WIDE-AREA RESOURCES ADEQUACY MONITORING AND TRACKING (NERC ACE-FREQUENCY)

Release 3.0

Plan for DOE Deployment, And User Training

August 23 and 24 2005
PLAN AND TIMELINE TO DEPLOY
THE NERC ACE FREQUENCY APPLICATION
AT DOE EMERGENCY CENTER
Recommended Approach for Enhancing DOE-EOC Electric Grid Monitoring

Current Conditions and System Status

North America Load-Generation Resources Adequacy (ACE-Frequency)

Impact Analysis and Assessment

Magnitude, Dimension and Location of Resources Inadequacy

Notification & Actions

Internal DOE Notification and Coordination with NERC and Reliability Coordinators

DOE Emergency Operations Center (Release 2.5 & 3.0)

Tailor Metrics and Visuals to DOE Requirements

DOE Electricity Emergency Center (Release-3.5)

Expand Notification and Coordination Processes With DOE Guide

Install NERC Modified Version – 3Q2005

4Q2005 – 1Q2006
**Recommended Timeline for DOE Enhancements**

- **July 20, 05**: NERC-DOE Agreement To Install a Modified Current Release-2 of NERC ACE-Frequency at DOE
- **July 20 To July 29**: Software Changes to Adapt Current ACE-Frequency Release-2 to Meet NERC Requirements
- **August 1**: Deliver CD and Documentation with the Adapted ACE-Frequency Release-2.5 to DOE. NERCC Username and Password for DOE
- **August 8 To August 22**: Implement NERC Required Modifications, Integration, Testing and Installation of ACE-Frequency Release-3, for DOE
- **August 23 & August 24**: End User Training at DOE
- **September**: Create Functional Specification for DOE Requested Enhancements For Real Time Monitoring
- **4Q05 To 1Q06**: Research, Development, Integration and Testing of Specified DOE Enhancements for Real Time Monitoring Tools
CERTS-NERC TOOLS PORTFOLIO ADDRESSING BLACKOUT RECOMMENDATIONS

Blackout Causes

- Failure to maintain adequate reactive power support
- Failure to ensure operation within secure limits
- Inadequate operator training
- Failure to identify emergency conditions and communicate that status to neighboring systems
- Inadequate regional-scale visibility over the bulk power system

Blackout Recommendations

- Develop reliability related tools and technologies
- Adopt better real time tools for operators and reliability coordinators
- Strengthen reactive power and voltage practices
- Improve quality system modeling data and data exchange practices
- Required use of time synchronized data recorders

CERTS-NERC Tools

- Resource Adequacy – ACE-Frequency, (AIE, CPS, Inadv.)
- Generation Control Adequacy – Frequency Response and Data Arching Using Phasor Measurements
- Transmission Adequacy – Real Time Dynamic Monitoring System -RTDMS
- Reactive Adequacy – VAR Management
- Wide Area Visibility – Grid-3P™
POWER FUNDAMENTALS
FROM NYISO TRAINING PROGRAM
3 Basic Components

Gens → Transmission Services → Load

plus some not so obvious, but very necessary services

From NYISO “Power Fundamentals”
Four basic Power System Concepts:

The Physical World

#1 “Load customers” determine Demand

#2 “Dispatch” determines where it’s generated

#3 The Laws of Physics normally determine how the power gets there

#4 Flows must be controlled
A Constant Balancing Act

- Load changes constantly
- Generation chases load
- Available generation changes
- Flows must be controlled
- Transmission system limitations
- 24 hours a day, 7 days a week

From NYISO “Power Fundamentals”
FUNDAMENTALS FOR DEMAND-RESOURCES ADEQUACY MONITORING AND TRACKING USING NERC-CERTS ACE-FREQUENCY APPLICATION (Release 3.0)
NERC ACE-Frequency Infrastructure

**A**
- ACE- Frequency Data Collection
- Data Validation
- Data Processing

**B**
- Abnormal Frequency Notification
- Frequency Alarms

**C**
- Real-Time Monitoring and Tracking
- Root Cause Identification

- 123 CONTROL AREAS SEND 1 MINUTE DATA THROUGH SECURE NERC-NET

- NERC Secure Ethernet (Princeton)

- NERC Database Server

- Multi-View, Geo-Graphic Reliability Coordinators Client (22)
  For Real-Time Monitoring of Abnormal Interconnection Frequency and For Root Cause Identification
POWER INDUSTRY OPERATIONAL, MONITORING AND TRACKING HIERARCHICAL LEVELS

Data is Produced at All Different Levels
Integrated Information is Required at New Levels

Visualization Solutions with Adequate Operational Information:
- Simple
- Intuitive
- Integrated
- Meaningful Information

- Wide-Area Reliability Tracking
- 16 Reliability Coordinators – Need to have a wide-area view of their operational jurisdictions
- ISOs and RTOs
- Transmission Providers
- Generation Serving Entities
- Load Serving Entities
Resource Adequacy 3 Fundamental Monitoring and Tracking Parameters:

- Time
- Operational Levels or Jurisdictions
- Performance Metrics
DEMAND-RESOURCES ADEQUACY MONITORING-TRACKING USING NERC-CERTS ACE-FREQUENCY APPLICATION - TIME AND OPERATIONAL LEVELS -

Recommended
Wide-Area
Monitoring Focus
For DOE

REAL TIME WIDE-AREA MONITORING - DOE

-1 Hour to Current

LOCAL MONITORING – NERC RELIABILITY COORDINATORS

16 Reliability Coordinators

-1/2 Hour to Current

4 Interconnections (Eastern, WECC, HQ, Texas)

-6 Hours to Current

143 Control Areas

Current Time -10 Minutes to Current

By: Carlos Martinez
DEMAND-RESOURCES ADEQUACY MONITORING-TRACKING USING NERC-CERTS ACE-FREQUENCY APPLICATION - METRICS

WIDE-AREA RESOURCES ADEQUACY MONITORING METRICS:
• Real Time Interconnections Frequency Alarms
• 1-Minute Interconnections Frequency
• Last Hour 10-Min Average Jurisdictions ACE
• Last ½ Hour 1-Min Control Performance Standard (CPS1)
• Last ½ Hour 1-Min Balancing Authority ACE Limit (BAAL)

LOCAL-AREA RESOURCES ADEQUACY MONITORING METRICS:
• Frequency Alarms
• Interconnection Frequency
• Area Control Error (ACE)

Recommended
Wide-Area
Monitoring Focus
For DOE

-6 Hours to Current

REAL TIME WIDE-AREA MONITORING – DOE

LOCAL MONITORING – NERC RELIABILITY COORDINATORS

-1/2 Hour to Current

143 Control Areas

Current Time

-10 Minutes to Current

4 Interconnections

DEMAND-RESOURCES ADEQUACY MONITORING-TRACKING USING NERC-CERTS ACE-FREQUENCY APPLICATION - METRICS

Recommended
Wide-Area
Monitoring Focus
For DOE

-6 Hours to Current

REAL TIME WIDE-AREA MONITORING – DOE

LOCAL MONITORING – NERC RELIABILITY COORDINATORS

-1/2 Hour to Current

143 Control Areas

Current Time

-10 Minutes to Current

4 Interconnections
RECOMMENDED FUTURE RESOURCES ADEQUACY MONITORING DASHBOARD TYPE VISUAL AND TRACKING PROCESS
**CERTS RECOMMENDED FUTURE WIDE-AREA RESOURCES ADEQUACY CHANGES - DASHBOARD TYPE VISUAL**

<table>
<thead>
<tr>
<th>Contingency</th>
<th>Within Normal Limits</th>
<th>Outside Normal But Within Emergency</th>
<th>Outside Emergency Limits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Within Normal Limits</td>
<td><strong>SECURE 1 Above 59.95 Hz</strong> *</td>
<td><strong>INSECURE 1 Below 59.908 Hz</strong></td>
<td>EMERGENCY Load Drop Below 59.82 Hz</td>
</tr>
<tr>
<td>Outside Normal But Within</td>
<td><strong>SECURE 2 Below 59.95 Hz</strong></td>
<td><strong>INSECURE 1 Below 59.908 Hz</strong></td>
<td></td>
</tr>
<tr>
<td>Emergency Limits</td>
<td><strong>SECURE 2 Below 59.95 Hz</strong></td>
<td><strong>INSECURE 2 Below 59.908 Hz</strong></td>
<td></td>
</tr>
</tbody>
</table>

**DEFINITIONS:**

- **SECURE 1** - Operation under acceptable load-generation balance able to sustain a worst first generation contingency
- **SECURE 2** - Operation under normal load-generation balance and generation contingencies indicate risk that an abnormal second generation contingency becomes greater than acceptable
- **INSECURE 1** - Operation under risk of an abnormal second generation contingency
- **INSECURE 2** - Operation under risk of an abnormal second generation contingency and contingencies indicating risk that an abnormal second contingency becomes greater than acceptable or that load has dropped
- **EMERGENCY** - Customers load has dropped, frequency relays operated

* Frequency thresholds taken from NERC new Balancing Authority ACE Limit (BAAL) performance metric for Eastern Interconnection
EASTERN INTERCONNECTION RESOURCES ADEQUACY

(Alarms Criteria and Recipients to Be Defined)

<table>
<thead>
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</tbody>
</table>

Actual
Within Normal Limits
Outside Normal But Within Emergency
Outside Emergency Limits

SECURE 1 Above 59.95 Hz *
SECURE 2 Below 59.95 Hz
INSECURE 1 Below 59.908 Hz
INSECURE 2 Below 59.908 Hz
EMERGENCY Load Drop Below 59.82 Hz

EASTERN INTERCONNECTION RESOURCES ADEQUACY

<table>
<thead>
<tr>
<th>Interconnection</th>
<th>Date/Time</th>
<th>Frequency</th>
<th>Freq_Delta</th>
<th>Expected_ACE</th>
<th>Actual_Net_ACE</th>
<th>Missing_ACE</th>
<th>Missing_ACE_Frac</th>
</tr>
</thead>
<tbody>
<tr>
<td>E</td>
<td>08/23/2005 00:13</td>
<td>59.90</td>
<td>0.001</td>
<td>43.9</td>
<td>31.3</td>
<td>357.3</td>
<td>81.3</td>
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<tr>
<td>Q</td>
<td>08/23/2005 00:13</td>
<td>59.96</td>
<td>-0.007</td>
<td>-194.5</td>
<td>28.5</td>
<td>-222.9</td>
<td>115</td>
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<tr>
<td>W</td>
<td>08/23/2005 00:13</td>
<td>59.05</td>
<td>0</td>
<td>100.2</td>
<td>0</td>
<td>100.2</td>
<td>100</td>
</tr>
</tbody>
</table>

Contingency EMERGENCY Load Drop Below 59.82 Hz

INSECURE 1 Below 59.908 Hz
INSECURE 2 Below 59.908 Hz

SECURE 2 Below 59.95 Hz
SECURE 1 Above 59.95 Hz
The A, B, C, D For Monitoring and Tracking Demand-Resources Adequacy Using ACE-Frequency

**OBJECTIVE:** Real time monitoring of demand and resources adequacy, using interconnection frequency, and quick identification and corrective action of root causes

**A**  Monitor jurisdictions ACE and its impact on interconnection frequency

**B**  Watch for frequency and ACE alarms

**C**  Verify Abnormalities with Disturbance Overview Display

**D**  Zoom–In to identify, verify and correct root causes

SHORT-TERM:  -EAST  
6/15/2005  8:04:00 AM(EDT) -  
Frequency Absolute value of two most recent 1-Minutes:  
ABS(59.997-60.034)=0.037Hz>=0.035Hz.
ACE-FREQUENCY MONITORING
APPLICATION RELEASE 3.0
VISUALS ARCHITECTURE
MENU STRUCTURE AND NAVIGATION
MULTIPLE-VIEW VISUALIZATION ARCHITECTURE

Geographic Menu
Real-Time Monitoring Panel

Tracking Panel
Forecast Panel

MULTIPLE-VIEW VISUALIZATION ARCHITECTURE

Real-Time Monitoring Panel

Tracking

Forecast Panel

Prediction

System Status Window

Text Window Menu

Text Data/Horizontal Scroll

Engineer’s Module Menu

Navigation Pad
RELEASE 3.0 MENU STRUCTURE

JURISDICTION SELECTION

Jurisdictional ACE-Frequency Graphs:
- 1 Minute ACE Cumulative Bars – 1 Hour
- 10 Minute Average ACE – 1 Hour
- 1 Minute ACE-Frequency Plots – 10 Min

Interconnection Frequency Plots:
- Daily Epsilon
- Monthly Epsilon

Select & Monitor Specific Jurisdiction

Visual Presentation Options

Balancing Authority ACE Limit (BAAL)
- 30 Minutes CPS1-BAAL Monitoring
- 30 Minutes CPS1-BAAL Tracking
RELEASE 3.0
NEW FUNCTIONS AND ENHANCEMENTS
R3 KEY FUNCTIONS AND ENHACEMENTS

1. ACE-Cumulative Bars and Frequency Line Plots
2. Enhanced Set Boundary Focus
3. On Display Alarms and Reports
4. Online Application News and Help
5. Enterable Frequency Alarm Thresholds
6. User Adjustable Monitoring Time-Window
7. CPS1 and BAAL Monitoring and Tracking
8. Alarm and Database Enhancements
Cumulative ACE bars overlapping a Frequency line-plot to show the selected jurisdiction control areas Net-ACE vs. Interconnection Frequency. The ACE value of each control area from the selected jurisdiction will be displayed as a segmented-cumulative bar chart in one-minute increments for the last hour. The summation of the entire bar for one-minute is equal to the net ACE value of the selected jurisdiction. The interconnection frequency is plotted on the same chart as a line-plot in one-minute increments for one hour on a secondary y-axis. Jurisdiction Control Areas with bad or missing ACE data are displayed in grey-color bar with a value derived from their yearly $L_{10}$.
2 - ENHANCED SET BOUNDARY FOCUS – Release 3

The Set Boundary Focus option now allows user selection of any jurisdiction to focus user monitoring only for the control areas belonging to the user selected jurisdiction.
3 - ON DISPLAY ALARMS AND REPORTS – Release 3

On display alarm and report capabilities have been added to the yellow information-window in the lower left-hand corner of the application to alarm two conditions: a) display the accumulated amount of missing ACE data per interconnection using Control Areas yearly L10 values for those control areas not reporting ACE data. When user clicks on the missing ACE values a report is displayed with appropriate data for users to take pro-active action to correct data quality problems, b) short, blink messages indicating “Failed Data Connection”....
The help-tab functions have been enhanced to present an index of application related news and help documents. Double clicking on any of the documents index, will display the full document in PDF-format. Help documents are archived now in a central location to facilitate its periodic update without issuing client updates.

Wide-Area ACE-Frequency Real-Time Monitoring System

**Online Information Help**

<table>
<thead>
<tr>
<th>Last Modified</th>
<th>Help Title</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>2006-06-30T00:00:00</td>
<td>ACE/ACE/Frequency Userguide 3.0</td>
<td>This document provides a comprehensive overview of how to use the application.</td>
</tr>
<tr>
<td>2006-06-15T00:00:00</td>
<td>Scenario 1: East Texas Blackout</td>
<td>This document illustrates what happened and how the ACE/Frequency application was used to assess the situation.</td>
</tr>
<tr>
<td>2004-09-08T00:00:00</td>
<td>Scenario 2: California blackout</td>
<td>This document illustrates what happened and how the ACE/Frequency application was used to assess the situation.</td>
</tr>
</tbody>
</table>
The visual presentation option window have been expanded to include the capability for setting the frequency alarm threshold per interconnection to something other than the recommended thresholds from NERC.

5-ENTERABLE FREQUENCY ALARM THRESHOLDS

Release 3
6 - CPS1 AND BAAL MONITORING (Field Trial)

To help monitor and track the impact of the new Balancing Authority ACE Limit (BAAL) metric during the Field-Trial in the Eastern Interconnection, a new 4-panel display has been created. Panel-1 shows last minute CPS1 geographically for the jurisdiction Control Areas selected, panel-2 shows, color-coded, the CPS1 for the last 30-minutes for all the selected Control Areas, panel-3 shows CPS1 line-plots for the last 30-minutes with thresholds indicating CPS1 and BAAL violations, and panel-4 shows the numerical values for data for the other 3 panels.
The application was limited to 1-hour and 10-minute monitoring windows. Now users can adjust the time window for any of the monitoring and tracking panels of the 4-panel displays for up to 6 hours with 1-minute resolution.
8 - ALARMS AND DATABASE ENHACEMENTS

- **New Frequency Alarm Threshold** – Instead of using the average frequency per minute to compare with alarm thresholds, the new frequency calculation uses the maximum frequency value if frequency has been below 60 Hz during the last minute, or the minimum frequency if the frequency has been below 60 Hz for the last minute. The average frequency is only use if the sample is above and below 60 Hz during the last minute.

- **New Frequency Alarms** – New frequency alarms have been created to indicate proximity to the three frequency thresholds that define the new BAAL performance metric.

- **Online and Archived Data** - The primary ACE-Frequency database will keep 90-days of data available online. A secondary database has been established that will archive up to 3 years of ACE/Frequency data. A utility application is embedded in Release 3 that will allow the user to query the archive data and save it to their local computer as comma-separated values (CSV) file.
RELEASE 3.0
CPS1 AND BAAL REAL TIME MONITORING AND TRACKING
**CPS1 AND BAAL REAL TIME MONITORING (Field-Trial)**

**OBJECTIVE:** Real time monitoring and tracking of 1-minute CPS1 and BAAL-Low and Baal-High violations correlating with interconnection frequency, and using CERTS ACE-Frequency Geo-Graphic, Multi-View Visualization.

Users can select any jurisdiction and monitor its 1-minute CPS1 performance, its BAAL high and low (CPS1 during last 30-minutes) correlating with interconnection frequency, and allowing users to track CPS1 and BAAL performance for any jurisdiction for the last 6-hours.
A. Select Jurisdiction to Monitor 1-Minute CPS1 And BAAL

B. Monitor Geographically Last Minute CPS1

C. Monitor BAAL Violations Via CPS1 for the last 30-minutes or Beyond For Multi Control Areas

D. Monitor and Track CPS1-BAAL for Selected Control Area
CPS1 AND BAAL REAL TIME MONITORING (Field-Trial)

Panel 1: Geographic View with Last Minute CPS1 for Control Areas in Selected Jurisdiction

Panel 2: 2D-Plot with BAAL Violation (Last 30-Minute of CPS1) for Control Areas of Selected Jurisdiction

Panel 3: Bar-chart for last 30-Min of CPS1 with Thresholds for CPS1 and BAAL violations correlated with frequency

Panel 4: Dynamic Data Text Window with actual data displayed in tabular fashion for each selection criteria
Recommended Enhancements for DOE Emergency Center
ACE-Frequency Enhancements for DOE Emergency Center – Conditions, Analysis

**Eastern, Western, and Ercot interconnections**

**load-generation adequacy condition**

**CONDITIONS**

For Eastern and Western interconnections:

**Normal** – EI Freq >59.950
Load-generation under acceptable balance and control

**Alarm** – EI Freq <59.950 for more than 30-minutes. Risk of 2nd contingency becomes greater than acceptable

**Emergency** – EI Freq >59.820. Frequency-related relays had tripped, load has been dropped

**ANALYSIS**

System analysis and assessment at the interconnection and Reliability Coordinator levels

**Magnitude** - EI MW of unbalance or drop originating alarm or emergency condition=Delta between EI current net ACE and net EI Balancing Authorities ACE Limits (BAAL). 24-hours tracking-scale

**Location** – Geo-graphic color-coded map showing EI Balancing Authorities with the worst delta MW

**Interregional Transfers** – Net interregional transfer MW = Estimated values, calculated as the difference between region net ACE minus its net frequency contribution, displayed geo-graphically

**Customers With Not Power** – Estimate based on correlation between unbalance delta or drop MW and estimated average MW consumption per Balancing Authority per customer
ACE-Frequency Enhancements for DOE Emergency Center – Actions, Events and Warnings

**Notifications and Actions**
- Notifications – Automatic cell-phone and/or email alarm to Secretary and DOE-NERC designees for emergency conditions
- Actions – Immediate access to names and phone numbers for the Reliability Coordinator(s) with jurisdiction over the worst unbalance Balancing Authorities. Direct line to NERC

**Events**
- Event summary when emergencies and blackouts occur
- Summaries – pre and post emergency data as above, arranged chronologically per minute and per jurisdiction

**Warning**
- Advance warning and tracking during critical system conditions
- Warning – Forecast data, Daily and Hourly Market Data. Warning and Tracking visuals with key parameters for critical days
SCENARIO 1

Pre and Post June 15, 2005
Eastern Texas Blackout
Monitoring and Analysis Using NERC-CERTS Wide-Area ACE-Frequency Monitoring Tool
Blackout Event and Impact On Customers

“What began as a 20-second cascade of failing power lines Wednesday evening ended with 150,000 Southeast Texas residents in the dark and a small but intense power-plant fire.

Tornadolike winds that roared through an area near China were blamed for the blackout, which stretched across eight counties served by Louisiana-based Entergy and included communities such as The Woodlands and Huntsville. By 11 that same night most of the power was restored....."
Pre-Disturbance Monitoring, Post Assessment Using NERC-CERTS ACE-Frequency Tool

- Frequencies of 60.029 and 60.033 Hz (Over-Generation)

- Continuous Period of Over-Generation By: FRCC, NEISO, NYISO, PJM, Duke, Entergy Average About 900 MW

- Over-Generation Increased 1100-2152 MW for Eastern Interconnection and by 500-1158 MW for Entergy

- 7:04 Alarms Issued Disturbance

- 7:10

- 7:25 Entergy Reduced Over-Generation to Zero
Pre-Disturbance – Over-Generation Indication
NERC-CERTS ACE-Frequency Tool

1750 MW of Over-Generation. It changed from about 300MW to 1724 MW from 6:50-7:04PM
Alarm - Sent at 7:04PM (CDT) Via Email, Pagers To RCs By NERC-CERTS ACE-Frequency Tool

SHORT-TERM: -EAST 6/15/2005 8:04:00 AM(EDT) - Frequency Absolute value of two most recent 1-Minutes: ABS(59.997-60.034)=0.037Hz>=0.035Hz.

This notice reflects the most current information available from Control Areas. These notice results depend on the quality and completeness of the data supplied and, accordingly, the accuracy of this notice cannot be assured.

This notice is provided solely for informational purposes.
Alarms - Worst Reliability Coordinators and Control Areas
At 7:04PM by NERC-CERTS Frequency-ACE Tool

7:04PM - Flashing Alarms for 5-Worst Control Areas

7:04PM – Color-Coded Alarms (Blue) Over-Generation For Reliability Coordinators

Reliability Coordinators Jurisdictional Boundaries

150,000 Customers Dropped
At 17:10 PM the Eastern Interconnection reached about 2152 MW of over-generation. At 7:01 PM (alarms issued) 9 of the 13 reliability coordinators jurisdiction were over-generating.

Over generation (Blue):
- 1158 MW
- 340 MW
- 227 MW
- 286 MW
- 141 MW

Eastern Reliability Coordinators

NERC-CERTS ACE-Frequency Tool
Disturbance – Entergy Performance
NERC-CERTS ACE-Frequency Tool

About 1158 MW of Over-Generation. It changed from about 500 MW to 1158 MW from 7:01-7:10PM
Post Disturbance Frequency and Entergy ACE
NERC-CERTS ACE-Frequency Tool

Entergy Reduced Over-Generation from 1158 MW to Zero MW in About 20-Minutes
(Reduction Maybe Was Required Because of a Drop of 1158 MW of Customer Load)