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United States Government

Department of Energy

memorandum

Bonneville Power Administration

DATE: April 14, 2009

REPLY TO
ATTN OF: TPP/OPP-3

SUBJECT: Performance Validation and Noise Injection Staged Tests

TO: Melvin Rodrigues – TPP/OPP3 Richard Ellison - TOD/DITT1
Jim Burns – TOT/DITT2 T. Snodgrass – TOV/MEAD

1. Summary and Objectives

The proposed test plan includes two phases:

- Phase 1: calibration and benchmarking of a wide-band probing signal
- Phase 2: periodic probing during 2009-2010 operating season

There are several benefits from a proposed PDCI probing:

- Base-lining inter-area oscillation damping and mode shapes with respect to the system operating conditions (current activity under North-American Synchro-Phasor Initiative and WECC DMWG)
- Model validation with respect to representing inter-area power oscillations (current WECC MVWG activity)
- Tuning of "mode" meters (several DOE, BPA, SCE, and CEC projects)
- Evaluation of feasibility of inter-area oscillation damping controls (current BPA project)

Phase 1: Calibration and benchmarking of a wide-band probing signal

This test will be performed in coordination with WECC technical groups such as the DMWG and M&VWG, and is scheduled for May 6, 2009 with alternate days of May 7 or May 12 that may be used in the event that the test date must be changed or portions of the test must be repeated. Dates may be revised by System Operations to meet system requirements.

The test will include the following staged events:

- Energization of the Chief Joseph dynamic brake
- Insertion of 20-minute pseudo-random noise by modulation of the Pacific HVDC Intertie, similar to one used during August 2008 probing tests

- Insertion of 20-minute wide-band pseudo-random noise by modulation of the Pacific HVDC Intertie

Close examination of system behavior will be made before and throughout the test to confirm that system conditions are suitable for testing, and that the test is proceeding as expected. WECC members having a PDC StreamReader are invited to participate in this, and to use associated spectral analysis software to observe frequency domain signatures for their service areas. Alternate toolsets for this include Real Time Dynamic Monitor System (RTDMS) and the DOE ModeMeter. Extended data access at the California ISO and at the Pacific Northwest National Laboratory permits almost total backup of the BPA for test monitoring.

WAMS data from this test will be recorded automatically. However, it is necessary that the operators of the measurement facilities assure that the recording systems are ready for this, and that the owners of the data be aware that copies of the records will be requested for analysis. Such activities will be coordinated through the WECC Disturbance Monitoring Work Group (DMWG).

Successful completion of Phase 1 is a pre-requisite for continuation with Phase 2.

Phase 2: scheduled periodic probing during 2009-2010 operating season

BPA performed probing signal tests since 1999. Original probing tests were mid-level probing included square-wave pulses +/- 125 MW at pre-determined frequencies. Most commonly 0.25 Hz probing was used to excite North-South power oscillations. During 2003 summer operating season, BPA performed about 100 probing tests, often several times daily. Most recently, probing signal included band-limited noise injection as a more effective method to get a picture of the inter-area oscillation modes in the Western Interconnection.

This time, wide-band probing signal will be used to test the system under a wide variety of operating conditions. The tests have the following purpose:

- determine how frequency, damping and shapes of major WECC modes change with the system conditions
- determine transfer functions from DC current order to various AC system signals

The tests will be scheduled at 8:30, 14:30 and 17:30 every second Wednesday (except by special arrangement) starting June 10 2009, as long as a test procedure does not conflict with a peak in operator workload.

Since the test objective is to test the power system under a variety of conditions, if the system conditions during prior to a test are similar to those already tested, the test will be canceled. Specifically, we would like to get several test points with respect to the following system measurements:

- Grand Coulee – Malin phase angle
- Grand Coulee – Devers phase angle
- BC – Northwest flows
- BC – Alberta flows (including the tie being out of service)

- California – Oregon Intertie flows
- Midpoint – Summer Lake flows
- Montana Intertie flows (including status of Colstrip generators)
- Path 15 flows
- Path 26 (Midway – Vincent) flows
- East of River flows
- Amount of wind generation in Pacific Northwest

The determination to conduct or cancel a test will be made 15 minutes prior to a test by Test Director.

2. Operating Conditions Required For Tests

Operating Conditions for Test Series

- Power system operation is normal, the system is within System Operating Limits
- Pacific HVDC Intertie (**PDCI**) in bipolar operation with North to South flow
- PDCI power transfer above 1000 MW and less than 3000 MW

3. Test Precautions and Termination Procedure

If at any time the Test Observers, security coordinators or system operators identify conditions under which the tests should not continue then the Test Director will suspend the test sequence until those conditions are no longer present.

Reasons for suspending, modifying, or terminating the test sequence include but are not limited to the following:

- System emergency exists within the WECC
- Interconnections operating outside normal limits
- Undamped or unacceptable levels of system oscillations
- Facility operator deems that facility is unsafe for test, or that the test procedure is interfering with proper operation of that facility
- Test procedure is conflicting with a peak in operator workload
- A disturbance just occurred resulting in system frequency below 59.75 Hz

If a disturbance occurs during a probing test, the test must be terminated immediately.

4. Sequence of Test Events – Phase 1

The list below shows specific test events to be performed. Times for these test events are in Pacific Daylight (Advanced) Time (PDT).

The time and the duration of specific test events can be adjusted, during the test itself, to minimize interference with smooth operation of the power system. Signal description is given in Section 9.

Test Series A: Calibration Checks on PDCI Probing Signals

Step A0 [9:00] Celilo instrumentation check using +/-10MW waveform. Check proper function of PSG using Celilo/Sylmar DC metering.

Step A1 [9:10] Calibration check on MSF-20/6/17 for ±5 MW noise probing to determine HVDC pole response. Noise bandwidth will be 20 Hz. Adjust scaling of Probing Signal Generator (PSG) if needed.

Step A2 [9:15] Apply MSF-20/6/17 for ±5 MW noise probing to determine HVDC pole response. Expected duration is 5 minutes or less.

Step A3 [9:20] Calibration check on MSF-1/2/6/100 for ±10 MW noise probing of inter-area modes. Adjust PSG scaling if needed.

Step A4 [9:25] Apply MSF-1/2/6/100 for ±10 MW noise probing of inter-area modes. Expected duration is 10 minutes, but additional time may be needed for coordination of real-time observations at remote locations.

Step A5 [10:10] Calibration check on MSF-1/5/1/100 for ±5 MW noise probing of inter-area modes. Adjust PSG scaling if needed.

Step A6 [10:30] Apply MSF-1/5/1/100 for ±10 MW noise probing of inter-area modes. Expected duration is 10 minutes, but additional time may be needed for coordination of real-time observations at remote locations.

Test Series B: Noise Probing – 5 MW, wide-band noise limited at 5 Hz

Step B1 [11:10] Measurement of ambient noise conditions

Step B2 [11:30] Apply a ±10 MW MSF-1/5/1/100 for a duration of 12 periods (20 minutes).

Test Series C: Noise Probing – 10 MW, wide-band noise limited at 5 Hz

Step C1 [13:10] Measurement of ambient noise conditions

Step C2 [13:30] Apply a ±20 MW MSF-1/5/1/100 for a duration of 12 periods (20 minutes).

Test Series D: Noise Probing – 2.5 MW, wide-band noise limited at 15 Hz

Step D1 [14:10] Calibration check on MSF-1/15/1/100 for ±2.5 MW noise probing of inter-area modes. Adjust PSG scaling if needed.

Step D2 [14:30] Apply MSF-1/15/1/100 for ±5 MW noise probing for 12 periods (20 minutes). Expected duration is 20 minutes, but additional time may be needed for coordination of real-time observations at remote locations.

Test Series E: Noise Probing – 5 MW, wide-band noise limited at 15 Hz

Step E1 [15:10] Measurement of ambient noise conditions

Step E2 [15:30] Apply a ±5 MW MSF-1/15/1/100 for a duration of 12 periods (20 minutes).

Test Series F: Cross Validation of Probing Methods

Step F1 [16:10] Insertion F1 of the Chief Joseph Dynamic Brake

Step F2 [16:15] Apply a ±20 MW MSF-1/5/1/100 for a duration of 12 periods (20 minutes).

Test Series G: Cross Validation of Probing Methods

Step G1 [17:10] Insertion G1 of the Chief Joseph Dynamic Brake

Step G2 [17:15] Apply a ±5 MW MSF-1/15/1/100 for a duration of 12 periods (20 minutes).

5. Sequence of Test Events – Phase 2

The probing signal for the Phase 2 will be selected based on analysis on the test results for Phase 1. The list below shows specific test events to be performed. Times for these test events are in Pacific Time. The tests will be performed every second Wednesday starting June 10, 2009.

Test Series A: Noise Probing 10 MW, wide-band noise limited at 5 Hz

Step A1 [8:10] Measurement of ambient noise conditions

Step A2 [8:30] Apply a wide-band probing signal for a duration of 12 periods (20 minutes).

Test Series B: Noise Probing 10 MW, wide-band noise limited at 5 Hz

Step B1 [14:10] Measurement of ambient noise conditions

Step B2 [14:30] Apply a wide-band probing signal for a duration of 12 periods (20 minutes)

Test Series C: Noise Probing 10 MW, wide-band noise limited at 5 Hz

Step C1 [17:10] Measurement of ambient noise conditions

Step C2 [17:30] Apply a wide-band probing signal for a duration of 12 periods (20 minutes)

6. Test Coordinator and Responsibilities

Test coordination will be as follows:

1. Jim Burns will schedule the tests through the BPA outage dispatcher.
2. Jim Burns (BPA technical staff) will post proposed test dates on the BPA Web page.
3. The day before each test, BPA will send a message on the WECC Net notifying of the tests.
4. If there are concerns about abnormal system conditions, BPA dispatcher should be contacted as early as possible to cancel a test. The test will be resumed the next hour after the system returns to normal.
5. The probing signal will be injected by an operator of Celilo converter station. The operator will clear with the BPA dispatcher before the signal injection.

A listing of contact persons and test observers with phone numbers and e-mail addresses is provided on page 13. A phone bridge will be available on the day of the test.

7. Measurement Requirements

WAMS data from these tests will be recorded automatically. However, it is necessary that the operators of the measurement facilities assure that the recording systems are ready for this, and that the owners of the data be aware that copies of the records will be requested for analysis.

Required measurements for Test Series

- Continuous PDC, PMU and PPSM recording is required at BPA locations for the period 0800 through 1800 PDT of the test day.
- Continuous PDC, PMU and PPSM recording is highly desirable at all other WECC locations for the period 0800 through 1800 PDT of the test day where this data is available.
- Continuous recording with the Celilo PPSM is required. It is desired that the recording rate be 960 sps, but 240 sps is acceptable. Data acquisition filters must be set appropriately. To limit file size, it is highly important that the point-on-wave ac signals (signals 16 through 39) not be recorded. It is desirable that a separate recorder be installed for this sometime in the future.

Required facilities for real-time analysis

A key objective in the proposed tests is to "Refine and validate methods that identify power system dynamics with minimal or no use of probing signals." Key real-time resources for this are PDC StreamReaders, located at key locations, plus the spectral analysis tool provided as an add-on for the PDC StreamReader. Other documents refer to this tool as Dynamic Signal Analyzer (**DSA**), and that terminology is used here. Equivalent functionalities can also be obtained from alternate toolsets such as RTDMS and the DOE ModeMeter.

It is essential that DSA analysis be immediately available to the Test Director throughout the test. StreamReaders with DSA are essential at Dittmer and highly desirable at Celilo and PNNL Richland. It is also suggested that California ISO and other organizations that have PDC StreamReaders or alternate toolsets use them to observe test results in their service areas.

The following paths must be monitored during the tests:

- Ingledow – Custer
- Montana Intertie
- California – Oregon Intertie
- Pacific HVDC Intertie
- Midway – Vincent
- Palo Verde - Devers

Power spectrum must be monitored at the following generators for any torsional activities:

- Colstrip (9.45 Hz)
- Columbia Generating Station (around 5.2 Hz)
- Boardman (around 10 Hz)
- Diablo Canyon
- San Onofre
- Navajo (16.06 Hz)
- Palo Verde (8.3 Hz)
- Four Corners (10.49 Hz)

8. Test Preparations

The Celilo Probing Signal Generator (PSG) will be furnished with a suitable menu of playback files. These playback files will be verified on site for MW scaling and other characteristics before their use in long term probing.

9. Test Signals

The following table describes various types of noise signal definitions, some of which will be used in the test.

File Name	Test	Type	Band Width or Frequency
MSF-20/6/17	A	Multi-sine fitted	20 Hz 6^{th} filter
MSF/1/2/6/100	B	Multi-sine fitted	1 Hz 6^{th} order filter, stop at 2 Hz
MSF/1/5/1/100	C, D, G	Multi-sine fitted	1 Hz 1st order filter, stop at 5 Hz
MSF/1/15/1/100	E, F, H	Multi-sine fitted	1 Hz 1st order filter, stop at 15 Hz

MSF/N1/N2/N3/N4

MSF:
N1 – highest frequency at which the signal amplitude is 1
N2 – frequency at which the signal amplitude is 0
N3 – signal roll-off rate
N4 – duration in seconds

Figure 1 illustrates the difference between an existing narrow band probing signal and a proposed wide-band probing.

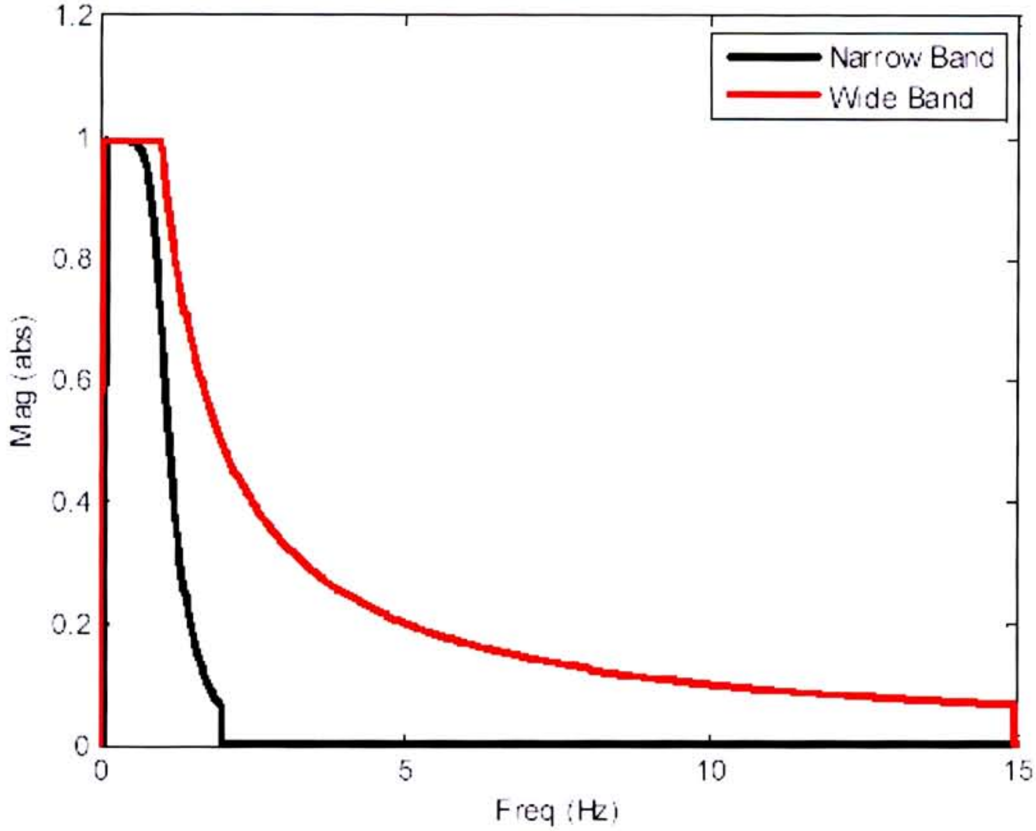

Figure 1: comparison between an existing narrow band and proposed wide-band probing signals

10. Peir Review

The test plan was reviewed by members of WECC Modeling and Validation Working Group and Disturbance Monitoring Working Group. The test plan was posted for 30-day comment period on WECC web-site. The only comment was received from BPA in support of the test.

11. Test Approvals

The test plan is submitted by:

Dmitry Kosterev - TPP
William A. Mittelstadt – TPM

Approved: James W Burns Date: 4/22/2009
Manager- Jim Burns, Technical Operations –TOT

Approved: R Ellison Date: 4/27/2009
Manager-Richard Ellison, Dittmer Dispatch - TOD

Approved: T Snodgrass Date: 4/16/09
Manager- T. Snodgrass, Munro Dispatch – TOV

Approved: Melvin Rodrigues Date: 4/20/09
Manager- Melvin Rodrigues, Transmission Planning – TPP

Table 1. Coordination and Contact Persons List

Contact	Utility	Function	Phone	Email
Jim Burns	BPAT	Test Director	360- 418-2331	jwburns@bpa.gov
Chief Dispachers	BPAT	All WECC dispachers		chiefdis@wscc.com
Richard Ellison	BPAT	Manager Dittmer Dispatch	360-418-2739	raellison@bpa.gov
Senior Operator	BPAT	Celilo	541-296-3615 X-300	
BPA Dispatcher	BPAT	Dittmer	360- 418-2281	
James Murphy	BPAT	Dittmer	360- 418-2413	jpmurphy@bpa.gov
Loren Anderson	BPAT	TESM-AMPN-2	360-418-2465	llanderson@bpa.gov
John Kerr	BPAT	System Operations	360-418-2340	jskerr@bpa.gov
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Melvin Rodrigues	BPAT	Nework Planning	360-418-8389	mtodrigues@bpa.gov
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DJ (Jack) Bernhardsen	NWSC	Reliability Coordinator	360-418-2956	jack@pnsc.center.com
Don Pape	NWSC	Reliability Coordinator	360-418-2966	dpape@wecc.biz
Greg Campbell	NWSC	Reliability Coordinator	360-418-8124	gregcampbell@nwsc.com
John Greenlaw	RMRC	Reliability Coordinator	970-461-7370	jgreenlaw@wecc.biz
G. Tillitson	CMRC	Reliability Coordinator	916-351-2434	gtillitson@caiso.com
Dave Strote	CGS	CGS Contact	509-377-8719	dlstrote@energy-northwest.com
John Dabney	CGS	CGS Contact	509-377-2129	jwdabney@energy-northwest.com
Ken Silver	DWP	Chief LA Load Dispatcher	818- 771-6748	kenneth.silver@ladwp.com
Bill Barlak	DWP	AC System Security	818-771-6779	william.barlak@ladwp.com
Brian Silverstein	BPAT	PCC Chair	360- 418-2122	blsilverstein@bpa.gov
Don Watkins	BPAT	OC Chair	360- 418-2344	dswatkins@bpa.gov
Tom Green	PSCO	TSS Chair	303-571-7223	thomas.green@xcelenergy.com
Perpetuo Tan	LADWP	PWG Chair	818-771-6776	perpetuo.tan@ladwp.com
Dave Hawkins	CAISO		916-351-4465	dhawkins@caiso.com
Bharat Bhargava	SCE	DMWG Chair	626 302 8684	bhargab@sce.com
Dmitry Kosterev	BPAT	MVWG Chair	360-619-6671	dnkosterev@bpa.gov
Steven L. Rueckert	WECC	Validation analysis	801- 582-0353	steve@wscc.com
Donald Davies	WECC		801- 582-0353	donald@wecc.biz
Henry Huang	PNNL	Data Analysis	509-372-6781	zhenyu.huang@pnl.gov
Ning Zhou	PNNL	Data Analysis	509-372-6438	ning.zhou@pnl.gov
John Hauer	PNNL	Data Analysis	509-375-4340	john.hauer@pnl.gov
John Pierre	UW	Data Analysis	307-766-4206	pierre@uwyo.edu
Dan Trudnowski	MSU	Data Analysis	406-491-2292	dtrudnowski@mtech.edu
Manu Parashar	EPG	Data Analysis	626-685-2015x130	parashar@electricpowergroup.com
Dan Hamai	WAPA	PDC	720-962-7382	ahamai@wapa.gov
Harry Lee	BCHT	PDC	604-528-3365	harry.lee@bchydro.bc.ca
Bill Mittelstadt	BPAT	Test facilitator	503-891-2246	wmittelstadt@bpa.gpv
Telephone Bridge		System Test Bridge	360-418-8001	pass code 0650#

References

[1] **Interim Report on the Model Validation Tests of June 7, 2000 -- Part 1: Oscillatory Dynamics**, principal investigator J. F. Hauer. WSCC Performance Validation Task Force (PVTF) of the Modeling and Validation Work Group, October 26, 2000.

[2] **Integrated Monitor Facilities for the Western Power System: WAMS Analysis in 2005**, J. F. Hauer, W. A. Mittelstadt, K. E. Martin, J. W. Burns, and Harry Lee. Interim report of the WECC Disturbance Monitoring Work Group, December 2005.

[3] **Use of the WECC WAMS in Staged System Tests for Validation of System Performance and Modeling: Summary Report for September 2005–August 2006,** J. F. Hauer, W. A. Mittelstadt, J W. Burns, K. E. Martin, Harry Lee, and D. J. Trudnowski**.** Interim report of the WECC Disturbance Monitoring Work Group, April 25, 2007. (Available at ftp://ftp.bpa.gov/pub/WAMS_Information/). Included as Chapter 14 in the **Power System Stability and Control** v2olume of **The Electric Power Engineering Handbook**, edition 2, L. L. Grigsby ed., CRC Press, Boca Raton, FL, 2007

Appendix A: Probing Test Simulations

A wide-band probing signal MSF/1/15/4/100 was simulated in GE PSLF program. System frequency, bus voltages and key flows were recorded and further analyzed.

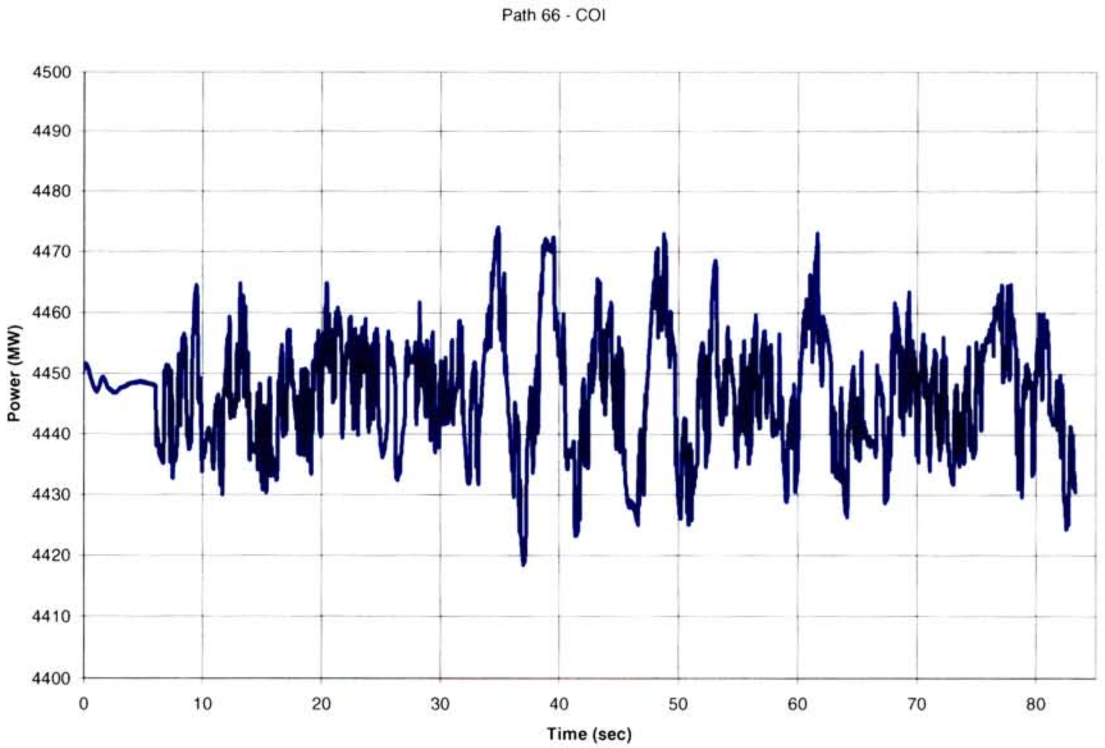


Figure A-1: COI power during +/- 25 Amp DC current wide-band probe

2008 Heavy Summer operating case was used in the simulations. Various disturbances were simulated during a probing test. Figure A-2 compares simulations of 2 Palo Verde outage during the probing test with a 2 Palo Verde outage without a probe. It is evident that probing test can degrade system damping performance if a disturbance to occur during the test. Therefore, probing tests must be supervised and, if a disturbance is detected, promptly terminated.

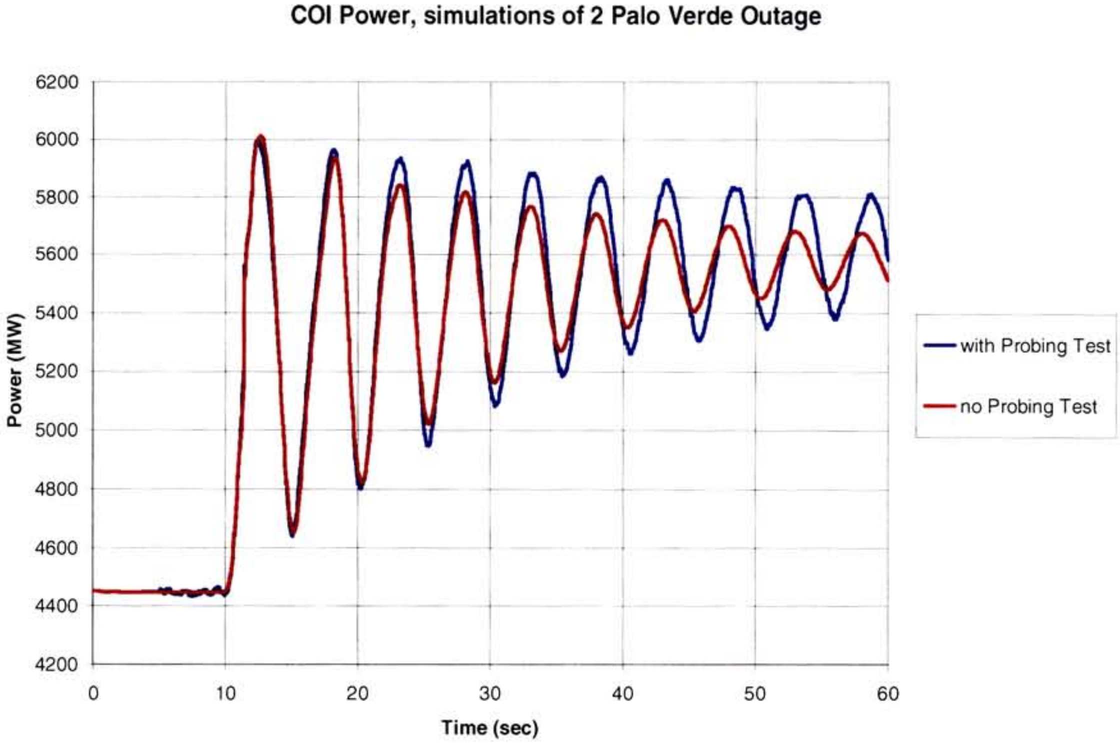


Figure A-2: simulations of 2 Palo Verde outage with and without a probe, 2008 heavy summer case

2011 Light Spring case was used in the simulations. Various disturbances were simulated during a probing test. Figure A-3 compares simulations of 2 Palo Verde outage during the probing test with a 2 Palo Verde outage without a probe. The effects of probing are not as pronounced as they were in the heavy summer case.

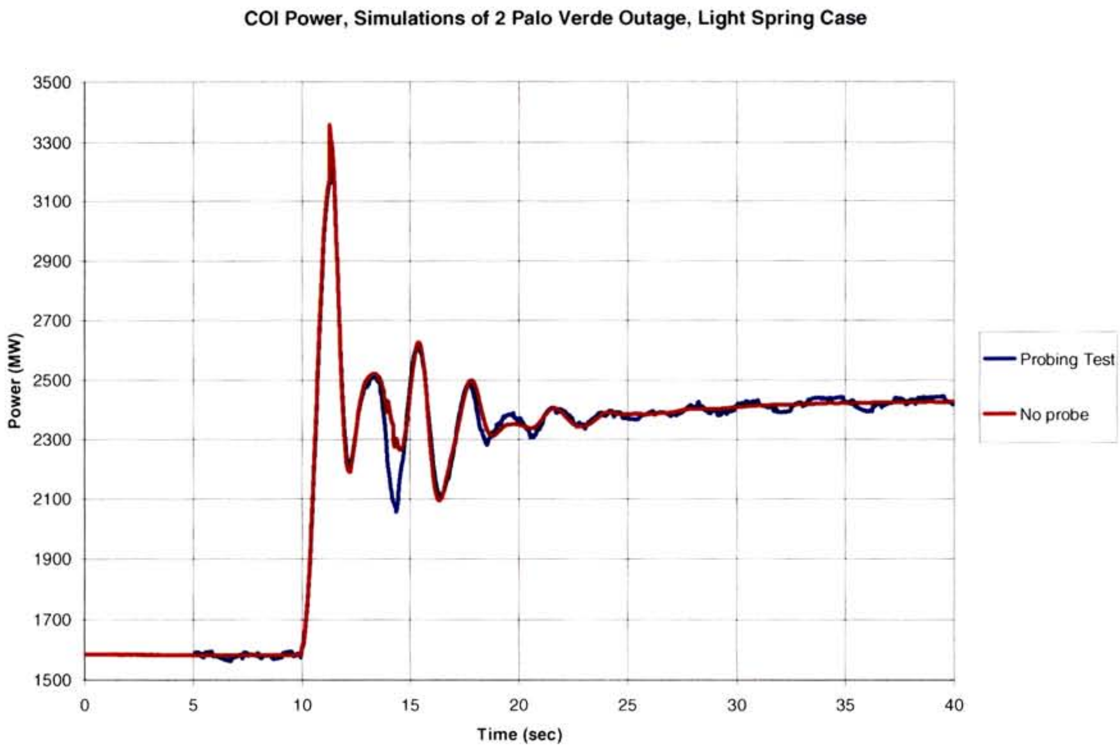


Figure A-2: simulations of 2 Palo Verde outage with and without a probe, 2011 light spring case

Appendix B: System Transfer Function Identification from August 2008 tests

Figure B-1 shows system transfer function identified during August 2008 tests. The objectives of 2009-2010 periodic probing program are:

- find how the transfer function changes with the system operating conditions
- find the signals which have the highest observability of the inter-area modes of interest
- extend the transfer function identification beyond 1.5 Hz

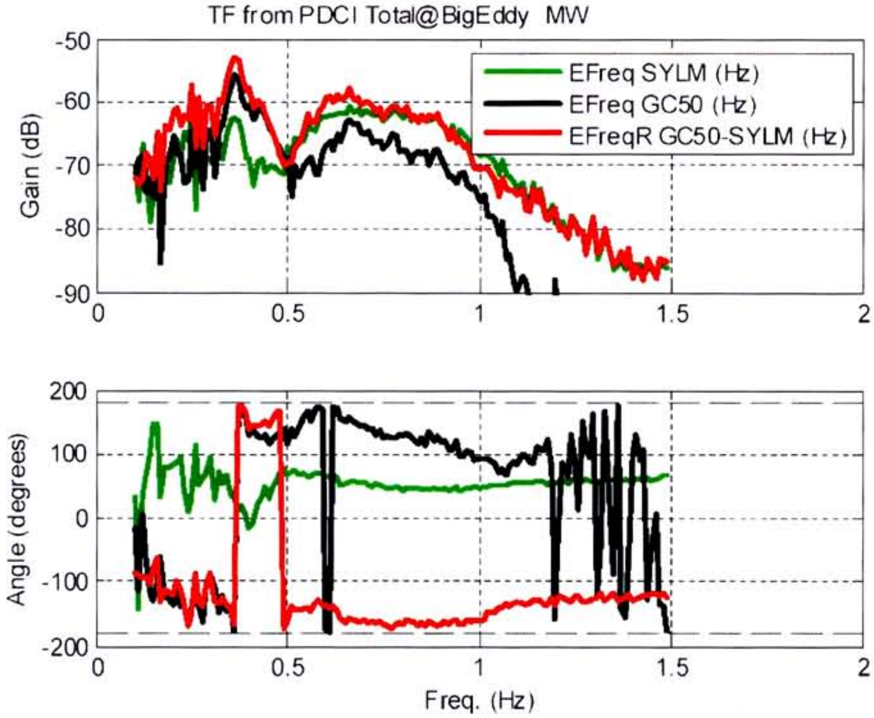


Figure B-1: system transfer function from August 2008 tests

Appendix C: Wide-Band Probing Signal

Figure C-1 shows signal MSF-1/15/1/100 in time and frequency domain. It has 1st-order roll off from 1 Hz to 15 Hz.

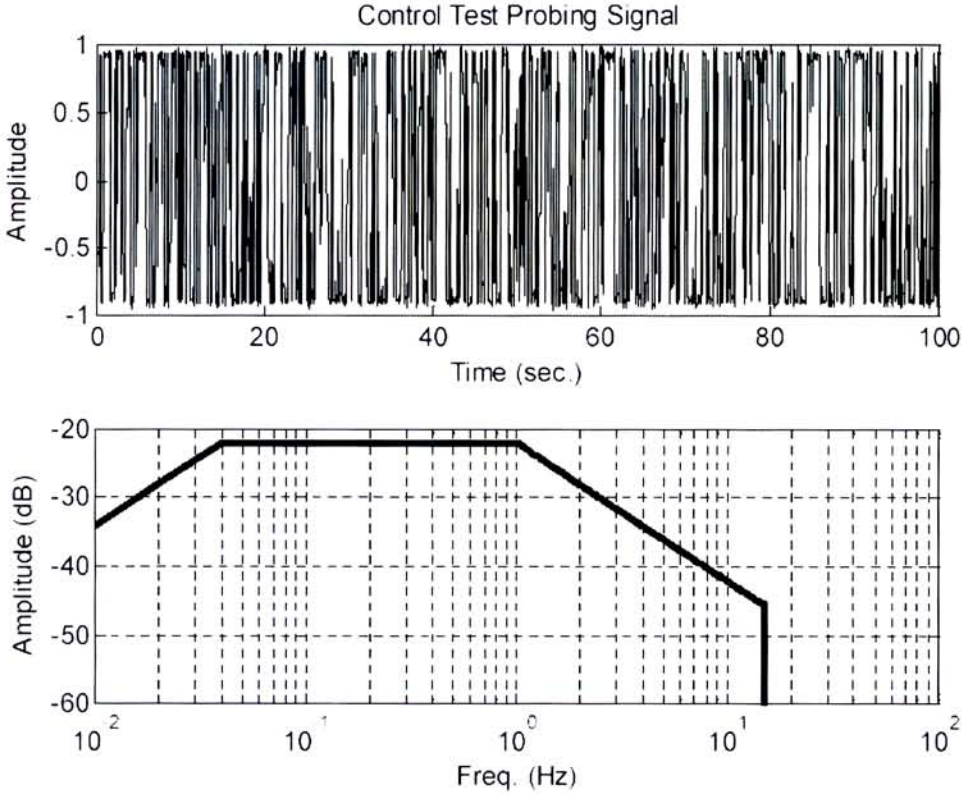


Figure C-1: probing signal MSF-1/15/1/100

Figure C2 compares MSF-1/15/1/100 at +5 MW with the previous wideband probing from 2005 (MSF-20/6/17).

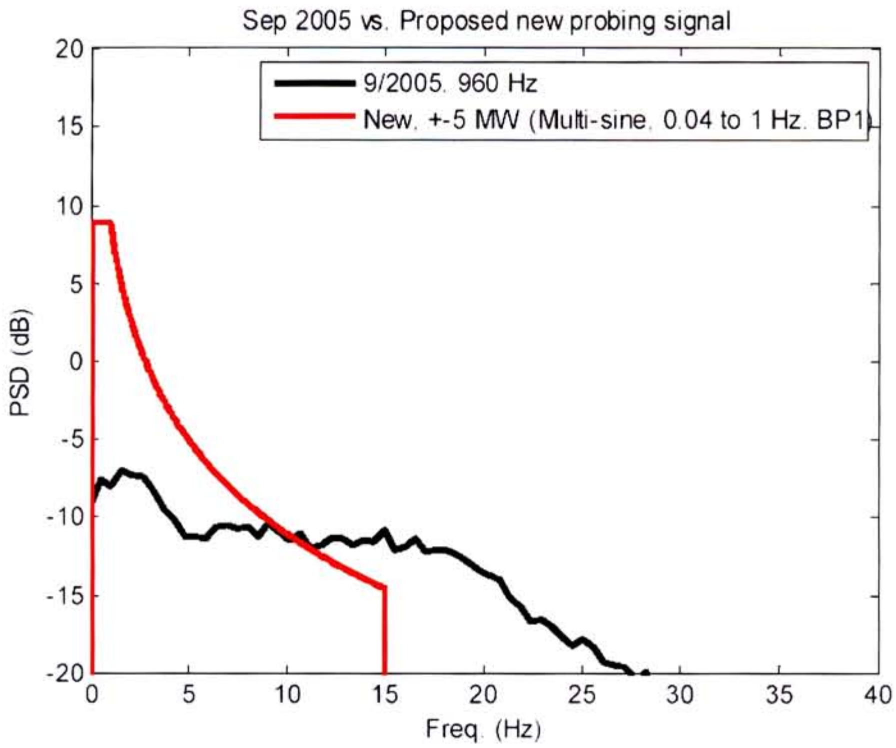


Figure C-2: comparing probing signal MSF-1/15/1/100 with MSF-20/6/17

Results 08hs01pr_prb Simulations

Working Note

Dan Trudnowski

Feb. 2009

This case applies a wide-band multi-sine PDCI probing signal to the PSLF simulation 08hs01. Figure 1 shows the probing signal and the spectrum. The remaining figures show the response of each generator. Note that the spectrum above 1 Hz rolls off very sharply. This indicates that PDCI modulation has low gain to the higher turbine modes.

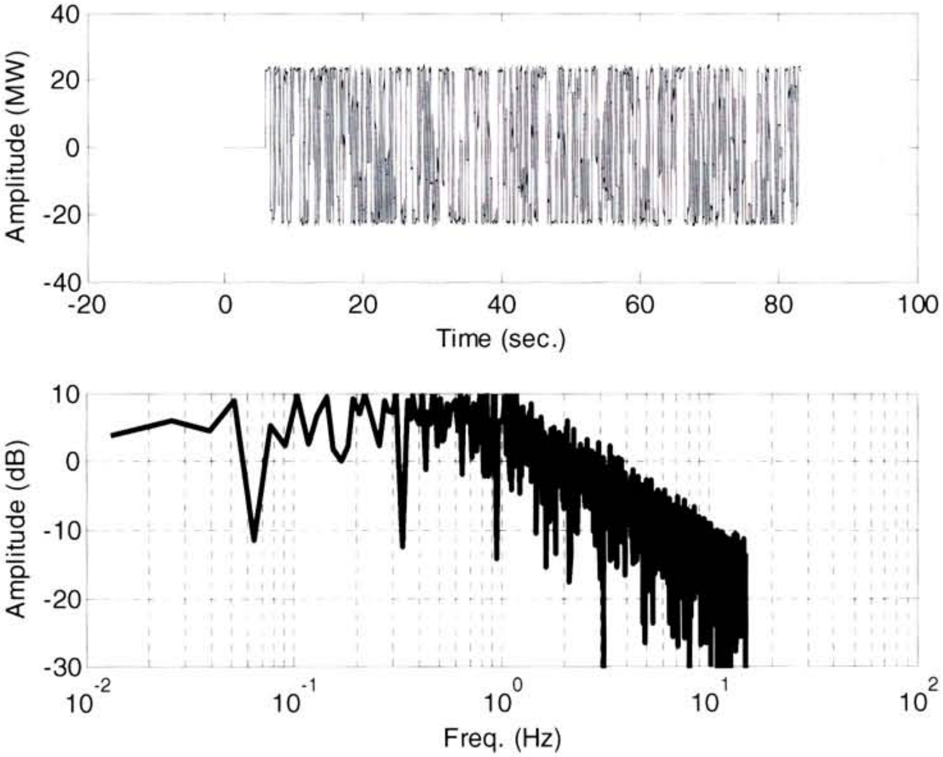
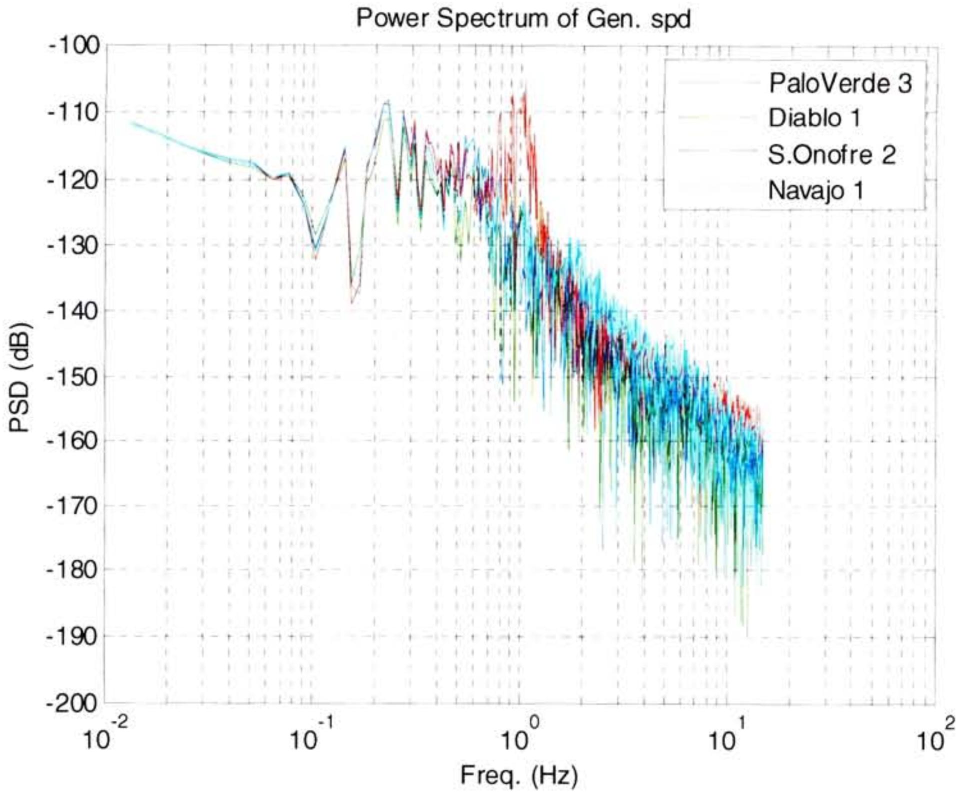
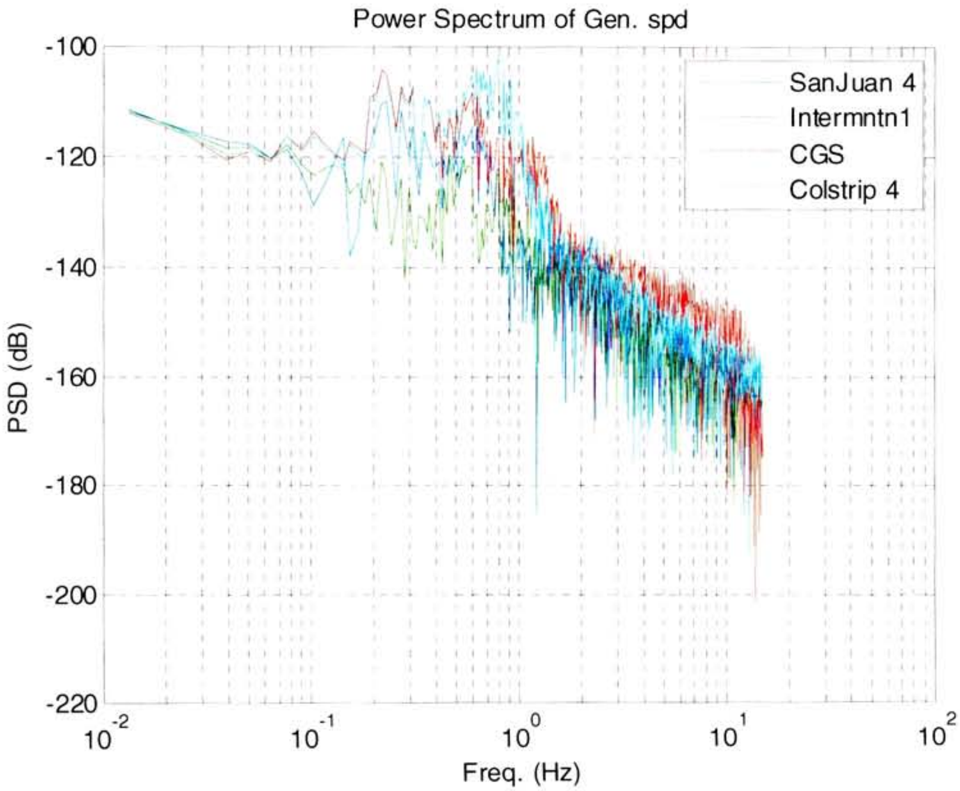
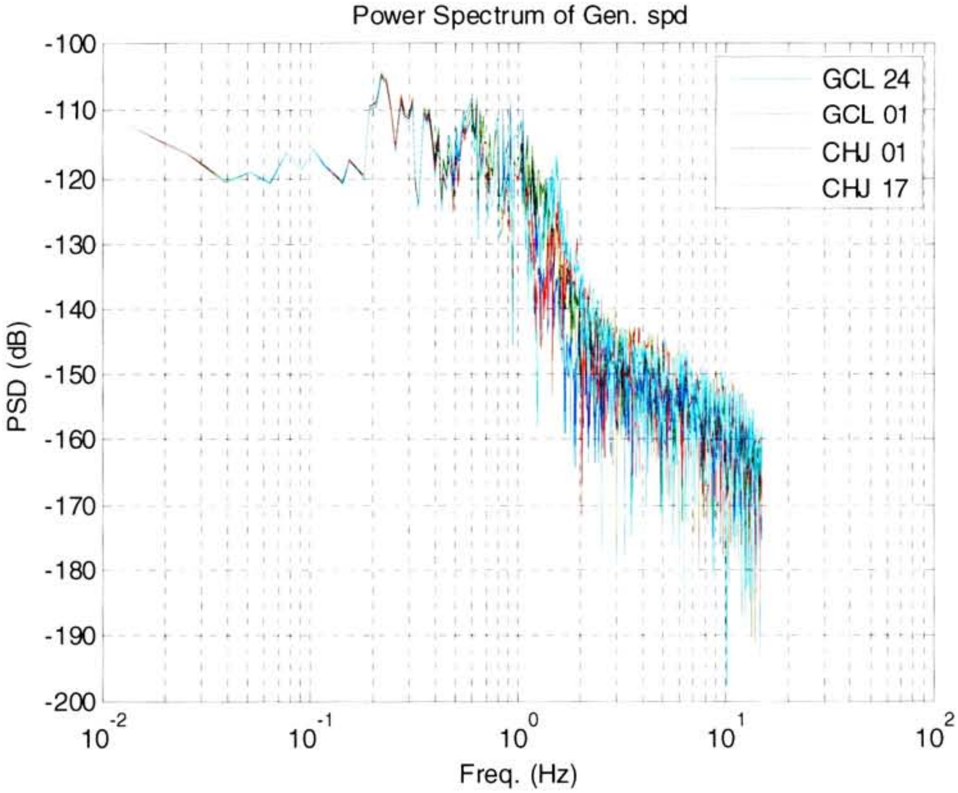
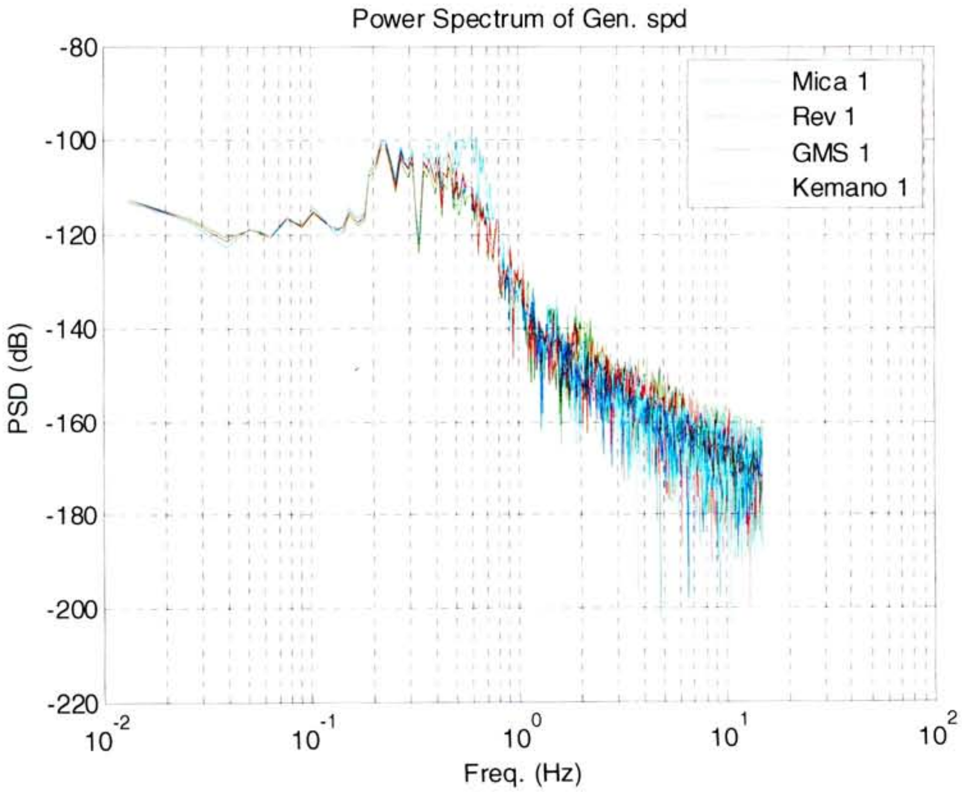


Figure 1: PDCI probing applied to 08hs01.


Power Spectrum of Gen. spd
PSD (dB)
Freq. (Hz)
PaloVerde 3
Diablo 1
S.Onofre 2
Navajo 1
-100
-110
-120
-130
-140
-150
-160
-170
-180
-190
-200
10^-2
10^-1
10^0
10^1
10^2


Power Spectrum of Gen. spd
PSD (dB)
Freq. (Hz)
SanJuan 4
Intermntn1
CGS
Colstrip 4
-100
-120
-140
-160
-180
-200
-220
10^-2
10^-1
10^0
10^1
10^2


Power Spectrum of Gen. spd
GCL 24
GCL 01
CHJ 01
CHJ 17
PSD (dB)
Freq. (Hz)


Power Spectrum of Gen. spd
Mica 1
Rev 1
GMS 1
Kemano 1
PSD (dB)
Freq. (Hz)

Results from Sept. 2005 Probing
Working Note
Dan Trudnowski
Feb. 2009

Test series B2 from the September 2005 probing test consisted of a ±5 MW PDCI probing signal applied for 5 minutes. The bandwidth of the signal was out to 20-Hz. This is the largest wide-band signal that has yet been applied [Hauer]. Figure 1 shows the time-domain PDCI responses. The red range is during B2 probing and the green range the ambient immediately after the probing. The spectrum of the probing is shown in Figure 3.

The figures that follow Figure 3 show that the AC system has very little response above the 1 Hz range due to the probing. There is no indication of interaction with higher turbine modes up to 15 Hz (the nyquist for PMUs).

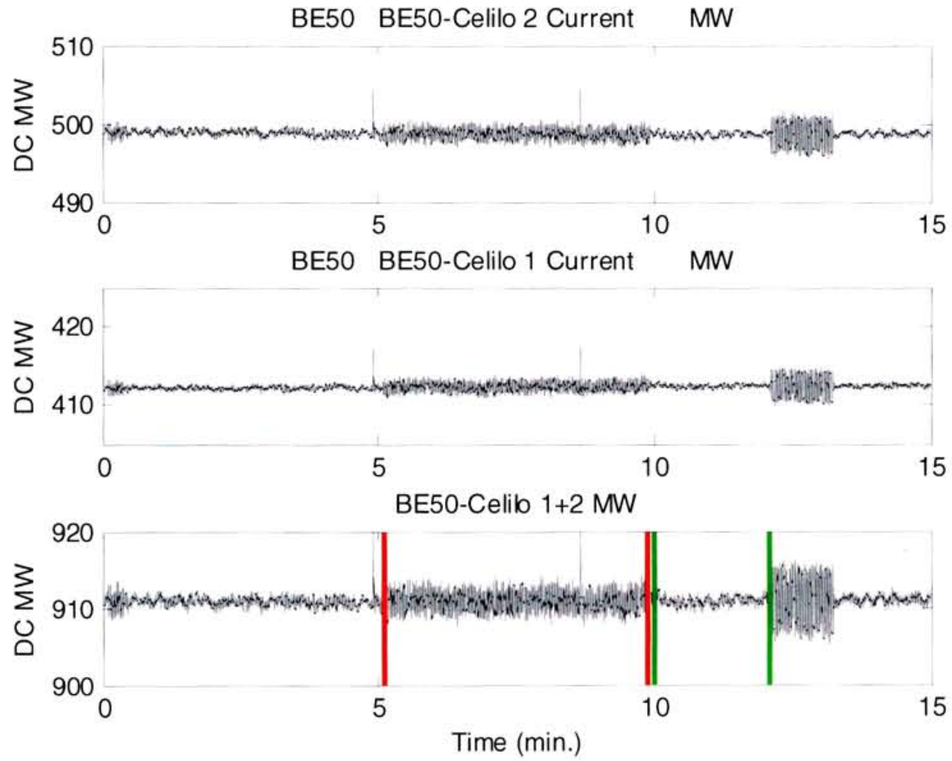


Figure 2: PDCI probing on Sept 2005, test series B2. Red range is test series B2. Green range is the ambient immediately after test series B2.

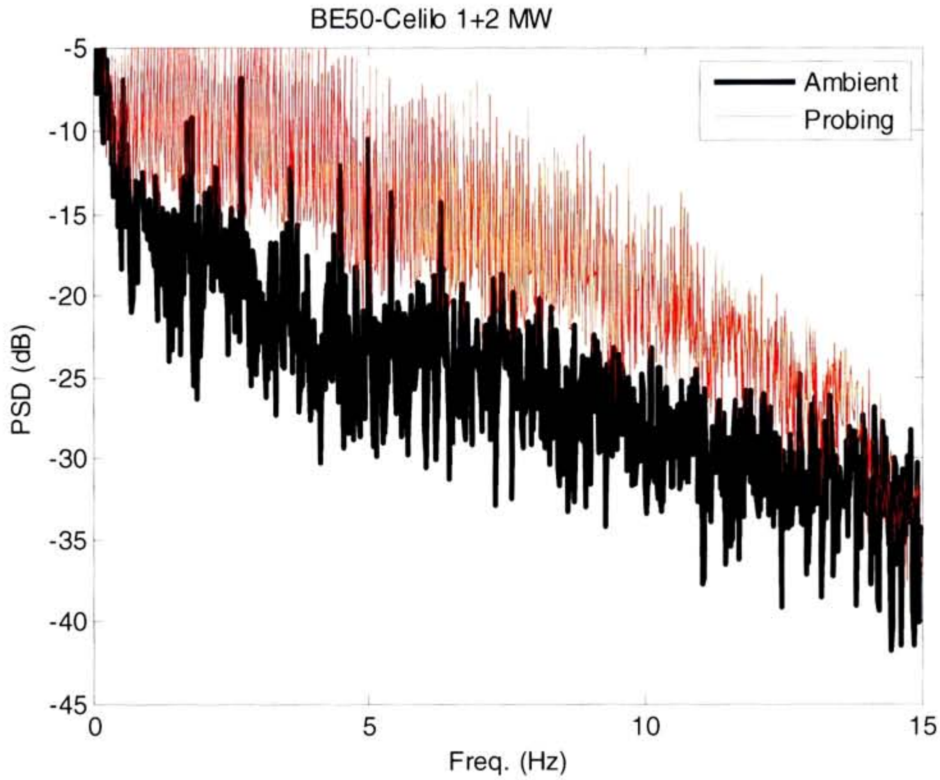
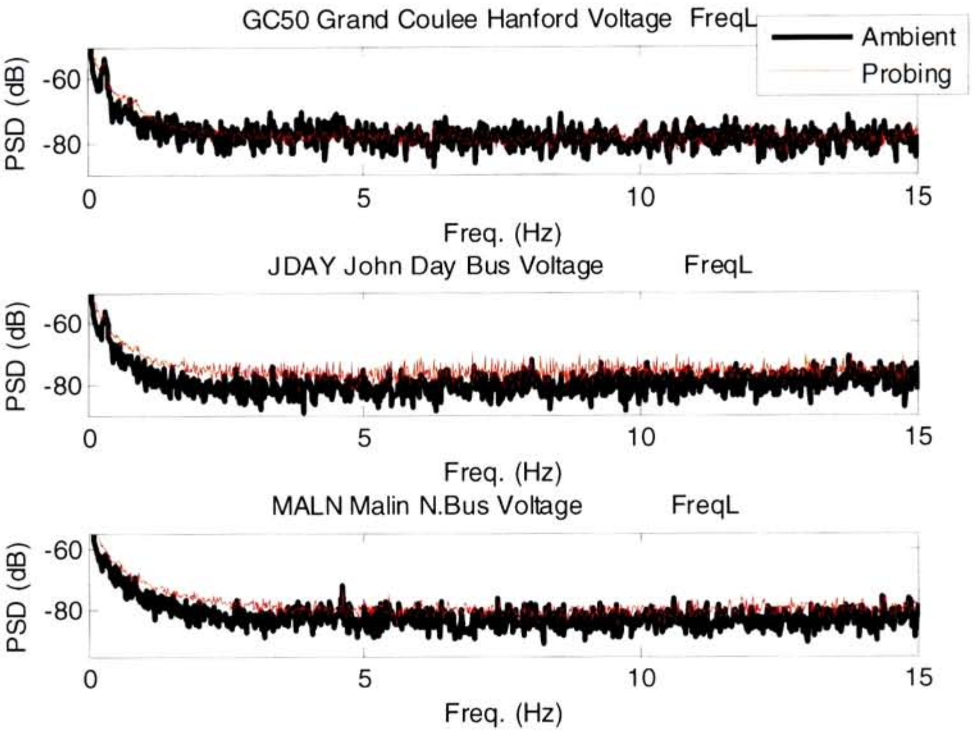
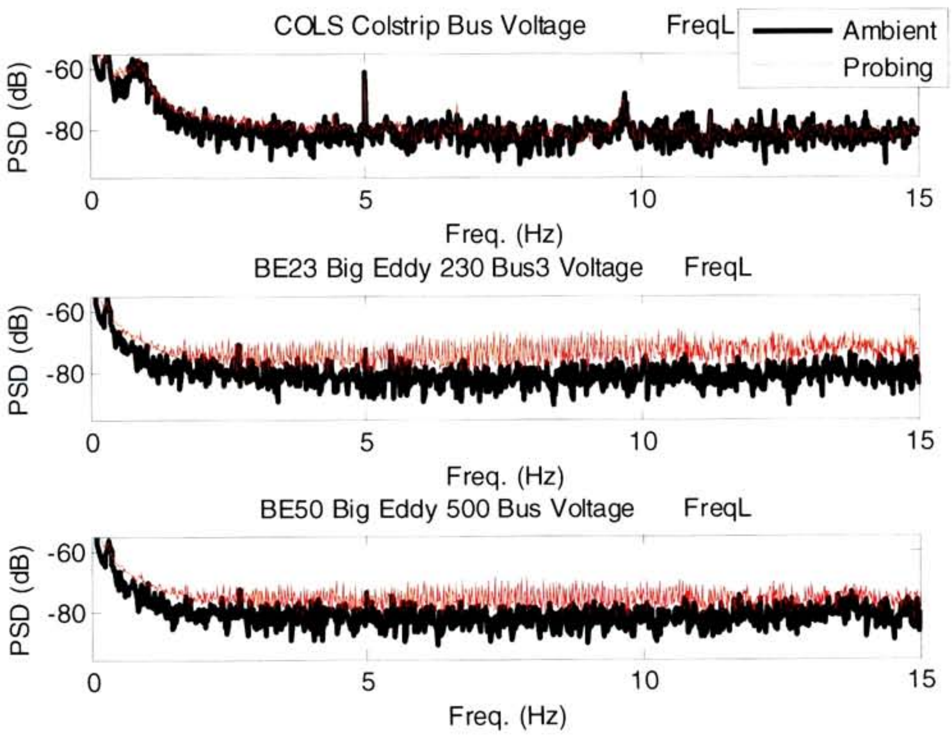
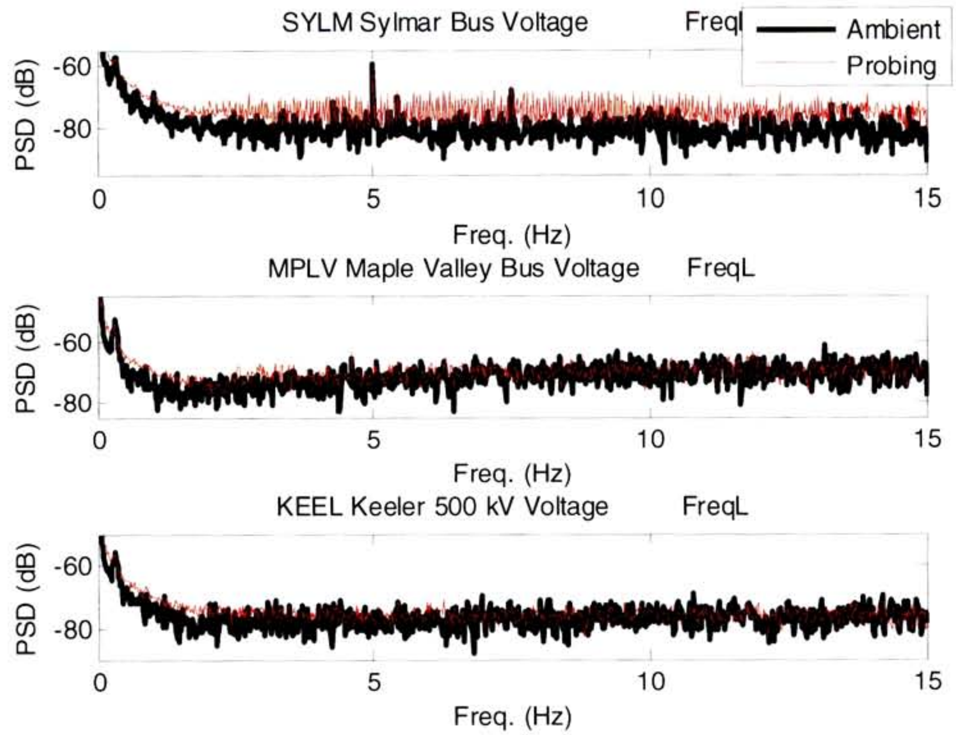
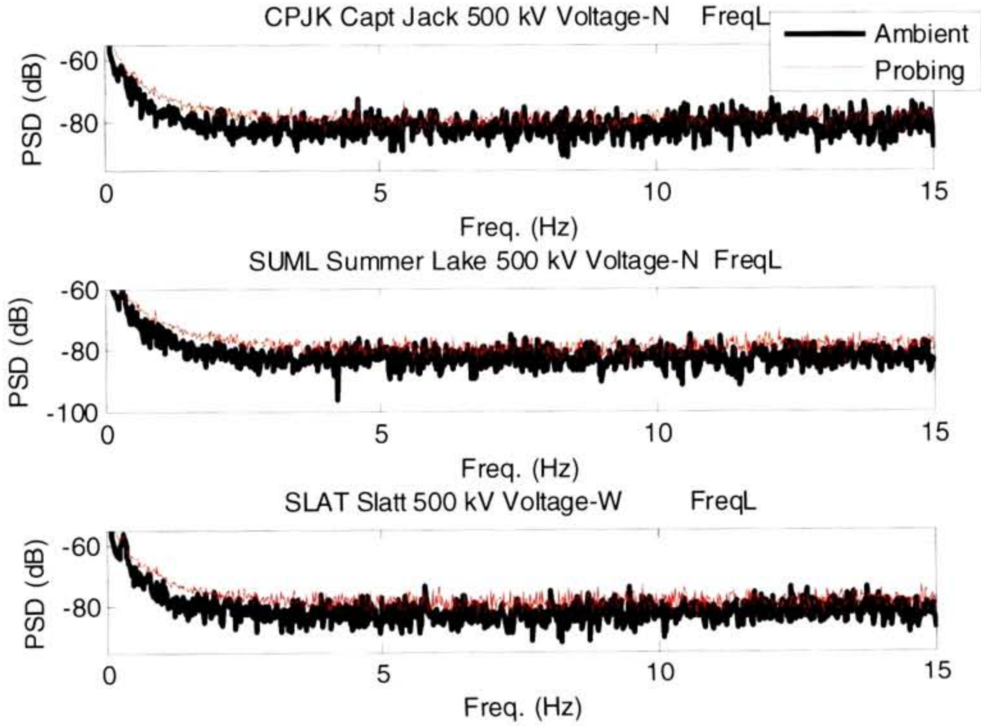


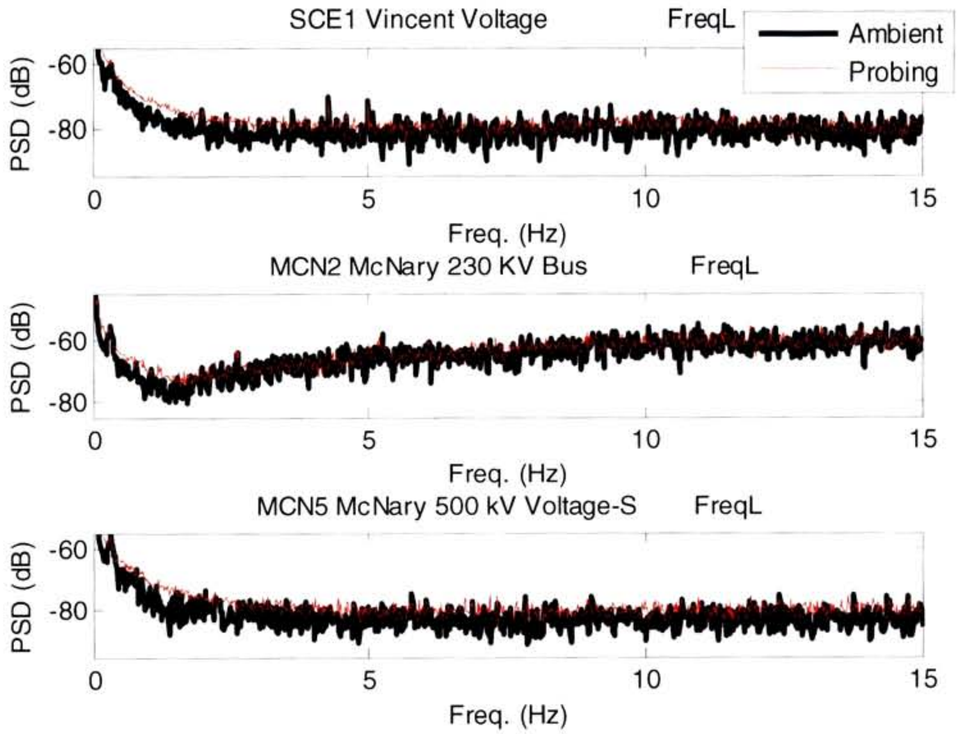
Figure 3: Power Spectral Density (PSD) of BE50-Celilo MW.

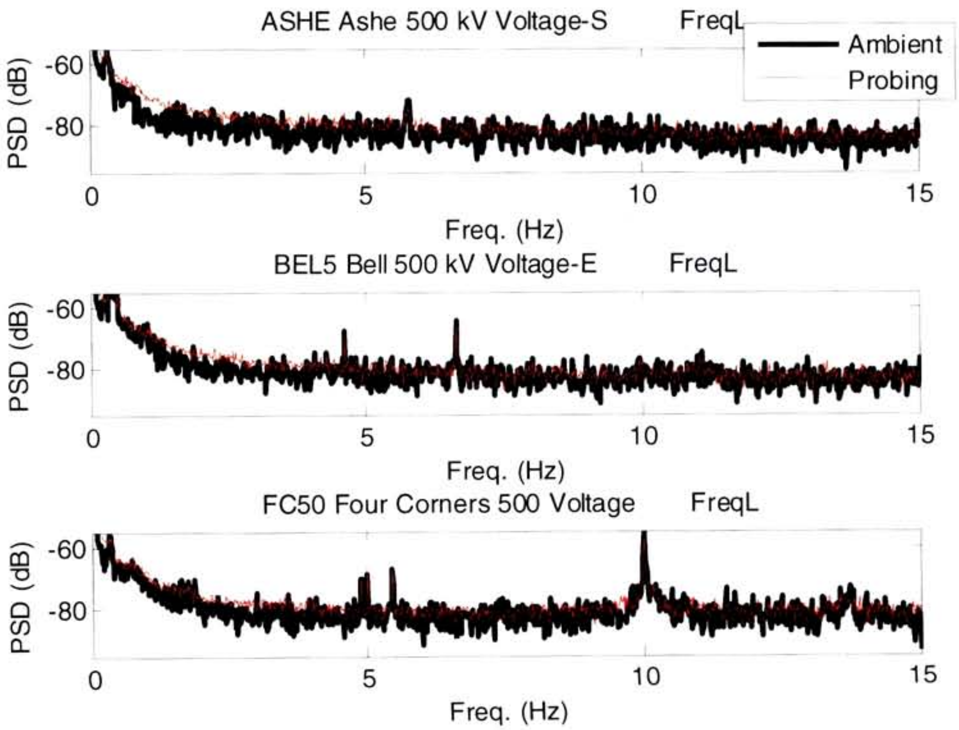

GC50 Grand Coulee Hanford Voltage FreqL
Ambient
Probing
PSD (dB)
-60
-80
0
5
10
15
Freq. (Hz)
JDAY John Day Bus Voltage FreqL
PSD (dB)
-60
-80
0
5
10
15
Freq. (Hz)
MALN Malin N.Bus Voltage FreqL
PSD (dB)
-60
-80
0
5
10
15
Freq. (Hz)

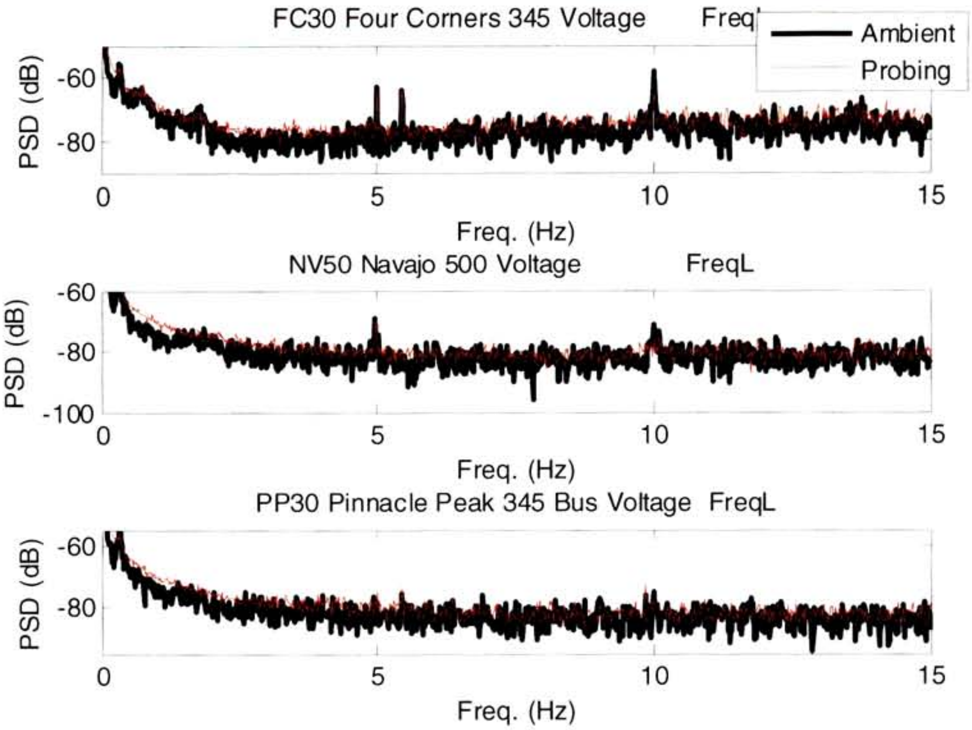

COLS Colstrip Bus Voltage FreqL
Ambient
Probing
PSD (dB)
-60
-80
0
5
10
15
Freq. (Hz)
BE23 Big Eddy 230 Bus3 Voltage FreqL
PSD (dB)
-60
-80
0
5
10
15
Freq. (Hz)
BE50 Big Eddy 500 Bus Voltage FreqL
PSD (dB)
-60
-80
0
5
10
15
Freq. (Hz)

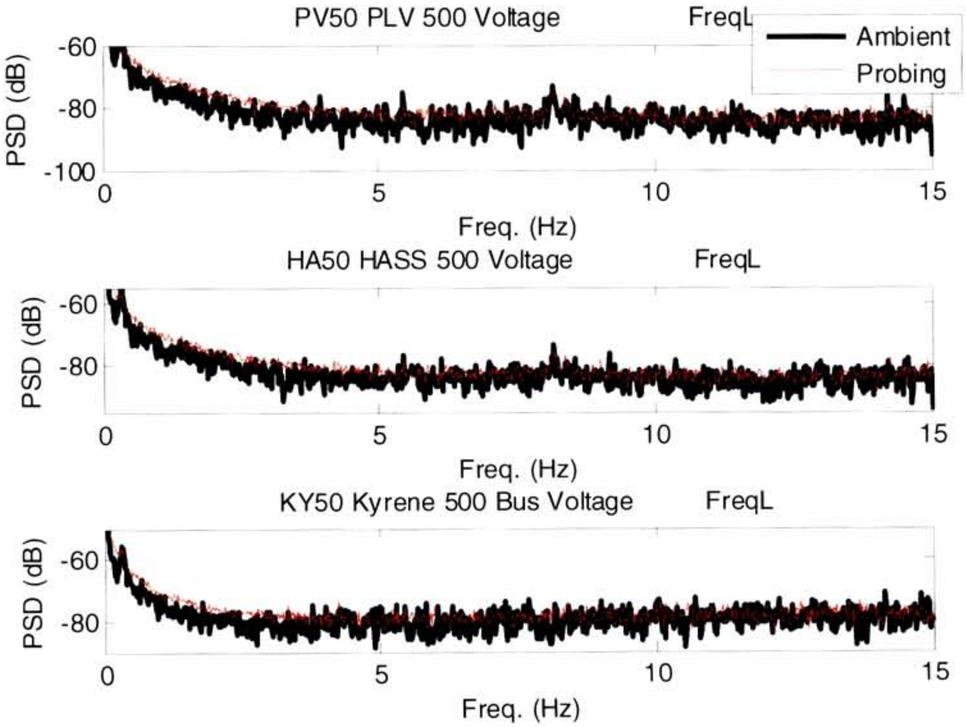

SYLM Sylmar Bus Voltage FreqL
Ambient
Probing
PSD (dB)
-60
-80
0
5
10
15
Freq. (Hz)
MPLV Maple Valley Bus Voltage FreqL
PSD (dB)
-60
-80
0
5
10
15
Freq. (Hz)
KEEL Keeler 500 kV Voltage FreqL
PSD (dB)
-60
-80
0
5
10
15
Freq. (Hz)

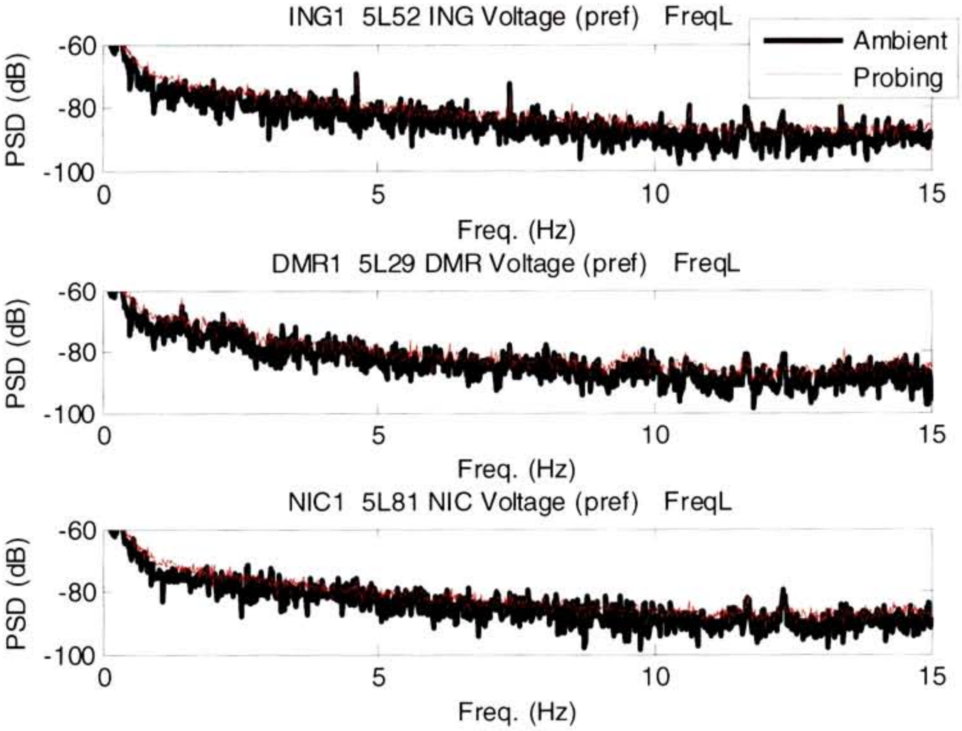

CPJK Capt Jack 500 kV Voltage-N FreqL
Ambient
Probing
PSD (dB)
-60
-80
0
5
10
15
Freq. (Hz)
SUML Summer Lake 500 kV Voltage-N FreqL
PSD (dB)
-60
-80
-100
0
5
10
15
Freq. (Hz)
SLAT Slatt 500 kV Voltage-W FreqL
PSD (dB)
-60
-80
0
5
10
15
Freq. (Hz)

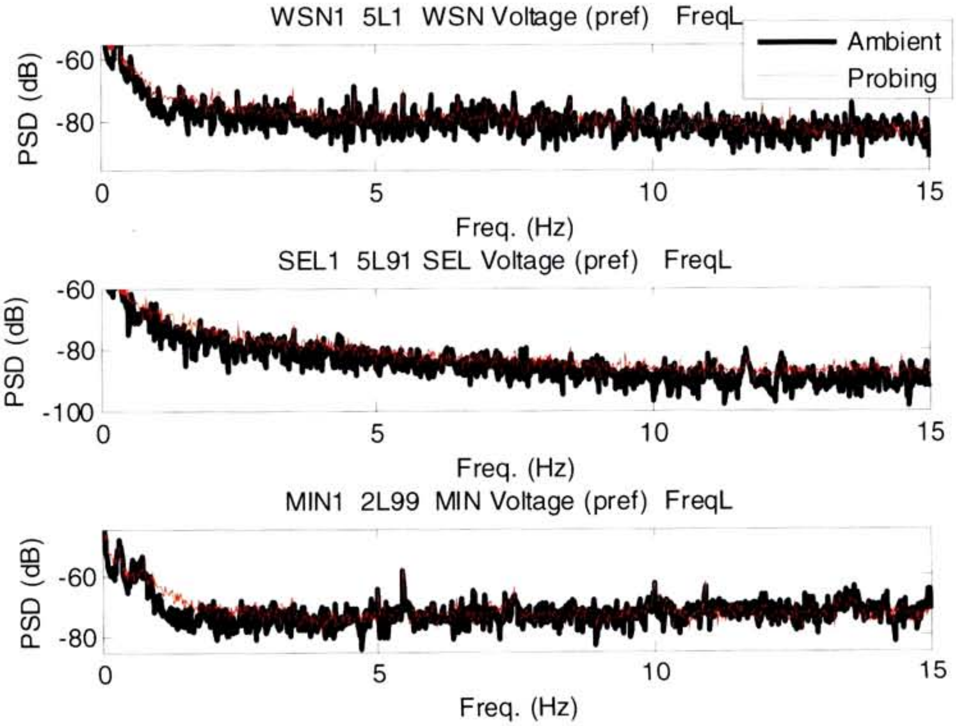

SCE1 Vincent Voltage FreqL
Ambient
Probing
PSD (dB)
-60
-80
0
5
10
15
Freq. (Hz)
MCN2 McNary 230 KV Bus FreqL
PSD (dB)
-60
-80
0
5
10
15
Freq. (Hz)
MCN5 McNary 500 kV Voltage-S FreqL
PSD (dB)
-60
-80
0
5
10
15
Freq. (Hz)


ASHE Ashe 500 kV Voltage-S FreqL
Ambient
Probing
PSD (dB)
-60
-80
0
5
10
15
Freq. (Hz)
BEL5 Bell 500 kV Voltage-E FreqL
PSD (dB)
-60
-80
0
5
10
15
Freq. (Hz)
FC50 Four Corners 500 Voltage FreqL
PSD (dB)
-60
-80
0
5
10
15
Freq. (Hz)


FC30 Four Corners 345 Voltage Freq
Ambient
Probing
PSD (dB)
-60
-80
0
5
10
15
Freq. (Hz)
NV50 Navajo 500 Voltage FreqL
PSD (dB)
-60
-80
-100
0
5
10
15
Freq. (Hz)
PP30 Pinnacle Peak 345 Bus Voltage FreqL
PSD (dB)
-60
-80
0
5
10
15
Freq. (Hz)


PV50 PLV 500 Voltage FreqL
Ambient
Probing
PSD (dB)
-60
-80
-100
0
5
10
15
Freq. (Hz)
HA50 HASS 500 Voltage FreqL
PSD (dB)
-60
-80
0
5
10
15
Freq. (Hz)
KY50 Kyrene 500 Bus Voltage FreqL
PSD (dB)
-60
-80
0
5
10
15
Freq. (Hz)


ING1 5L52 ING Voltage (pref) FreqL
Ambient
Probing
PSD (dB)
-60
-80
-100
0
5
10
15
Freq. (Hz)
DMR1 5L29 DMR Voltage (pref) FreqL
PSD (dB)
-60
-80
-100
0
5
10
15
Freq. (Hz)
NIC1 5L81 NIC Voltage (pref) FreqL
PSD (dB)
-60
-80
-100
0
5
10
15
Freq. (Hz)


WSN1 5L1 WSN Voltage (pref) FreqL
Ambient
Probing
PSD (dB)
-60
-80
0
5
10
15
Freq. (Hz)
SEL1 5L91 SEL Voltage (pref) FreqL
PSD (dB)
-60
-80
-100
0
5
10
15
Freq. (Hz)
MIN1 2L99 MIN Voltage (pref) FreqL
PSD (dB)
-60
-80
0
5
10
15
Freq. (Hz)

Illustrations of Applied Test Signals

The following figures are illustrative of the system response to signals that will be applied during this test. Additonal information on the test signals and system response is provided in [3] and in various other documents cited there.

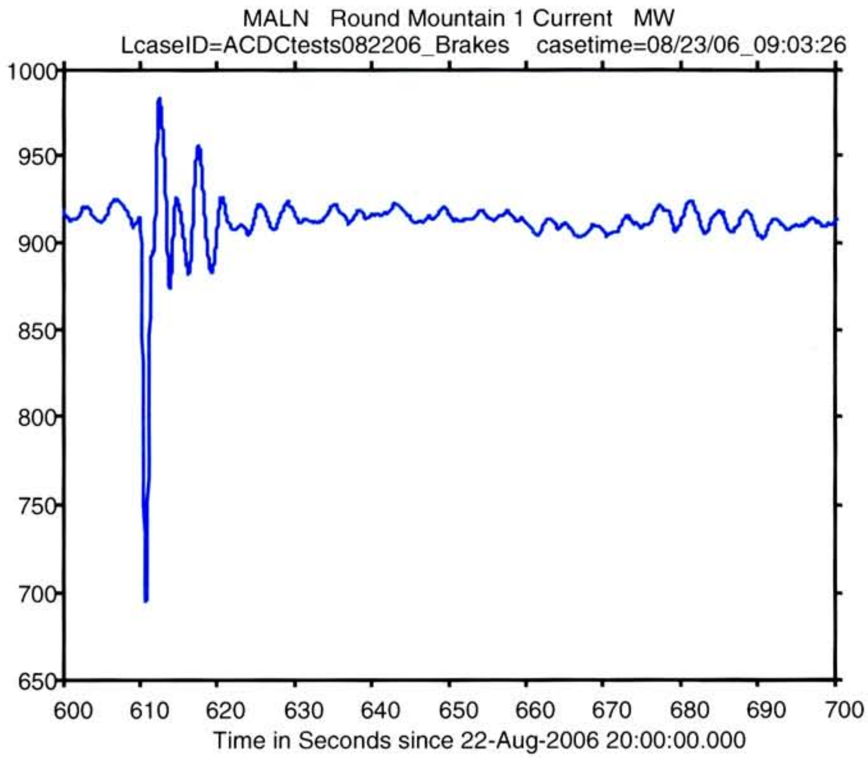


Figure 1. Malin-Round Mtn MW respionse to Chief Joseph Brake Application B1, 08/22/06

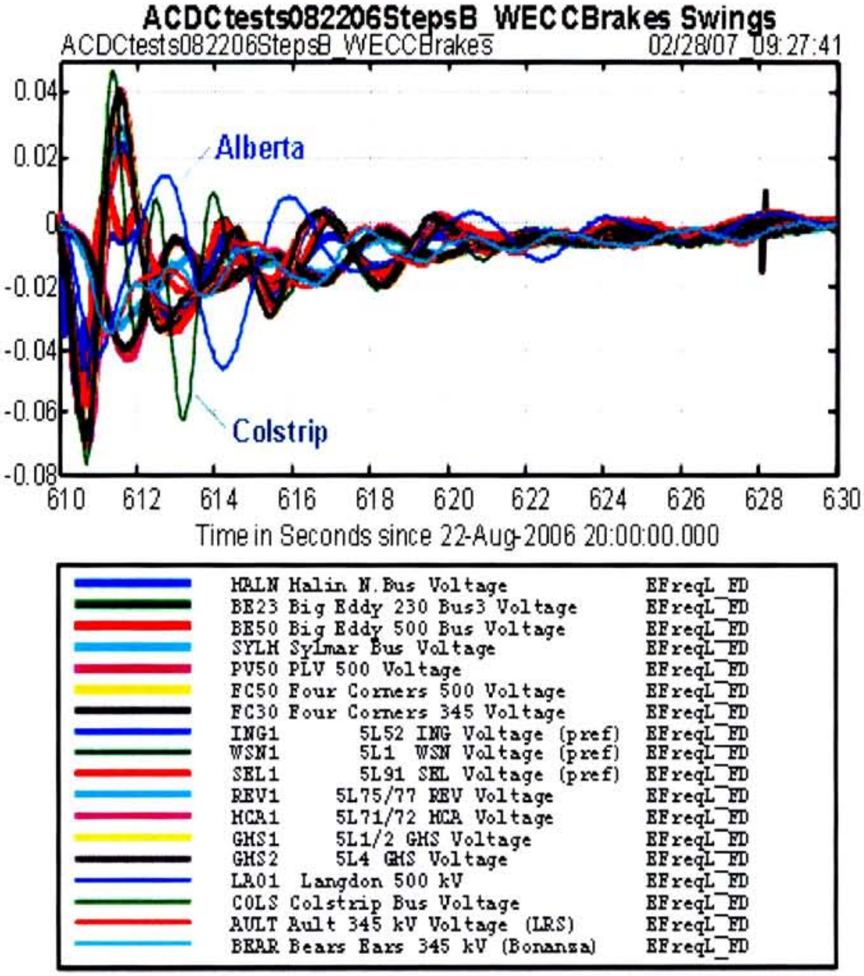


Figure 2. Frequency swings for Chief Joseph Brake Application B1, 08/22/06

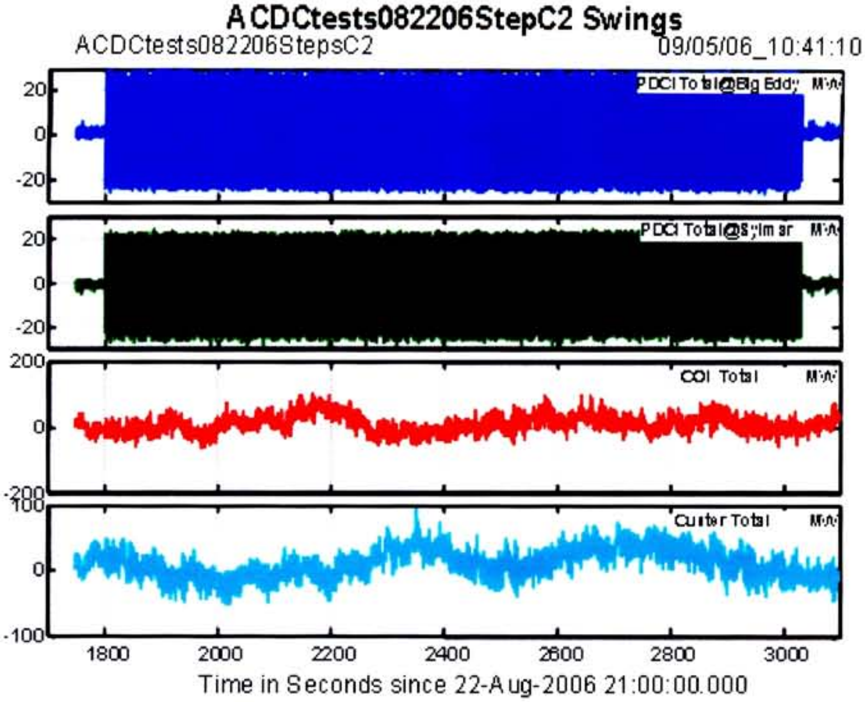


Figure 3. Response to ±25 MW noise modulation, test step C2 on 08/22/06

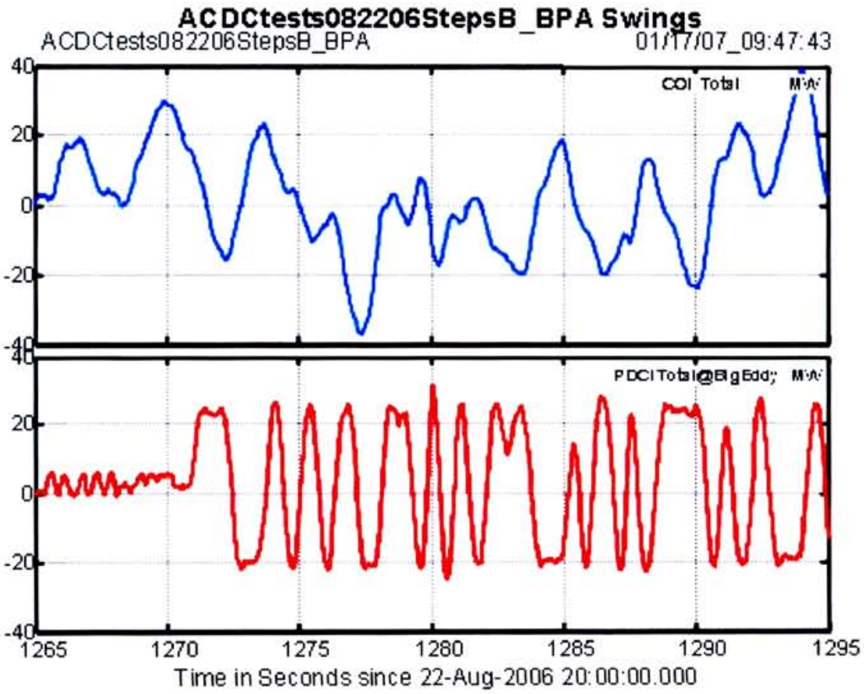


Figure 5. Startup of ±25 MW noise modulation, test step B3 on 08/22/06

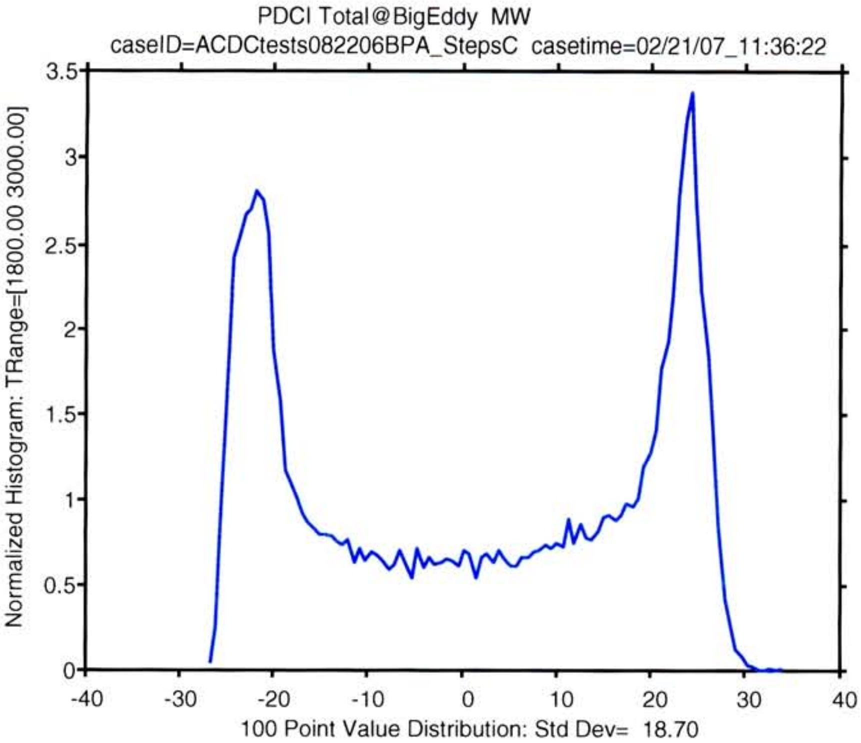


Figure 6. Histogram for Celilo DC MW response to low level noise probing, test step C2 on 08/22/06

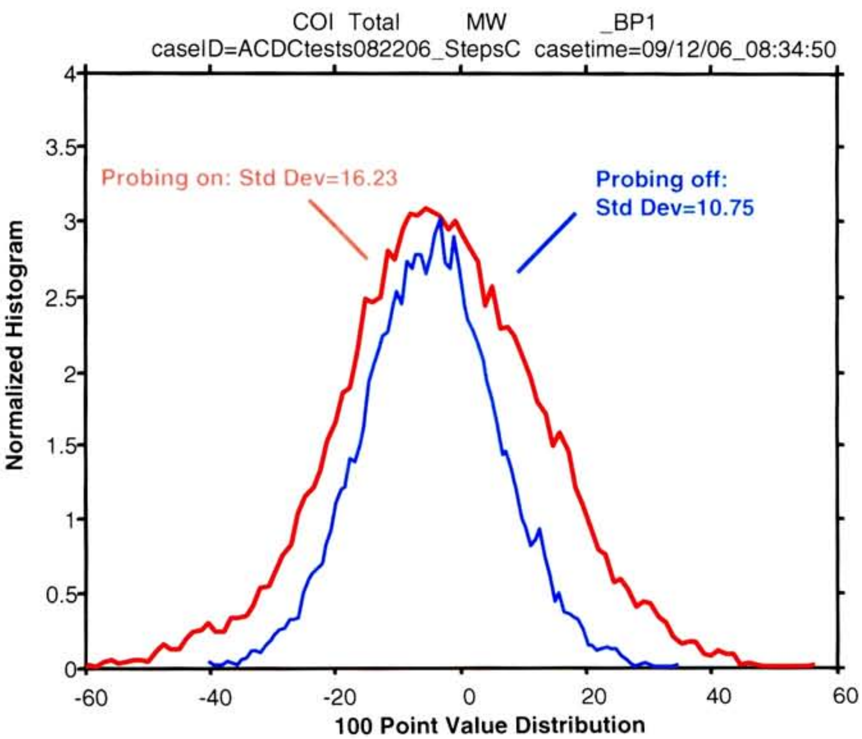


Figure 7. Histogram for COI MW response to low level noise probing, test steps C on 08/22/06

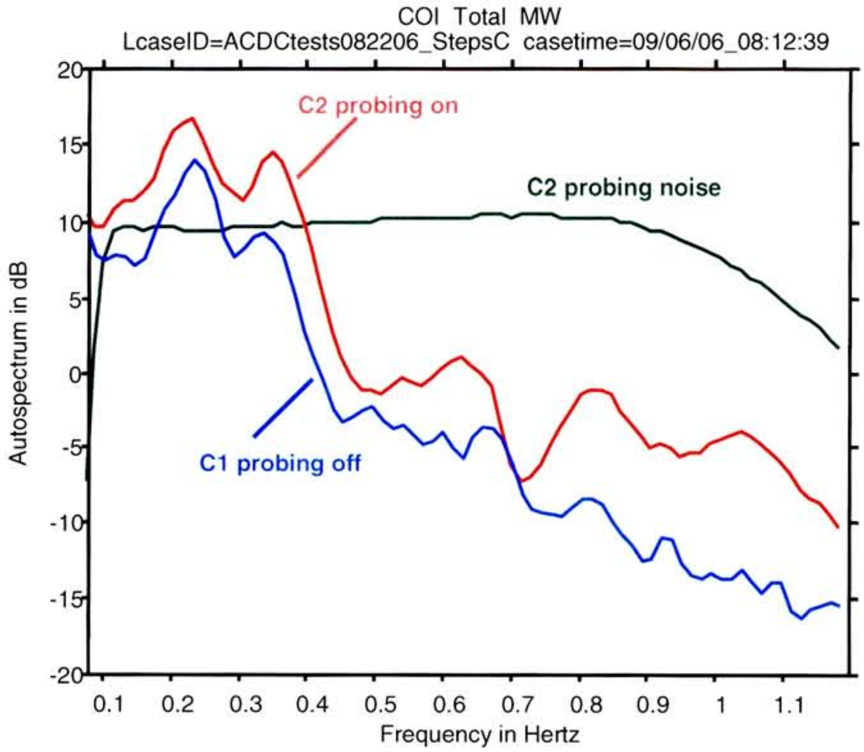


Figure 8. Key autospectra for level noise probing, test steps C on 08/22/06

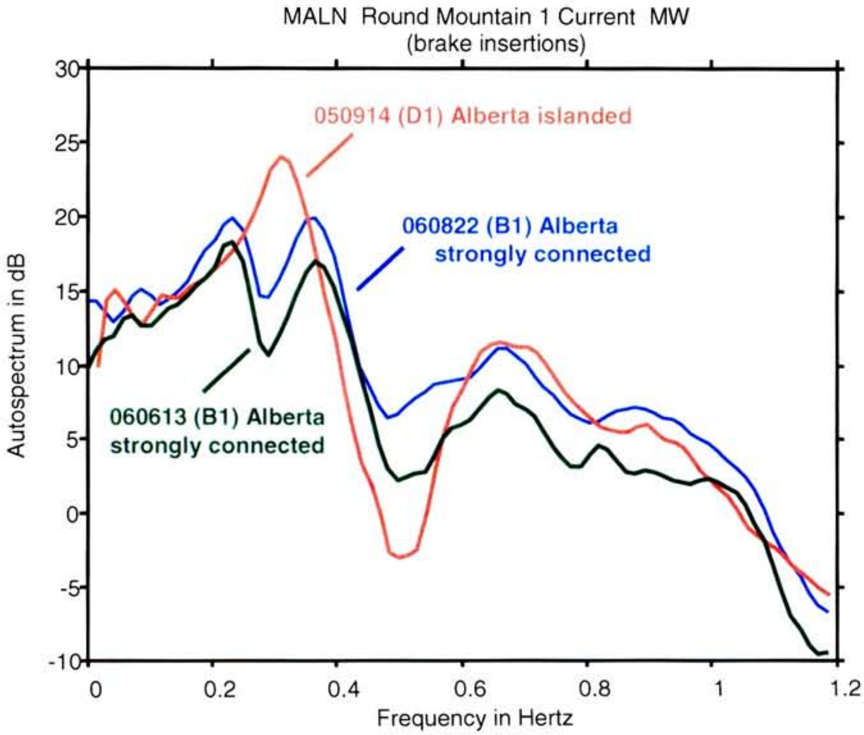


Figure 9. Efect of Albertra connection on response to insertions of the Chief Joseph dynamic brake