# Texas Reliability Entity
# Event Analysis

# Event:
# November 29, 2011 DCS Event
# Category 3 Event

Texas Reliability Entity
March 30, 2012

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# Executive Summary

On November 29, 2011, a mechanical failure tripped a large, base-load unit in the ERCOT region. Reliability Coordinator (RC) and Balancing Authority (BA) personnel and systems operated effectively to restore system frequency by deploying reserves, and then afterwards restored those reserves. This report provides: (1) an overview of the event; (2) background on system conditions just prior to the event; (3) the detailed sequence of events; (4) an analysis of the causal and contributing factors for concerns that arose in this event; and (5) recommendations for follow-up action.

## I. Event Overview

At 03:29:11 on November 29, 2011, a large base-load unit tripped in the ERCOT region due to a ground fault in the stator winding.

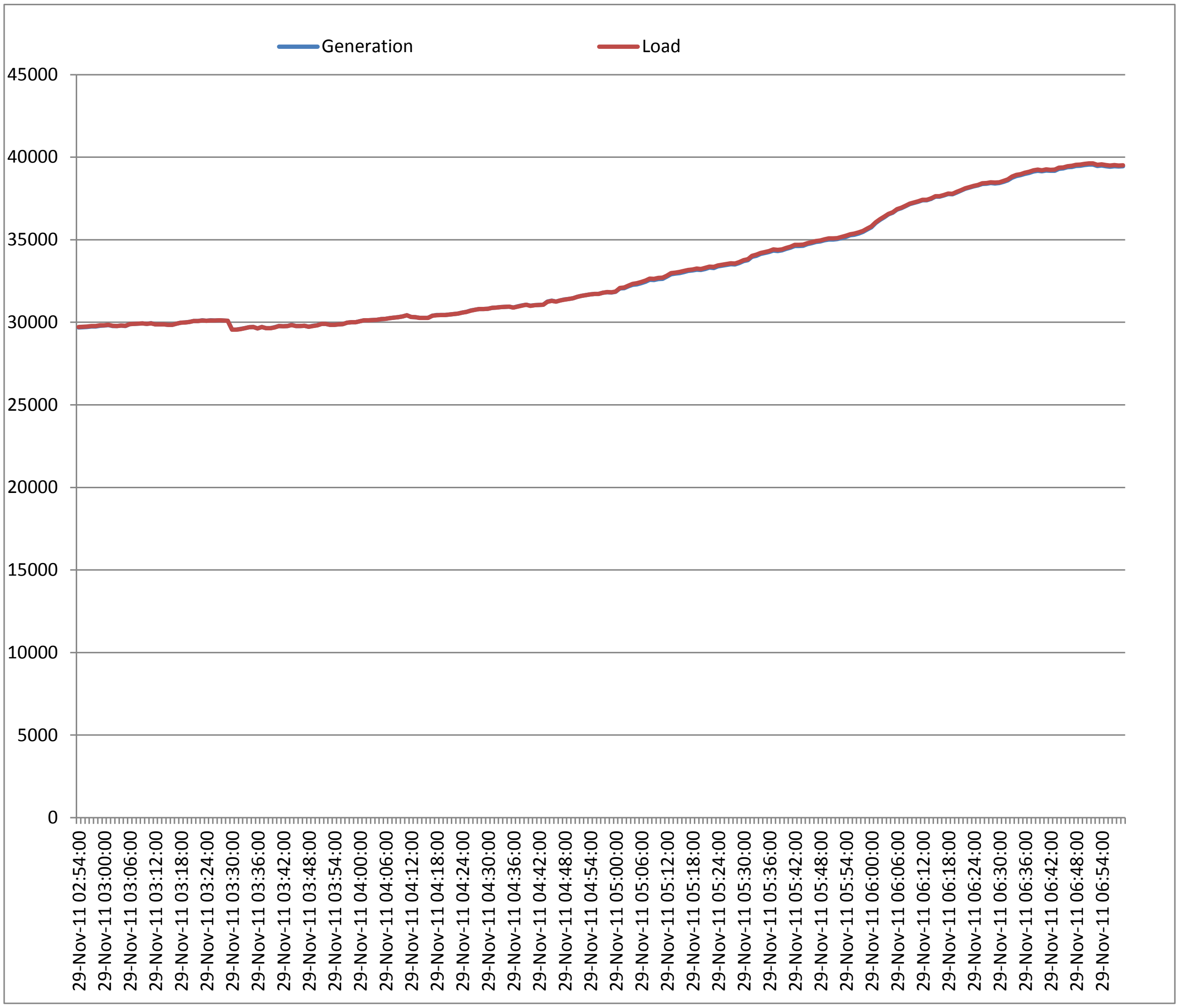
System frequency measured at the RC's control center dropped from 59.999 Hz to 59.732 Hz, based on 2-second scans, as a consequence of the loss of generation. High-speed frequency recorders indicated that frequency dropped to 59.694 Hz. The drop was arrested by governor action of ERCOT region generators, aided by automatic deployment of 91 MW of generation responsive reserve as well as automatic deployment of 739 MW of Load Resources (LR) by underfrequency relay action. These actions led to system frequency recovery within 5 minutes and 41 seconds to the pre-disturbance value of 60 Hz (at 03:34:52).

The RC responded to the first event as a NERC Disturbance Control Standard (DCS) event in the ERCOT region. The event also met the definition of a Category 3a event under NERC's Event Analysis Working Group (EAWG) procedure.

# II. Forecasts and Initial System Conditions Prior to Event

*<u>11/29/2011 Current Day Report forecast reflecting 08:00 Peak (Pk)</u>*:

| | |
|---|---|
| Forecasted Pk HR Demand: | 41,032 MW |
| Actual Demand: | 29,823 MW |
| Wind Generation Actual: | 1271 MW |
| Generation for Pk HR Demand | 42,999 MW |
| System Frequency: | 60.001 Hz |
| Area Control Error (Total): | ~ 6 MW |
| Net Spin Reserves: | 3653 MW |
| Physical Responsive Capability: | ~4712 MW |



## III. Sequence of Events on 11/29/2011

- 03:29:00 ERCOT region frequency prior to disturbance was 60.001 Hz.
- 03:29:12 Unit trips causing the loss of 1365 MW of net generation.
- 03:29:16 ERCOT region frequency dropped to approximately 59.732 Hz (59.694 Hz High-Speed Frequency Recorder Data) immediately after the trip.
- 03:29:16 739 MW of Load Resources (LR) tripped offline on Under Frequency Relay (UFR) action.
- 03:34:52 ERCOT region frequency recovered to 60 Hz.
- 03:35 Hot-line calls were made to the Qualified Scheduling Entities (QSE's) to notify them that a low frequency event had occurred, and instructed to all QSE's to restore the Load Resources that tripped during the event.

# IV. Analysis of Initial Unit Trips

### *A. Generation Unit Trip*

The Generator Operator reported that at 03:29 CDT on November 29, 2011, one of its units tripped due to a ground fault.

Subsequent investigation revealed that the unit tripped due to a leak in one or more hollow strand(s) of a stator coil allowing moisture to travel inside the coil over an extended period of time. The moisture degraded the resin in the coil over time allowing the conductor bundle to come loose and allow individual conductor strands to vibrate. The strand-to-strand vibrations and movement eventually wore away the insulation between the strands creating strand-to-strand shorts. The accumulation of strand-to-strand shorts caused excessive heating thermally damaging the coil until it eventually failed. As the affected area grew, more heat was created until the coil melted and eventually arced violently across the missing melted area. A generator ground fault occurred after melted copper exited the ground wall of the coil slot. The melted copper degraded the groundwall insulation and a ground fault occurred.

The following is the sequence of events leading up to the unit trip:

- On November 26, 2011 at approximately 2100 hours, the unit control room received a Stator Coil Water Differential Temperature high alarm. The plant operators responded by implementing their standard annunciator response procedure.

- On November 27, 2011 at approximately 0200 hours, the instrumentation and control (I&C) technicians clipped onto the coil thermocouple post and reported to the control room that the coil thermocouple was reading 160.7 °F, still below the 174 °F threshold for engineering input. At the time that 160.7 °F was communicated from the field, the control room indication for the same thermocouple was 163 °F leading the plant staff to believe the thermocouple was malfunctioning. Shortly after the I&C Technicians disconnected their testing equipment, at approximately 0222 hours, thermocouple coil temperature rose to 168 °F and continued to rise unnoticed until it read greater than 175 °F. It was believed the higher temperature indicated a malfunctioning thermocouple based on the I&C maintenance crews recent report that the coil thermocouple was reading 160.7 °F at the generator.

  At 0244 hours, the control room received the Generator Condition Monitor (GCM) verified alarm. At 0254 hours, the GCM Verified Alarm cleared.

  At 0342 hours, the crew removed the coil thermocouple from service by substituting a constant value for the thermocouple data.

- On November 29, 2011 at 0216 hours, the GCM Warning Alarm began to cycle in and out. The staff was focused on other activities and believed the GCM was malfunctioning as believed on November 27. At 0229, the GCM Verified Alarm was received. At 0310 hours, the control room received Stator Cooling System Trouble alarm and promptly redirected the plant operator to check the Stator Cooling Water System. When the plant operator arrived at the Stator Cooling Water skid, he noted that the tank level was high and water conductivity was rising. The plant operator immediately contacted personnel to sample the cooling water for conductivity. At 0329 hours, the unit tripped.

The apparent cause of the unit damage was a leak that appears to have existed in a hollow strand within stator coil. This leak most likely existed for a long time and allowed moisture to travel inside the coil. The moisture degraded the resin in the coil over time allowing the conductor bundle to come loose from the ground wall and allow some individual conductor strands to move and vibrate. The strand-to-strand vibrations and movement eventually wore away the insulation between the strands and created strand-to-strand shorts. The shorts caused excessive heating. The area affected by these shorts grew as the coil insulation was thermally damaged and failed. As the affected area grew, more heat was created until the coil melted and eventually arced violently across the missing melted area of the coil.

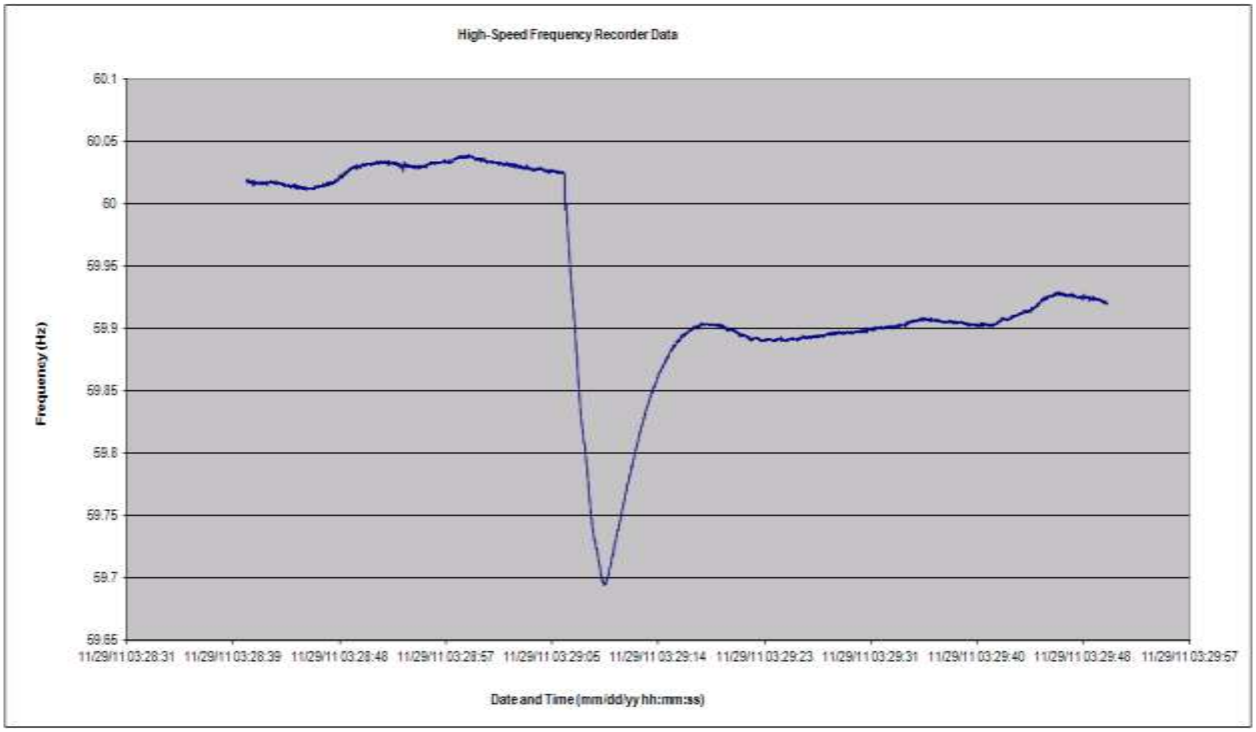
The breakers and protection system operated properly as designed. There were no personnel injuries.

## V. Response Analysis

### *A. Initial Response*

The loss of generation in the ERCOT Region during the morning of November 29, 2011 constituted a significant disturbance to grid. The Balancing Authority used the Region's resources and reserves to balance resources and demand and return system frequency to pre-disturbance frequency well within the 15 minute target set by NERC Standards.

ERCOT region frequency was at 60.001 Hz immediately prior to the disturbance. Immediately after the disturbance, system frequency dropped to 59.732 Hz, based on 2-second scans. High-speed frequency recorders indicated that frequency dropped to 59.694 Hz. The following are among the actions that registered entities initially took to stabilize the system:

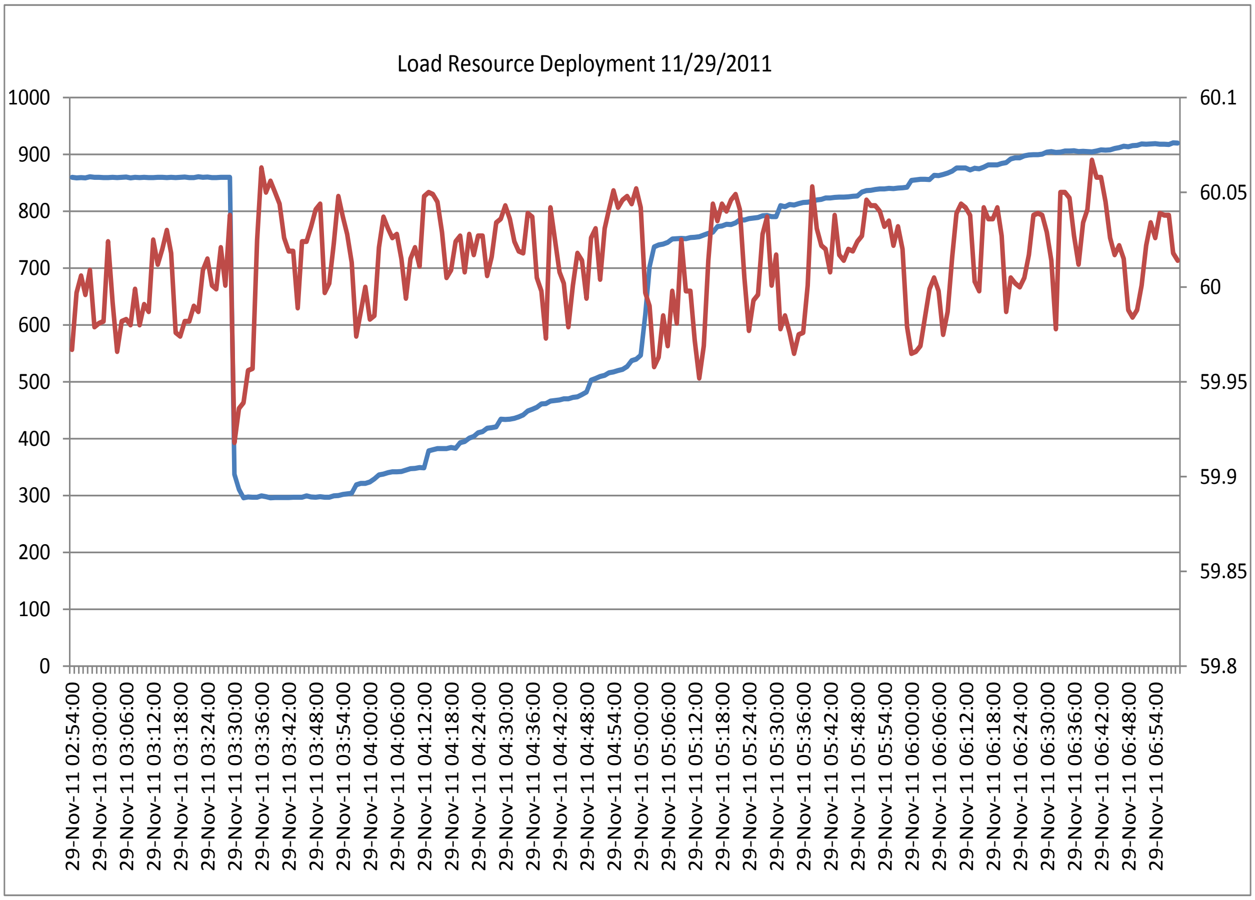


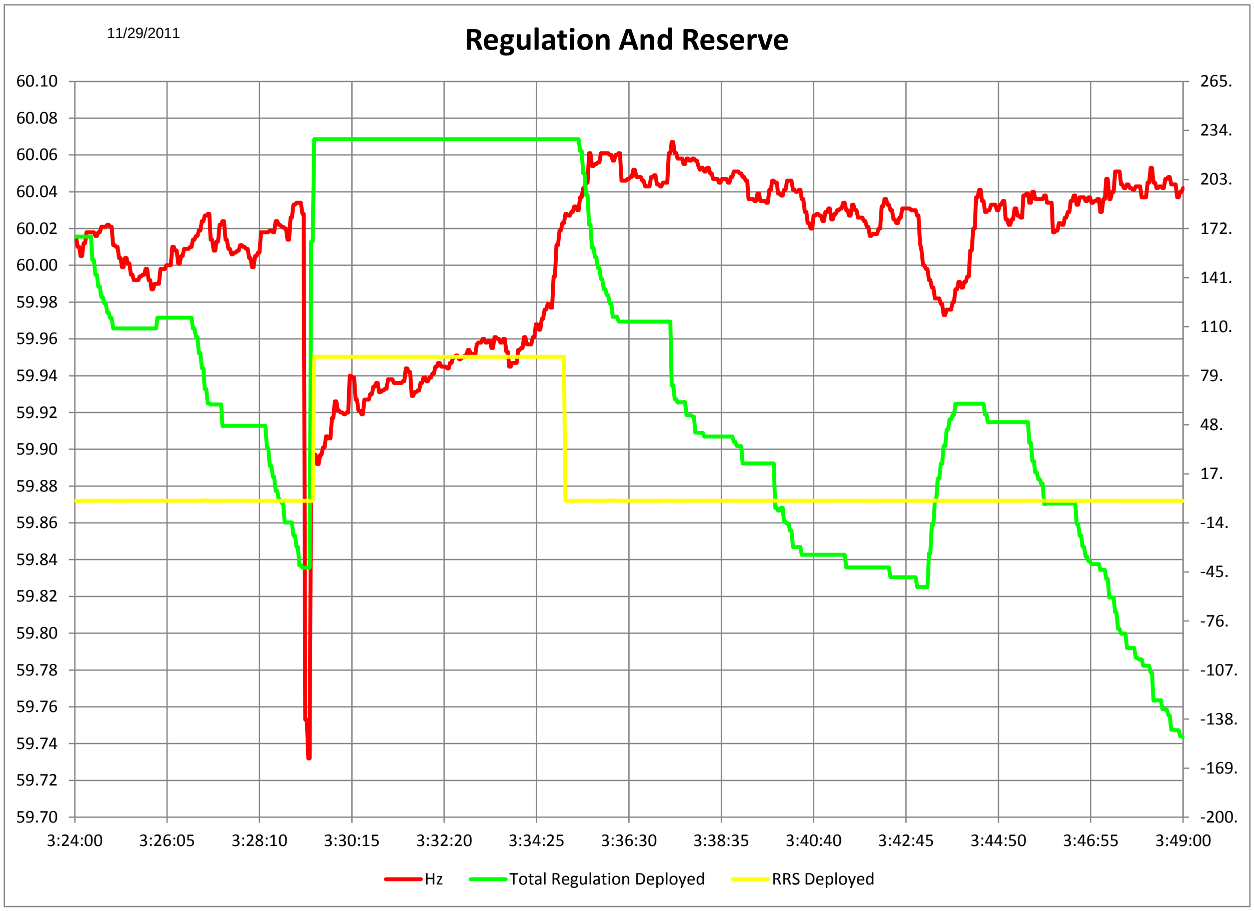

*High-Speed Frequency Recorder Data on November 29, 2011.*

- Generator governor response arrested the frequency decline, as analyzed by the Performance, Disturbance, Compliance Working Group (PDCWG) in its draft report. The initial calculated system frequency response, termed the "B" point, was 765.83 MW/0.1 Hz, which met the target of 420 MW/0.1 Hz established in Regional Protocols 5.9.2. The second calculated response point, termed "B+30" to denote that it measures how well response is sustained 30 seconds after the event, increased to 926.76 MW/0.1 Hz, which also met the minimum response level. The excellent response was due to a combination of governor action from the on-line generation resources as well as the response from Load Resources which tripped automatically due to the low frequency condition. The PDCWG also noted that 110 out of 138 units (units running that were not excluded) (79.7%) sustained governor response for this event.
    - The 'sustained' governor response rate continues to improve across the last large generation loss events in the ERCOT system; 6/23/2010 – 62.1%, 8/20/2010 – 66.6%, 11/3/2010 – 70.4%, 12/11/2010 – 70.9%; 3/23/2011 – 86.4%; and 5/19/2011 – 71.8% sustained performance.
    - Frequency overshoot (i.e. high frequency after recovery from large generation unit trips) is common for events of this magnitude. System frequency reached a high of 60.07 Hz during the recovery. This is comparable to the high frequency from previous similar events: 6/23/2010 – 60.13 Hz, 8/20/2010 – 60.09 Hz, 11/3/2010 – 60.14 Hz, 12/11/2010 – 60.05 Hz; 3/23/2011 – 60.04 Hz; and 5/19/2011 – 60.07 Hz.

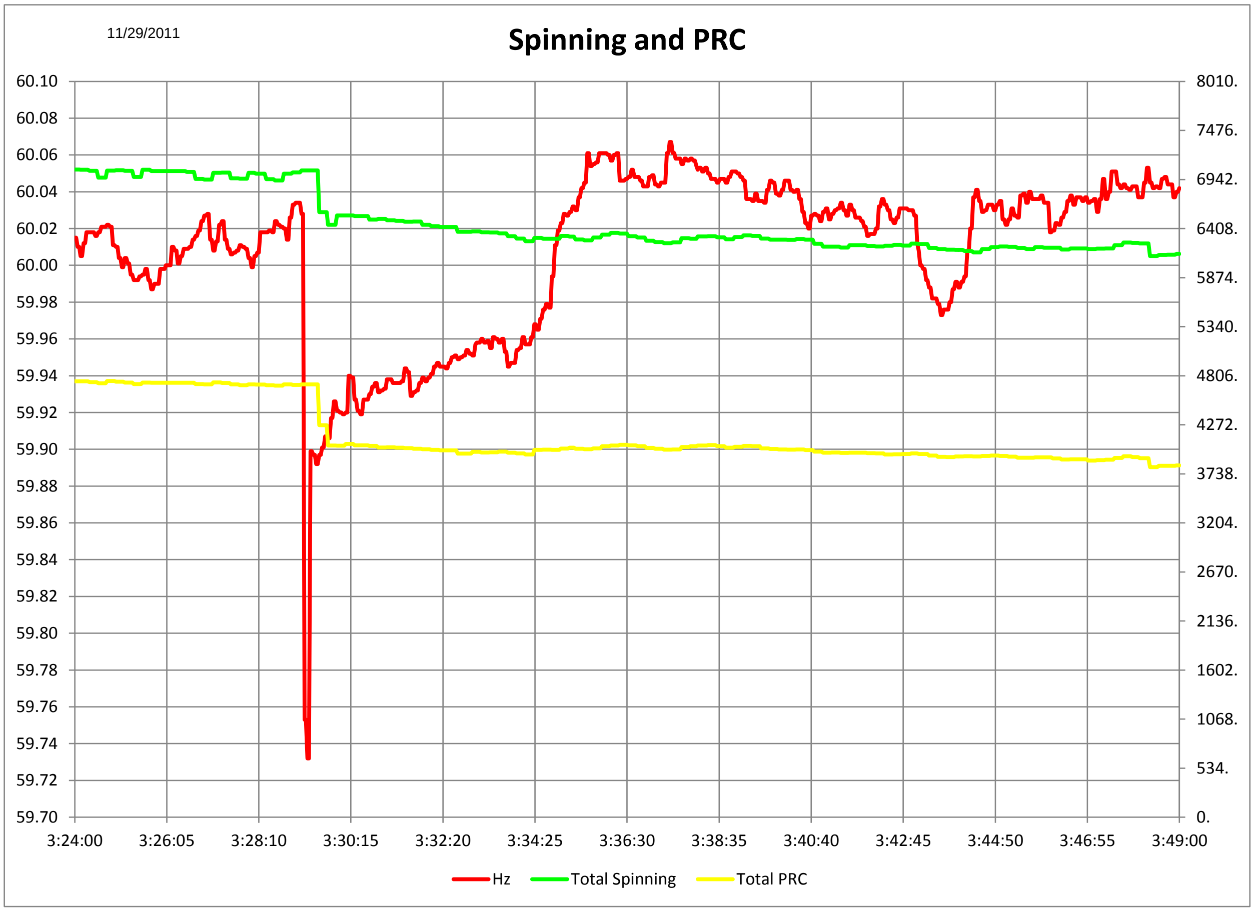
- The BA's control center computer made a step deployment of 268 MW of generation regulation, within 10 seconds of the frequency bottom, modifying the setpoint sent to QSEs to accomplish this deployment. Texas RE did not identify any problems with this automatic deployment by ERCOT's system or the response from QSEs to ramp their generators output up within 10 minutes as required. Similarly, 91 MW of Responsive Reserve Service (RRS) from generators was deployed 12 seconds after the event, per the BA event report.
- Automatic deployment of 739 MW of LR by underfrequency relay action aided the frequency recovery.

The result of these actions was that system frequency returned to its pre-disturbance value of 60 Hz within 5 minutes and 41 seconds.





11/29/2011
Regulation And Reserve
60.10
60.08
60.06
60.04
60.02
60.00
59.98
59.96
59.94
59.92
59.90
59.88
59.86
59.84
59.82
59.80
59.78
59.76
59.74
59.72
59.70
265.
234.
203.
172.
141.
110.
79.
48.
17.
-14.
-45.
-76.
-107.
-138.
-169.
-200.
3:24:00
3:26:05
3:28:10
3:30:15
3:32:20
3:34:25
3:36:30
3:38:35
3:40:40
3:42:45
3:44:50
3:46:55
3:49:00
Hz
Total Regulation Deployed
RRS Deployed




*B. Reserves*

The Physical Responsive Capability remained above 3800 MW for the duration of the event. The Load Resources that deployed by UFR action were recalled by the System Operator at 03:47.

*C. Generation Unit Response*

The Generator Operator for the unit that tripped is completing the following items to return the unit to service:

- Remove and replace damaged stator core iron (on-site)
- Complete refurbishment of rotor (off-site)
- Complete refurbishment of exciter (off-site)
- Replace all stator coils (onsite)
- Complete stator cooling system flush (on-site)
- Complete testing and re-termination of all stator coil thermocouples
- Evaluate improvements to protective relaying, fault recording and sequence of event recording

*D. Demand Side Resource Response*

Approximately 739 MW of demand side resources tripped automatically due to the action of underfrequency relays. The BA may base up to 1150 MW of its 2300 MW of RRS on such demand side resources, termed Load Resources (LRs) at the time of this event, although less than that amount were awarded during this event. LR's providing RRS are expected to have this capability set to 59.7 Hz within 20 cycles. Data collected data from ten high resolution frequency recorders in the Region show that frequency went below 59.7 HZ. The recorders indicate slightly different readings across the grid which is typical for events such as this. 59.697 HZ was the average low reading for the 10 recorders. However, 4 recorders in the western part of the Region, and one of the recorders in the northern areas indicated that frequency did not go below 59.7 HZ for more than 20 cycles, which is the requirement for UFR type Load Resources. Based on this data there were no misoperations noted with the Load Resource performance. Thus the partial automatic activation of underfrequency relays can be attributed to the close proximity of the dip in frequency to the relay set-point at which these resources should be activated and slight variations in the frequency sensed at different locations.

## VI. Conclusions

In general, the steps taken in the recovery from this event achieved the desired results. System Operators handled the situation effectively.

Last, frequency response from generators and LR performed to effectively address the initial frequency response and met the minimum levels on the "B" and "B+30" calculation of system frequency response. 110 out of 138 units evaluated during this event (i.e. units running that were capable of providing governor response) provided the 'sustained' governor response for this event.

Demand side resources contributed significantly to the recovery from this event. Subtle differences in relay setting sensitivity and the frequency at different points of the grid resulted in a partial deployment that was still effective.