

# Texas Reliability Entity Event Analysis

**Event:**  
**March 23, 2011 Loss of Generation  
Category 3 Event**

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## Executive Summary

On March 23, 2011 at 14:46:55, a 345 kV Current Transformer (CT) failed on circuit breaker XX (Substation E to Substation A 345 kV line) at the Transmission Entity A Substation A 345 kV substation. The CT failure caused the 345 kV bus protective relays to trip, simultaneously causing loss of the Substation A to Substation B 345 kV line, from Substation A to Substation C 345 kV line, from Substation A to Substation D 345 kV line, the Substation A 345/138 kV Autotransformer, and the Substation A to Substation E 345 kV line causing the loss of two combined cycle units operated by Generation Entity A, units A and B, loaded to approximately 1014 MW generation.

This event caused a frequency deviation from 59.973 Hz to 59.700 Hz at 14:46:50 per ERCOT Region high-speed frequency recorder data. Reliability Coordinator (RC) system operators implemented Level 1 of its Energy Emergency Alert (EEA) at 14:50 as reserves dropped below 2300 MW. Note: Balancing Authority (BA) reserves consist of Physical Responsive Capability (PRC) (spinning reserve and hydro synchronous reserve) plus Non-Controllable-Load-Resources (NCLR) providing Responsive Reserve Service (RRS) for the ERCOT Region. Up to 50% (1150 MW) of RRS can be from NCLR's, deployed automatically by underfrequency relays set at 59.7 Hz or manually upon directive issued by the Reliability Coordinator. The BA requested 1873 MW of Non-Spinning Reserve Services (NSRS) at 14:58. By 15:14 reserve levels went above 3000 MW and EEA Level 1 was cancelled at 15:23. Frequency recovered within 5 minutes and 40 seconds to 60 Hz at 14:52:30.

At 14:47:30 Generation Entity B unit C was generating 383 MW when the unit started ramping back and tripped at 14:48:55.

1014 MW tripped within the first minute of the event and an overall total of 1397 MW of generation tripped during the course of the event.

RC and BA personnel and systems operated effectively to restore system frequency by deploying reserves, and then afterwards restoring 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 14:46:55 on March 23, 2011, a 345 kV Current Transformer (CT) failed on circuit breaker XX (Substation E to Substation A 345 kV line) at the Transmission Entity A Substation A 345 kV substation. The CT failure caused the 345 kV bus protective relays to trip, simultaneously causing loss of the Substation A to Substation B 345 kV

line, from Substation A to Substation C 345 kV line, from Substation A to Substation D 345 kV line, the Substation A 345/138 kV Autotransformer, and the Substation A to Substation E 345 kV line. The loss of the Substation A to Substation E 345 kV line caused the loss of two combined cycle units (both 2x1 combined cycle units) operated by Generation Entity A, units A and B, loaded to approximately 1014 MW generation. Thirty-five (35) seconds later (14:47:30), Unit A at the Generation Entity B plant started to ramp back and tripped two minutes after the initial event at 14:48:55, causing the loss of 383 MW of generation. The trip was due to a Master Fuel Trip.

1014 MW tripped within the first minute of the event and an overall total of 1397 MW of generation was tripped over the course of the event.

List of Bulk Electric System (BES) transmission elements that tripped during the event:

Bulk Electric System Elements	
1	Substation A - Substation B 345 kV line
2	Substation A - Substation C 345 kV line
3	Substation A - Substation D 345 kV line
4	Substation A - Substation E 345 kV line
5	Substation A 345/138 kV Autotransformer
6 & 7	Substation E – Substation F 345 kV lines

System frequency dropped from 59.973 Hz to 59.700 Hz as a consequence of the loss of generation. The drop was arrested by governor action of ERCOT Region generators, aided by deployment of regulation of 106 MW and responsive reserve of 393 MW. These actions led to system frequency recovery within 5 minutes and 40 seconds to the pre-disturbance value of 60 Hz (at 14:52:30).

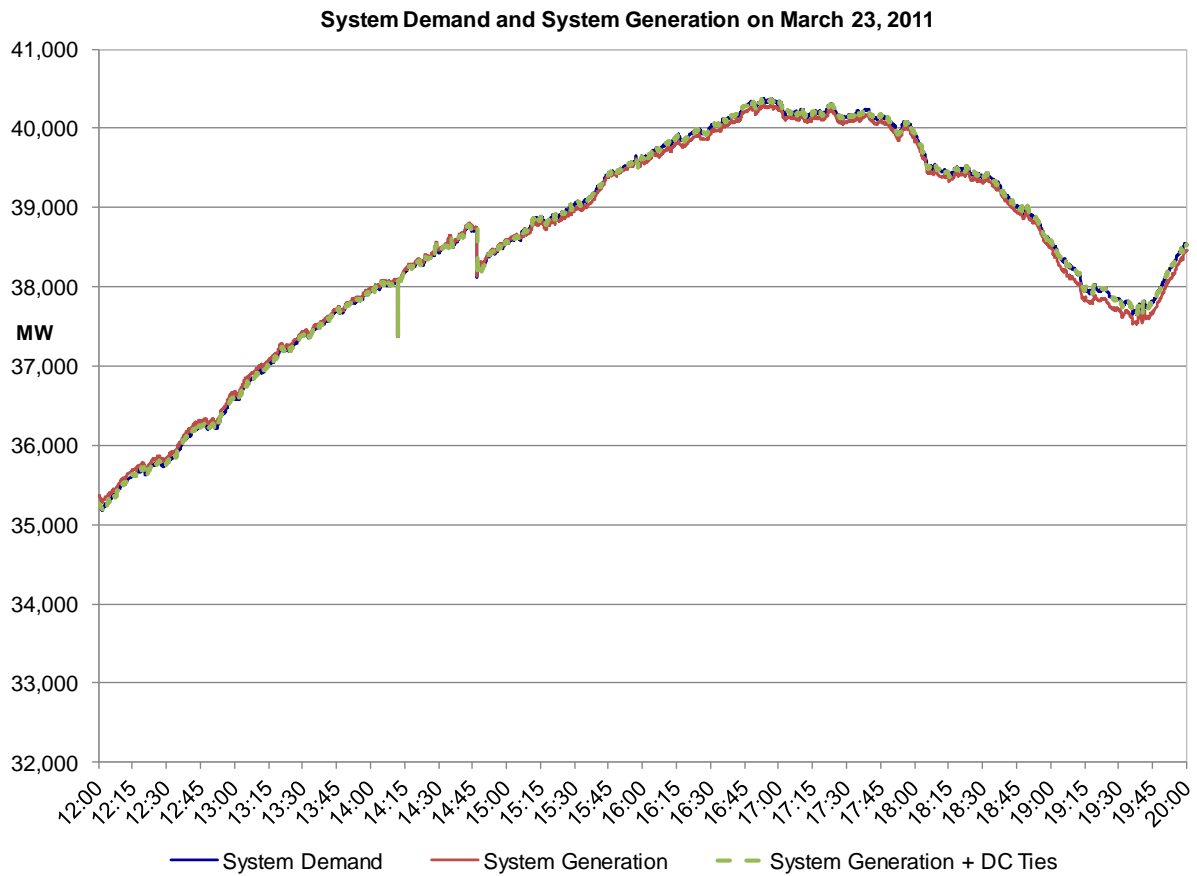
At 14:50, BA reserve levels fell below the minimum target of 2300 MW set by ERCOT Protocols during recovery from the event, causing the RC to declare an EEA Level 1. The BA requested 1873 MW NSRS services to deploy at 14:58. Reserve levels recovered and the RC cancelled the EEA Level 1 at 15:23.

This event did not meet the criteria as a NERC Disturbance Control Standard (DCS) event since the loss of generation was below the 1083 MW threshold within one minute for the ERCOT Region. The event met the definition of a Category 3a event (loss of load or generation of 1,000 MW or more in the ERCOT Region) under NERC's Event Analysis Working Group procedure.

## II. System Conditions Prior to Event

System conditions on March 23, 2011 were based on the ERCOT Morning Report:

System Projected Peak Load:	39,702 MW @ 17:00
Actual Load at 14:46:	38,735 MW
System Frequency:	59.973 Hz
Adjusted Responsive Reserves:	3223 MW
Number of 345 kV Line Outages:	12
Scheduled Generation Outages:	17,414 MW
Forced Generation Outages:	5917 MW



## III. Sequence of Events on March 23, 2011

- 14:46:48    ERCOT Region frequency prior to disturbance was 59.973 Hz

- 14:46:50 Substation A 345 kV bus tripped, causing the Generation Unit Combined Cycles Units A and B to come off line with approximately 1014 MW
- 14:46:50 ERCOT Region frequency dropped to approximately 59.700 Hz
- 14:47:30 Generation Entity B unit C ramp back from 383 MW
- 14:48:55 Generation Entity B unit C trips
- 14:50 RC declared EEA Level 1. Reserves dropped below 2300 MW
- 14:52:30 ERCOT Region frequency recovered to 60 Hz
- 14:58 1873 MW NSRS was requested
- 15:23 EEA Level 1 was cancelled
- 15:38 Substation A 345 kV bus returned to service  
Substation A – Substation B 345 kV line returned to service  
Substation A – Substation D 345 kV line returned to service
- 16:00 Generation Entity B unit A on-line
- 16:25 Substation A – Substation C 345 kV line returned to service
- 16:38 Substation A 345 kV Autotransformer returned to service
- 3/24/2011 17:00 Substation A – Substation E 345 kV line returned to service

## **IV. Analysis of Unit Trips**

### *A. Generation Unit – Combined Cycle Units A and B*

Generation Entity A (GO/GOP) combined cycle unit A and B tripped offline on March 23, 2011 at 14:46:55 when the Generation Unit plant was separated from the ERCOT Region. The units were loaded at 1014 MW and have a rated MW value of 1376 MW (74% of capacity).

Plant personnel performed a grid swap to backfeed power from the Transmission Operator. Investigation indicated that the cause of event was external to plant facilities. Transmission Entity A field service personnel contacted the plant to inform them that the event was initiated at the Substation A Substation, due to the failure of the CT monitoring C phase power on circuit breaker XX. Transmission Entity A applied to the RC for a metering exemption that would allow use of circuit breaker XX while monitoring only A and B phase power. Transmission Entity A field personnel notified Generation Entity A at 17:12 on March 24, 2011 that circuit breaker XX was back in service. Generation Entity A notified the QSE and returned to scheduled dispatch as of 03:00 on March 25, 2011.

Post event inspections identified a Heat Recovery Steam Generator (HRSG) leak on unit B. Generation Unit B remained out of service following the event through 19:55 on April 1, 2011 in order to affect repairs to HRSG. It is unknown if this event caused this damage to the B unit. The trip did not cause any damage to the remaining units.

### *B. Generation Entity B – Unit C*

Generation Entity B (GO/GOP) identified the cause of the Unit C trip due to a Master Fuel Trip (MFT). The unit was loaded at 383 MW and has a rated MW value of 415 MW (92% of capacity).

The unit C plant Distributed Control System logged a low frequency alarm (59.884 Hz) at 14:45:39 (Note: There is a one minute, 15 second time discrepancy between the unit C plant time versus the RC sequence of events time). At 14:46:06, the 3B and 3C feeders tripped which supply power to the pulverizers. At 14:46:07, the plant logged a low furnace pressure alarm (recorded value of -8.010 inWC). At 14:46:10, 3A feeder tripped. At 14:46:13.588, the MFT Relay tripped the boiler. At 14:49:15.248, the reverse power relay removed the generator from the grid as designed.

During the event, the boiler furnace draft control experienced an excursion caused by the Mills feeder trips.

The unit C did not suffer any damage as a result of the trip.

### *C. Transmission Entity A - Substation A Bus Fault*

At approximately 14:46 on March 23, 2011, a “C” phase free standing metering CT on the bus side of 345 kV circuit breaker (CB) XX suffered a catastrophic failure at the Substation A 345 kV substation. This CT is used for metering of the circuit from Substation E. The Substation A 345 kV bus is designed and operated as a single bus-single breaker station. The C-phase bus differential relay operated opening 345 kV CBs AA, BB, CC, XX and 138 kV CB YY (low side of Auto Transformer connected to bus). During this event, no autotransformer protection relays operated; however, the autotransformer differential lockout relays operated causing 345 kV high-side switch ZZ to open. The autotransformer disconnected from the system during the initial bus clearance, therefore there was no additional impact to the system due to the switch opening; however, the root cause of this operation is under review. At Substation A, after an initial bus differential relay operation, the bus differential relays will reset indicating the fault was isolated from the transmission system and the appropriate breakers opened. The Substation A 345 kV bus differential scheme allows a single reclose using Substation A 345 kV CB BB to energize the bus (this checks to see if the fault was successfully cleared). For the event of March 23, the fault was still present when CB BB reclosed and the bus differential relay operated again, initiating an operation of the bus differential lockout relay. The lockout relay tripped CB BB and blocked reclosing of the other breakers. The remote end of CB BB is Substation C (CB DD/EE) and it tripped on ground instantaneous when Substation A CB BB reclosed, which operated as per design. At 15:38 the 345 kV Substation A Bus and the 345 kV Substation A - Substation C line were returned to service, and the Substation A 345/138 kV Autotransformer was returned to service at 16:25 that same day. At 17:00 on March 24, 2011, 345 kV CB XX and the 345 kV Substation A - Substation E line was returned to service ending the sustained outage.

The Substation A RTU went down from 14:47:06 until 15:03:01 limiting visibility of both the Substation A 345 kV and 138 kV buses. The remote ends remained in service. The significance of this was that Transmission Entity A didn't have visibility of the 138 kV bus for that period of time; however, since Transmission Entity A had SCADA on the remote ends, this did not cause a problem.

Breakers involved operated as per design during this event. No personnel injuries or other equipment damage were identified.



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#### *D. Discussion – ERCOT Region Most Severe Single Contingency*

The Generation Unit A & B facility has a total capacity greater than 1000 kW, per the ERCOT Resource Asset Registration Form (RARF) tables. The Generation Unit station is connected to the ERCOT Region grid through a double-circuit 345 kV transmission path from the Generation Unit plant to Substation E. From the Substation E substation, there is a single 345 kV circuit to the Substation A.

The loss of the double-circuit (since they are on a common tower), or the loss of the single circuit, in effect, causes the loss of the entire Generation Unit A & B facility, as is the case during this event.

At the time of this event, the declared most severe single contingency in the ERCOT Region per NERC BAL-002-0 is 1354 MW. As you can see, the loss of the Generation Unit plant based on the single contingency loss exceeded this value.

Subsequent to this event, on April 14, 2011, the BA issued a Market Notice (W-B041411-01 Operations) that stated, effective April 22, 2011, the most severe single contingency for the ERCOT Region was being revised to 1375 MW. This revised rating will also cover the loss of the Generation Unit plant. No change has been announced for the current reserve limit of 2300 MW based on this revision of the most severe single contingency.

## **V. Response Analysis**

### *A. Initial Response*

The loss of 1397 MW of generation in the ERCOT Region on March 23, 2011 constituted a significant disturbance to grid operations (generation loss represented 3.5% of ERCOT Region load). The BA used the Region's resources and reserves to balance resources and demand and return system frequency to pre-disturbance frequency.

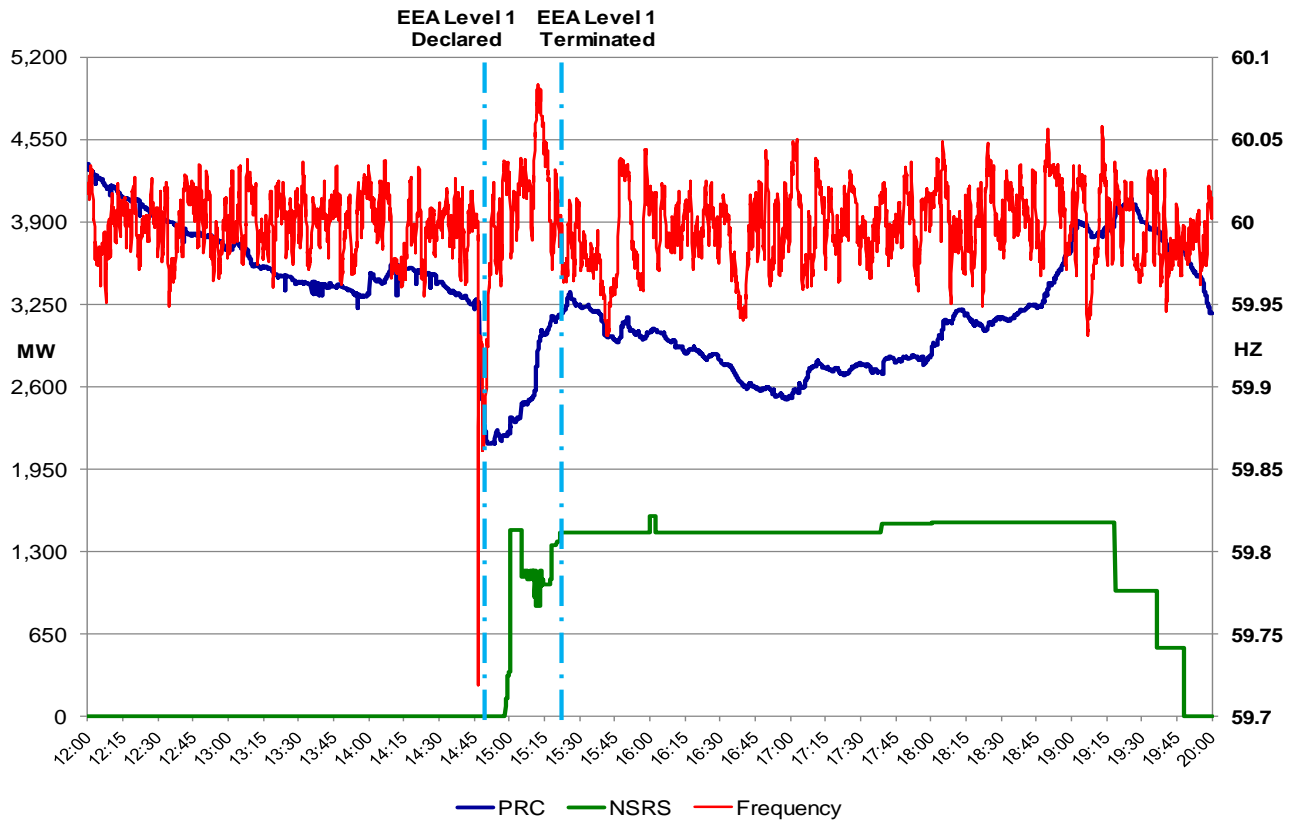
ERCOT Region frequency (measured at the RC control center) was at 59.973 Hz immediately prior to the disturbance. Immediately after the disturbance, system frequency dropped to 59.700 Hz. The following are among the actions that registered entities initially took to stabilize the system:

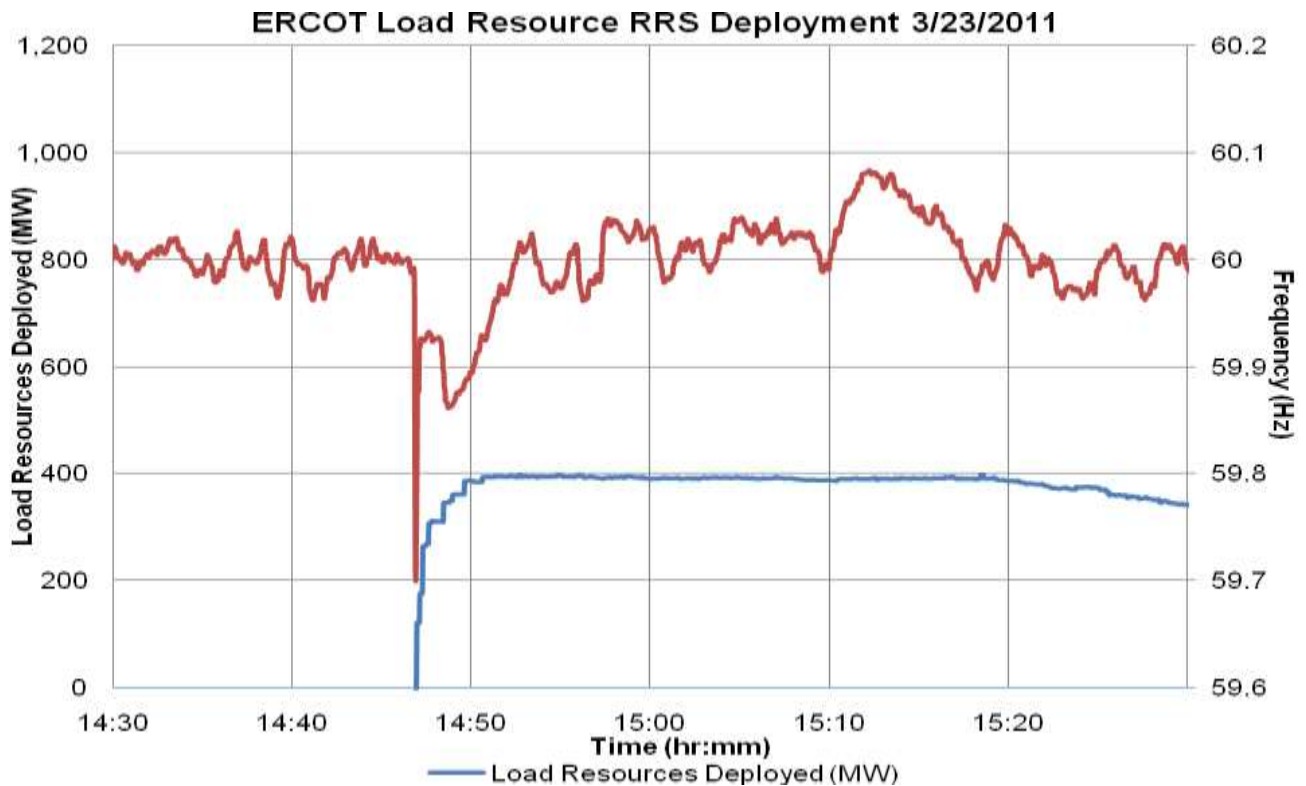
- Generator governor response arrested the frequency decline, as analyzed by the Performance, Disturbance, Compliance Working Group (PDCWG) in its draft report. The initial calculated system frequency response, termed the "B" point, was 1378.44 MW/0.1 Hz, which met the target of 420 established in ERCOT Protocols. The second calculated response point, termed "B+30" to denote that

it measures how well response is sustained 30 seconds after the event, was 1345.8.18 MW/0.1 Hz, which also met the minimum response level.

- Upon the loss of the Generation Entity A generation, the BA made step deployments of 106 MW of regulation, 282 MW of responsive reserve plus an additional 393 MW of NCLR providing RRS that deployed by underfrequency relay action, within 22 seconds of the frequency bottom.
- Upon the loss of the Generation Entity B Unit A generation, the BA made additional step deployments of 449 MW of responsive reserve.

The result of these actions was that system frequency returned to its pre-disturbance value of 60 Hz within 5 minutes and 40 seconds.





### *B. Reserves*

The recovery from the initial disturbance caused the reserve level to drop below 2300 MW at 14:50. The RC declared an EEA Level 1 and the BA requested 1873 MW NSRS services to deploy at 14:58. Reserve levels recovered and the RC cancelled the EEA Level 1 at 15:23.

### *C. Registered Entity Corrective Actions*

Equipment owners have taken the following actions to address the problems noted:

- Transmission Entity A is investigating the autotransformer differential lockout relays operation which tripped the 345 kV autotransformer high side switch 3368. Normal operation of the autotransformer differential lockout relays should have included either the operation of the autotransformer differential relays, or the autotransformer sudden pressure relays. No relay target was found on any of the fault sensing relays yet the lockout relay operated. This unnecessary relay operation had no impact on the transmission system since the 345 kV bus lockout included tripping of the autotransformer as a result of the sustained fault on circuit breaker XX.

- Transmission Entity A applied to the RC for a metering exemption that would allow use of circuit breaker XX while monitoring only A and B phase power until the CT can be replaced. Lead time on the replacement CT is approximately 30-36 weeks.
- A team of individuals from Transmission Entity A and the CT manufacturer completed the inspection of the failed CT. The team consisted of a factory representative, two individuals from Transmission Entity A's Equipment Support, and an M&C Supervisor from Transmission Entity A's District Support. Currently, Transmission Entity A is waiting for the manufacturer to complete its analysis concerning the suspected root cause of the failure. Transmission Entity A plans to follow-up with the CT manufacturer.
- Generation Entity B noted that no changes to frequency response are required for the unit C. Generation Entity B will address the tuning of the boiler controls if ultra-low sulfur test fuel continues to be used at the generation facility.

## **VI. Conclusions**

In general, the steps taken in the recovery from this event achieved the desired results. Given the number (three) of unit trips during the event, and the high volume of incoming communications, RC and BA operators handled the situation effectively.

Equipment owners have taken actions to address problems as noted above.

121 out of 140 units (running that were not excluded) (86.4%) provided the 'sustained' governor response for this event. 19 units did not contribute to system response for the event. The 'sustained' governor response rate continues to improve across the last large generation loss events (> 1000 MW) in the ERCOT Region; 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%.