Compendium of
Texas Synchrophasor Network Reports
for
2011 and 2012

Prof. Mack Grady
Department of Electrical & Computer Engineering
Baylor University
Waco, Texas
mack@ieee.org

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Plot 2. Time Trend of Modal Frequencies and Magnitudes

110120.0110000000000000.UT.Austin.3378.csv. UT_3378_A1[036].Value

<table>
<thead>
<tr>
<th>Minute of the Interval</th>
<th>Hz</th>
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**Max Mag** = 59.08

**Top 5% Mag >=** = 5.052

**Top 1/4 Mag >=** = 1.209

**Top 1/2 Mag >=** = 0.583

**Top 3/4 Mag >=** = 0.255

Main Modes: Freq = 0.52, Damp. Ratio = 0.32

To copy to your clipboard, click anywhere on the form and then use Ctrl+Alt+PrintScreen.
The ERCOT Rolling Blackout

Wednesday, Feb. 2, 2011

• This new winter peak of 53334 MW was only 500 MW greater than the 2010 winter peak

• BUT, 5000 MW of generation was out of service due to the effect of extreme cold
Wind MW generation is not presently available on ERCOT’s public web site. However, by observing the voltage phase angle of West Texas with respect to U.T. Austin (i.e., central ERCOT), we believe that wind MW generation was low but on the rise at 5am when grid problems began, and that wind MW generation rose to moderate levels (approx. 10% of total generation) through the troubled 5am – 10am generation shortage period.
2-minute wide frequency window at the lowest point

Corresponding West Texas phase angle with respect to central ERCOT

West Texas Phase Angle Increases with Wind Generation to Help Arrest the Freq Drop
Progression of Ringdowns, 5 am to 6 am
West Texas Voltage Phase Angle with respect to Central Texas
Average Hourly Price for Generation in ERCOT, $ / MWh, Feb. 1, 2, 3, 2011
Hourly Price Multiplied by Load, $Millions / Day, Feb. 1, 2, 3, 2011
(Is this what we were expecting from the Texas Nodal Market during an emergency?)

Feb. 1                                Feb. 2 (Rolling Blackout)                           Feb. 3
Texas Nodal Market Creates a New West Texas Oscillation Mode with Time Period $\approx 30$ minutes

One Example, Sunday Morning, April 17, 2011

Voltage Phase Angles Relative to Central ERCOT, 1-Minute Averages

Five Hours Beginning 00:00 CDT, Sunday, April 17, 2011

Texas Nodal Market Has Created a New West Texas Oscillation Mode with Time Period $\approx 30$ minutes

1. Unusual large, slow angle rings I had not noticed before. Period $\approx 30$ mins, $10^\circ$ to $15^\circ$ peak-to-peak.

Texas Nodal Market Has Created a New West Texas Oscillation Mode with Time Period $\approx 30$ minutes

Prof. Mack Grady, U.T. Austin

Texas Nodal Market Has Created a New West Texas Oscillation Mode with Time Period $\approx 30$ minutes

**Sunday Morning, April 17, 2011**

Voltage Phase Angles Relative to Central ERCOT, 1-Minute Averages

- McD
- UTPA

Five Hours Beginning 00:00 CDT, Sunday, April 17, 2011

Prof. Mack Grady,
U.T. Austin
McDonald Observatory Voltage Phase Angle Relative to Central ERCOT

Hour of March 11, 2011

Texas Synchrophasor Network’s graph of West-to-Central ERCOT Voltage Angle

ERCOT’s graph of West-to-North P flow
McDonald Observatory Voltage Phase Angle Relative to Central ERCOT

UT Pan Am Voltage Phase Angle Relative to Central ERCOT

Texas Synchrophasor Network’s graph of West-to-Central ERCOT Voltage Angle

Texas Synchrophasor Network’s graph of South-to-Central ERCOT Voltage Angle
West Texas Voltage Phase Angle Advances 80+ Degrees in 6 Hours

Voltage Phase Angle Relative to UT Austin
1-Minute Averages, Tuesday, April 26, 2011, Beginning 09:00 CDT

Hour of the Week, CDT

Degrees

McD

PanAm
Strong 30-Minute Oscillations Caused by Texas Nodal Market Price Fluctuations Continue to Break Out in West Texas Phase Angle

http://users.ece.utexas.edu/~grady/Texas_Synchrophasor_Network.html

Texas Synchrophasor Network. Funding provided by EPRI, equipment provided by Schweitzer Engineering Labs, Utility members are Austin Energy and (new) Brazos Electric Cooperative, Waco.
Strong 30-Minute Oscillations Due to Texas Nodal Market Price Fluctuations Are Now Observed in South Texas Voltage Phase Angle

http://users.ece.utexas.edu/~grady/Texas_Synchrophasor_Network.html

Texas Synchrophasor Network. Funding provided by EPRI, equipment provided by Schweitzer Engineering Labs, Utility members are Austin Energy and (new) Brazos Electric Cooperative, Waco.
McDonald Observatory Average Voltage Phase Angle
1-Minute Intervals, Beginning Sunday, January 1, 2012

Waco Average Voltage Phase Angle
1-Minute Intervals, Beginning Sunday, January 1, 2012

UT Pan Am Average Voltage Phase Angle
1-Minute Intervals, Beginning Sunday, January 1, 2012

ERCOT Power Flow North to South
ERCOT Power Flow South to North

South Texas Exports
South Texas Imports

West Texas Exports
West Texas Imports

370 miles
100 miles
280 miles

Straight-Line Miles

Page 1 of 2
Harris 69kV Substation Minimum Frequency
1-Minute Intervals, Beginning Sunday, January 1, 2012

Harris 69kV Substation Maximum Frequency
1-Minute Intervals, Beginning Sunday, January 1, 2012
McDonald Observatory Average Voltage Phase Angle
1-Minute Intervals, Beginning Sunday, January 8, 2012

Waco Average Voltage Phase Angle
1-Minute Intervals, Beginning Sunday, January 8, 2012

UT Pan Am Average Voltage Phase Angle
1-Minute Intervals, Beginning Sunday, January 8, 2012

ERCOT Power Flow North to South
ERCOT Power Flow South to North

South Texas Exports
South Texas Imports

West Texas Exports
West Texas Imports
Harris Minimum Frequency
1-Minute Intervals, Beginning Sunday, January 8, 2012

Harris Maximum Frequency
1-Minute Intervals, Beginning Sunday, January 8, 2012
Harris Minimum Frequency
1-Minute Intervals, Beginning Sunday, January 15, 2012

Harris Maximum Frequency
1-Minute Intervals, Beginning Sunday, January 15, 2012
McDonald Observatory Average Voltage Phase Angle
1-Minute Intervals, Beginning Sunday, January 22, 2012

Waco Average Voltage Phase Angle
1-Minute Intervals, Beginning Sunday, January 22, 2012

UT Pan Am Average Voltage Phase Angle
1-Minute Intervals, Beginning Sunday, January 22, 2012

• Profs: Mack Grady and Surya Santoso at U.T. Austin, Jaime Ramos at U.T. Pan American
• Equipment and Engineering Support: Donated by Schweitzer Engineering Labs.
• Utility Partners: Austin Energy, Brazos Electric Power Coop

Friends: Thanks to Schweitzer, we are rich in equipment. However, to be honest, we are out of cash. There is no better way to support a future power engineer than through this project. You can do that by sending a check to any one of us, made out to our respective university. Make sure the phrase “to support Prof XXX’s synchrophasor research” is somewhere on the check. Thank you.
Comments – Synchronized rms voltage measurements are also useful. The top graph shows consecutive deep rms voltage sags at UT Pan Am (red). The lower graph shows a zoom-in of the Harris 69 substation (adjacent to UT Austin campus), and Waco. We used the Harris substation voltage instead of UT Austin because it was less choppy. McDonald voltage showed no response. Point spacing is 30 points per second. Though low in magnitude, the voltage sags are clearly visible at Austin and Waco. Synchronization confirms the timing of the sag points.
Texas Synchrophasor Network, Sunday, Feb. 19, 2012, 03:17 GMT
740 MW Trip Causes ERCOT Frequency to Drop to 59.73 Hz
ERCOT Load = 33301 MW

Two minute window