection.

2. One of the primary concerns of the standard drafting team when initiating the field trial was how the replacement of CPS2 by BAAL would affect transmission constraints. During the field trial no case of increased numbers or magnitudes of transmission constraints was identified and attributed to BAAL on the Eastern Interconnection. On the Western Interconnection, during the field trial there were transmission constraints; however, there is no conclusive evidence that these transmission constraints were a direct result of BAAL.

3. BAAL in conjunction with NERC Standard BAL-003-1 Frequency Response and Frequency Bias Setting meets the requirements set forth in Paragraph 355 of FERC Order No. 693.[4] Moreover,

[3] On the ERCOT and Hydro-Quebec single-BA interconnections, BAAL reduces to the Frequency Trigger Limit (FTL), and managing to the FTL has had no adverse impact on transmission reliability. While FTL replaces CPS2 in the Hydro-Quebec interconnection, it is a whole additional constraint on the ERCOT Interconnection which has operated since 2003 under a waiver from CPS2.

[4] FERC Order No. 693, Paragraph 355. "Taking into account commenters' concerns about defining a significant deviation as a frequency deviation of 20 milliHertz lasting longer than the 15 minute recovery period, the Commission will not direct a specific change. Instead, we direct the ERO, through the Reliability Standards development process, to modify this Reliability Standard to define a significant deviation and a reportable event, taking into account all events that have an impact on frequency, e.g., loss of supply, loss of load and significant scheduling problems, which can cause frequency disturbances and to address how balancing authorities should respond. As suggested by NRC, this or a related Reliability Standard should also include a frequency response requirement. The present Control Performance Standards represent the monthly and yearly averages which are appropriate for measuring long-term trends but may not be appropriate for

instead of defining a separate, absolute, fixed threshold for a significant deviation and a reportable event, BAAL sets a variable joint MW limit (BAAL) that is dependent on concurrent interconnection frequency in Hz. The standard drafting team believes that this method better, more precisely, defines interconnection frequency and imbalance limits than does setting separate limits on either frequency deviation or ACE magnitude alone and is consistent with FERC Order No. 693.

Specific Technical Conclusions

To date, the SDT has reached the following detailed technical conclusions based on the field trial:

- The BAAL Requirement focuses on Frequency Control for the Interconnection.
- The correlation between CPS1 and BAAL provides information allowing the System Operator to make corrective actions to support frequency.
- The BAAL is a proportional allocation of responsibility across all BAs.
- BAAL captures all conditions that impact Interconnection frequency.
- The BAAL exceedance time duration of 30 consecutive clock-minutes has proven to be appropriate.
- The BAAL field trial results validate the Frequency Trigger Limits (FTLs) at 3 times epsilon 1.
- The BAAL appears to have no effect on NERC Inadvertent Interchange.
- There is no conclusive evidence that BAAL has any effect on congestion management/unscheduled flow within the Western Interconnection.
- The BAAL appears to have no adverse impact on Frequency Error.
- BAs should remain under the field trial until BAL-001-2 becomes effective.
- The SDT should continue to add BAs under the field trial so that BA operators gain experience under the BAAL prior to making it effective.

Rationale for Continuing the BAAL Field Trial

The BAAL field trial (also known as the Reliability Based Control, or RBC field trial), began in 2005 and continues to date. Based upon results of the field trial to date, the Standards Development Team (SDT) recommends that the field trial continue until the final disposition of the BAL-001-2 standard is known. NERC continues to add BAs to the field trial and believes additional BAs should be encouraged to join so that they can gain experience with BAAL before it becomes effective as a Standard. This would also

---

measuring short-term events. In addition, the measures should be available to the balancing authorities to assist in real-time operations.*****

* It is the Commission's understanding that the Balancing Authority ACE Limit Standards that are currently being field tested are triggered on frequency deviations and can be used as feedback to the real-time operations personnel."

improve the evaluation of operations under the BAAL requirement as BA participation moves closer to 100% in the Eastern and Western Interconnections. In addition, the SDT believes that it is prudent to continue the field trial rather than require many BAs to revert to CPS2 and then possibly reinstate BAAL upon approval of the BAL-001-2 standard by the Federal Energy Regulatory Commission (Commission or FERC). There will be risk and cost associated with moving BAs back to CPS2 and then back to BAAL once the standard is approved.

Technical Background

Control Performance methodologies have changed over time. As systems became more interconnected it became evident to the industry that a common methodology was needed for coordinated operations on the Interconnections.

As a result, the A1-A2 Control Performance Policy was implemented in 1973. A1 required the BA's ACE to return to zero within 10 minutes of previous zero crossing of ACE. A2 required that the BA's averaged ACE for each 10-minute period must be within limits. The A1-A2 policy had three main short-comings:

- It lacked theoretical justification;
- Large values of ACE were treated the same as a small values of ACE, regardless of direction; and
- It was independent (did not require support) of Interconnection frequency.

In 1997, the NERC Board of Trustees approved NERC Policy 1, Generation Control and Performance, developed by the NERC Performance Subcommittee (now Resources Subcommittee), which replaced A1-A2 with the Control Performance Standard 1 (CPS1) and Control Performance Standard 2 (CPS2). CPS1 is:

- A statistical measure of ACE variability.
- A measure of ACE in combination with the Interconnection's frequency error.
- Based on an equation derived from frequency-based statistical theory.

CPS2 is designed to limit a BA's unscheduled power flows, similar to the old A2 criteria. CPS2 was not designed to address Interconnection frequency. Currently, it measures the ability of a BA to maintain its ten-minute average ACE within a fixed limit of plus or minus a MW value called L_{10}[5].

To be compliant, a BA must demonstrate its average ACE value during a consecutive 10-minute period was within the L_{10} bound for at least 90 percent of all 10-minute periods over a one-month period. While this standard does require the BA to correct its ACE to not exceed specific bounds, it fails to recognize the positive or negative impact of that action on Interconnection frequency.

For example, the BA may be increasing or decreasing generation to meet its CPS2 bounds, even if this is a direction that reduces reliability by moving Interconnection frequency further from its scheduled value. CPS2 allows a BA to be outside its ACE bounds for up to 10 percent of the ten-minute periods within a month. In other words, on average there are over 72 hours per month that a BA's ACE can be

[5] $L_{10\ is}$ the megawatt equivalent of a 10-minute epsilon interpreted as a limit placed on the product of (a) the frequency deviation caused by the BA's ACE, times (b) the frequency deviation the BA's ACE would be a response to.

outside its L_{10} limits and be compliant with CPS2 no matter what the impact on Interconnection frequency. In summary, CPS2:

- Does not have a frequency component.
- Can and does give BAs an indication to move their ACE opposite to the direction which would support scheduled frequency.
- Requires compliance in only 90 percent of the 10-minute intervals, allowing for essentially unbounded ACE for 10% of the hours in a given month.

After review of various candidate measures and industry comments, the Balance Resources and Demand Standard Drafting Team {"BRDSDT") developed the BAAL which was derived based on reliability studies and analysis which defined a FTL bound measured in Hz. The FTL is equal to Scheduled Frequency, plus or minus three times an Interconnection's Epsilon 1 value. Epsilon 1 is the "root mean square"[6] frequency error limit for each Interconnection, as recommended by the NERC Resources Subcommittee and approved by the NERC Operating Committee. Epsilon 1 values for each Interconnection are unique.

The proposed BAAL requirement will provide dynamic limits that are BA and Interconnection specific. These limits are based on identified Interconnection frequency limits to ensure the Interconnection returns to a reliable state when the ACE of one or more BAs times the Interconnection frequency deviates into an area that contributes too much risk to reliability. This requirement replaces and improves upon CPS2. CPS2 is not dynamic, requires control action even if detrimental to Interconnection frequency, and allows for a BA's ACE value to be unbounded for a specific amount of time during a calendar month regardless of the impact on Interconnection frequency. Interconnection frequency is directly related to the net balance of all BAs in the Interconnection; by design, the BAAL limits the coincident behavior of multiple BAs when ACE is detrimental to Interconnection frequency beyond the limits provided to each BA and in a manner not addressed by CPS2.

In summary, BAAL:

- Is unique for each BA and provides dynamic limits for its Area Control Error (ACE) value as a function of its Interconnection frequency.
- Drives corrective BA action in a direction that supports Interconnection Frequency.
    - When a BA's operation is not supporting Interconnection Frequency, the BAAL gets tighter for the BA as the frequency moves away from 60 Hz.
    - When a BA's operation is supporting Interconnection Frequency, the BAAL relaxes for the BA as the frequency moves closer to 60 Hz.
- When exceeded, means that the BA is contributing more than its allowed share of the risk that the Interconnection will exceed its FTL.
- Assures that, when all BAs are within their BAAL (high and low), the Interconnection frequency will be within its high and low FTLs.

[6] This is the square root of the mean of the squared frequency errors.

History

The BRDSDT asked the Standards Authorization Committee (now Standards Committee) to approve its Proof-of-Concept field trial plan at its Jan 13, 2005 Conference Call Meeting. The Standards Authorization Committee deferred this approval pending the Standards Authorization Committee's receipt of recommendations from the Operating Committee and Director of Compliance.

The BRDSDT asked the NERC Operating Committee (during the March 16-17, 2005 Operating Committee Meeting) to endorse the field trial and support a waiver of compliance to CPS2 for those BAs who volunteer to participate in the field trial. The NERC Operating Committee deferred endorsing the field trial until the BRDSDT responded to 3 requests:

- Consider the MW size of the participant group with a phase-in plan as the test progresses;
- Attain Reliability Coordinator Working Group ("RCWG") endorsement and provide an explanation of how the Reliability Coordinators will address power flow issues that new standard might cause; and
- Provide how the drafting team will monitor the test.

The BRDSDT revised the field trial plan to address the identified concerns. The BRDSDT obtained consensus that the Reliability Coordinators understood how they can control the field trial. The BRDSDT agreed to have each participating BA provide confirmation to their Reliability Coordinator that they are ready to participate in the field trial as specified in the field trial documentation. At its June 14, 2005 meeting RCWG support was gained for the field trial implementation. The RCWG further recognized that any Reliability Coordinator may suspend the field trial as specified in the field trial documentation.

In June 2005 enhancements were made to the Consortium for Electric Reliability Technology Solutions tool for ACE-frequency monitoring and alarming for July implementation. Reliability Coordinators were provided with a copy of the "Resources Subcommittee Proposed Frequency Monitoring and Response Process for the Eastern Interconnection" report.

Having addressed the concerns of the Operating Committee, the field trial was begun in the Eastern Interconnection on July 6, 2005 under a phased implementation. In April 2007, the proposed suite of Balance Resources and Demand Standards (which included the proposed BAAL requirement) failed to pass balloting. The comments associated with ballots included concerns about the:

- possibility of excess flows due to the high limits when a BA is supporting frequency,
- proposed retirement of the Disturbance Control Standard after a separate field trial,
- fairness to smaller BAs, and
- asymmetry of limits during Time Error Corrections.

In the summer of 2007, the BRDSTD proposed a new SAR addressing these concerns, as well as FERC Order No. 693 directives and other topics related to frequency and transmission loading — frequency deviations associated with ramping of on-/off-peak schedules and timely actions to provide congestion relief. The members of the Balance Resources and Demand Standard Drafting Team asked for authorization to extend and expand the field test to add new participants. With the endorsement of the NERC Operating Committee, the Standards Committee approved continuation of the field trial and authorized the SAR under Project 2007-18 Reliability-based Control. Field trial participation increased, and in January 2009 MISO began operation as a BA and field trial participant, consolidating 26 BA Areas including six already under the field trial.[7]

The NERC Standards Committee approved the merger of Project 2007-05 BA Controls and Project 2007-18 Reliability-based Control as Project 2010-14 BA Reliability-based Controls on July 28, 2010. The NERC Standards Committee also approved the separation of Project 2010-14 Balancing Authority Reliability-based Controls into two phases and moving Phase 1 (Project 2010-14.1 Balancing Authority Reliability-based Controls - Reserves) into formal standards development on July 13, 2011.

The Project 2010-14.1 Phase 1 proposed revisions to BAL-001-0.1a Real Power Balancing Control. BAL-001-2 was approved by the industry and adopted by the NERC Board of Trustees on August 15, 2013 and has been filed with FERC. Based on the NERC Operating Committee's approval, the field trial continues pending regulatory outcome of the standard.

[7]ALTE, ALTW, CIN, MECS, NIPS and WEC operated under the field trial until January 2009 when MISO began its operation as a Balancing Authority and field trial participant.

Field Trial Results

Eastern Interconnection

Number of Participating Balancing Authorities

Under a phased implementation, the field trial began in the Eastern Interconnection in July 2005, and by the end of that year, seven BAs representing approximately 60 percent of the non-coincident peak demand in the Eastern Interconnection were operating under the field trial. Since then, BAs have been added to the field trial while others have been consolidated into larger BA Areas. There are currently eleven BAs operating under the field trial, which represents approximately 75 percent of the non-coincident peak demand in the Eastern Interconnection.

Frequency Performance

There is positive performance in the Eastern Interconnection under the field trial. The most notable improvement in the Eastern Interconnection's frequency performance was a reduction in the total minutes of frequency beyond the FTL. It should be noted this improvement corresponded with the recession toward the end of 2008 and the startup of the MISO as a BA[8] in January 2009. As illustrated by Figure 1, the Eastern Interconnection since that time has trended at a lower level of clock-minutes below the low FTL or above the high FTL. There are many factors that can impact frequency performance within a multi-BA Interconnection including, but not limited to, a) active RTO/ISO and bilateral markets that increase energy scheduling and ramping activities, b) coincident behavior driven by high demand and limited resources, or low demand and excess online resources, and c) BA consolidation. Overall, as efficiencies are achieved that may reduce overall reserve requirements and free up capacity for energy sales, the Interconnection frequency may see the impact of there being less "spinning" resources providing inertia and frequency response to the Interconnection.

By limiting the duration that any BA's clock-minute ACE may be outside its BAAL, Interconnection frequency should be more often within the predefined bounds of the Frequency Trigger Limits incorporated within the BAAL calculation. One measure of the effectiveness of the BAAL at the Interconnection level could be the limited duration that frequency remains outside the FTL bounds. Though not all BAs are operating under the field trial in the Eastern Interconnection, the results to date demonstrate the points above. Figure 1 illustrates the total number of clock-minutes that Interconnection frequency was lower than

[8] The MISO BA consolidated the areas of 26 BAs, 6 of which were previously under the field trial.

the low Frequency Trigger Limit (FTL_{Low}) of 59.95 Hz and higher than the high Frequency Trigger Limit (FTL_{High}) of 60.05 Hz since the start of the field trial through the end of 2013.

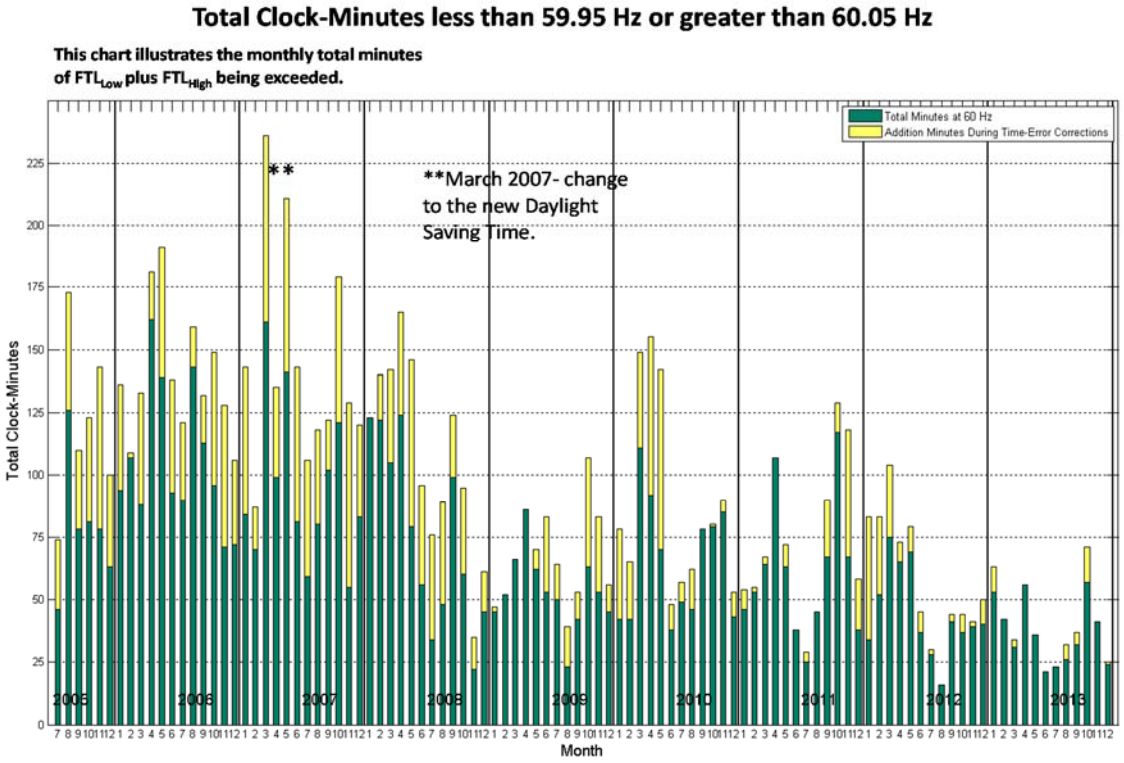

Figure 1

Total number of clock-minutes that Interconnection frequency was lower than the low Frequency Trigger Limit (FTL_{Low}) of 59.95 Hz or higher than the high Frequency Trigger Limit (FTL_{High}) of 60.05 Hz since the start of the field trial through the end of 2013.

Currently eleven of the thirty-five BAs in the Eastern Interconnection are operating to the BAAL under the field trial.[9] The eleven BAs represent approximately 75% of the non-coincident peak demand in the Eastern Interconnection. Since 2005, the number of clock-minutes that actual frequency has been beyond the Frequency Trigger Limits has decreased.

Manual Time Error Corrections

Over the course of the field trial, the Eastern Interconnection frequency has moved from being slightly biased above 60 Hz operation, with almost all manual Time Error Corrections being

[9] The participants in the Eastern Interconnection have changed over time primarily due to BA reconfiguration. Please refer to Attachment 1 for details.

called to correct for fast time error with Scheduled Frequency set to 59.98 Hz, to being centered more closely to 60 Hz.

Average Interconnection Control Performance Standard (CPS)

In the early implementation of the field trial, some BAs found that their CPS1 scores started to trend lower as operator focus was placed primarily upon the BAAL and not overall performance under CPS1. Under CPS2, though unbounded for 10% of the ten-minute periods within the month, operators were used to operating within the fixed CPS2 L_{10} bounds and taking actions to balance no matter what the impact on the Interconnection frequency. However, absent a fixed bound with focus placed on only BAAL, operators initially failed to recognize that operation approaching the BAAL impacted CPS1 to the extent that every minute close to the BAAL had to be offset by minutes of good performance under CPS1. The BAAL under BAL-001-2 is equivalent to minus 700 percent CPS1. Individually, each BA determined how information was presented to their operators allowing them to meet the performance requirements of CPS1 and BAAL. Similarly, the Standard Drafting Team revised certain workbooks posted on the field trial tools webpage to display a wider range of Real-time performance under both CPS1 and BAAL to aid the operator in the visualization of performance.

Prior to the field trial it was recognized that CPS2 compliance would have to be waived in order to allow the BAs to operate under the BAAL. The CPS2 L_{10} could be exceeded during times when the BA's ACE was supporting the Interconnection frequency, viewed as good performance under both CPS1 and BAAL. Many BAs under the field trial no longer required their operators to monitor CPS2; however, performance continued to be reported under the provisions of the field trial. As expected, CPS2 scores decreased under the field trial.

Unscheduled Flow Events

Throughout the duration of the field trial, no BA, Reliability Coordinator or other reliability entity, has cited problems with unscheduled flows associated with operation under the field trial.

Western Interconnection

Number of Participating Balancing Authorities

The Western Interconnection began its participation in the BAAL field trial on March 1, 2010. During the field trial, CPS2 (i.e. Requirement R2 of currently-effective Reliability Standard BAL-001-1) is waived for participating BAs; however, the requirements for participating BAs to calculate and report CPS2 performance for informational purposes remains in effect.

In the Western Interconnection, initially 26 out of 37 BA Areas participated in the field trial; currently 27 out of 38 are participating. For a list of participating BA Areas, please refer to Appendix A.

The participating BA Areas represent approximately 90% of the non-coincident peak Demand in the Western Interconnection.

ACE Transmission Limit

The Western Interconnection aggressively tested the BAAL during the field trial by stressing the limits while measuring the reliability of the Western Interconnection. The BAAL approaches infinity when frequency is at 60 Hz. The Western Interconnection elected to evaluate operations at various multiples of L_{10} during the field trial to gather data, analyze and determine the possible effect on transmission flows as a direct result of BAAL. Therefore, an ACE Transmission Limit (ATL) was established to limit the BAAL during the initial periods of the field trial. The participating BAs first started with an ATL of two times L_{10} on March 1, 2010. On November 1, 2010 at 00:00 Central Daylight Time (CDT) the ATL was moved to 4 times L_{10}. On April 1, 2011 at 00:00:00 CDT, the participating BAs were allowed to move to an ATL of 100 times L_{10}. Since March 1, 2013, the ATL limit has been changed back to 4 times L_{10}.

Frequency Error

It was observed on the Western Interconnection that the maximum one-minute frequency error increased since 2009 from 10 mHz to 18 mHz, with the sharpest increase in 2010, coincident with the beginning of the field trial. However, this is still within the Western Interconnection Epsilon1 limit of 22 mHz.

Manual Time Error Corrections

There has been an increase in all measures of manual time error correction after 2010. In 2013, there was a decrease in the effectiveness in the time error corrections in that the same amount of time was spent correcting fewer total seconds.

As all manual time error measurements in 2010 were commensurate with previous years (2009 being somewhat anomalous), the increases in 2011 seem to correlate with the increase in participation in the field trial.

NERC Inadvertent Interchange of the participating Balancing Authorities

Similar trends for the absolute value of NERC Inadvertent Interchange and the Accumulated Primary Inadvertent Interchange were noticed. Figure 2 below indicates the trend for NERC Primary Inadvertent Interchange.

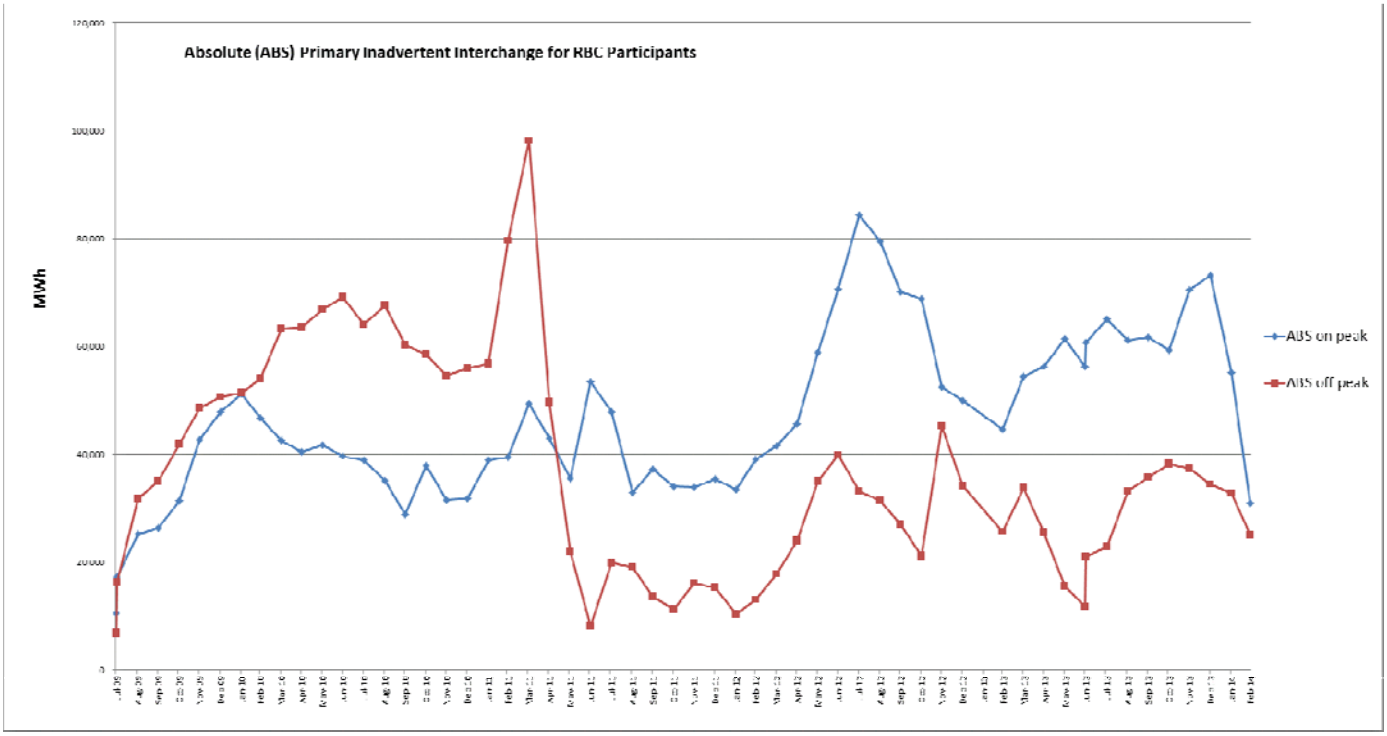

Figure 2

The accumulated absolute value of NERC Inadvertent Interchange (Inadvertent Interchange for participating BAs) from the effective date of the ATEC standard (BAL-004-WECC-001 – July 1, 2009) to end of March 2014 is illustrated above.

The decrease of Off-Peak NERC Inadvertent Interchange that began in April 2011 is due to the payback of the accumulated Primary Inadvertent Interchange MW by one BA (the accumulation occurred due to an Energy Management System (EMS) error). In addition, some BAs increased their hourly Primary Inadvertent Interchange payback to manage Primary Inadvertent Interchange accumulations which also helps maintain NERC Inadvertent Interchange. It is difficult to draw a correlation between Inadvertent Interchange trends and the inception of the field trial because of other factors affecting Inadvertent Interchange such as various BAs' control problems that have been identified and corrected. Recently, BAs were advised to manage their Primary Inadvertent Interchange accumulation to meet the new BAL-004-WECC-02 requirements that limits the end-of-month Primary Inadvertent Interchange accumulations to 150 percent of peak load or generation. The decrease in the Primary Inadvertent Interchange values might be attributed to the expected implementation of the standard.

Average Interconnection Control Performance Standard (CPS)

Figure 3 below illustrates the average CPS1 scores for the participating BAs in the Western Interconnection since 2008. Since the start of the field trial in March of 2010, the CPS1 scores averaged 140% of the minimum required level in accordance with standard BAL-001.

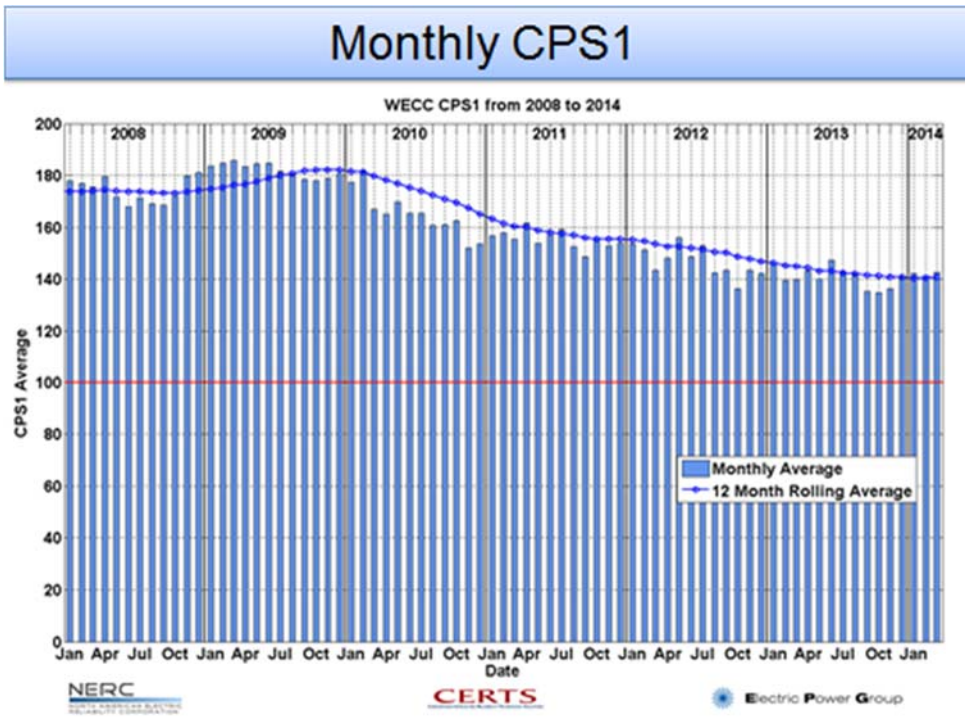

Figure 3

Unscheduled Flow Events

The hours of coordinated operations of the phase shifters increased during the field trial period; however, due to changing seasonal patterns, a changing resource mix, unusual operating conditions, and other events, it is not possible to conclusively associate the increased hours of phase shifter operations with the field trial. For additional detail please refer to WECC staff report to the Board of Directors at the following link *http://www.wecc.biz/committees/BOD/20130123/Lists/Minutes/1/2013%2001%2023%20Board%20Packet.pdf* and the WECC Performance Working Group report at the following link http://www.wecc.biz/committees/StandingCommittees/OC/OPS/PWG/Shared%20Documents/RBC%20Field%20Trial%20Report%20v11.pdf

Balancing Authority with smaller Frequency Bias

The range of Frequency Bias Settings in the Western Interconnection varies from -2 MW/0.1 Hz to -700 MW/0.1 Hz.

The current CPS2 L_{10} limits are set proportionally larger for smaller BAs. For example, a BA with a Frequency Bias Setting of -2 MW/0.1Hz would be assigned a CPS2 L_{10} of plus and minus 7.54 MW, whereas a BA 100 times its size with a Frequency Bias Setting of -200 MW/0.1Hz would be assigned a CPS2 L_{10} of plus and minus 75.4 MW. The limits under BAAL are based upon the Frequency Bias Setting in a manner that proportionally places the same control performance requirement on all BAs; no matter what the BA size, the BAAL is equivalent to a clock-minute CPS1 of minus 700%. A BA with a Frequency Bias Setting ten times larger than another BA will have limits under both CPS1 and BAAL set ten times larger than the other BA. However, when compared to the limits set under CPS2, the BAAL formula appears to require proportionally more control performance from BAs with smaller Frequency Bias Settings. For example, for a BA with Frequency Bias Setting of -2 MW/0.1 Hz (160 MW BA), the low BAAL becomes more restrictive than the low CPS2 L_{10} value at frequency of 59.987 Hz; however, for a BA with a Frequency Bias Setting value of -200 MW/0.1 Hz, it becomes more restrictive at 59.877 Hz. It is important to note that for frequency below scheduled frequency as in this example, only BAs with negative ACE are bounded by their low BAAL; BAs with positive ACE are not limited as they were under CPS2 when supporting Interconnection frequency.

Single BA Interconnections: ERCOT and QUEBEC

Of the Interconnections in North America, two Interconnections have only one BA – ERCOT and Québec. ERCOT joined the BAAL field trial in December 2009 and Québec joined the field trial in September 2010. While ERCOT was already under a waiver from CPS2 since 2002, Quebec chose not to request a waiver from CPS2 while operating under the field trial, As single BA Interconnections, ERCOT and Québec were affected differently than most BAs by the BAAL requirement. If the Frequency Bias Setting for the single BA interconnection is set approximately equal to the Frequency Response, the BAAL limit is equivalent to having a frequency limit for the interconnection of 3 times Epsilon 1 that shall not be exceeded for longer than 30 consecutive clock-minutes. This occurs because the ACE Equation is reduced to the Frequency Bias term alone for the single BA interconnection since the single BA interconnection has no tie lines and, therefore, no tie error term in its ACE Equation.

Both single BA interconnections found that currently implemented control methodologies were sufficient to easily meet the requirements specified by BAAL and the BAs' only challenge was to implement the performance measurement to assure they could meet any audit and reporting requirement associated with BAAL.

Technical Conclusions

As explained herein, the field trial results to date demonstrate that proposed Reliability Standard BAL-001-2 supports frequency and improves reliability.

The standard drafting team has drawn the following further conclusions from observations made during the field trial.

- The selection of 30 consecutive clock minutes is appropriate and actually improves reliability.

  During the initial development of the Balancing Authority ACE Limit under the Balance Resources and Demand Standard Drafting Team, the 30-consecutive-clock-minute response time was selected to provide Real-time system operators with a fixed, easy to follow response requirement that provides sufficient time to take appropriate action. The initial methodology proposed by the SDT was to use a 50% probability of the next resource contingency as the maximum duration allowed under BAAL; however, under that methodology the duration that the BA would have been allowed to operate outside the bounds turned out to be much greater than 30 minutes. The SDT did not feel that the industry would accept a value of longer duration than 30 minutes, especially given the concern at the time that operation under the BAAL may cause parallel flows in certain areas, which has since been addressed. Similar to the approach taken to address an IROL where operators are provided 30 minutes to assess options for mitigation, the team chose to use the more conservative limit of 30 minutes, well within the risk-based criteria of the next resource loss, while also providing appropriate time for the operator to assess the current situation and take corrective actions as needed.[10] Actual experience operating under the proposed standards has met with the support of all participating Real-time system operators.

- BAAL has had no effect on NERC Inadvertent Interchange.

  Accumulated NERC Inadvertent Interchange varied during the field trial. However, for the Western Interconnection which has a regional standard associated with Inadvertent Interchange, the Western Interconnection has been able to specifically track the changes during the field trial.

  In the Western Interconnection, accumulated NERC Inadvertent Interchange reached high levels several times during the field trial among both participants and non-

[10] As an additional consideration, the SDT assessed the time-based risk of violating FTL and found it was directly proportional to the rate of frequency change and not a fixed value. The SDT decided that a variable time limit would not be acceptable and presented the 30-minute limit to the industry in the first draft of the standards. The question was asked of industry if they preferred a variable time limit or a fixed time limit and the reply was overwhelmingly for a fixed value.

participants, but is currently declining. However, because of known BA EMS errors at various times during the field trial, no relationship between the field trial and accumulated Inadvertent Interchange could be established.

Therefore, the drafting team believes no relationship between the field trial and NERC accumulated Inadvertent Interchange can be established with the results to date.

- There is no conclusive evidence that BAAL has any effect on congestion management/unscheduled flow within the Western Interconnection.

  Since the BAAL approaches infinity when frequency is at scheduled frequency, the Western Interconnection field trial participants established an ATL to cap the BAAL at various levels during the field trial to limit its effect on transmission flows. The ATL varied between two times L_{10} to 100 times L_{10}. In addition, it is important to understand under the field trial the BA is required to balance its resources and demand in Real-time so its clock-minute average ACE does not exceed its BAAL for more than 30 consecutive clock-minutes. Also, the BA in coordination with the Transmission Operator must be aware of any exceedance of transmission operating limits, which also employ the 30 consecutive clock-minute metric.

  During the field trial and the testing of ATL, the number of hours of coordinated operations of phase shifters increased dramatically in 2011 for path 36 and in 2012 for path 66. Several system conditions contributed to increase flow on theses paths, and some of these conditions were:

  - Increase imports scheduled into California driven by various plant outages in California (SONGS Units), poor hydro conditions in Northern California and others;
  - Increase in exports out of the Northwest driven by high water in the Northwest;
  - Various transmission outages; and,
  - Outage of one of the major phase shifters used to provide relief from coordinated operations of Phase shifters.

  Due to changing seasonal patterns, a changing resource mix, unusual operating conditions, and other events, and even with the increased hours of coordinated operations of the phase shifters during the field trial, it is not possible to conclusively associate the increased hours of phase shifter operations and any congestion with the field trial.

For more details please refer to the Reliability-based Control Field Trial Report for the WECC Board of Directors Western Electricity Coordinating Council January 23-24, 2014 meeting[11] and the WECC PWG Field Trial report dated May 29, 2014.[12]

- Operating under BAAL has had no adverse reliability impacts on Frequency Error.

  Figures 4-a through 4-d below compares the Interconnection frequency error for all time intervals up to 60-minutes with the corresponding epsilon target profile for years 2011 through March 31, 2014. During the field trial frequency error has not adversely impacted the reliability of the Interconnections.

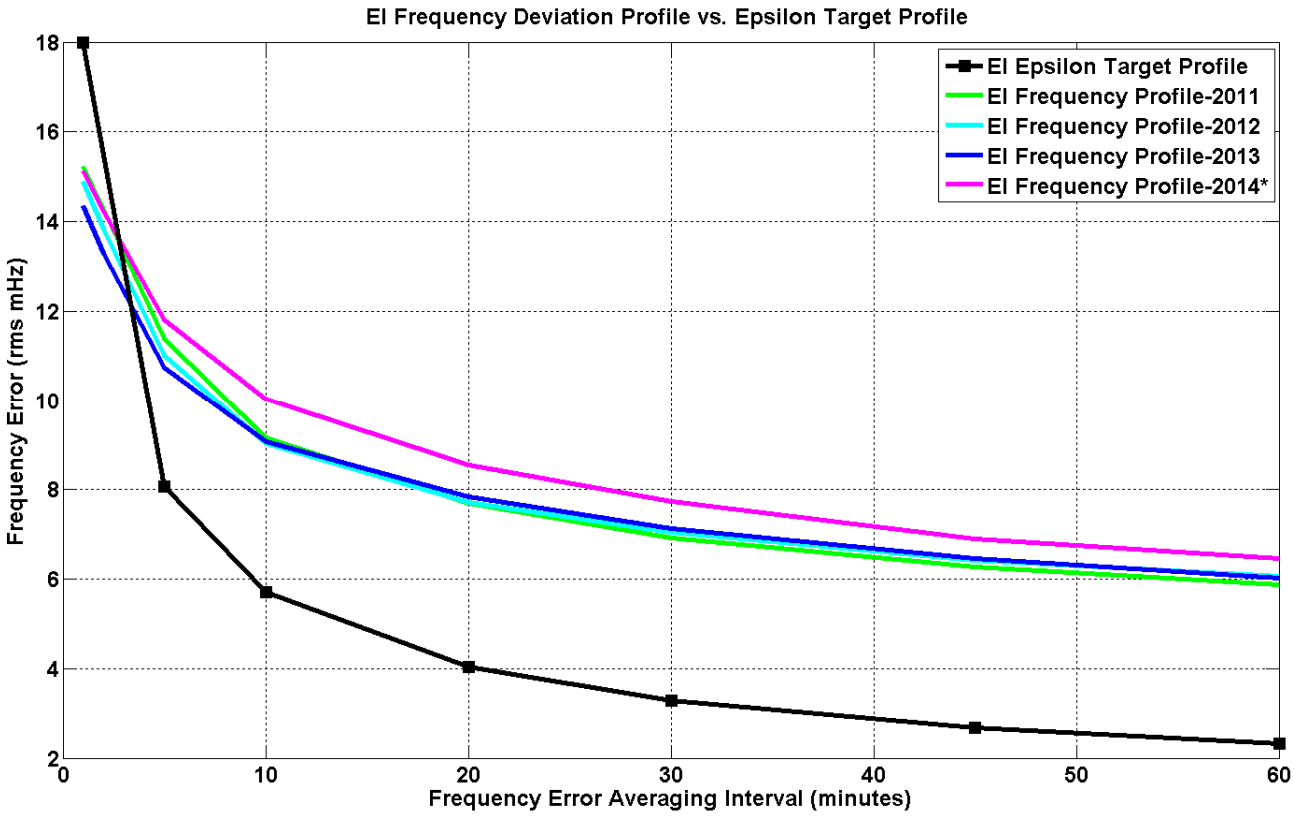

Figure 4-a

[11] *http://www.wecc.biz/committees/BOD/20130123/Lists/Minutes/1/2013%2001%2023%20Board%20Packet.pdf*.

[12] http://www.wecc.biz/committees/StandingCommittees/OC/OPS/PWG/Shared%20Documents/RBC%20Field%20Trial%20Report%20v11.pdf.

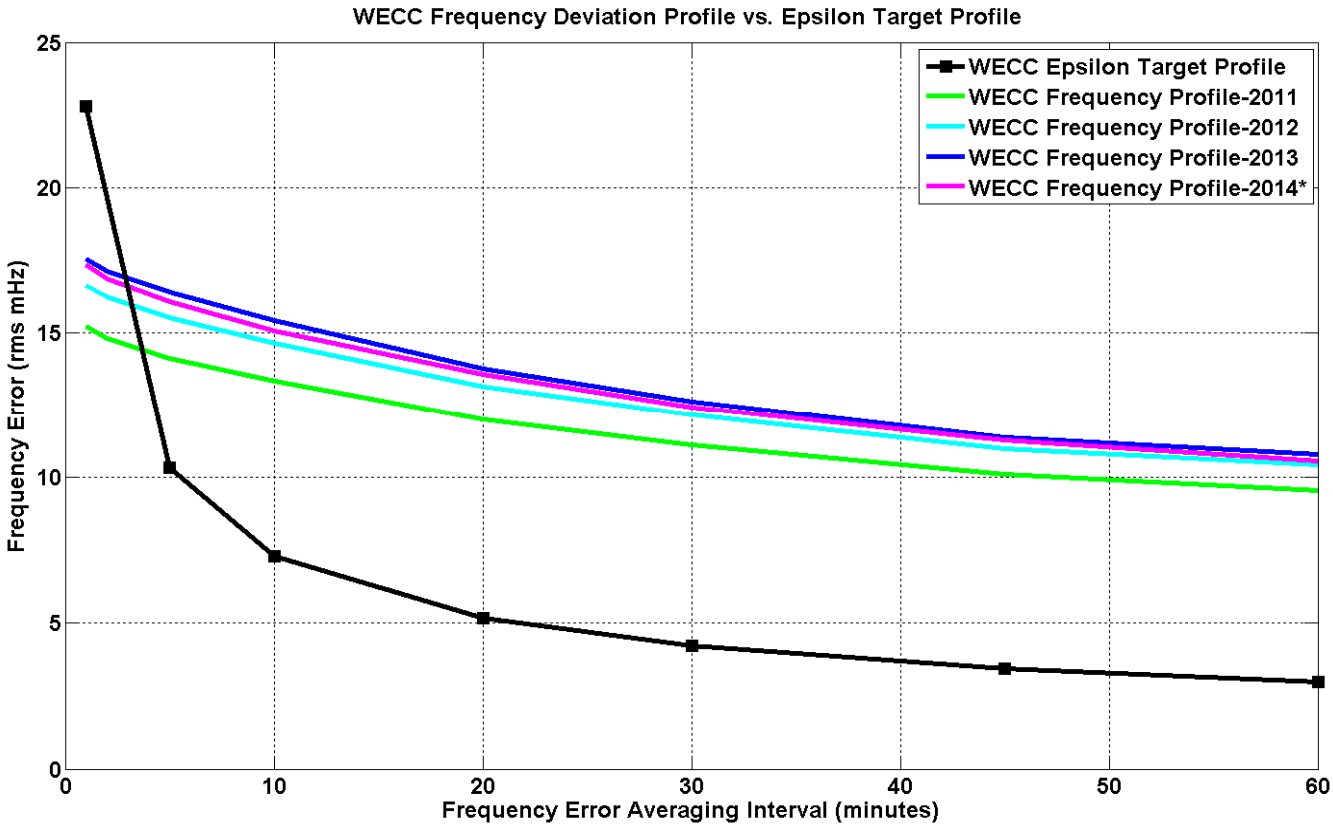

Figure 4-b

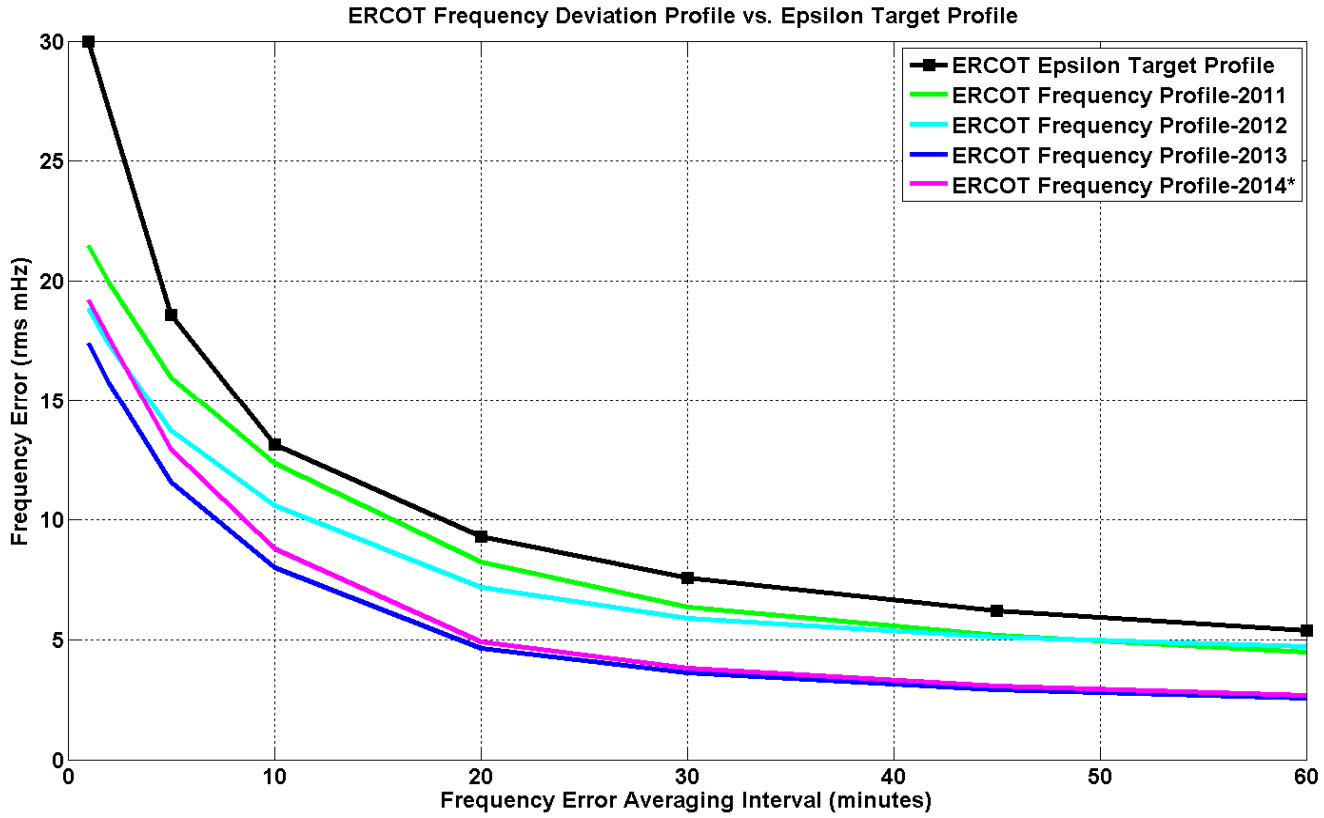

Figure 4-c

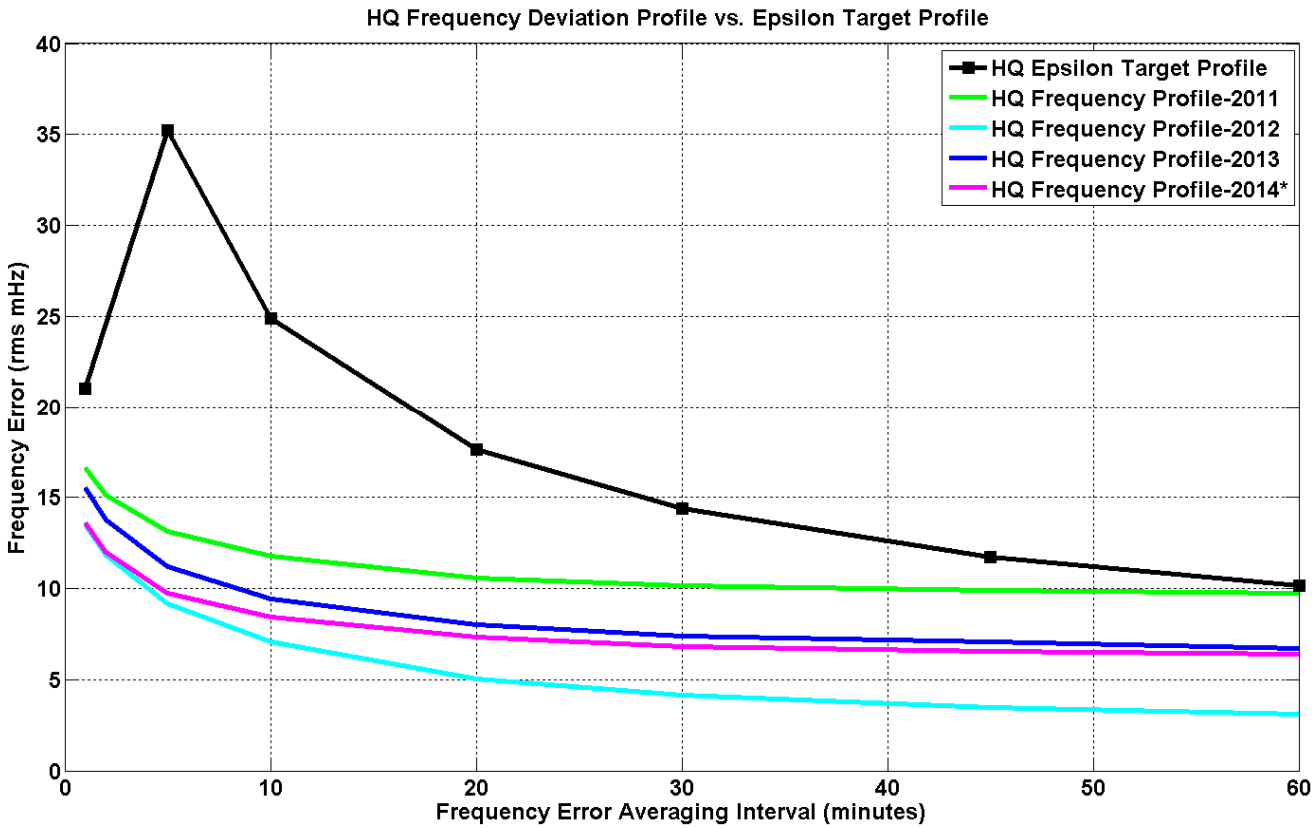

Figure 4-d

- BAAL drives corrective actions that are always in support of scheduled frequency.

  CPS1 is a long-term statistical measure of a BA's performance balancing resources and demand, and assigns each BA a share of the responsibility for controlling in a manner supportive of the Interconnection frequency. The share of responsibility is directly related to the size of each BA's Frequency Bias Setting. CPS1 is reported to NERC on a monthly basis and averaged over a 12-month moving window.

  BAAL is a Real-time measure of a BA's required performance. BAAL encourages operation in support of the Interconnection frequency and drives corrective action back within predefined ACE limits when operation is detrimental to the Interconnection frequency. Compliance with BAAL requires that the BA's clock-minute average Reporting ACE shall not exceed[13] its clock-minute BAAL for more than thirty consecutive clock-minutes. As actual frequency moves away from scheduled frequency, the ACE limit becomes tighter for entities not supporting the Interconnection frequency as BAAL asymptotically approaches zero on the ACE versus frequency graph.

[13] "Exceed" is often used when comparing magnitudes of related values in quadrants 1 and 3. For example, a BA is exceeding the BAAL in quadrant 3 when its negative clock-minute average Reporting ACE is larger in magnitude that the related clock-minute low BAAL.

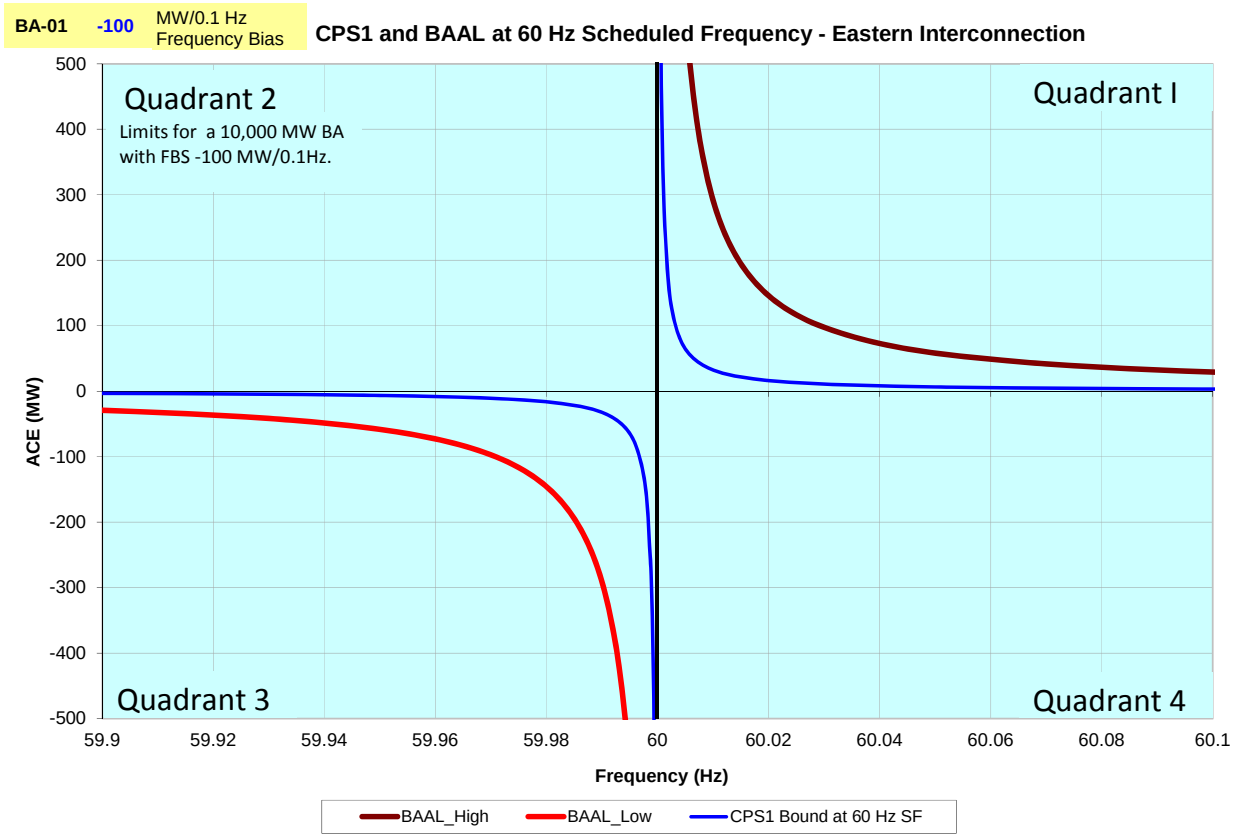

Figure 5

The results of the field trial indicate that the BAAL is effective in encouraging operation when in support of the Interconnection frequency and in driving corrective action to get ACE back within predefined limits when operation is detrimental to the Interconnection frequency. Operating within the BAAL limits ensures that a BA is not leaning on the Interconnection more than its proportionate share based upon the Interconnection frequency, but it does not require that the BA support the Interconnection frequency at all times. For example, in quadrants one and three of the ACE versus Frequency chart in Figure 5 for when Scheduled Frequency equals 60 Hz, a BA's ACE limits become more restrictive as actual frequency deviates from Scheduled Frequency in either direction.

A BA would be operating in quadrant one if the BA's ACE is positive when frequency is greater than Scheduled Frequency. Similarly, a BA would be operating in quadrant three if the BA's ACE is negative when Interconnection frequency is less than Scheduled Frequency. Operation in either of these quadrants indicates that the BA is not supporting Interconnection frequency. In both quadrants one and three, each clock-minute a BA operates between the CPS1 limit and the BAAL, it results in a clock-minute CPS1 score less than 100% to as low as -700% when the BA operates on the BAAL curve.

The second and fourth quadrants are ideal operating quadrants for a BA since in these quadrants a BA's ACE would always be supporting the Interconnection frequency. A BA would be operating in quadrant two if the BA's ACE is positive when the Interconnection frequency is less than Scheduled Frequency. Similarly, a BA would be operating in quadrant four if the BA's ACE is negative when the Interconnection frequency is greater than the Scheduled Frequency. Each clock-minute a BA operates in quadrant two or quadrant four results in a clock-minute CPS1 score greater than 200%.

- BAAL focuses on a frequency range for the Interconnection.

  BAAL focuses on controlling within a frequency range. This allows BAs to move generation less since they are not regulating to maintain balance within an artificial limit. Instead, as long as a BA is operating within its pre-defined bounds, the BA need not move units back and forth constantly. By operating the units in a steadier manner, unnecessary control actions and associated wear and tear costs can be reduced. Preliminary studies indicate this reduction in control action is between approximately 25% and 35%. In addition, the operational efficiency of units should be increased. These cost reductions are likely to be passed on to the ultimate consumer.

  Another benefit related to the reduced wear and tear on units is to lower the cost to integrate loads and generation that do not match traditional types of load or generation, such as variable generation. By not being required to be within a specified limit (CPS2), regardless of frequency, the BA is not required to adjust its generation for small variations related to loads and generation when supporting frequency.

  The reduction in generation adjustments can allow some generators to provide other services. This may include allowing more efficient generation to generate more energy, committing fewer units to meet demand, and fewer curtailments of renewable energy resources.

  These cost savings are difficult to quantify. However, the logic is simple to follow. There is a maintenance cost related to using a generating unit. These costs increase if stress on the unit increases in a given period. If the unit experiences less stress, the maintenance costs can be reduced or incurred less frequently.

- BAAL captures and establishes symmetrical trigger limits for all conditions that impact frequency.

  The BAAL bounds are symmetrical about scheduled frequency which was done to assure frequency would be targeted at scheduled frequency. The symmetry provides as much feedback to the BAs in the Interconnection to push frequency towards scheduled frequency from the high side as from the low side of scheduled frequency.

The origin of the low frequency limits was started with low frequency relay limits and the likelihood of the frequency approaching those relay limits. Low frequency is associated with resource deficiency. There are many causes of resource deficiency: missed schedules, unit trips, loads higher than planned, unexpected load restoration, resources (variable and conventional) which failed to ramp as planned, loss of system elements. During the research and development of BAAL limits, the drafting team realized that Disturbance Control Standard BAL-002 at times conflicts with the purpose of BAL-001 as the loss of a resource at times may be supportive of Interconnection frequency. Thus BAL-002 may not be necessary once the industry is fully experienced with the BAAL. The drafting team understands that data will need to be collected and analyzed once BAL-001 is fully implemented to assure Interconnection reliability is maintained or enhanced. Therefore, the drafting team has moved forward with revising BAL-002, which will provide the industry continuity until they have fully evaluated BAAL. BAAL always provides the correct signal to the BA even in those circumstances where BAL-002 is not triggered, or where BAL-002 may force a BA to deploy reserves when the frequency is at scheduled frequency or higher and thereby move the Interconnection to a less reliable state.

The main issue on the high side of frequency is generator over-speed relays which are set much wider than the low frequency relay limits. The targeted research indicated that the high FTL and associated high BAAL could be set at a larger margin from scheduled frequency than the comparable lower bounds. But, to provide symmetry around scheduled frequency, high frequency limits were set to mirror the low frequency limits. Conditions which may lead to high frequency conditions may include: missed schedules, loss of load, load being lower than planned, resources which failed to ramp down as expected, variable resources which ramped up unexpectedly, loss of system elements.

High frequency conditions are easier to address than low frequency events. Traditional resources are easier to ramp down or take offline than the reverse. Tripping a unit offline has a high degree of certainty whereas putting a unit online has a lower degree of certainty and takes longer. The same is true when pushing load up on a unit which may require adding a feeder or a boiler feed pump.

In FERC Order No. 693 paragraph 355, the Commission noted that the Control Performance Standards at the time measured yearly (CPS1) and monthly (CPS2) performance averages which the Commission pointed out may not be appropriate for measuring short-term events. Somewhat viewing BAL-002 as the only Real-time standard requiring corrective ACE action, FERC directed the ERO to capture a larger

range of events for such Real-time mitigation, taking into account all events that have an impact on frequency. The Commission stated:

> we direct the ERO, through the Reliability Standards development process, to modify this Reliability Standard to define a significant deviation and a reportable event, taking into account all events that have an impact on frequency, e.g., loss of supply, loss of load and significant scheduling problems, which can cause frequency disturbances and to address how balancing authorities should respond. As suggested by NRC, this or a related Reliability Standard should also include a frequency response requirement. The present Control Performance Standards represent the monthly and yearly averages which are appropriate for measuring long-term trends but may not be appropriate for measuring short-term events. In addition, the measures should be available to the balancing authorities to assist in real-time operations.

At the time that FERC Order No. 693 was issued, NERC was already testing the BAAL as a Real-time measure which considers the state of Interconnection frequency in the BAAL calculation in order to limit ACE when contributing to a frequency deviation, independent of the circumstances causing ACE to be beyond the BAAL. The BAAL captures not only the deviations in Interconnection frequency that can be caused by an event within a BA, but also the deviations caused by coincident behavior of multiple BAs with ACE negatively impacting Interconnection frequency, and this is of particular importance on the worst of summer or winter days.

Loss of load can cause a mismatch in supply and demand that results in a positive change in frequency. The BAAL formulation ensures that if frequency is beyond FTL_{high}, then at least one BA's ACE is beyond its associated $BAAL_{high}$. Thus, returning all BAs' ACE within the $BAAL_{high}$ is sufficient for returning frequency within FTL. By design, the FTLs capture all frequency deviations beyond the desired statistical distribution of three standard deviations from the Interconnection epsilon1, and this adequately captures any significant frequency deviations on the Interconnection, meeting and considerably exceeding FERC's directive (FERC Order No. 693 paragraph 355) in that regard. BAAL has been shown to be effective in limiting the duration that the Interconnection frequency is impacted by loss of supply, loss of load, or any other conditions causing a Balancing Authority to exceed its BAAL.

- BAAL is a proportional allocation of responsibility across all BAs.

  Consistent with the calculation of CPS1, the calculation of BAAL is based upon the Frequency Bias Setting in a manner that proportionally allocates the limits applied

across all BAs. The BAAL is equivalent to a clock-minute CPS1 performance of minus 700% no matter what the BA size or Interconnection in which it operates.

- Thus far the field trial results have validated the FTLs at three times Epsilon 1.

  The field trial confirms that the selection of an FTL of three times Epsilon 1 is an appropriate value upon which to base the BAAL.[14] By setting the FTL at this value most of the random frequency error resulting from control actions to meet CPS1 falls within the natural statistical bounds defined by the FTL. This portion of the frequency error requires no additional control action. At the same time appropriate control action is required when these natural statistically based limits are exceeded or when an individual BA contributes more than its share of the distributed risk related to exceeding this frequency limit.

  The field trial results indicate improvements in frequency control on the Eastern Interconnection confirming the FTL is set in a manner that is not too relaxed. Additionally, the field trial results indicate a reduction in required control actions on the Eastern Interconnection, also confirming the FTL is set in a manner that is not too restrictive. Thus we can conclude that 3 times Epsilon 1 is an appropriate FTL for the Eastern Interconnection.

  In the Western Interconnection, the field trial results indicate an increase in frequency error. This increase has been attributed to other changes in control taking place concurrently with the field trial and the vigorous testing of BAAL. Preliminary results illustrate the change in frequency error will be limited at a value less than Epsilon 1 for the Western Interconnection as indicated by the decline in the rate of change in frequency error as it has approached the Epsilon 1 value for the Western Interconnection. This indicates the FTL has not been set to a value that is too restrictive. Additionally, the field trial results indicate a reduction in required control actions on the Western Interconnection, also confirming the FTL is set in a manner that is not too

[14] The BAAL field trial was initiated on the Eastern Interconnection with a +/- 50 mHz FTL before it was realized that the methodology used to set the FTL would not work on the other interconnections. This fact was highlighted in a preliminary report delivered as part of the directed research initiated by the Balance Resources and Demand standard drafting team (BRDSDT). That same report recommended an alternative method commonly used in statistics could be used with a value of three or four times the standard deviation of the frequency error. At that time the standard deviation of the frequency error for the Eastern Interconnection was slightly greater than 16 mHz giving a recommended value between 48 and 64 mHz, and would provide a value consistent with the value of 50 mHz already in use in the field trial. Since the standard deviation of the actual frequency error of any interconnection would vary from year to year, it was decided to use a value based upon the Epsilon 1 for the interconnection which would not vary based on variations in year to year control. The more conservative value of 3 times Epsilon 1 rather than 4 times Epsilon 1 was eventually chosen. On the Eastern Interconnection, this resulted in a FTL of 54 mHz, a value close to that already chosen for the Eastern Interconnection field trial. Since the values are close to each other, the FTL for the Eastern Interconnection field trial has not yet been modified but, as BAs from other interconnections joined the field trial, values for the FTL were selected based upon the Epsilon 1 of their Interconnection.

relaxed. Thus we can conclude that 3 times Epsilon 1 is an appropriate FTL for the Western Interconnection.

No conclusions can be drawn from the field trial results from the Quebec or ERCOT interconnections because the BAAL requirement did not require changes in control actions.

The overall conclusion from the field trial is that setting the FTL at 3 times Epsilon 1 is reasonable and results in both improvement in frequency control and reductions in control actions necessary to maintain reliable frequency control.

- BAs should remain under the field trial until BAL-001-2 becomes effective.

  The subject has been raised as to whether the BAs under the field trial should move back under CPS2 until the effective date of BAL-001-2. There are several reasons to continue the field trial directly into the implementation of the standard. The reasons are:

  Reliability impacts: It is unknown what the impact may be to the Interconnection frequency if participating BAs were instructed to operate again under CPS2; from the perspective of the SDT, it would be moving the Interconnection to a less-desired state. In addition, much of the load in Interconnections has been migrated to BAAL over time which allowed the BAs to adapt to the changes gradually. Canceling the field trial would subject the Interconnections to risk twice:

  i. First when removing the control systems used by field trial participants and re-implementing the controls needed to meet CPS-2, and
  ii. The second time to reverse the systems again while adding those that have not participated.

  The Interconnection's series of control systems operate in parallel to control the frequency and stability of the Interconnection. When working with systems such as the ones that control the Interconnection, control theory tells us that you want to make small smooth incremental adjustments to allow the system to remain within control parameters. Pushing all of the BAs back to CPS2 at one time would be like putting a step function into a control system. Another possibility would be to move the BAs in small groups dispersed across the Interconnection and allow a few months for the Interconnection to settle out. This could require six months to a year to complete just in time to start moving the BAs back to BAAL. There would be additional risk during implementation of the standard as the BAs move back to BAAL since this would be done in a relatively short implementation window. Continuing the field trial, adding a few BAs at a time until all of them are on the standards, seems to present the least risk to reliability.

  There are substantial reliability risks associated with conversion back to CPS2. Most EMS systems can only have one Automatic Generation Control (AGC) Algorithm in place

at a given time. Although modification of the source code and re-compilation could be done in advance, that would more likely require modifying the source code when the change is made. Additionally, many of the EMS systems have been changed out since the implementation of the field trial. CPS2 displays for the operator were replaced with BAAL displays and this would require reinstallation of the displays and the appropriate drivers. All of these (essentially temporary) changes would require extensive design and testing prior to implementation.

When AGC changes are made in an EMS system, AGC must be tuned to allow the system to operate efficiently and to meet CPS1. This tuning is usually done on a unit by unit basis, and often requires direct vendor support. There are a limited number of EMS vendors and a very large number of generators within the Interconnections; so the time required to sequentially work through all the unit tunings will be substantial. During this period, the Interconnections and their constituent BAs will be in a transitional state, which increases the risk of uncoordinated operation (some BAs on BAAL, some on CPS2, some in various stages of transition).

Therefore, the reliability risks associated with conversion back to CPS2 and then back to BAAL again would be substantial, with no significant offsetting reliability benefits.

Field Trial Participation: Balancing Authorities interested in participating in the field trial can contact Darrel Richardson (Darrel.Richardson@nerc.net). The BARC SDT intends to continue to have participants supply the field trial data and will hold monthly calls to discuss the results. Field trial tools for the Eastern and Western Interconnections can be downloaded from the field trial website at:

http://www.nerc.com/pa/Stand/Pages/Project-2007-18-Reliability-Based-Control-FieldTrial-Tools-RF.aspx