Mechanical Loads Test Report for the U.S. Department of Energy 1.5-Megawatt Wind Turbine

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Mechanical Loads Test Report

for the

DOE 1.5-MW Wind Turbine

in

Golden, Colorado, USA

Conducted for

U.S. Department of Energy Office of Energy Efficiency and Renewable Energy
Wind and Water Power Program
Forrestal Building
1000 Independence Avenue, SW
Washington, DC 20585

Conducted by

National Wind Technology Center
National Renewable Energy Laboratory
15013 Denver West Parkway
Golden, Colorado 80401

Rick Santos and Jeroen van Dam

September 2014

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1 Background

The U.S. Department of Energy (DOE) acquired and installed a 1.5-megawatt (MW) wind turbine at the National Wind Technology Center (NWTC) at the National Renewable Energy Laboratory. This turbine (hereafter referred to as the DOE 1.5) is envisioned to become an integral part of the research initiatives for the DOE Wind Program, such as Atmosphere to Electrons (A2e). A2e is a multiyear DOE research initiative targeting significant reductions in the cost of wind energy through an improved understanding of the complex physics governing wind flow into and through wind farms. For more information, visit http://energy.gov/eere/wind/atmosphere-electrons.

To validate new and existing high-fidelity simulations, A2e must deploy several experimental measurement campaigns across different scales. Proposed experiments include wind tunnel tests, scaled field tests, and large field measurement campaigns at operating wind plants. Data of interest includes long-term atmospheric data sets, wind plant inflow, intra-wind plant flows (e.g., wakes), and rotor loads measurements. It is expected that new, high-fidelity instrumentation will be required to successfully collect data at the resolutions required to validate the high-fidelity simulations.

The large-scale field measurement campaigns are expected to use the DOE 1.5 as it is of sufficient enough size to represent current technology, and turbines of this size are widely deployed in U.S. wind plants.

Expected future use of the DOE 1.5 at the NWTC may include the following (leading up to the large files measurement campaigns at operating plants):

- Deployment and validation of high-fidelity instrumentation prior to large-scale deployment at a wind plant
- Deployment of advanced controls algorithms
- Characterization of inflow, aerodynamics, turbine loads, and wake propagation on an unwaked turbine.

A series of tests were conducted to characterize the baseline properties and performance of the DOE 1.5 to enable research model development and quantify the effects of future turbine research modifications.

The tests included:

- Power performance per International Electrotechnical Commission (IEC) 61400-12-1
- Power quality per IEC 61400-21
- Acoustic noise per IEC 61400-11
- Mechanical loads per IEC 61400-13
- Modal testing.

The DOE 1.5 is built on the platform of GE's 1.5-MW SLE commercial wind turbine model. It was installed in a nonstandard configuration at the NWTC with the objective of supporting DOE Wind Program research initiatives such as A2e. Therefore, the test results may not represent the performance capabilities of other GE 1.5-MW SLE turbines.

This report describes the test setup and results of the mechanical loads test.

2 Test Objective

The objective of the test was to obtain a baseline characterization of the mechanical loads of the DOE 1.5 wind turbine located at NREL. The test was conducted in accordance with the International Electrotechnical Commission (IEC) Technical Specification, IEC 61400-13 *Wind Turbine Generator Systems – Part 13: Measurement of mechanical loads; First Edition 2001-06* [1].

The National Wind Technology Center (NWTC) at NREL conducted this test in accordance with its quality system procedures so that the final test report meets the full requirements of its accreditation by the American Association for Laboratory Accreditation (A2LA). NREL's quality system requires that all applicable requirements specified by A2LA and International Standards Organization/IEC 17025 be met or to note any exceptions in the test report.

3 Test Summary

This test commenced on March 3 and ended on March 25, 2011. According to the Standard [1], enough data was collected to meet the capture matrix requirements for model validation (Figure 1); however, this is not the case if only files are counted with all load channels being valid simultaneously.

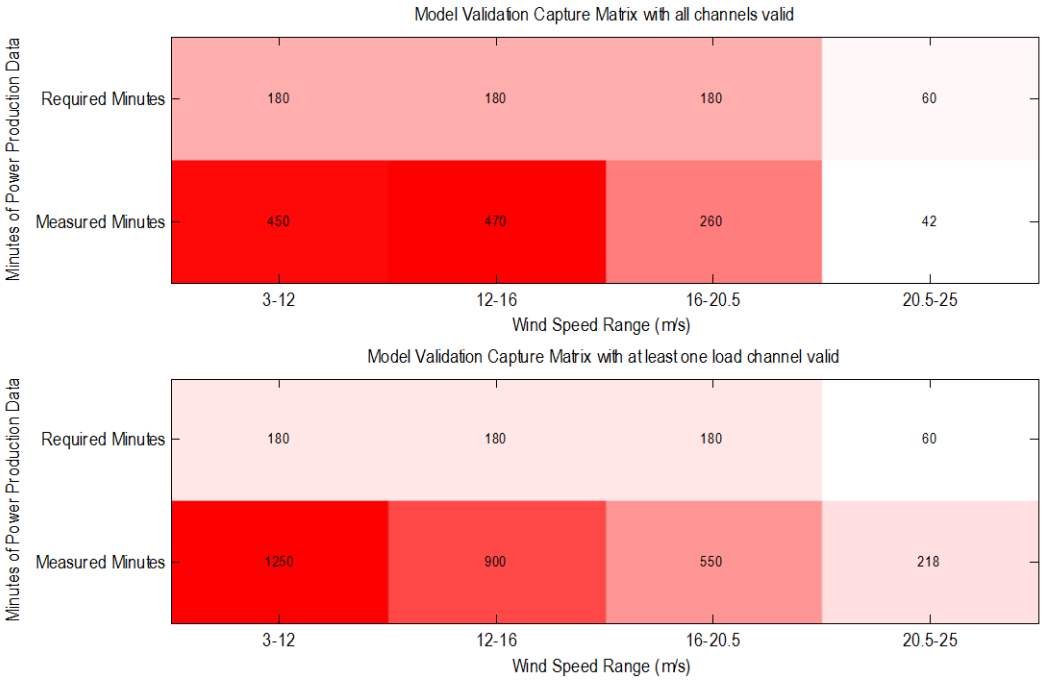


Figure 1. Model validation capture matrix

NREL kept a logbook, a copy of which is available on request. No special maintenance activities that could impact the test results were observed by or reported to NREL.

4 Test Turbine Configuration

The DOE 1.5 is based on a GE 1.5 SLE wind turbine. The test turbine was a horizontal axis, three-bladed upwind wind turbine with full span pitch control. Table 1 provides the key descriptive information on the test turbine. Figure 2 shows the test turbine. As the wind turbine manufacturer was not actively engaged in the test campaign, values for several critical turbine parameters had to be estimated based on either the measurement of dimensions, parameters from prior field tests, or dimensions of a dynamometer test article.

Table 1. Test Turbine Configuration and Operational Data

Turbine Manufacturer and Address	GE Energy 300 Garlington Rd., P.O. Box 648 Greenville, SC 29602-0648
Model	GE 1.5 SLE
Serial Number	Nacelle head # W79227A
Rated Power (kW)	1500
Number of Blades	3
Blade Tip Pitch Angle (deg)	Variable
Blade Make, Type, Serial Number	GE37c, S00028,S00029,S00030
Variable or Constant Speed	Variable
Hub Height	80
Nominal Rotor Diameter	77
Rated Wind Speed (rpm)	14
Rated Rotor Speed (rpm)	18.3
Rotor Speed Range (rpm)	10-25
Rated Generator Speed (rpm)	1436
Gearbox Ratio	1:78.472
Cut-In Wind Speed (m/s)	3.5
Cut-Out Wind Speed (m/s)	25
Control Philosophy	Full span pitch control
Description of Control System (Device)	ESS
Design Lifetime (Years)	20
Type Class	IEC IIa

Figure 2. The DOE 1.5 wind turbine at Site 4.0. ***Photo by Jeroen van Dam, NREL***

5 Test Site Description

The turbine is located at Test Site 4.0 of the NWTC, approximately 8 miles south of Boulder, Colorado. Figure 3 shows the turbine and meteorological (met) tower locations. This figure also shows nearby obstructions and topographical features of the site. To minimize the influence of obstructions and terrain during this test (Table 2), NREL has established a measurement sector from 243° to 310°. Only data from inside the measurement sector is used for this report.

NREL also completed a site assessment per Annex A of the IEC 61400-12-1 standard for power performance [3]. The results are given in Table 3. The terrain does not meet all the requirements due to a small gulley south of the turbine and would thus require a site calibration for the purpose of power performance testing. It was decided not to perform a site calibration.

Table 2. Neighboring Turbines and Obstacles

Obstacle or Turbine	Relative to:	Distance (m)	Bearing (deg T)	Equiv. Dia. (m)	Obstructed Sector	
					Start (deg T)	End (deg T)
Controls Advanced Research Turbine (CART)-2	Test Turbine	557	211	40	194	227
CART-3	Test Turbine	422	214	43	195	233
Siemens	Test Turbine	718	199.5	101	177	222
Alstom	Test Turbine	219	203	101	164	242
Test Turbine	Met Tower	153.4	96	77	46	146
CART-2	Met Tower	513	195	40	177	212
CART-3	Met Tower	376	193	43	172	213
Siemens	Met Tower	699	187	101	165	210
Alstom	Met Tower	228	163	101	124	201

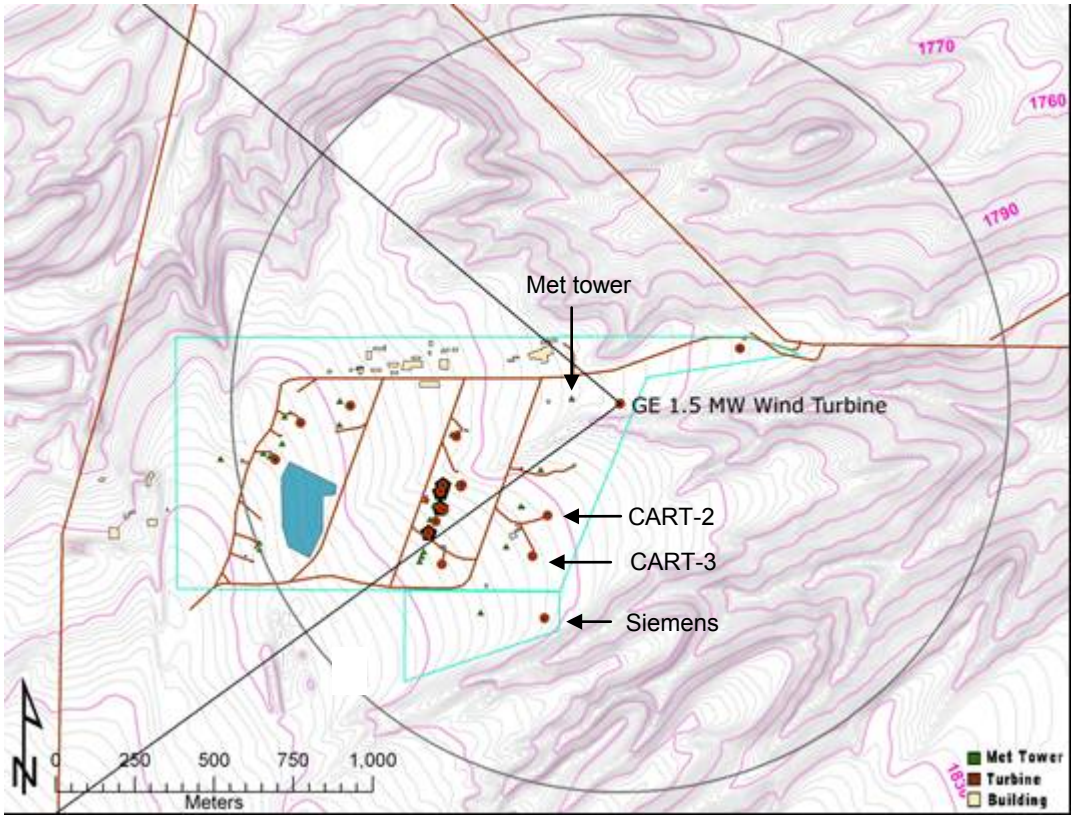


Figure 3. Map of the test site

Table 3. Results of Site Assessment

GE **Site: 4.0**

Preliminary Measurement Sector: **243** to **310** deg True

Criteria for Test Site without Site Calibration Testing

Criterion	Description	Distance	Sector (deg)	*allowable*	Test Site Condition	Pass/Fail
1	Maximum slope of best fit plane < 3%	<2L	360	*3%*	2.4%	Pass
2	Maximum variation from best fit plane < 0.04 (H + D)	<2L	360	*+/-5.9m*	15.7	**Fail**
3	Maximum slope of best fit plane < 5%	2-4L	In	*5%*	1.5%	Pass
4	Maximum variation from best fit plane < 0.08 (H + D)	2-4L	In	*+/-11.8m*	2.6	Pass
5	Steepest slope maximum < 10%	2-4L	Out	*10%*	1.7%	Pass
6	Maximum slope of best fit plane < 10%	4-8L	In	*10%*	2.1%	Pass
7	Maximum variation from best fit plane < 0.13 (H + D)	4-8L	In	*+/-19.2m*	19.2	Pass
8	No neighboring and operating turbines	$<2D_n$	360	*0*	0	Pass
9	No obstacles	$<2D_e$	360	*0*	0	Pass

Site Calibration Required? **yes**

absolute value used for site condition
In = Inside Preliminary Measurement Sector
Out = Outside Preliminary Measurement Sector

6 Test Instrumentation

The data acquisition (DAQ) system used for this test is based on the National Instruments EtherCAT hardware. DAQ modules were distributed over the turbine as indicated in Table 6. Synchronization occurs through the use of EtherCAT protocol, which is a deterministic Ethernet protocol. The data is stored in 100-Hz 10-minute long files.

The data channels that were collected by the DAQ system are listed in Table 4 and Table 5. Table 6 maps the signals to the DAQ signal conditioning modules. Instrumentation details for tower-top acceleration and rotor azimuth were not documented.

For all sensors, end-to-end checks were performed to verify proper installation.

Table 4. Summary of Instrumentation; Nonload Channels

Signal	Sensor Make/Model	Serial Number	Cal Due Date
Primary Wind Speed	Thies Clima First Class	0909219	December 20, 2011
Wind Speed 87 m	MetOne SS 201	K16689	January 19, 2012
Wind Direction	MetOne SD 201	K16689	December 10, 2011
Air Pressure	Vaisala, PTB101B	B2130018	December 22, 2011
Air Temperature	MetOne T200	0673552	December 22, 2011
Availability	Supervisory control and data acquisition (SCADA)	NA	NA
Pitch Angle Blade 1	SCADA	NA	NA
Pitch Angle Blade 2	SCADA	NA	NA
Pitch Angle Blade 3	SCADA	NA	NA
Generator Speed	SCADA	NA	NA
Generator Torque	SCADA	NA	NA
Yaw Position	SCADA	NA	NA
Operational Status	SCADA	NA	NA
State Fault	SCADA	NA	NA
Turbine Power	SCADA	NA	NA
Nacelle Wind Speed	SCADA	NA	NA
Tower-Top Lateral Acceleration	NA	NA	NA
Tower-Top Acceleration Normal	NA	NA	NA
Rotor Azimuth	NA	NA	NA

Table 5. Summary of Instrumentation for Loads Channels

Signal	Sensor Make/Model	Gage Factor	Calibration Method
Tower-Base Bending 1	Vishay LWK-06-W250D-350	2.02	Yaw Sweep/ Theoretical
Tower-Base Bending 2	Vishay LWK-06-W250D-350	2.02	Yaw Sweep/ Theoretical
Tower-Top Torque	Vishay CEA-06-125UW-350	2.02	Theoretical/Shunt
Tower-Top Bending 1	Vishay LWK-06-W250D-350	2.02	Yaw Sweep/ Theoretical
Tower-Top Bending 2	Vishay LWK-06-W250D-350	2.02	Yaw Sweep/ Theoretical
Blade 1 Flap Bending	Vishay WK-09-250MQ-10C/w	2.05	Slow Roll/Pitch Sweep
Blade 2 Leadlag Bending	Vishay WK-09-250MQ-10C/w	2.05	Slow Roll/Pitch Sweep
Blade 1 Flap Bending	Vishay WK-09-250MQ-10C/w	2.05	Slow Roll/Pitch Sweep
Blade 2 Leadlag Bending	Vishay WK-09-250MQ-10C/w	2.05	Slow Roll/Pitch Sweep
Blade 3 Flap Bending	Vishay WK-09-250MQ-10C/w	2.05	Slow Roll/Pitch Sweep
Blade 3 Leadlag Bending	Vishay WK-09-250MQ-10C/w	2.05	Slow Roll/Pitch Sweep
Main Shaft Bending 0	Vishay LWK-06-250D-350	2.02	Theoretical/Slow Roll
Main Shaft Bending 90	Vishay LWK-06-250D-350	2.0	Theoretical/Slow Roll
Main Shaft Torque	Vishay LEA-06-W125F-350/3R	2.03	Theoretical/Shunt

Table 6. Map Between Signals and DAQ Module

Signal Name	Module				Chassis/Location
	Type	SN	Slot	Cal Due Date	
Primary Wind Speed	9205	12E9CD3		August 21, 2011	Network Split
Reference Wind Speed					
Wind Direction					
Air Pressure					
Air Temperature	9217	12BD192		August 21, 2011	
Tower_base_bending_1	9237	1342666	1	February 19, 2010	Chassis 0 - Tower Base
Tower_base_bending_2					
Tower_base_torque					
Tower_top_bending_1	9237	1357162	1	March 26, 2009	Chassis 1 - Tower Top
Tower_top_bending_2					
Tower_top_torque					
Tower_top_accel_x	9239	158B4F4	2	January 10, 2012	
Tower_top_accel_y					
Main_shaft_azimuth	9239	158B478	1	January 10, 2012	Chassis 2 - Nacelle
Main_shaft_bending_0					
Main_shaft_bending_90					
Main_shaft_torque					
Blade 1 Flap Bending	9237	1357177	1	March 26, 2009	Chassis 3 - Hub
Blade 1 Leadlag Bending					
Blade 2 Flap Bending					
Blade 2 Leadlag Bending					
Blade 3 Flap Bending	9237	136D7A2	2	May 14, 2009	
Blade 3 Leadlag Bending					

Note that in some of the plots in the appendices, leadlag bending is sometimes referred to as edge bending.

6.1 Met Tower Signals

The met tower was located 153 m from the turbine at a bearing of 276° relative to true north. Figure 4 shows the met tower configuration; the wind vane and MetOne reference anemometer are mounted off the same boom, side by side (Figure 5). All booms are pointing in the 278° direction. Air temperature was measured in a radiation shield mounted off the met tower. The air pressure sensor was mounted in an enclosure on the tower and connected to the outside air through a perforated pipe to measure static pressure.

An *in-situ* comparison was performed on the anemometers which showed that the primary anemometer maintained its calibration over the test period.

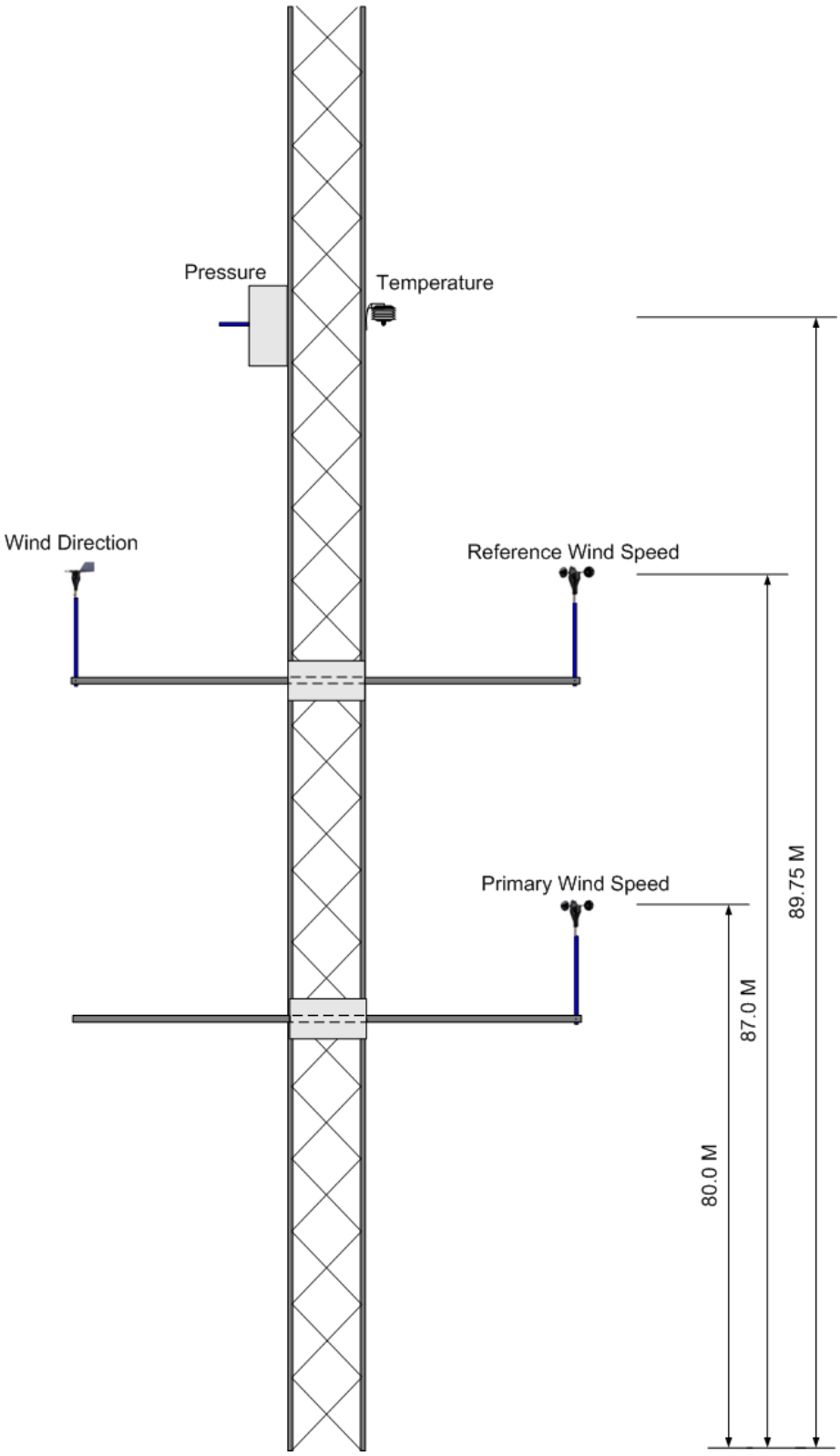


Figure 4. Met tower schematic showing measurement heights. ***Illustration by Ismael Mendoza, NREL***

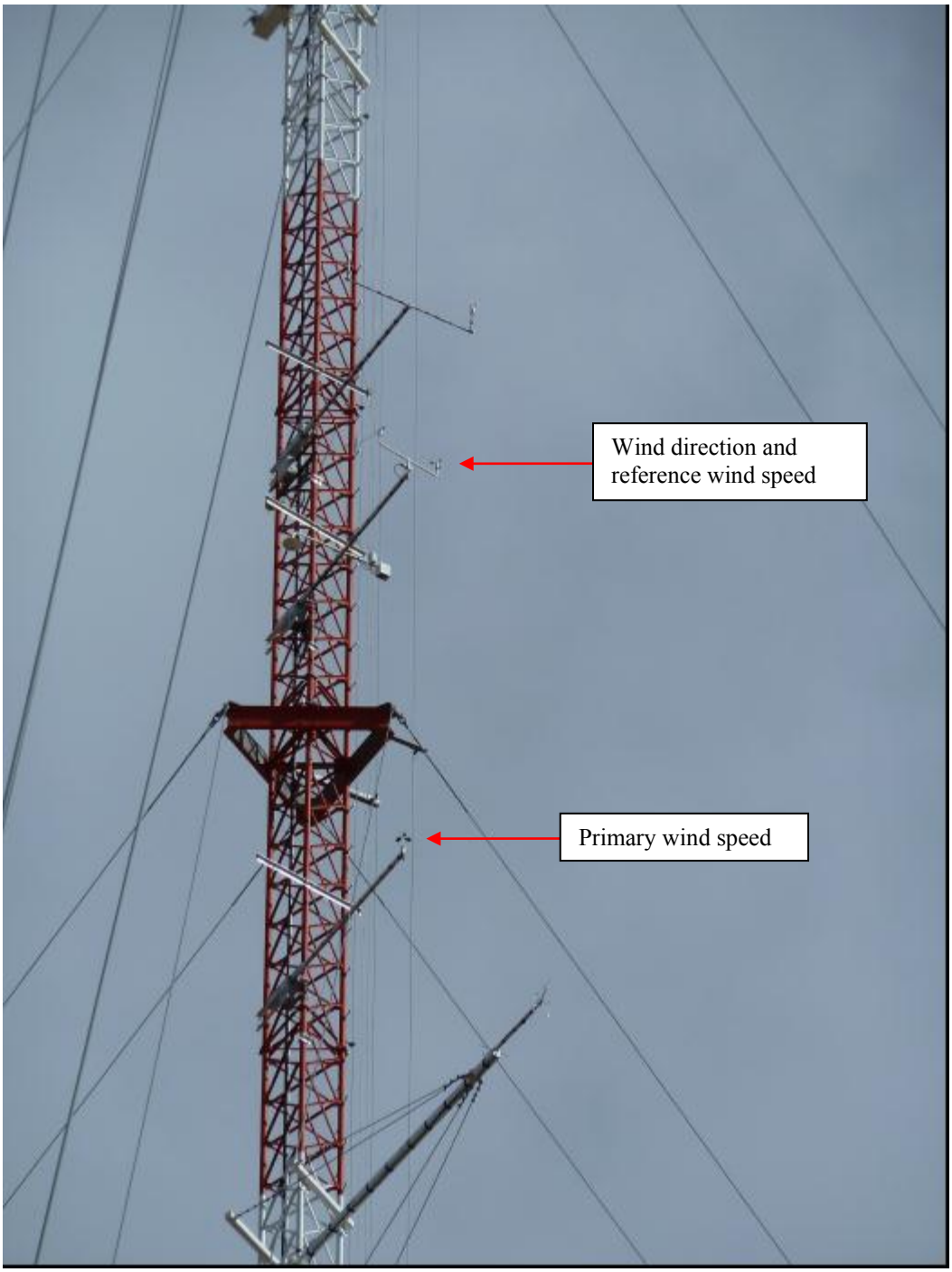


Figure 5. Met tower. ***Photo by Jeroen van Dam, NREL***

6.2 Blade Signals

All blade-bending moments were measured using nontemperature-compensated, full bridges with matching strain gages for each leg. Flap and leadlag bending gages were mounted on the inside of the root. The leadlag gages were mounted at a distance of 500 mm from the blade flange to the gage center, along the chord line. The flap gages were mounted at a distance of 500 mm from the blade flange to the gage center, 90 degrees from the chord line. The chord line is defined by the indicator glued to the inside surface of the blade root for each blade. An example of a blade strain gage is given in Figure 6.

Figure 6. Example of blade strain gage locations. ***Photo by Garth Johnson, NREL***

6.3 Tower Signals

The tower was instrumented at two levels. These are referred to as: base and top.

6.3.1 Tower Base

All tower-base moments were temperature-compensated, full bridges ("T" configuration) with matching strain gages on each leg. Tower-base gages were mounted 4.95 m above the top of the tower-base flange (Figure 7). The bridges were placed at 276°–96°N and 6°–186°N.

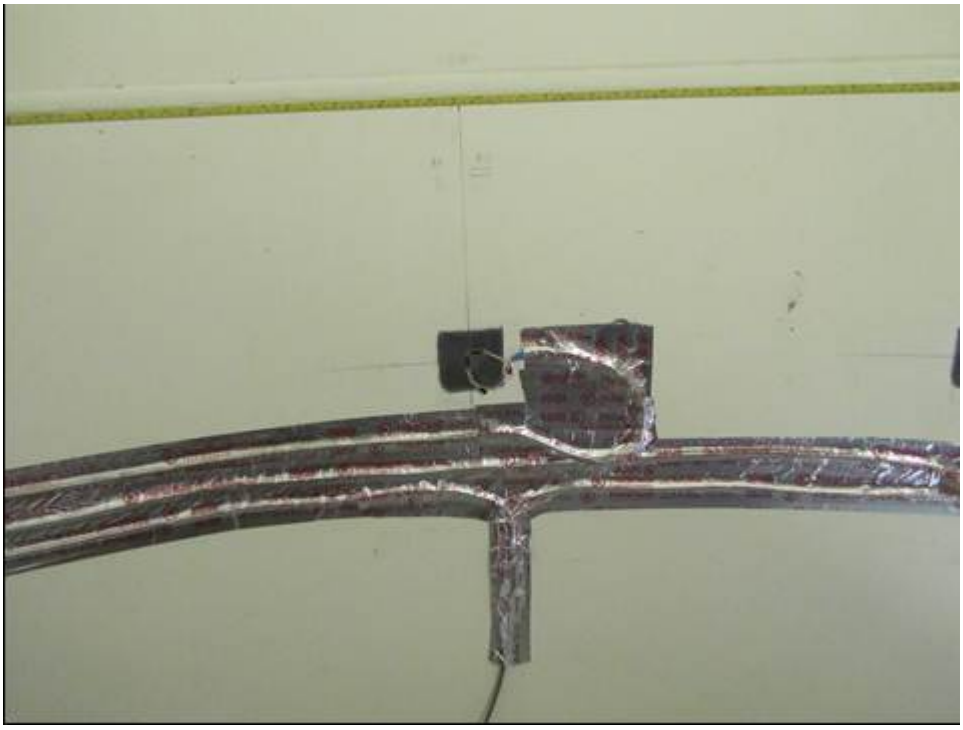


Figure 7. Example of tower-base strain gages. ***Photo by Mark Murphy, NREL***

6.3.2 Tower Top

All tower-top bending moments were measured using temperature-compensated, full bridges ("T" configuration) with matching strain gages on each leg. Tower-top gages were mounted 457 mm above the upper work platform (Figure 8). The bridges were placed at 276°–96°N and 6°–186°N. Tower-top torque was measured using a full torque bridge with elements under a 45-degree angle from vertical.

Figure 8. Example of strain gage location at the tower top. ***Photo by Mark Murphy, NREL***

6.4 Main Shaft Signals

The main shaft was instrumented with two bending signals and a full torque bridge. All main-shaft loads were measured using nontemperature-compensated, full bridges with matching strain gages for each leg. Gages were installed 0.80 m downwind of the main shaft upwind bearing. The 0° bending gages were installed in line with Blade 2, whereas the second bridge was placed at 90°. Main shaft torque gages were placed at 45° from the 0° bending gages at the same shaft cross section (Figure 9).

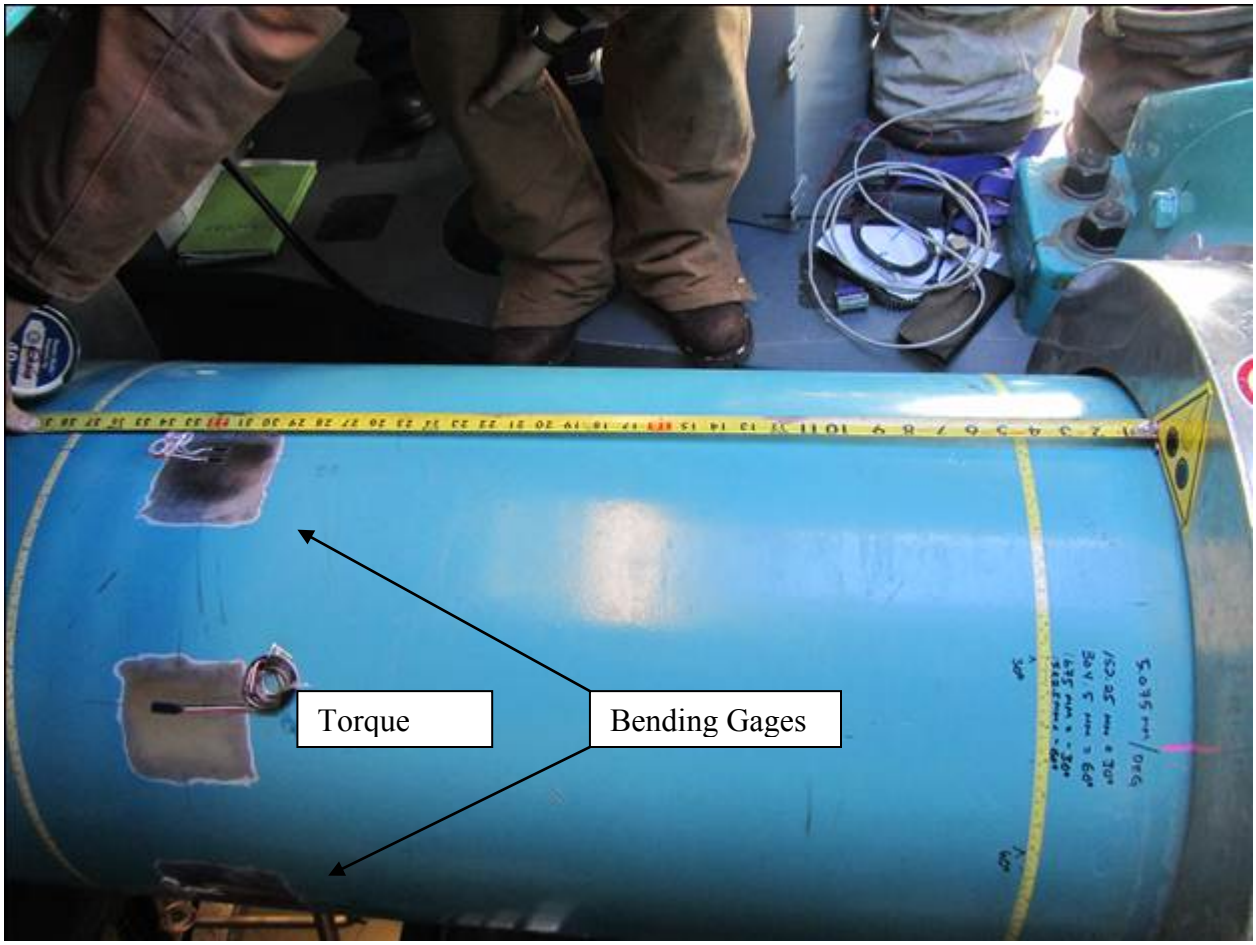


Figure 9. Main shaft gaging. ***Photo by Jerry Hur, NREL***

6.5 Other Signals

6.5.1 Controller Signals

Several GE controller signals were used for this test and were provided digitally to the NREL DAQ system using the NI Publish-Subscribe Protocol (PSP). The following signals were used:

- Availability
- Pitch Angle Blade 1
- Pitch Angle Blade 2
- Pitch Angle Blade 3
- Generator Speed
- Gen Torque
- Yaw Position
- Operational Status
- State Fault

- Turbine Power
- Nacelle Wind Speed.

6.5.2 Rotor Azimuth

The rotor azimuth was measured using four targets per revolution on the high-speed shaft connected to a quadrature encoder and a once-per-revolution reset on the main shaft. Blade azimuth is zero when blade 1 is pointing up.

7 Calibrations

For the load channels, the calibration method is indicated in Table 5 and described in this section. Calibration sheets for the DAQ system and the sensors can be found in Appendix G and Appendix I.

Several turbine signals were provided through the GE supervisory control and data acquisition (SCADA) system. For these signals, NREL does not have traceable calibration sheets. End-to-end calibrations were performed from the point of interconnection.

7.1 Blade Signals

Shunt calibrations were performed to check the DAQ functionality by putting a 174.65 kOhm resistor in parallel with Signal+ and Excitation+, and Signal- and Excitation+, respectively. The results of the shunt calibration are shown in Figure 255 through Figure 260 and Table 87 through Table 92 in Appendix F. The measured results of the shunt calibrations correlated well with the predictions.

The blade signals were calibrated by using the overhang moments provided in Table 7. The provided overhang moments were not corrected for the blade mass inboard of the strain gages.

Table 7. Blade Overhang Moments Used for Calibration of Blade Bending

Serial Number	Blade Overhang Moment [kgm]
S00028	69,128
S00029	69,041
S00030	69,027

Slow rolls were performed with -1° and 85° pitch angles to obtain the slope of the flap and leadlag bending. A slow roll with a pitch angle at 65° was performed to verify crosstalk.

Additionally, pitch sweeps were performed with the blade at 3 o'clock and 9 o'clock (blade horizontal on both sides of the nacelle), with each blade being pitched from 0 to 90 degrees in 5-degree increments.

The blade zero calibrations were performed throughout the testing period. In low winds (below 3 m/s), the data files were searched for startup sequences where the pitch settles at 65 degrees for several rotor revolutions and the turbine torque converter is not yet engaged. The zero calibrations used for the test campaign are given in Table 9.

Table 8. Blade Sensitivity Matrices

	Blade 1		Blade 2		Blade 3	
	Nm/V/V Flap	Nm/V/V Leadlag	Nm/V/V Flap	Nm/V/V Leadlag	Nm/V/V Flap	Nm/V/V Leadlag
Flap Moment	2.7956E+6	-20.3611	2.5039E+6	-1.444E+3	2.5433E+E6	-521.161
Leadlag Moment	-2.07771E+3	-2.4677E+6	10.4622	-2.2337E+E6	1.1223E+E3	-2.4078E+E6

Table 9. Blade Offset Values

Comparison	Mean Gage Offset (V)	Stdev of Gage Offsets (V/V)	Number of Zeroes	Type-B Uncertainty (kNm)
Blade 1 Leadlag Bending	8.5053E-4	2.0623E-5	219	3.77
Blade 2 Leadlag Bending	-4.1341E-6	6.4426E-6	126	1.41
Blade 3 Leadlag Bending	-4.7054E-4	4.6535E-6	102	1.24
Blade 1 Flap Bending	-1.5273E-5	5.7485E-6	219	3.90
Blade 2 Flap Bending	-5.7944E-4	5.2036E-6	126	1.43
Blade 3 Flap Bending	-2.0409E-4	6.8447E-6	102	1.14

7.2 Tower Signals

For the tower signals, the signal sensitivities were calculated using a yaw sweep and the nacelle overhang moment in Table 10. For the tower torque and validation of the calibration of the bending moments the tower properties given in Table 11 were used. Shunt calibrations were performed on all tower gages (Table 96 through Table 100 and Figure 264 through Figure 268).

Table 10. Tower Properties Used for Calculation of Tower Calibration Coefficients

Level	Inner Diameter	Outer Diameter	E Modulus	Poisson's Ratio
	[mm]	[mm]	[N/mm^2]	[-]
Base	4255	4297	2.1E+5	0.3
Top	2540	2564	2.1E+5	0.3

Table 11. Nacelle Overhang Moment Use for Tower Bending Calibrations

Component	Mass (kg)	CG Location From Yaw Axis (m)	Mass Moment (kg-m)	Overhang Moment (kNm)
Nacelle and Rotor	87,000	-1.107	-9.63E+04	-943.83

The tower-top gages appeared to be placed too high in the tower and may have picked up some nonlinear strain from yaw-bearing deflection. Figure 246 shows the nacelle 360 rotation and the relative placement of the tower-top strain gages. As the rotor-side of the nacelle passes over the gage locations, the stress starts out higher than expected and then drops as the nacelle front sits over the gage. As the nacelle continues to yaw, the strain increases again and exceeds the expected value. This is an unfortunate situation and although the tower-top calibration can be corrected by using a gain multiplier that is a function of yaw position, the resulting calibration is highly uncertain.

The tower-top and tower-base offset values were taken whenever the turbine was idle or parked while facing the wind in winds less than 3 m/s. The used values are given in Table 12.

Table 12. Tower Offset Values

Comparison	Mean Gage Offset (V)	Stdev of Gage Offsets (V/V)	Number of Zeroes	Type-B Uncertainty (kNm)
Tower-Top 1 Bending	5.7452E-5	1.9776E-5	207	11.36
Tower-Top 2 Bending	9.8383E-5	9.2502E-6	207	7.39
Tower-Top Torque	3.1135E-5	7.7567E-6	207	5.25
Tower-Base 1 Bending	3.2487E-5	3.8648E-6	207	13.26
Tower-Base 2 Bending	3.0446E-4	3.5900E-6	207	12.99

Table 13. Comparison of Tower Calibrations

Comparison	Nacelle 360 (kNm/V/V)	Analytical (kNm/V/V)	% Diff	Comments
Tower-Top 1 Bending	8.27E+06	9.77E+06	15.4%	Nacelle 360 used because of a lack of tower mechanical properties.
Tower-Top 2 Bending	1.15E+07	9.77E+06	18.1%	Nacelle 360 used because of a lack of tower mechanical properties.
Tower-Top Torque	-	9.77E+06	-	Only one method of calibration used.
Tower-Base 1 Bending	5.08E+07	4.80E+07	5.8%	Nacelle 360 used because of a lack of tower mechanical properties.
Tower-Base 2 Bending	5.27E+07	4.80E+07	9.7%	Nacelle 360 used because of a lack of tower mechanical properties.

*Values in green are used for conversions.

7.3 Main Shaft Signals

Analytical calibrations of the shaft signals were carried out using the main shaft properties listed in Table 14. Those properties were compared to the values obtained from the estimated overhang moments (Table 15) during slow rolls. Shunt calibrations were performed to verify the overall DAQ functionality (Figure 261 through Figure 263 and Table 93 through Table 95).

Main shaft torque was calibrated by using a time series of normal power production near rated power. The main shaft theoretical torque is calculated by dividing the rotor power (electric power divided by the drivetrain efficiency) by the main shaft rotational speed. To remove noise from the signal, a low-pass filter is applied to both rotor power and the main shaft torque gage. The result is given in Figure 10.

Table 16 and Table 17 show the calibration slopes and offsets that were used.

Table 14. Inputs Used for Analytical Shaft Calibration

Shaft Dimensions at Measurement Plane			
D	0.581	[m]	Outer Diameter
d	0.040	[m]	Inner Diameter
k	2.02	[-]	Gage Factor
E	2.1E+11	[N/m^2]	Young's Modulus
nhu	0.3	[-]	Poisson's Ratio
G	8.08.E+10	[N/m^2]	Shear Modulus

Table 15. Calculation of Overhang Moment at Main Shaft Strain Gage Location

Rotor Overhang Calculation		
Distance from Y-axis to Hub Center of Gravity (CG)	-3.96	m
Distance from Y-axis to Hub Flange	-2.57	m
Distance from Hub CG to Hub Flange	-1.39	m
Distance from Hub Flange to Bearing	-0.51	m
Distance from CG to Upwind (UW) Bearing	-1.90	m
Overhang Moment from Hub to UW Bearing	-622.32	kNm
Gage Location		
Distance from UW Bearing to Gage	0.84	m
Distance from Center of Bear to Mark	0.21	m
Distance from Center of Bearing to Gage	1.04	m
Distance from Mark to Gearbox	1.53	m
Moment at Gage		
Moment at Gage	-198.0	kNm

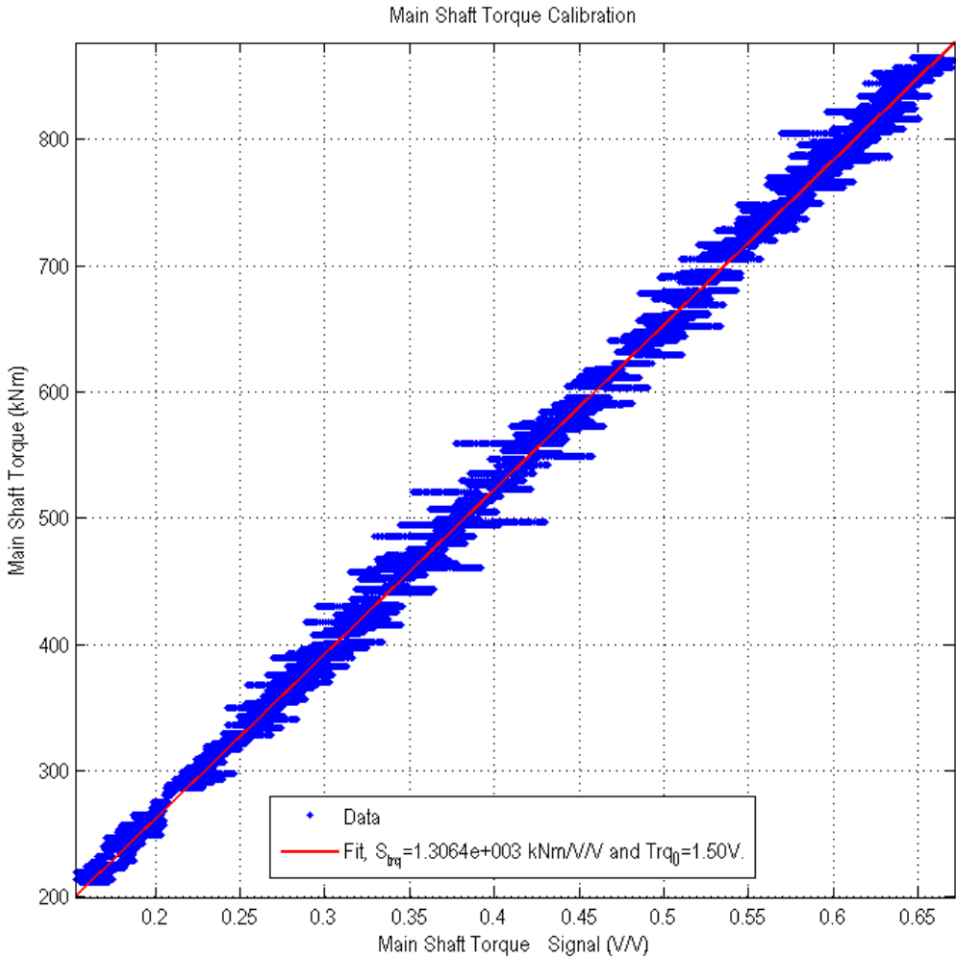


Figure 10. Main shaft torque calibration

Table 16. Comparison of Main Shaft Calibrations

Comparison	External Calibration (kNm/V)	Analytical Calibration (kNm/V)	% Diff	Comments
Main Shaft Bending 0	6.66E+02	667.88	-0.3%	Analytical calibration values used because of uncertain boundary conditions on slow rolls.
Main Shaft Bending 90	6.68E+02	667.88	0.0%	Analytical calibration values used because of uncertain boundary conditions on slow rolls.
Main Shaft Torque	1.31E+03	1022.45	27.8%	External calibration used because of large error in analytical calibration.

*Values in green are used for conversions.

Table 17. Main Shaft Offset Values

Comparison	Mean Gage Offset (V)	Stdev of Gage Offsets (V)	Number of Zeroes	Type-B Uncertainty (kNm)
Main Shaft Bending 0	1.1866	0.0124	213	0.56
Main Shaft Bending 90	1.6184	0.0148	214	0.67
Main Shaft Torque	1.4900	0.0154	226	1.34

7.4 Yaw Position

Yaw position was calibrated by pointing the nacelle at two distant landmarks and the met tower. A slope and offset were then calculated and applied. The nacelle was then pointed at the three landmarks again for verification. Figure 11 and Table 18 show the results of the verification. The yaw position signal had a 1-degree resolution.

Table 18. Verification of Slope and Offset for Yaw Position

Target	Bearing [°T]	Measured Bearing [°T]	Residual [°]
Coal Creek Peak	248	247	1
Shirttail Peak	293	292	1
Met Tower	281	281	0

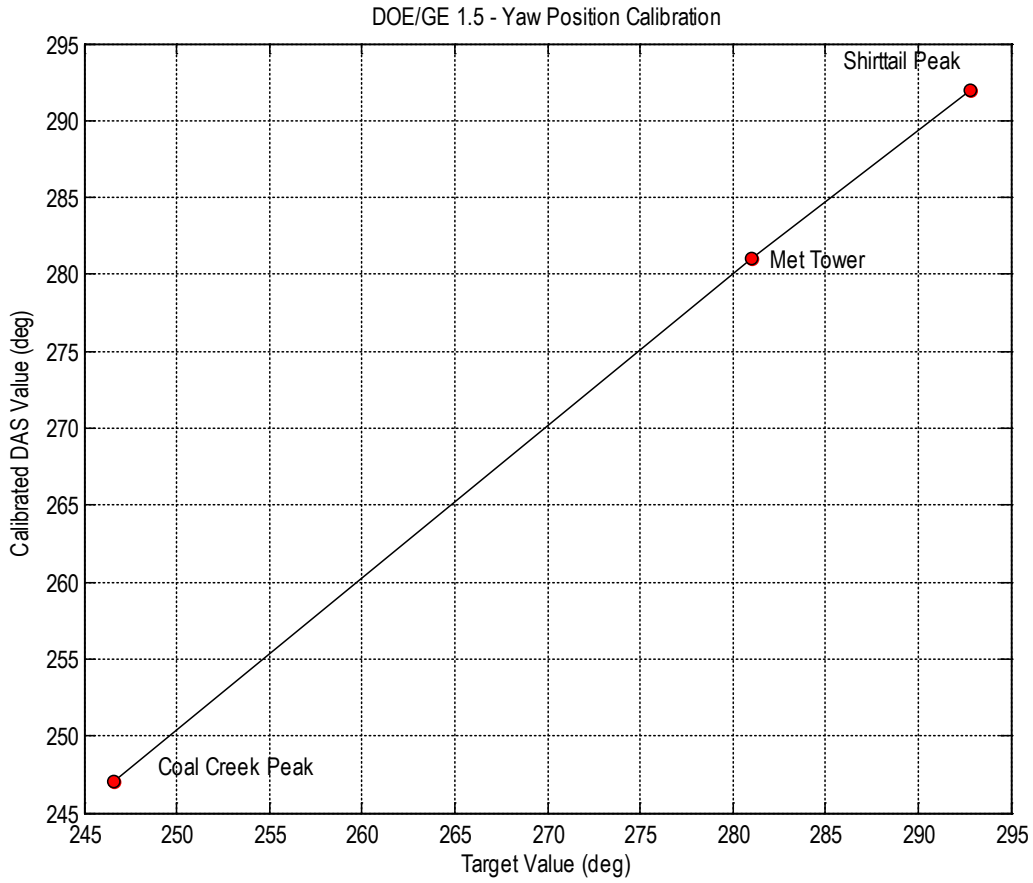


Figure 11. Regression of measured versus predicted yaw position

8 Data Processing Procedure

Test data was collected continuously. For all data files, the following steps were followed in the processing procedure:

1. Filtering
2. Adding calculated channels
3. Validation (including spike detection)
4. Post-process data to results.

8.1 Data Filtering

Data was removed for:

1. Any obvious problems with the DAQ (dropouts, flat lined)
2. Wind direction outside the measurement sector
3. Observations of icing on the blades or anemometer impacted by icing.

8.2 Calculated Channels

In addition to the signal coming from the DAQ, additional measurement quantities were calculated for:

- Air density
- Tower-top lateral bending moment
- Tower-top normal bending moment
- Tower-base lateral bending moment
- Tower-base normal bending moment.

The coordinate system used in this report is given in Appendix H.

8.3 Data Validation

All of the measured signals were checked for validity. An automated system was used to give a first-pass evaluation as to whether the data was valid or not. These automated checks were as follows:

1. Maximum of measured signal must be below acceptable predetermined maximum for that channel.
2. Minimum of measured signal must be above acceptable predetermined minimum for that channel.
3. The standard deviation for measured signal must be above threshold for that channel (detects frozen signal).
4. The running standard deviation of 10-second width, must be above a predetermined threshold (detects frozen signal for only part of the measured time series).

5. Signals were investigated for spikes.
6. Mean blade in-plane loads were compared to the main shaft torque.
7. Main shaft torque was compared to electrical power divided by shaft speed.
8. Main shaft torque was compared to tower lateral bending.
9. Tower normal bending was compared to summation of the out-of-plane blade bending.
10. Power spectral densities of blade loads were used to check for crosstalk.
11. Data collected when the turbine was idling data at low wind speeds was used to quantify gage drift.

8.4 Post-Processing

The following post-processing was performed.

Table 19. Analysis of 10-Minute Blocks

	Scatterplots	Bin, All TI	Azimuth Binning	PSD	Rainflow Counting	Damage Equivalent Load
Electrical Power	✓	✓				
Rotor Speed	✓	✓				
Generator Speed	✓	✓				
Blade 1 Flap Bending	✓	✓	✓	✓	✓	✓
Blade 1 Leadlag Bending	✓	✓	✓	✓	✓	✓
Blade 2 Flap Bending	✓	✓	✓	✓	✓	✓
Blade 2 Leadlag Bending	✓	✓	✓	✓	✓	✓
Blade 3 Flap Bending	✓	✓	✓	✓	✓	✓
Blade 3 Leadlag Bending	✓	✓	✓	✓	✓	✓
Main Shaft Torque	✓	✓	✓	✓	✓	✓
Main Shaft Bending 0	✓	✓	✓	✓	✓	✓
Main Shaft Bending 90	✓	✓	✓	✓	✓	✓
Tower-Top Normal Bending	✓	✓		✓	✓	✓
Tower-Top Lateral Bending	✓	✓		✓	✓	✓
Tower-Top Torque	✓	✓		✓	✓	✓
Tower-Base Normal Bending	✓	✓		✓	✓	✓
Tower-Base Lateral Bending	✓	✓		✓	✓	✓
Blade Pitch Angle #1	✓	✓				
Blade Pitch Angle #2	✓	✓				
Blade Pitch Angle #3	✓	✓				
Wind Speed at 87m	✓	✓				
Hub-Height Wind Speed	✓	✓				
Air Pressure	✓	✓				
Air Temperature	✓	✓				

8.4.1 Ten-Minute Record Statistics

For each 10-minute data file the mean, minimum, maximum, and standard deviation of all channels were calculated.

8.4.2 Azimuth Averaging Analysis

A process similar to the bin averaging was used to compute the azimuth averaging. Thirty-six separate bins were used for the analysis.

8.4.3 Power Spectral Density Analysis

The power spectral density (PSD) was estimated via Welch's method that returns the PSD estimate, Pxx, of a discrete-time signal vector X using Welch's averaged, modified periodogram method. By default, X was divided into eight sections with 50% overlap; each section was windowed with a Hamming window and eight modified periodograms were computed and averaged.

If the length of X was such that it could not be divided exactly into eight sections with 50% overlap, then X was truncated accordingly. Pxx is the distribution of power per-unit frequency. For real signals, such as those measured during this test, the one-sided PSD was returned. Note that a one-sided PSD contains the total power of the input signal.

8.4.4 Cycle Counting Analysis

Load data cycles were counted using a version of ASTM E 1049-85 [2] rainflow count algorithm. The results of the cycle counting analysis are displayed on semi-logarithmic plots for all of the load channels. The following settings were used:

- 128 rainflow cycle bins
- Half-cycles count as 0.5; full-cycles count as 1.0.

8.4.5 Damage Equivalent Loads

Damage equivalent loads (DELs) were calculated for all load channels for each 10-minute data file. The DELs were calculated in accordance with the IEC 61400-13 for slopes with values of 3, 6, 9, and 10.

The 10-minute rainflow counts were left as raw cycles for the computation.

8.4.6 Lifetime Fatigue Spectra

The lifetime fatigue spectra for the loads channels were computed as follows:

1. All valid data sets were binned by wind speed only.
2. For each wind speed bin, all files were rainflow counted as described above.
3. For each wind speed bin, the rainflow cycles were summed and scaled to 20 years for IEC Class II and Class III wind speed distributions.

   The scaled cycles for each wind speed were then added to achieve the lifetime fatigue spectra.

9 Results

Graphical and tabular results are given in Appendix A. The results are divided in three sections:

1. Normal power production
2. Transients
3. Parked/idling.

9.1 Power Production

For normal power production, the 10-minute data files were filtered to meet the following criteria:

1. Mean wind direction within the measurement sector
2. Minimum rotor speed >10.5
3. Maximum of blade pitch angle 1 <50
4. Mean of power >0.

For power production, the capture matrix is provided in Figure 22 and Figure 1.

For each signal, the following information is provided:

- Scatterplot of 10-minute statistics as a function of hub-height wind speed
- Table with binned data versus wind speed
- Example time series at a four different wind speeds.

In addition to the information listed above for the loads channels, the following things are added:

- Plots of DELs as a function of wind speeds for several m values
- Plots of binned DELs as a function of wind speed for several m values
- Table with binned DELs versus wind speed
- Plot of 20-year fatigue load spectra for IEC Class II and III
- Plots of azimuth binned loads for four different wind speeds
- PSDs at four different wind speeds.

The four wind speed files used for time series, azimuth averaging, and PSDs are as follows:

- 7.4 m/s: FastWaveforms 2011_03_08 19_30_38 100Hz
- 14.0 m/s: FastWaveforms 2011_03_09 12_46_23 100Hz
- 18.3 m/s: FastWaveforms 2011_03_09 14_56_33 100Hz
- 19.8 m/s: FastWaveforms 2011_03_11 08_37_17 100Hz.

9.2 Transients

The capture matrices for the transient events are provided below in Table 20.

Transients are identified by applying the following filters to the data:

1. Wind direction inside measurement sector
2. Turbine goes from producing power to not generating power (stop) or vice versa (start).

Plots and tables with results of example transients are provided in Figure 171 through Figure 200 and Table 78 through Table 83.

Table 20. Capture Matrix for Normal Transients

Event	Wind Speed Range	Duration	Required	Obtained
Normal Startup	3–12 m/s	Transient	3	57
	12–16 m/s	Transient	3	4
	>16 m/s	Transient	2	3
Normal Shutdown	3–12 m/s	Transient	3	72
	12–16 m/s	Transient	3	5
	>16 m/s	Transient	2	2

9.3 Parked/Idling

The capture matrix for parked/idling is provided in Table 21.

For parked/idling, 10-minute data files were used that met the following criteria:

1. Wind direction inside measurement sector
2. Maximum of power <0.

Table 21. Capture Matrix for Parked/Idling

Event	Wind-Speed Range	Duration	Required [2-min files]	Obtained [10-min files]
Parked/Idling	3–12 m/s	2 min	10	7
	12–16 m/s	2 min	10	3
	>16 m/s	2 min	10	39

Plots and tables with results of example transients are provided in Table 84 through Table 86 and Figure 201 through Figure 215.

9.4 Turbine Dynamic Analysis

As per the Standard, a simple analysis of the turbine natural frequencies was performed. The results for major structural components are presented in Table 22 and Figure 12 through Figure 16 below. For each component, a particular test case was identified that would allow the best opportunity to isolate that component's natural frequency.

Table 22. Turbine Structural Natural Frequencies

Mode	Frequency (Hz)	Test Condition	Notes	File
First Tower Normal	0.35	Normal Stop at 10.4 m/s	Taken from ringing of tower-base normal bending after normal stop	2011_03_11_14_27_45
First Tower Lateral	0.36	Normal Stop at 12.5 m/s	Taken from ringing of tower-base lateral bending after normal stop	2011_03_03_16_28_03
First Tower Normal	0.36	Normal Operation at 18.3 m/s	Taken from tower-base normal bending signal during normal operation above rated	2011_03_09 14_56_33
First Tower Lateral	0.35	Normal Operation at 18.3 m/s	Taken from tower-base lateral bending signal during normal operation above rated	2011_03_09 14_56_33
First Drivetrain	2.15	Normal Stop at 14.0 m/s	Taken from ringing of shaft torque after normal-stop, condition is considered free-free	2011_03_09_12_46_23
First Blade Flap	0.61	Normal Operation at 14.0 m/s	Taken from blade 1 flap-bending signal during normal operation above rated	2011_03_09_12_46_23
First Blade Leadlag	1.22	Normal Operation at 14.0 m/s	Taken from blade 1 leadlag bending signal during operation above rated	2011_03_09_12_46_23

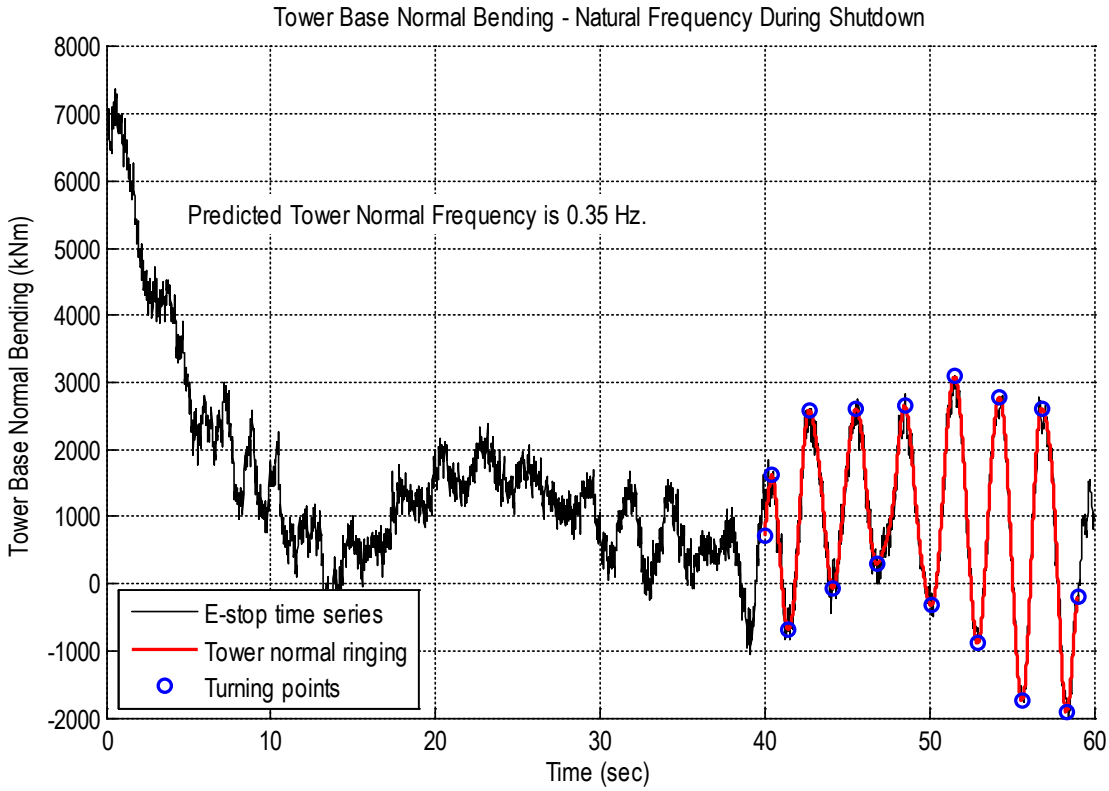


Figure 12. Tower normal natural frequency during shutdown

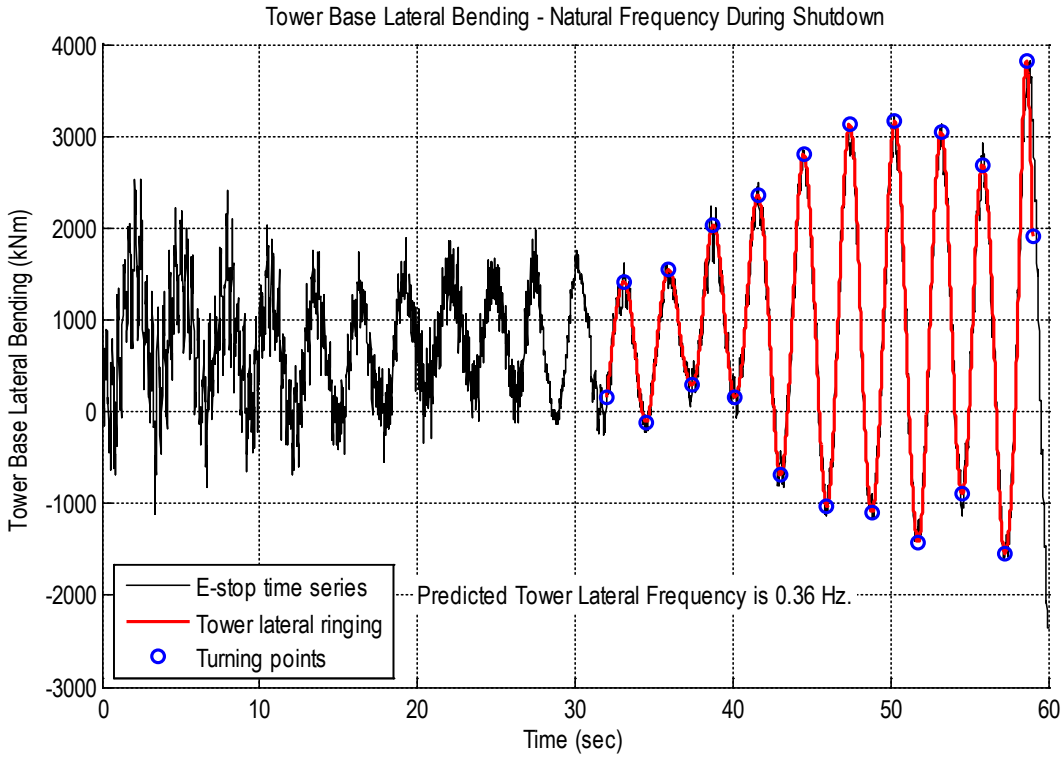


Figure 13. Tower lateral natural frequency during shutdown

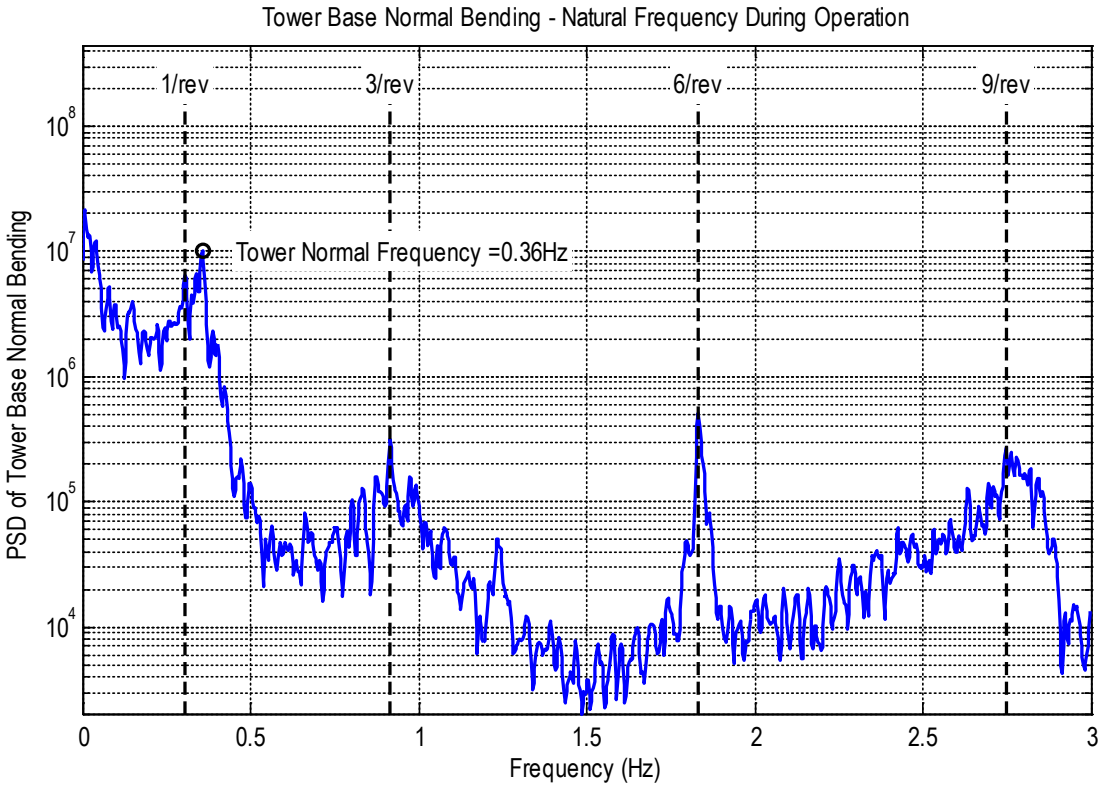


Figure 14. Tower normal natural frequency during normal operation

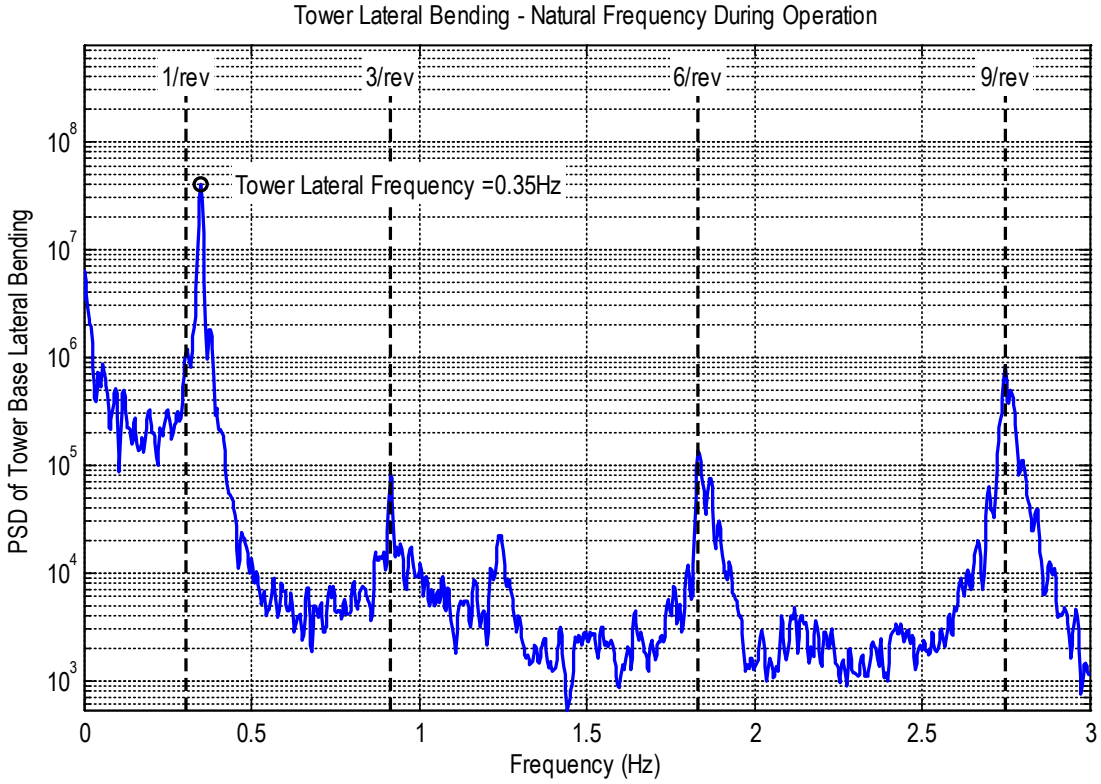


Figure 15. Tower lateral natural frequency during normal operation

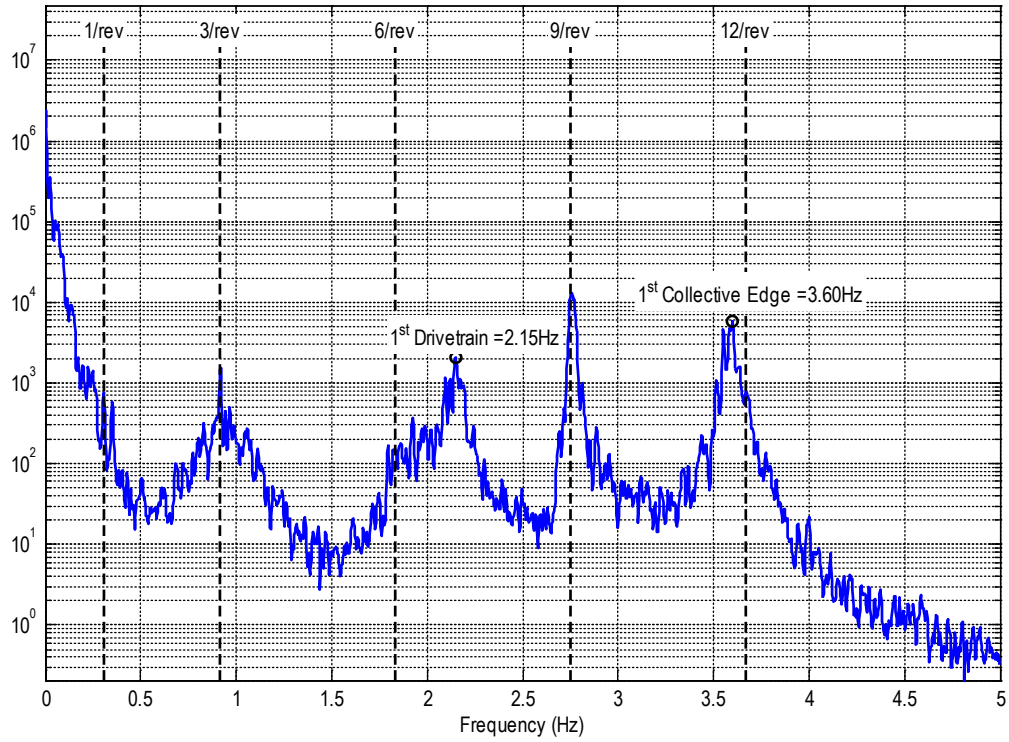


Figure 16. Drivetrain natural frequency after normal stop

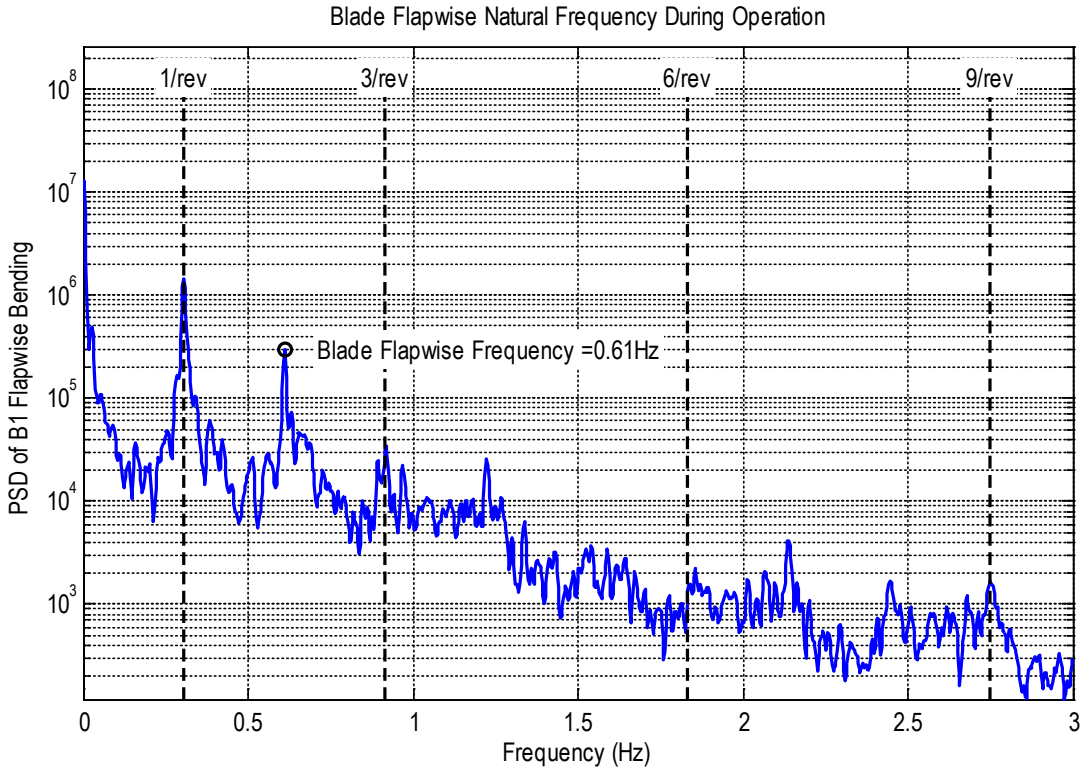


Figure 17. Blade 1 flap natural frequency normal operation

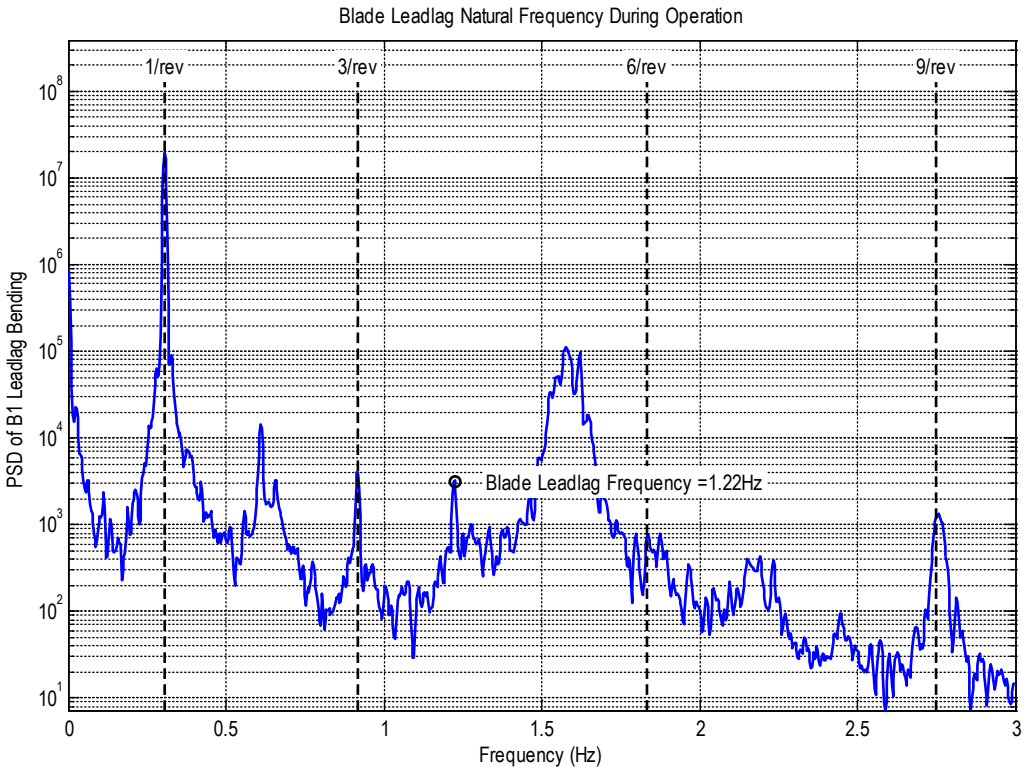


Figure 18. Blade 1 leadlag natural frequency during normal operation

10 Uncertainty

The uncertainty for the loads channels has been estimated based on the calibration uncertainties and variations found in the offset values. For each loads channel the inputs and assumptions are given in Table 23 through Table 36. It should be noted that these uncertainties do not include all uncertainties associated with estimating some of the turbine properties.

Table 23. Uncertainty Analysis for Blade 1 Flap Bending

Uncertainty Source	Estimated Value	Uncertainty	Units	Distribution/Divisor	Sensitivity Coefficient	Type	Degrees of Freedom	Distribution Divisor	Standard Uncertainty
Mass of blade	5800.0	50	kg	Rectangular	1.03E+02	B	inf	1.73	3.0
CG location of blade	10.6	0.1	m	Rectangular	5.66E+04	B	inf	1.73	3.3
tilt angle	5.0	0.2	deg	Rectangular	5.25E+04	B	inf	1.73	6.1
pitch angle	90.0	0.2	deg	Rectangular	3.68E-11	B	inf	1.73	0.0
Zero Calibration	-1.53E-05	1.39E-06	V/V	Normal	6.00E+05	A	30	1.00	0.8
Effective Degrees of Freedom	**2.00E+05**								
Coverage factor (95% Confidence)	**1.98**								
Combined Standard Uncertainty	**8**	kNm							
Expanded Uncertainty	**15**	kNm							

Table 24. Uncertainty Analysis for Blade 2 Flap Bending

Uncertainty Source	Estimated Value	Uncertainty	Units	Distribution/Divisor	Sensitivity Coefficient	Type	Degrees of Freedom	Distribution Divisor	Standard Uncertainty
Mass of blade	5800	50	kg	Rectangular	1.03E+02	B	inf	1.73	3.0
CG location of blade	10.6	0.1	m	Rectangular	5.66E+04	B	inf	1.73	3.3
tilt angle	5	0.2	deg	Rectangular	5.25E+04	B	inf	1.73	6.1
pitch angle	90	0.2	deg	Rectangular	3.68E-11	B	inf	1.73	0.0
Zero Calibration	-5.79E-04	5.72E-07	V/V	Normal	6.00E+05	A	29	1.00	0.3
Effective Degrees of Freedom	**6.66E+07**								
Coverage factor (95% Confidence)	**1.98**								
Combined Standard Uncertainty	**8**	kNm							
Expanded Uncertainty	**15**	kNm							

Table 25. Uncertainty Analysis for Blade 3 Flap Bending

Uncertainty Source	Estimated Value	Uncertainty	Units	Distribution/Divisor	Sensitivity Coefficient	Type	Degrees of Freedom	Distribution Divisor	Standard Uncertainty
Mass of blade	5800	50	kg	Rectangular	1.03E+02	B	inf	1.73	3.0
CG location of blade	10.6	0.1	m	Rectangular	5.66E+04	B	inf	1.73	3.3
tilt angle	5	0.2	deg	Rectangular	5.25E+04	B	inf	1.73	6.1
pitch angle	90	0.2	deg	Rectangular	3.68E-11	B	inf	1.73	0.0
Zero Calibration	-5.79E-04	5.72E-07	V/V	Normal	6.00E+05	A	29	1.00	0.3
Effective Degrees of Freedom				**6.66E+07**					
Coverage factor (95% Confidence)				**1.98**					
Combined Standard Uncertainty				**8**	kNm				
Expanded Uncertainty				**15**	kNm				

Table 26. Uncertainty Analysis for Blade 1 Leadlag Bending

Uncertainty Source	Estimated Value	Uncertainty	Units	Distribution/Divisor	Sensitivity Coefficient	Type	Degrees of Freedom	Distribution Divisor	Standard Uncertainty
Mass of blade	5800.0	50	kg	Rectangular	1.03E+02	B	inf	1.73	3.0
CG location of blade	10.6	0.1	m	Rectangular	5.66E+04	B	inf	1.73	3.3
tilt angle	5.0	0.2	deg	Rectangular	5.25E+04	B	inf	1.73	6.1
pitch angle	0.0	0.2	deg	Rectangular	0.00E+00	B	inf	1.73	0.0
Zero Calibration	8.51E-04	1.39E-06	V/V	Normal	6.00E+05	A	28	1.00	0.8
Effective Degrees of Freedom				**1.88E+05**					
Coverage factor (95% Confidence)				**1.98**					
Combined Standard Uncertainty				**8**	kNm				
Expanded Uncertainty				**15**	kNm				

Table 27. Uncertainty Analysis for Blade 2 Leadlag Bending

Uncertainty Source	Estimated Value	Uncertainty	Units	Distribution/Divisor	Sensitivity Coefficient	Type	Degrees of Freedom	Distribution Divisor	Standard Uncertainty
Mass of blade	5800.0	50	kg	Rectangular	1.03E+02	B	inf	1.73	3.0
CG location of blade	10.6	0.1	m	Rectangular	5.66E+04	B	inf	1.73	3.3
tilt angle	5.0	0.2	deg	Rectangular	5.25E+04	B	inf	1.73	6.1
pitch angle	0.0	0.2	deg	Rectangular	0.00E+00	B	inf	1.73	0.0
Zero Calibration	-4.13E-06	5.73E-07	V/V	Normal	6.00E+05	A	27	1.00	0.3
Effective Degrees of Freedom				**6.15E+06**					
Coverage factor (95% Confidence)				**1.98**					
Combined Standard Uncertainty				**8**	kNm				
Expanded Uncertainty				**15**	kNm				

Table 28. Uncertainty Analysis for Blade 3 Leadlag Bending

Uncertainty Source	Estimated Value	Uncertainty	Units	Distribution/Divisor	Sensitivity Coefficient	Type	Degrees of Freedom	Distribution Divisor	Standard Uncertainty
Mass of blade	5800.0	50	kg	Rectangular	1.03E+02	B	inf	1.73	3.0
CG location of blade	10.6	0.1	m	Rectangular	5.66E+04	B	inf	1.73	3.3
tilt angle	5.0	0.2	deg	Rectangular	5.25E+04	B	inf	1.73	6.1
pitch angle	0.0	0.2	deg	Rectangular	0.00E+00	B	inf	1.73	0.0
Zero Calibration	-4.71E-04	4.58E-07	V/V	Normal	6.00E+05	A	29	1.00	0.3
Effective Degrees of Freedom				**1.62E+07**					
Coverage factor (95% Confidence)				**1.98**					
Combined Standard Uncertainty				**8**	kNm				
Expanded Uncertainty				**15**	kNm				

Table 29. Main Shaft Bending 0 Uncertainty

Uncertainty Source	Estimated Value	Uncertainty	Units	Distribution/Divisor	Sensitivity Coefficient	Type	Degrees of Freedom	Distribution Divisor	Standard Uncertainty
Mass of blade	5800	50	kg	Rectangular	103.48	B	inf	1.73	3.0
CG location of blade	10.6	0.1	m	Rectangular	56621.55	B	inf	1.73	3.3
tilt angle	5	0.2	deg	Rectangular	52509.68	B	inf	1.73	6.1
pitch angle	0.5	0.2	deg	Rectangular	5237.7651	B	inf	1.73	0.6
Zero Calibration	8.51E-04	2.06E-05	V/V	Normal	600188.44	A	219	1.00	12.4

Effective Degrees of Freedom	**411**			Mean Load at Rated (kNm)	**298**
Coverage factor (95% Confidence)	**1.98**			Standard Uncertainty at Rated	**5%**
Combined Standard Uncertainty	**14.5**	kNm		Expanded Uncertainty at Rated	**10%**
Expanded Uncertainty	**28.7**	kNm			

Table 30. Main Shaft Bending 90 Uncertainty

Uncertainty Source	Estimated Value	Uncertainty	Units	Distribution/Divisor	Sensitivity Coefficient	Type	Degrees of Freedom	Distribution Divisor	Standard Uncertainty
Modulus of Elasticty	2.1E+11	2.10E+10	Pa	Rectangular	4.78E-06	B	inf	1.73	58.0
Outer Diameter	0.581	0.001	m	Rectangular	5.19E+06	B	inf	1.73	3.0
Inner Diameter	0.04	0.001	m	Rectangular	2.26E+03	B	inf	1.73	0.0
Gage Factor	2.02	0.01	-	Rectangular	1.00E+06	B	inf	1.73	5.8
Gage Resistance	350	3.5	Ohms	Rectangular	2.86E+03	B	inf	1.73	5.8
Shunt Resistance	1.74E+05	1.74E+02	Ohms	Rectangular	5.76E+00	B	inf	1.73	0.6
Zero Calibration	1.62E+00	0.0148	V/V	Normal	6.68E+02	A	214	1.00	9.9

Effective Degrees of Freedom	**443**			Mean Load at Rated (kNm)	**152**
Coverage factor (95% Confidence)	**1.98**			Standard Uncertainty at Rated	**8%**
Combined Standard Uncertainty	**11.9**	kNm		Expanded Uncertainty at Rated	**15%**
Expanded Uncertainty	**23.5**	kNm			

Table 31. Uncertainty Analysis for Main Shaft Torque

Uncertainty Source	Estimated Value	Uncertainty	Units	Distribution/Divisor	Sensitivity Coefficient	Type	Degrees of Freedom	Distribution Divisor	Standard Uncertainty
Modulus of Elasticty	2.1E+11	5.91E+09	Pa	Rectangular	7.30E-06	B	inf	1.73	24.9
Poisson Ratio	0.3	5.77E-03	m	Rectangular	6.85E+05	B	inf	1.73	2.3
Outer Diameter	0.581	0.001	m	Rectangular	7.91E+06	B	inf	1.73	4.6
Inner Diameter	0.04	0.001	m	Rectangular	2.24E+03	B	inf	1.73	0.0
Gage Factor	2.03	0.01	-	Rectangular	4.38E+03	B	inf	1.73	0.0
Gage Resistance	350	1	Ohms	Rectangular	4.37E+03	B	inf	1.73	2.5
Shunt Resistance	1.75E+05	1.75E+02	Ohms	Rectangular	3.50E+01	B	inf	1.73	3.5
Zero Calibration	1.49E+00	1.54E-02	V/V	Normal	1.31E+03	A	75	1.00	20.2
Effective Degrees of Freedom				**5.08E+03**					
Coverage factor (95% Confidence)				**2.01**					
Combined Standard Uncertainty				**33**	kNm				
Expanded Uncertainty				**65**	kNm				

Table 32. Uncertainty Analysis for Tower-Top Torque

Uncertainty Source	Estimated Value	Uncertainty	Units	Distribution/Divisor	Sensitivity Coefficient	Type	Degrees of Freedom	Distribution Divisor	Standard Uncertainty
Modulus of Elasticty	2.1E+11	5.91E+09	Pa	Rectangular	2.86E-05	B	inf	1.73	97.5
Poisson Ratio	0.3	5.77E-03	m	Rectangular	2.64E+07	B	inf	1.73	87.9
Outer Diameter	2.858	1.00E-03	m	Rectangular	2.52E+08	B	inf	1.73	145.7
Inner Diameter	2.810	1.00E-03	m	Rectangular	1.58E+08	B	inf	1.73	91.5
Gage Factor	2.02	0.000202	-	Rectangular	3.43E+04	B	inf	1.73	0.0
Gage Resistance	350	1.4	Ohms	Rectangular	3.42E+04	B	inf	1.73	27.7
Shunt Resistance	1.75E+05	1.75E+01	Ohms	Rectangular	2.74E+02	B	69	1.73	2.8
Zero Calibration	4.36E-06	7.96E-06	V/V	Normal	2.44E+07	A	69	1.00	194.2
Effective Degrees of Freedom				**286**					
Coverage factor (95% Confidence)				**1.96**					
Combined Standard Uncertainty				**277**	kNm				
Expanded Uncertainty				**543**	kNm				

Table 33. Uncertainty Analysis for Tower-Top Bending 1

Uncertainty Source	Estimated Value	Uncertainty	Units	Distribution/Divisor	Sensitivity Coefficient	Type	Degrees of Freedom	Distribution Divisor	Standard Uncertainty
Nacelle + Rotor Mass	87000	2.50E+03	Pa	Rectangular	7.83E-01	B	inf	1.73	1.1
Nacelle + Rotor Center of Gravity	1.107	0.1	m	Rectangular	6.15E+04	B	inf	1.73	3.6
Yaw Angle Measurement	45	2	deg	Rectangular	6.81E+04	B	inf	1.73	78.6
Zero Calibration	3.25E-05	1.93E-06	V/V	Normal	5.08E+07	A	217	1.00	98.2

Effective Degrees of Freedom	**586**		Mean Load at Rated (kNm)	**12000**
Coverage factor (95% Confidence)	**1.98**		Standard Uncertainty at Rated	**1%**
Combined Standard Uncertainty	**125.8**	kNm	Expanded Uncertainty at Rated	**2%**
Expanded Uncertainty	**249.6**	kNm		

Table 34. Uncertainty Analysis for Tower-Top Bending 2

Uncertainty Source	Estimated Value	Uncertainty	Units	Distribution/Divisor	Sensitivity Coefficient	Type	Degrees of Freedom	Distribution Divisor	Standard Uncertainty
Nacelle + Rotor Mass	87000	2.50E+03	Pa	Rectangular	7.83E-01	B	inf	1.73	1.1
Nacelle + Rotor Center of Gravity	1.107	0.1	m	Rectangular	6.15E+04	B	inf	1.73	3.6
Yaw Angle Measurement	45	2	deg	Rectangular	6.81E+04	B	inf	1.73	78.6
Zero Calibration	3.04E-04	1.80E-06	V/V	Normal	5.27E+07	A	217	1.00	94.6

Effective Degrees of Freedom	**622**		Mean Load at Rated (kNm)	**12000**
Coverage factor (95% Confidence)	**1.98**		Standard Uncertainty at Rated	**1%**
Combined Standard Uncertainty	**123.1**	kNm	Expanded Uncertainty at Rated	**2%**
Expanded Uncertainty	**244.2**	kNm		

Table 35. Uncertainty Analysis for Tower-Base Bending 1

Uncertainty Source	Estimated Value	Uncertainty	Units	Distribution/Divisor	Sensitivity Coefficient	Type	Degrees of Freedom	Distribution Divisor	Standard Uncertainty
Nacelle + Rotor Mass	87000	2.50E+03	Pa	Rectangular	7.83E-01	B	inf	1.73	1.1
Nacelle + Rotor Center of Gravity	1.107	0.1	m	Rectangular	6.15E+04	B	inf	1.73	3.6
Yaw Angle Measurement	45	2	deg	Rectangular	6.81E+04	B	inf	1.73	78.6
Zero Calibration	3.04E-04	1.80E-06	V/V	Normal	5.27E+07	A	217	1.00	94.6

Effective Degrees of Freedom	**622**		Mean Load at Rated (kNm)	**12000**
Coverage factor (95% Confidence)	**1.98**		Standard Uncertainty at Rated	**1%**
Combined Standard Uncertainty	**123.1**	kNm	Expanded Uncertainty at Rated	**2%**
Expanded Uncertainty	**244.2**	kNm		

Table 36. Uncertainty Analysis for Tower-Base Bending 2

Uncertainty Source	Estimated Value	Uncertainty	Units	Distribution/Divisor	Sensitivity Coefficient	Type	Degrees of Freedom	Distribution Divisor	Standard Uncertainty
Nacelle + Rotor Mass	87000	2.50E+03	Pa	Rectangular	7.83E-01	B	inf	1.73	1.1
Nacelle + Rotor Center of Gravity	1.107	0.1	m	Rectangular	6.15E+04	B	inf	1.73	3.6
Yaw Angle Measurement	45	2	deg	Rectangular	6.81E+04	B	inf	1.73	78.6
Zero Calibration	3.25E-05	1.93E-06	V/V	Normal	5.08E+07	A	217	1.00	98.2

Effective Degrees of Freedom	**586**		Mean Load at Rated (kNm)	**12000**
Coverage factor (95% Confidence)	**1.98**		Standard Uncertainty at Rated	**1%**
Combined Standard Uncertainty	**125.8**	kNm	Expanded Uncertainty at Rated	**2%**
Expanded Uncertainty	**249.6**	kNm		

11 Exceptions

11.1 Exceptions to the Test Plan

The exceptions to the test plan include the following:

- Power signal is taken from the SCADA not from the NREL sensor.
- Main shaft gages upwind of main bearing were not used in analysis because of poor signal quality. Only results from the gages downwind of the bearing are shown.
- Tower-top gages were placed at a different location than what was specified.
- Loads channels were recorded at 100 Hz instead of 50 Hz.

11.2 Exceptions to the Standard

None.

11.3 Exceptions to NWTC Quality Assurance System

Four signal conditioning modules (sn: 1342666, 1357162, 1357177, and 136D7A2) were used past their calibration due date. Post-test calibrations were performed and the modules were found to be within tolerance. The post-test calibration sheets are included in Appendix I.

- Details of sensor used for rotor speed and azimuth not documented
- Details on lot or batch number for strain gages not documented.

References

1. "Wind Turbine Generator Systems – Part 13: Measurement of Mechanical Loads." TS IEC 61400-13 first edition, 2001-06.
2. "ASTM E 1049-85 (Reapproved 1997), Standard practices for cycle counting in fatigue analysis." *Annual Book of ASTM Standards*. Vol. 03.01, Philadelphia, PA. 1999; pp. 710-718.
3. "Wind turbines – Part 12-1: Power performance measurements of electricity producing wind turbines," TS IEC 61400-13 First edition, 2005-12

Appendix A. Result Plots and Tables

Turbulence Intensity

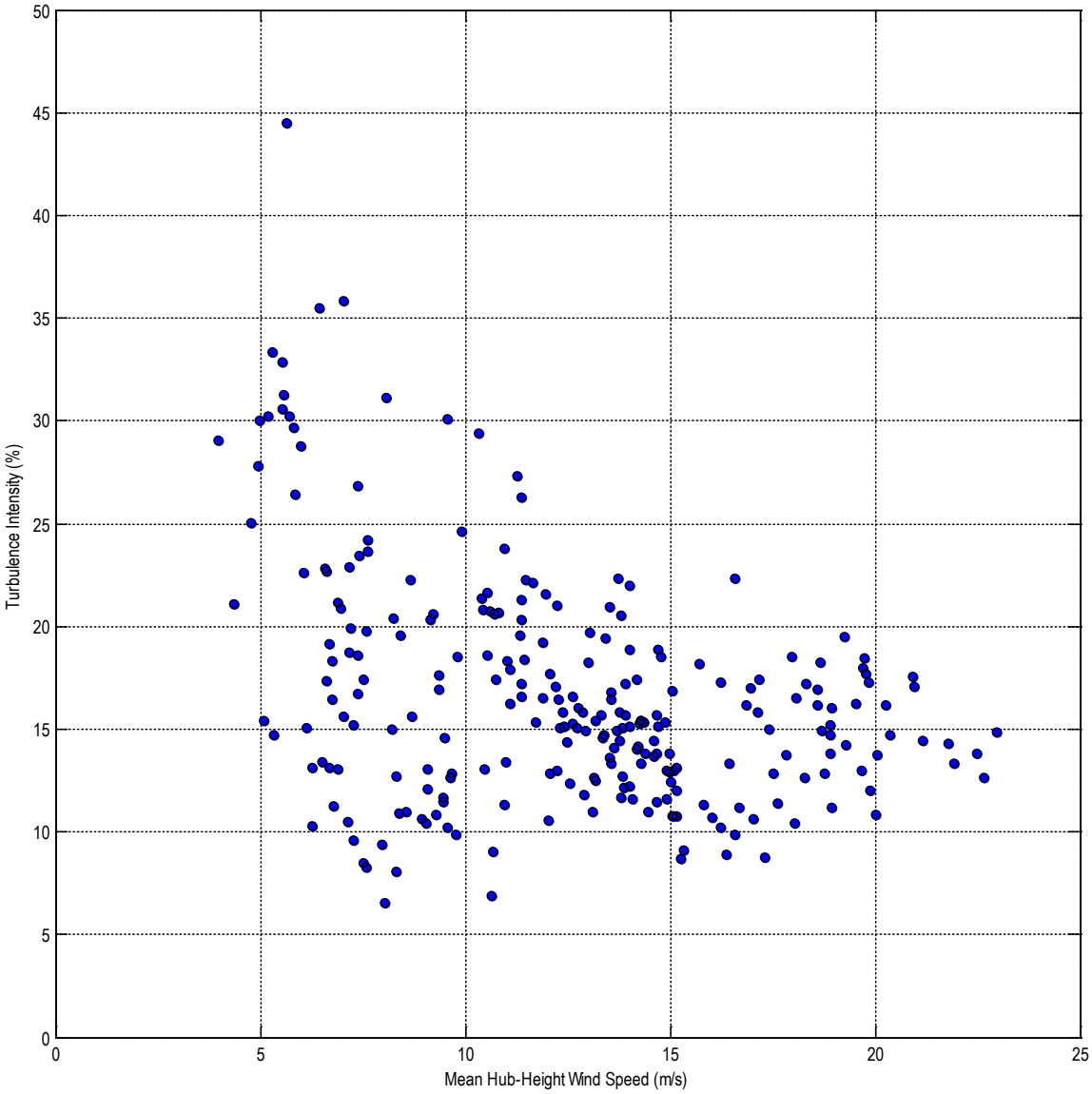
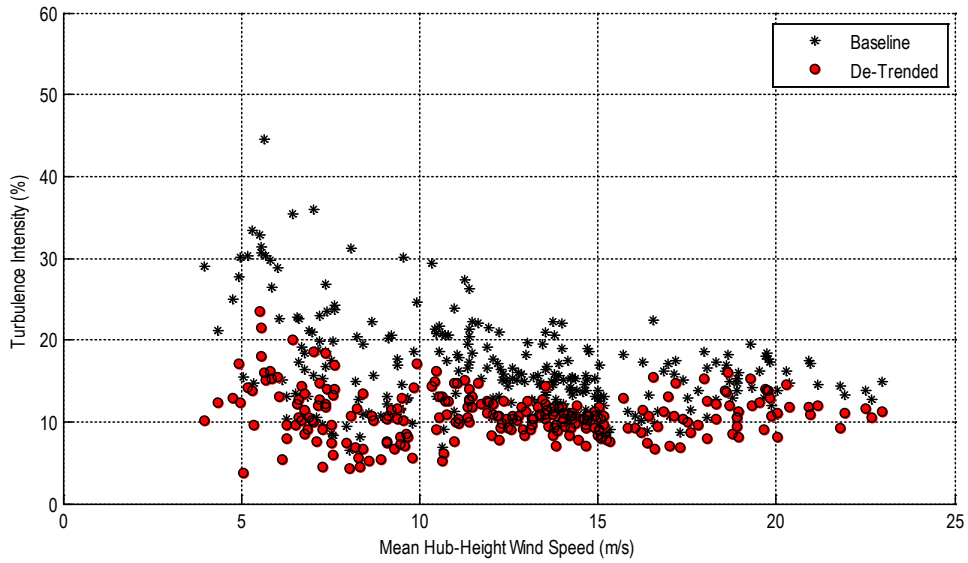


Figure 19. Turbulence intensity

Wind Speed Trend Detection

Turbulence Intensity



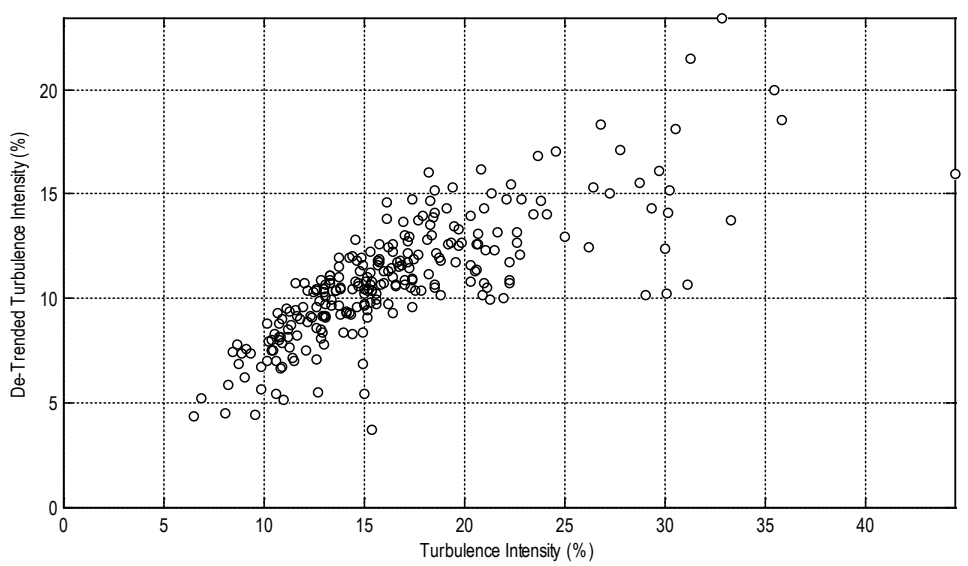


Figure 20. Indication of presence of wind speed trending in data set

Air Density

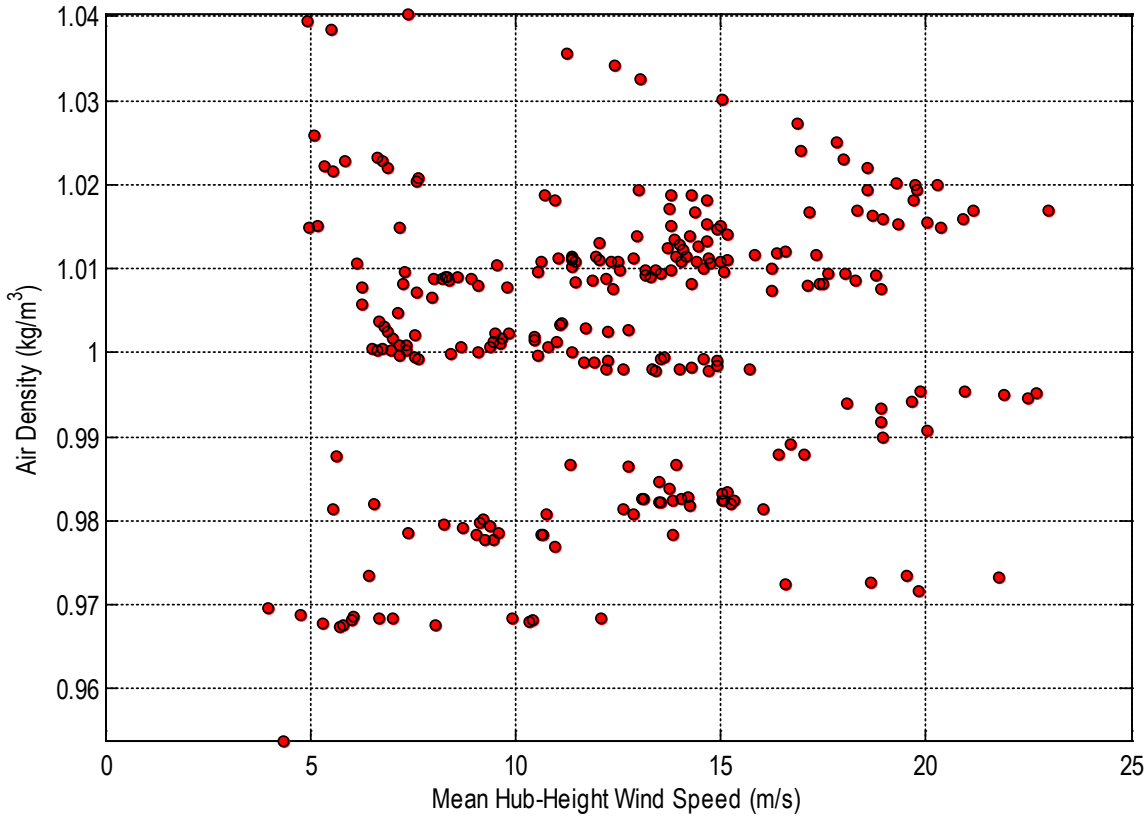


Figure 21. Scatterplot versus wind speed for air density

Global Capture Matrix with All Loads Channels Operating

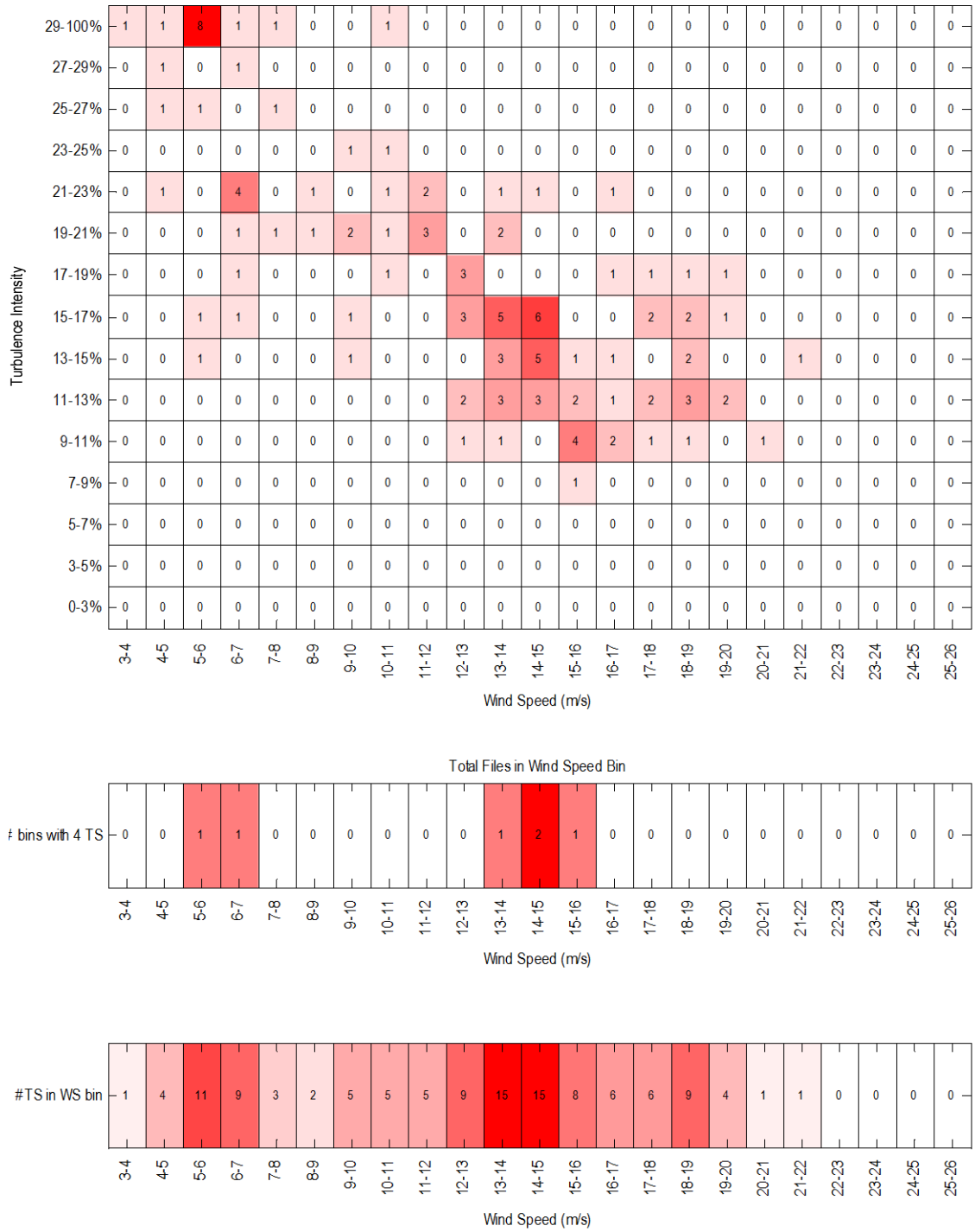


Figure 22. Global capture matrix with all loads channels operating

Power Production Data

Electric Power

Turbulence Intensity	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-11	11-12	12-13	13-14	14-15	15-16	16-17	17-18	18-19	19-20	20-21	21-22	22-23	23-24	24-25	25-26
29-100%	1	1	8	1	1	1	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
27-29%	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
25-27%	0	1	1	0	1	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
23-25%	0	0	0	0	3	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
21-23%	0	1	0	4	1	1	0	2	5	1	1	1	0	1	0	0	0	0	0	0	0	0	0
19-21%	0	0	0	3	2	2	2	5	3	0	5	0	0	0	0	0	2	0	0	0	0	0	0
17-19%	0	0	0	3	4	0	3	2	8	3	2	5	1	3	2	2	6	3	0	0	0	0	0
15-17%	0	0	1	3	6	1	1	0	6	11	8	8	2	2	2	7	1	2	0	0	0	0	0
13-15%	0	0	1	7	0	2	3	2	2	5	9	10	2	1	2	4	2	4	3	3	0	0	0
11-13%	0	0	0	1	0	2	7	1	0	3	5	6	4	1	2	3	2	0	0	1	0	0	0
9-11%	0	0	0	2	6	6	5	1	0	1	1	2	4	4	1	1	0	1	0	0	0	0	0
7-9%	0	0	0	0	4	2	0	0	0	0	0	0	1	2	2	0	0	0	0	0	0	0	0
5-7%	0	0	0	0	0	2	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3-5%	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0-3%	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Wind Speed (m/s)

Total Files in Wind Speed Bin

	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-11	11-12	12-13	13-14	14-15	15-16	16-17	17-18	18-19	19-20	20-21	21-22	22-23	23-24	24-25	25-26
# bins with 4 TS	0	0	1	2	4	1	2	1	3	2	4	4	2	1	0	2	1	1	0	0	0	0	0

Wind Speed (m/s)

	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-11	11-12	12-13	13-14	14-15	15-16	16-17	17-18	18-19	19-20	20-21	21-22	22-23	23-24	24-25	25-26
#TS in WS bin	1	4	11	25	28	19	24	16	26	24	31	32	14	14	11	17	13	10	3	4	0	0	0

Wind Speed (m/s)

Figure 23. Capture matrix for electric power

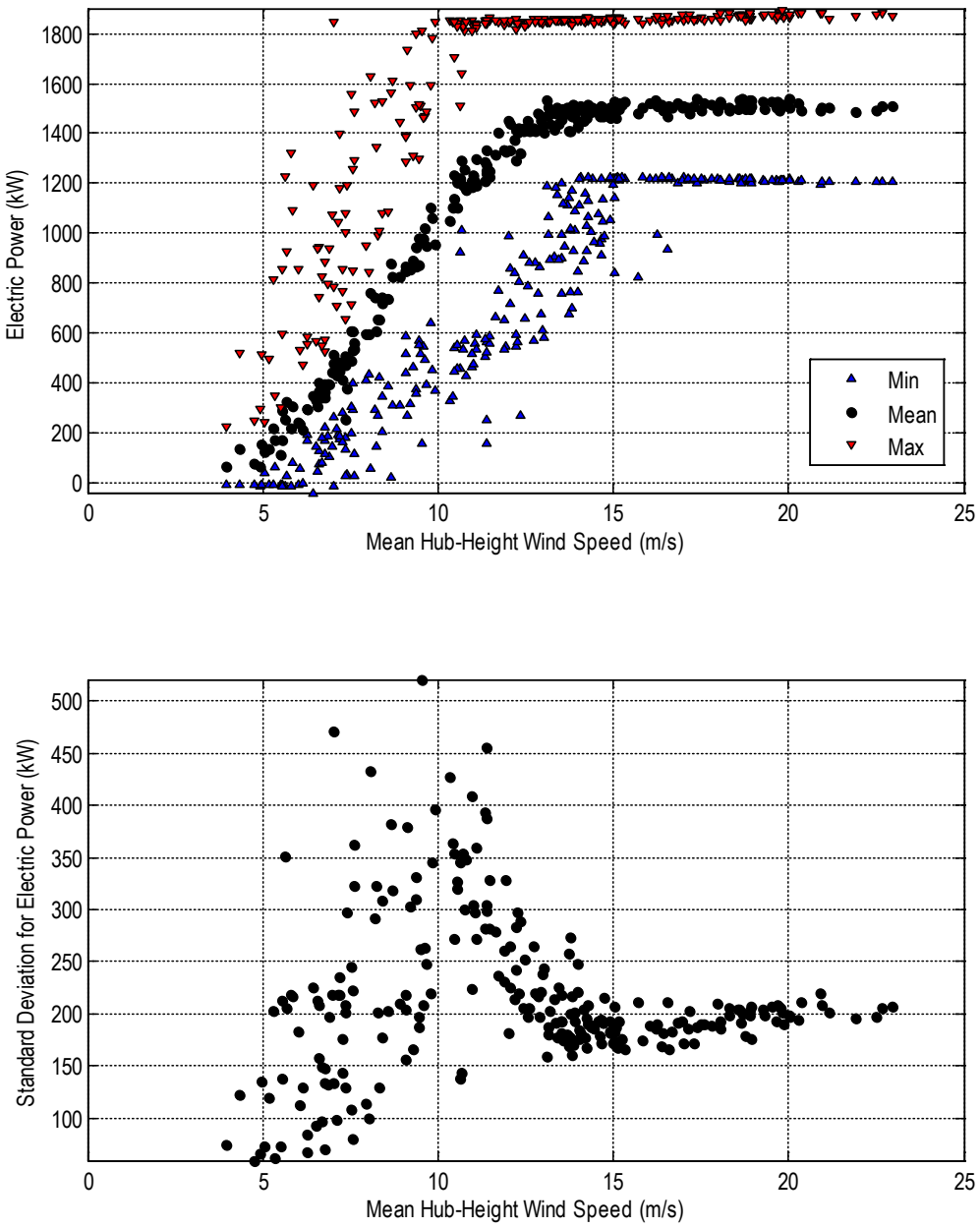


Figure 24. Scatterplot for electric power

Table 37. Binned Data for Electric Power

Bin #	Bin WS Low	Bin WS High	Mean WS	# Files	Min of Minimums	Mean of Means	Max of Maximums
1	3.0	4.0	4.0	1	-9.79	66.25	225.65
2	4.0	5.0	4.8	4	-12.18	106.94	517.22
3	5.0	6.0	5.5	11	-10.13	210.57	1,317.44
4	6.0	7.0	6.6	25	-39.33	339.20	1,191.74
5	7.0	8.0	7.4	28	-11.68	485.76	1,847.05
6	8.0	9.0	8.4	19	23.94	720.79	1,626.33
7	9.0	10.0	9.5	24	160.79	947.77	1,843.93
8	10.0	11.0	10.6	16	327.61	1,187.95	1,850.85
9	11.0	12.0	11.4	26	158.81	1,269.56	1,860.77
10	12.0	13.0	12.5	24	270.11	1,412.08	1,856.71
11	13.0	14.0	13.5	31	581.65	1,471.84	1,857.82
12	14.0	15.0	14.5	32	850.05	1,485.22	1,863.80
13	15.0	16.0	15.3	14	824.09	1,507.02	1,861.46
14	16.0	17.0	16.6	14	935.38	1,509.50	1,873.11
15	17.0	18.0	17.5	11	1,201.41	1,508.14	1,872.26
16	18.0	19.0	18.6	17	1,202.73	1,514.55	1,895.27
17	19.0	20.0	19.6	13	1,205.37	1,512.38	1,892.58
18	20.0	21.0	20.4	10	1,194.92	1,508.22	1,883.35
19	21.0	22.0	21.4	3	1,205.34	1,497.59	1,870.25
20	22.0	23.0	22.8	4	1,206.54	1,503.80	1,880.97
21	23.0	24.0	0.0	0	0.00	0.00	0.00
22	24.0	25.0	0.0	0	0.00	0.00	0.00
23	25.0	26.0	0.0	0	0.00	0.00	0.00

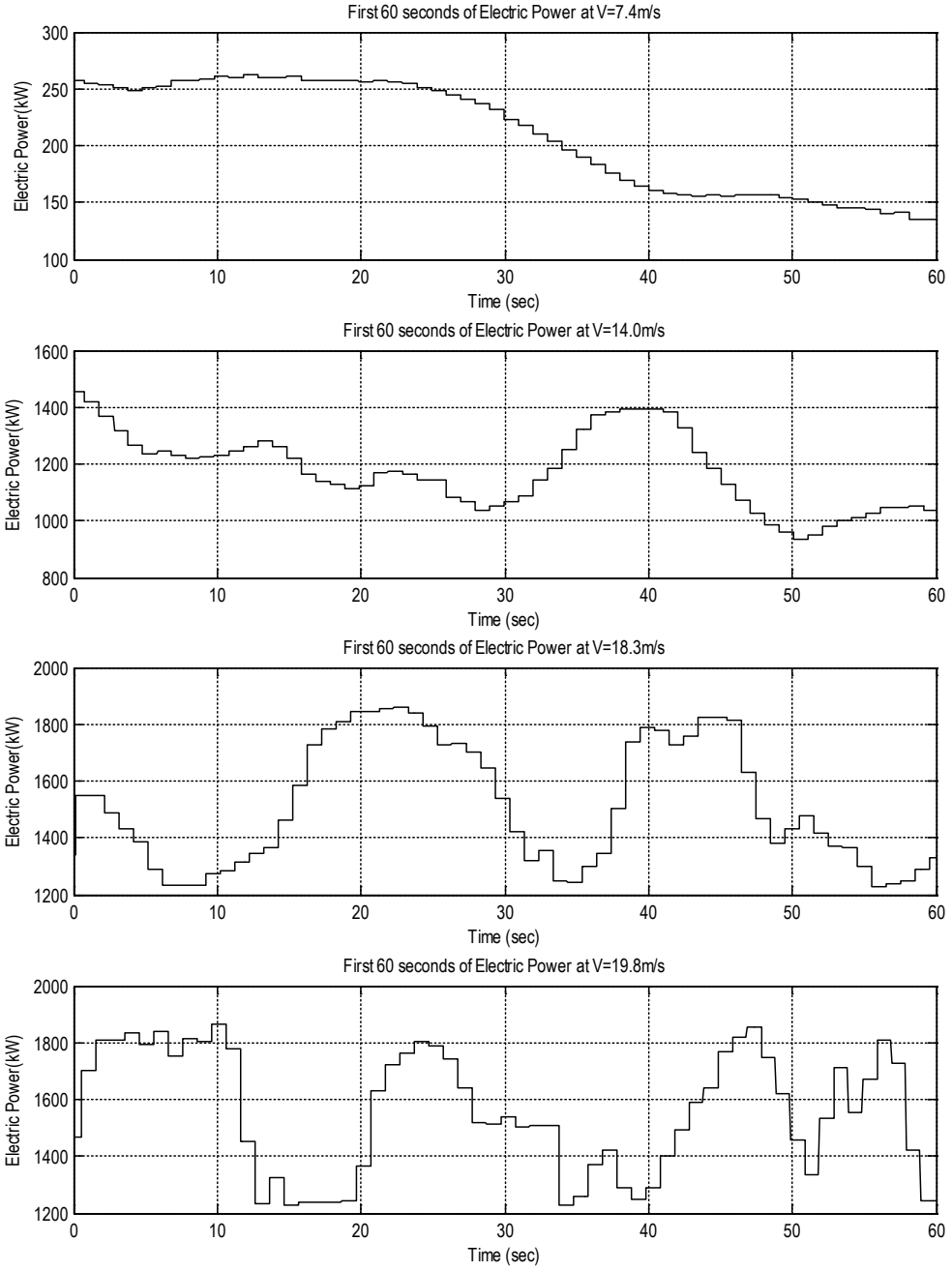


Figure 25. Time series for the first 60 seconds of electric power

Rotor Speed

Turbulence Intensity	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-11	11-12	12-13	13-14	14-15	15-16	16-17	17-18	18-19	19-20	20-21	21-22	22-23	23-24	24-25	25-26
29-100%	1	1	8	1	1	1	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
27-29%	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
25-27%	0	1	1	0	1	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
23-25%	0	0	0	0	3	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
21-23%	0	1	0	4	1	1	0	2	5	1	1	1	0	1	0	0	0	0	0	0	0	0	0
19-21%	0	0	0	3	2	2	2	5	3	0	5	0	0	0	0	0	2	0	0	0	0	0	0
17-19%	0	0	0	3	4	0	3	2	8	3	2	5	1	3	2	2	6	3	0	0	0	0	0
15-17%	0	0	1	3	6	1	1	0	6	11	8	8	2	2	2	7	1	2	0	0	0	0	0
13-15%	0	0	1	7	0	2	3	2	2	5	9	10	2	1	2	4	2	4	3	3	0	0	0
11-13%	0	0	0	1	0	2	7	1	0	3	5	6	4	1	2	3	2	0	0	1	0	0	0
9-11%	0	0	0	2	6	6	5	1	0	1	1	2	4	4	1	1	0	1	0	0	0	0	0
7-9%	0	0	0	0	4	2	0	0	0	0	0	0	1	2	2	0	0	0	0	0	0	0	0
5-7%	0	0	0	0	0	2	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3-5%	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0-3%	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Wind Speed (m/s)

Total Files in Wind Speed Bin

	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-11	11-12	12-13	13-14	14-15	15-16	16-17	17-18	18-19	19-20	20-21	21-22	22-23	23-24	24-25	25-26
# bins with 4 TS	0	0	1	2	4	1	2	1	3	2	4	4	2	1	0	2	1	1	0	0	0	0	0

Wind Speed (m/s)

	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-11	11-12	12-13	13-14	14-15	15-16	16-17	17-18	18-19	19-20	20-21	21-22	22-23	23-24	24-25	25-26
#TS in WS bin	1	4	11	25	28	19	24	16	26	24	31	32	14	14	11	17	13	10	3	4	0	0	0

Wind Speed (m/s)

Figure 26. Capture matrix for rotor speed

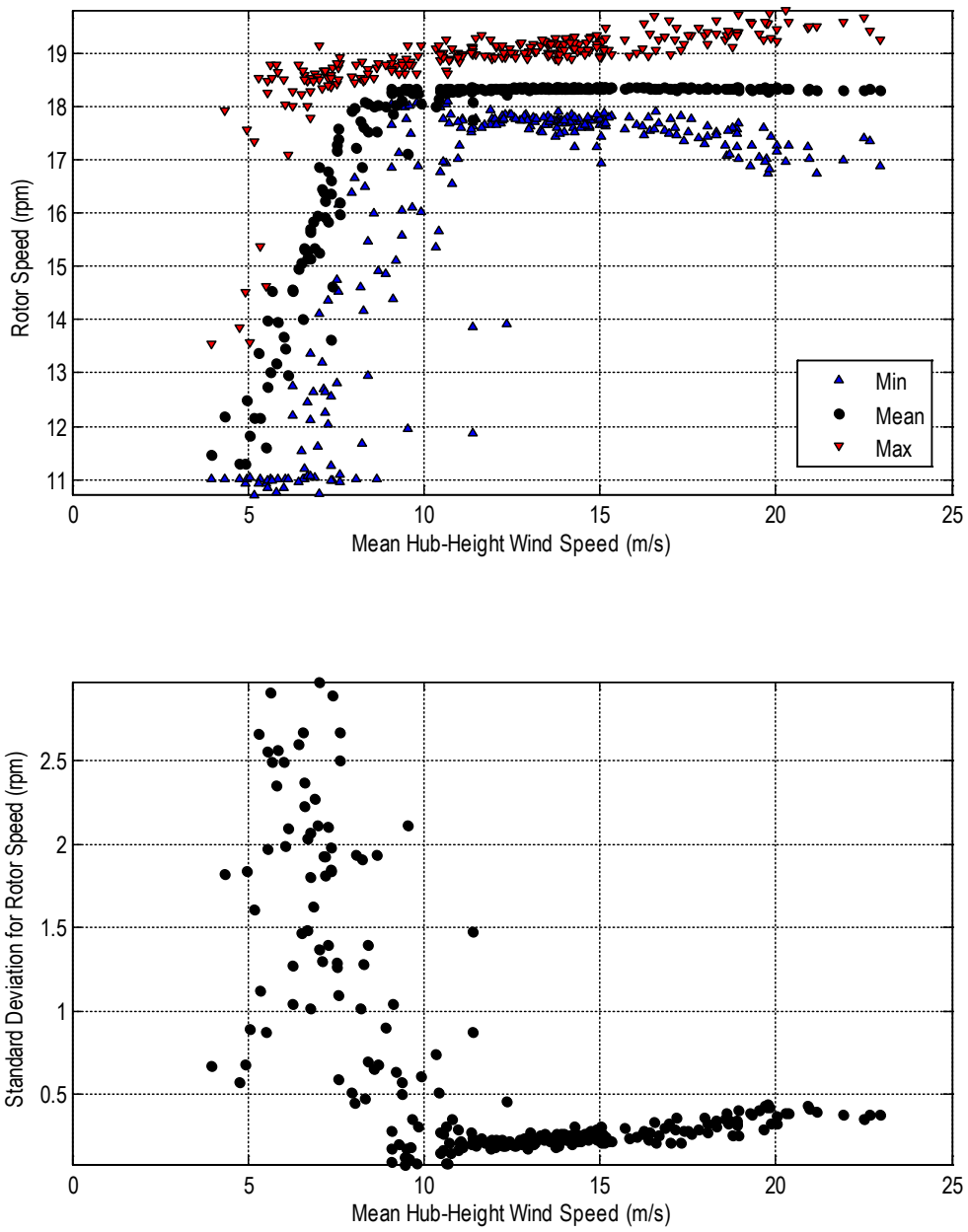


Figure 27. Scatterplot for rotor speed

Table 38. Binned Data for Rotor Speed

Bin #	Bin WS Low	Bin WS High	Mean WS	# Files	Min of Minimums	Mean of Means	Max of Maximums
1	3.0	4.0	4.0	1	11.01	11.47	13.55
2	4.0	5.0	4.8	4	10.94	11.81	17.90
3	5.0	6.0	5.5	11	10.73	12.95	18.78
4	6.0	7.0	6.6	25	10.86	14.97	18.77
5	7.0	8.0	7.4	28	10.75	16.49	19.14
6	8.0	9.0	8.4	19	11.02	17.79	18.82
7	9.0	10.0	9.5	24	11.96	18.14	19.13
8	10.0	11.0	10.6	16	15.38	18.27	19.24
9	11.0	12.0	11.4	26	11.89	18.28	19.31
10	12.0	13.0	12.5	24	13.92	18.33	19.19
11	13.0	14.0	13.5	31	17.43	18.34	19.26
12	14.0	15.0	14.5	32	17.24	18.33	19.33
13	15.0	16.0	15.3	14	16.95	18.34	19.46
14	16.0	17.0	16.6	14	17.47	18.34	19.69
15	17.0	18.0	17.5	11	17.30	18.34	19.47
16	18.0	19.0	18.6	17	17.02	18.33	19.72
17	19.0	20.0	19.6	13	16.74	18.32	19.74
18	20.0	21.0	20.4	10	16.96	18.32	19.81
19	21.0	22.0	21.4	3	16.75	18.31	19.58
20	22.0	23.0	22.8	4	16.90	18.31	19.66
21	23.0	24.0	0.0	0	0.00	0.00	0.00
22	24.0	25.0	0.0	0	0.00	0.00	0.00
23	25.0	26.0	0.0	0	0.00	0.00	0.00

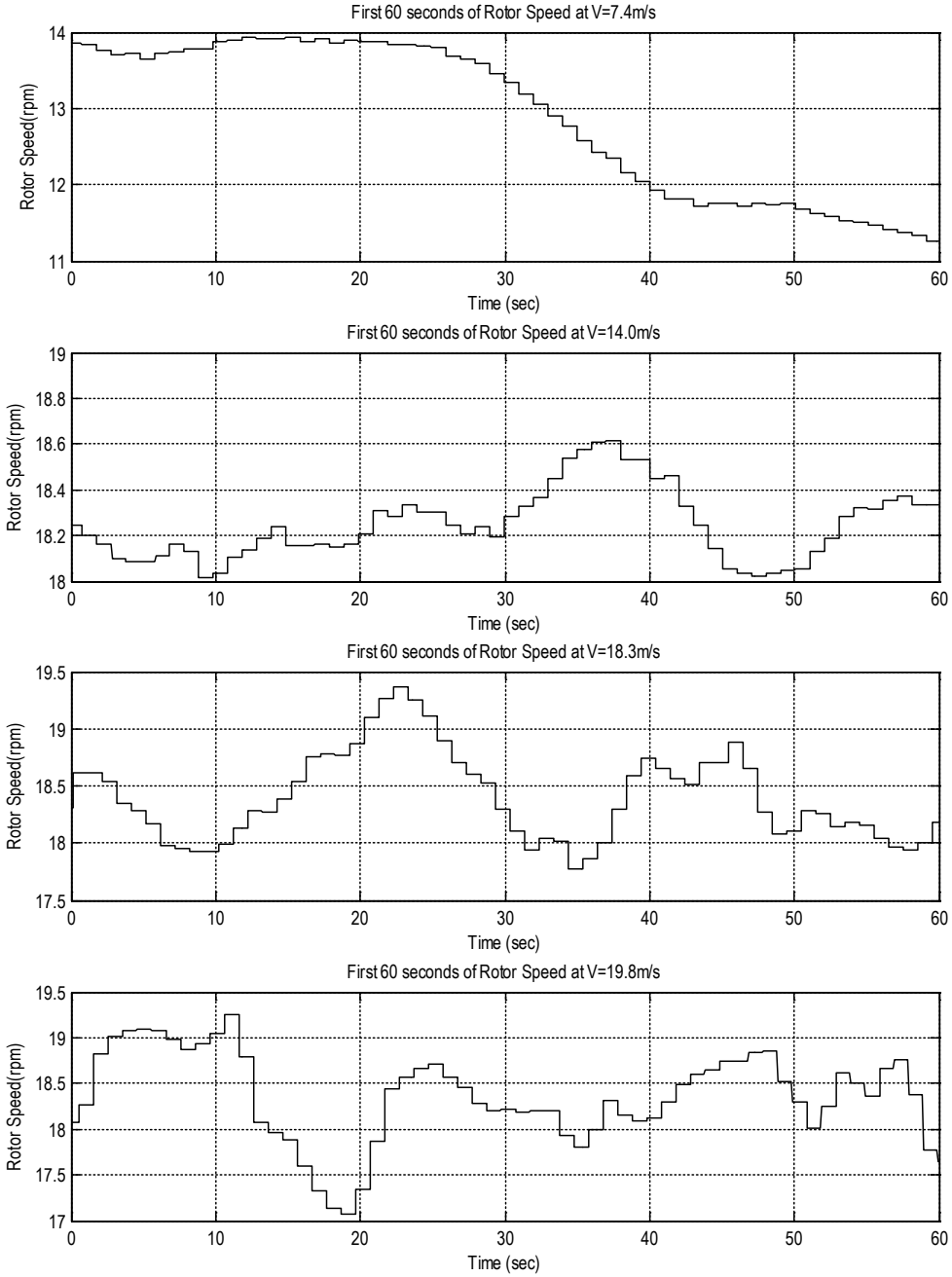


Figure 28. Time series for first 60 seconds of rotor speed

Generator Speed

Turbulence Intensity	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-11	11-12	12-13	13-14	14-15	15-16	16-17	17-18	18-19	19-20	20-21	21-22	22-23	23-24	24-25	25-26
29-100%	1	1	8	1	1	1	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
27-29%	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
25-27%	0	1	1	0	1	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
23-25%	0	0	0	0	3	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
21-23%	0	1	0	4	1	1	0	2	5	1	1	1	0	1	0	0	0	0	0	0	0	0	0
19-21%	0	0	0	3	2	2	2	5	3	0	5	0	0	0	0	0	2	0	0	0	0	0	0
17-19%	0	0	0	3	4	0	3	2	8	3	2	5	1	3	2	2	6	3	0	0	0	0	0
15-17%	0	0	1	3	6	1	1	0	6	11	8	8	2	2	2	7	1	2	0	0	0	0	0
13-15%	0	0	1	7	0	2	3	2	2	5	9	10	2	1	2	4	2	4	3	3	0	0	0
11-13%	0	0	0	1	0	2	7	1	0	3	5	6	4	1	2	3	2	0	0	1	0	0	0
9-11%	0	0	0	2	6	6	5	1	0	1	1	2	4	4	1	1	0	1	0	0	0	0	0
7-9%	0	0	0	0	4	2	0	0	0	0	0	0	1	2	2	0	0	0	0	0	0	0	0
5-7%	0	0	0	0	0	2	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3-5%	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0-3%	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Wind Speed (m/s)

Total Files in Wind Speed Bin

	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-11	11-12	12-13	13-14	14-15	15-16	16-17	17-18	18-19	19-20	20-21	21-22	22-23	23-24	24-25	25-26
# bins with 4 TS	0	0	1	2	4	1	2	1	3	2	4	4	2	1	0	2	1	1	0	0	0	0	0

Wind Speed (m/s)

	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-11	11-12	12-13	13-14	14-15	15-16	16-17	17-18	18-19	19-20	20-21	21-22	22-23	23-24	24-25	25-26
#TS in WS bin	1	4	11	25	28	19	24	16	26	24	31	32	14	14	11	17	13	10	3	4	0	0	0

Wind Speed (m/s)

Figure 29. Capture matrix for generator speed

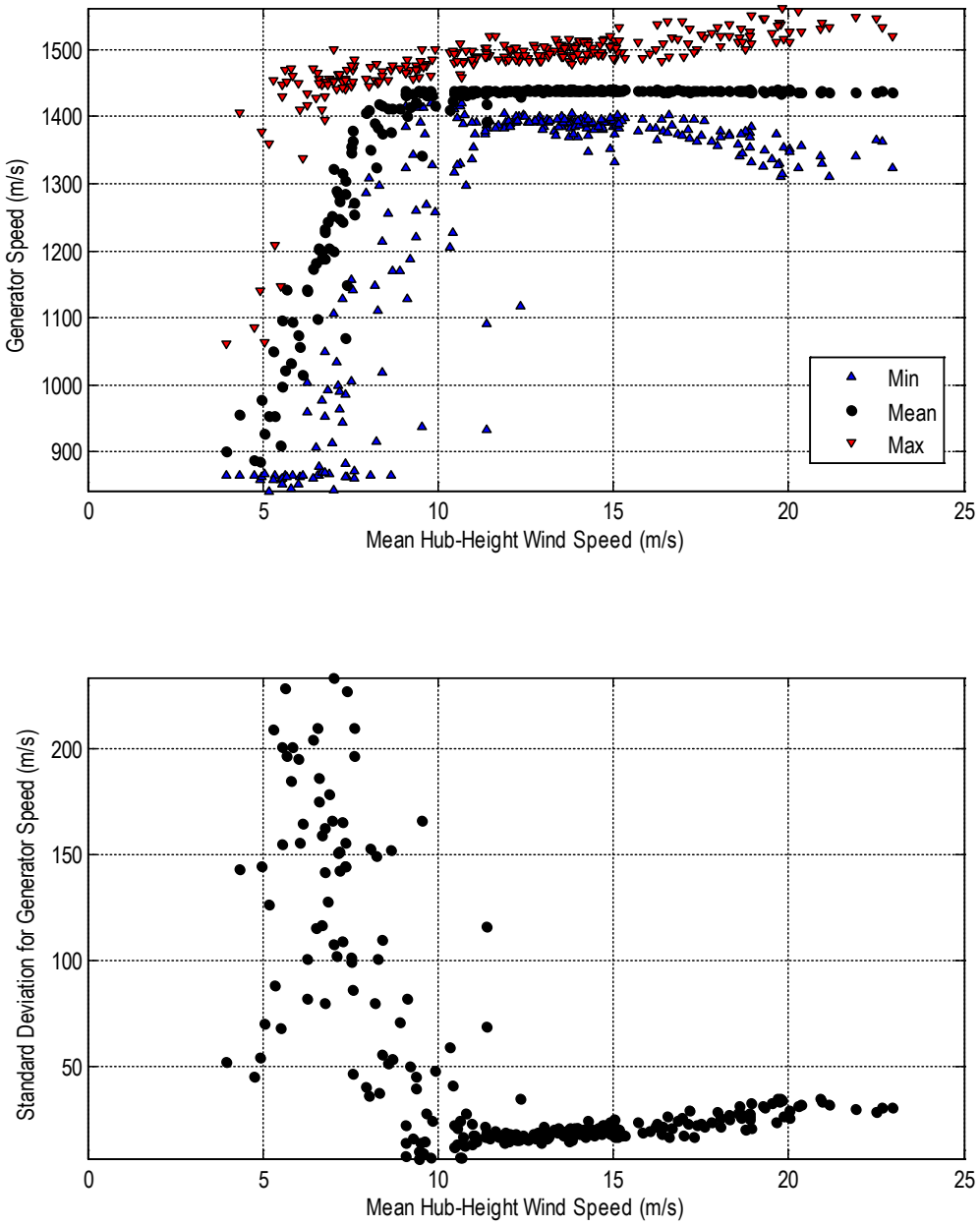


Figure 30. Scatterplot for generator speed

Table 39. Binned Data for Generator Speed

Bin #	Bin WS Low	Bin WS High	Mean WS	# Files	Min of Minimums	Mean of Means	Max of Maximums
1	3.0	4.0	4.0	1	865.03	899.82	1,061.93
2	4.0	5.0	4.8	4	859.37	926.92	1,405.25
3	5.0	6.0	5.5	11	842.67	1,016.34	1,470.99
4	6.0	7.0	6.6	25	853.26	1,174.66	1,471.56
5	7.0	8.0	7.4	28	844.42	1,293.91	1,500.82
6	8.0	9.0	8.4	19	865.89	1,396.05	1,477.11
7	9.0	10.0	9.5	24	938.25	1,423.13	1,500.32
8	10.0	11.0	10.6	16	1,206.48	1,433.37	1,508.48
9	11.0	12.0	11.4	26	933.37	1,434.42	1,518.60
10	12.0	13.0	12.5	24	1,117.66	1,437.86	1,505.47
11	13.0	14.0	13.5	31	1,369.41	1,438.76	1,514.34
12	14.0	15.0	14.5	32	1,349.41	1,438.56	1,520.02
13	15.0	16.0	15.3	14	1,333.95	1,439.21	1,533.76
14	16.0	17.0	16.6	14	1,366.13	1,438.79	1,542.22
15	17.0	18.0	17.5	11	1,356.20	1,438.66	1,533.13
16	18.0	19.0	18.6	17	1,332.81	1,438.39	1,551.20
17	19.0	20.0	19.6	13	1,311.71	1,437.64	1,562.34
18	20.0	21.0	20.4	10	1,324.28	1,437.68	1,557.21
19	21.0	22.0	21.4	3	1,310.50	1,436.28	1,548.40
20	22.0	23.0	22.8	4	1,323.80	1,436.96	1,546.62
21	23.0	24.0	0.0	0	0.00	0.00	0.00
22	24.0	25.0	0.0	0	0.00	0.00	0.00
23	25.0	26.0	0.0	0	0.00	0.00	0.00

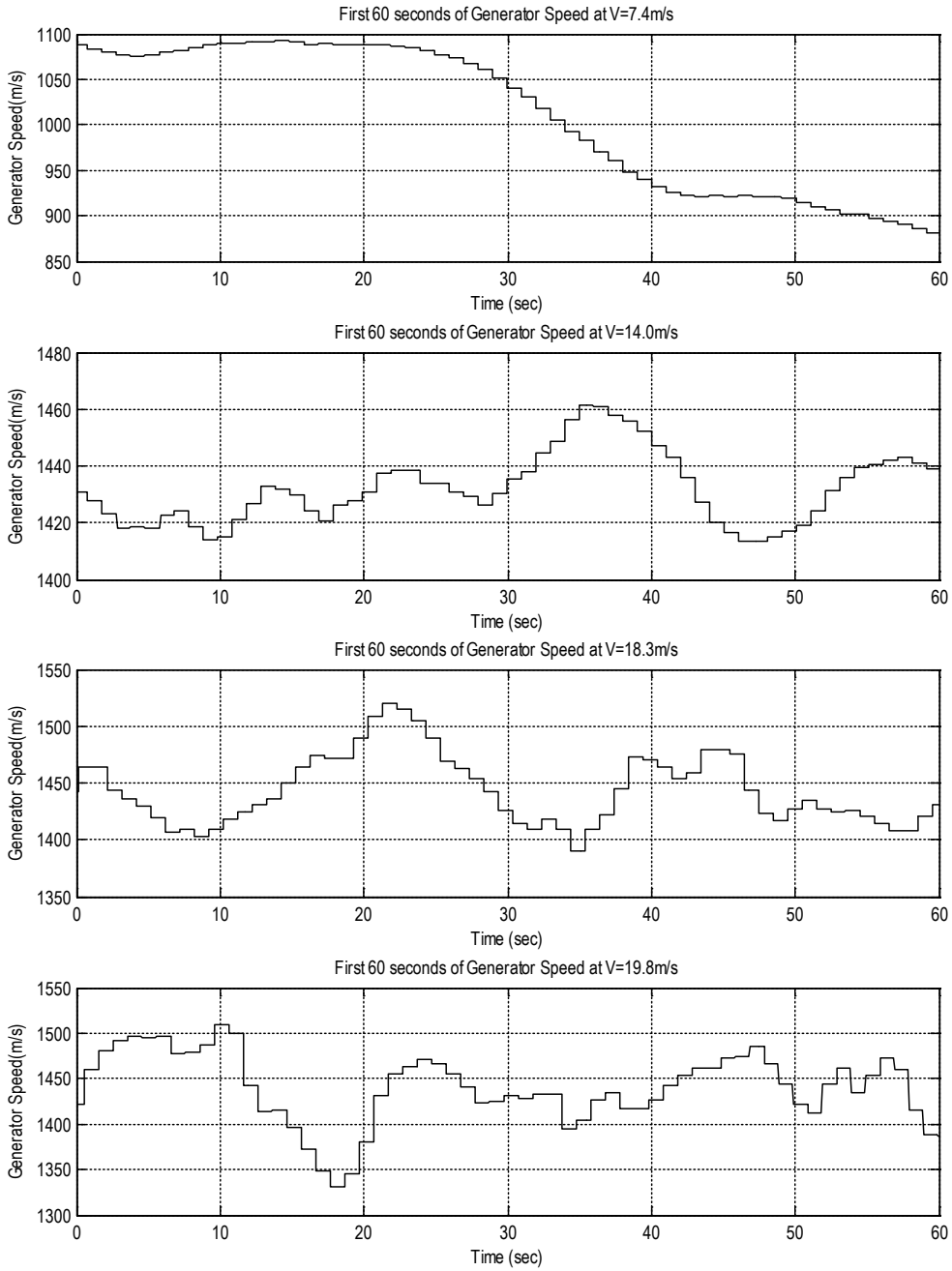


Figure 31. Time series for the first 60 seconds of generator speed

Blade 1 Pitch Position

Turbulence Intensity	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-11	11-12	12-13	13-14	14-15	15-16	16-17	17-18	18-19	19-20	20-21	21-22	22-23	23-24	24-25	25-26
29-100%	1	1	8	1	1	1	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
27-29%	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
25-27%	0	1	1	0	1	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
23-25%	0	0	0	0	3	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
21-23%	0	1	0	4	1	1	0	2	5	1	1	1	0	1	0	0	0	0	0	0	0	0	0
19-21%	0	0	0	3	2	2	2	5	3	0	5	0	0	0	0	0	2	0	0	0	0	0	0
17-19%	0	0	0	3	4	0	3	2	8	3	2	5	1	3	2	2	6	3	0	0	0	0	0
15-17%	0	0	1	3	6	1	1	0	6	11	8	8	2	2	2	7	1	2	0	0	0	0	0
13-15%	0	0	1	7	0	2	3	2	2	5	9	10	2	1	2	4	2	4	3	3	0	0	0
11-13%	0	0	0	1	0	2	7	1	0	3	5	6	4	1	2	3	2	0	0	1	0	0	0
9-11%	0	0	0	2	6	6	5	1	0	1	1	2	4	4	1	1	0	1	0	0	0	0	0
7-9%	0	0	0	0	4	2	0	0	0	0	0	0	1	2	2	0	0	0	0	0	0	0	0
5-7%	0	0	0	0	0	2	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3-5%	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0-3%	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Wind Speed (m/s)

Total Files in Wind Speed Bin

	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-11	11-12	12-13	13-14	14-15	15-16	16-17	17-18	18-19	19-20	20-21	21-22	22-23	23-24	24-25	25-26
# bins with 4 TS	0	0	1	2	4	1	2	1	3	2	4	4	2	1	0	2	1	1	0	0	0	0	0

Wind Speed (m/s)

	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-11	11-12	12-13	13-14	14-15	15-16	16-17	17-18	18-19	19-20	20-21	21-22	22-23	23-24	24-25	25-26
#TS in WS bin	1	4	11	25	28	19	24	16	26	24	31	32	14	14	11	17	13	10	3	4	0	0	0

Wind Speed (m/s)

Figure 32. Capture matrix for blade 1 pitch position

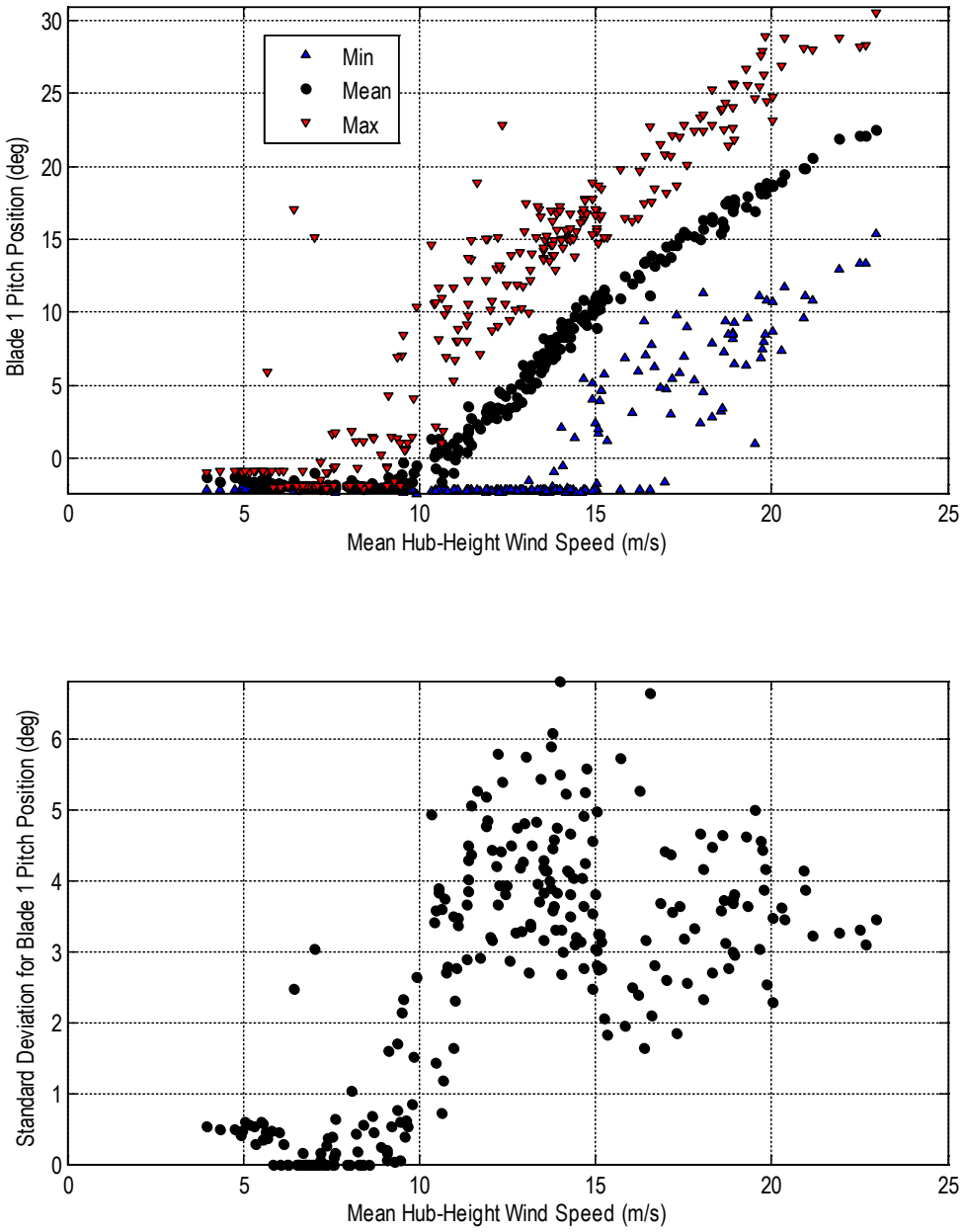


Figure 33. Scatterplot for blade 1 pitch position

Table 40. Binned Data for Blade 1 Pitch Position

Bin #	Bin WS Low	Bin WS High	Mean WS	# Files	Min of Minimums	Mean of Means	Max of Maximums
1	3.0	4.0	4.0	1	-2.05	-1.33	-0.94
2	4.0	5.0	4.8	4	-2.13	-1.33	-0.84
3	5.0	6.0	5.5	11	-2.12	-1.70	5.89
4	6.0	7.0	6.6	25	-2.20	-1.91	17.01
5	7.0	8.0	7.4	28	-2.29	-1.90	15.12
6	8.0	9.0	8.4	19	-2.13	-1.89	1.84
7	9.0	10.0	9.5	24	-2.35	-1.49	10.30
8	10.0	11.0	10.6	16	-2.24	0.21	14.62
9	11.0	12.0	11.4	26	-2.25	1.60	18.86
10	12.0	13.0	12.5	24	-2.26	4.12	22.79
11	13.0	14.0	13.5	31	-2.29	6.84	17.43
12	14.0	15.0	14.5	32	-2.29	9.35	18.87
13	15.0	16.0	15.3	14	-2.18	10.82	19.74
14	16.0	17.0	16.6	14	-2.14	13.11	22.66
15	17.0	18.0	17.5	11	2.41	14.85	23.28
16	18.0	19.0	18.6	17	2.91	16.63	25.62
17	19.0	20.0	19.6	13	1.05	17.99	28.86
18	20.0	21.0	20.4	10	7.40	19.24	30.82
19	21.0	22.0	21.4	3	10.85	20.99	28.73
20	22.0	23.0	22.8	4	13.39	22.30	30.50
21	23.0	24.0	0.0	0	0.00	0.00	0.00
22	24.0	25.0	0.0	0	0.00	0.00	0.00
23	25.0	26.0	0.0	0	0.00	0.00	0.00

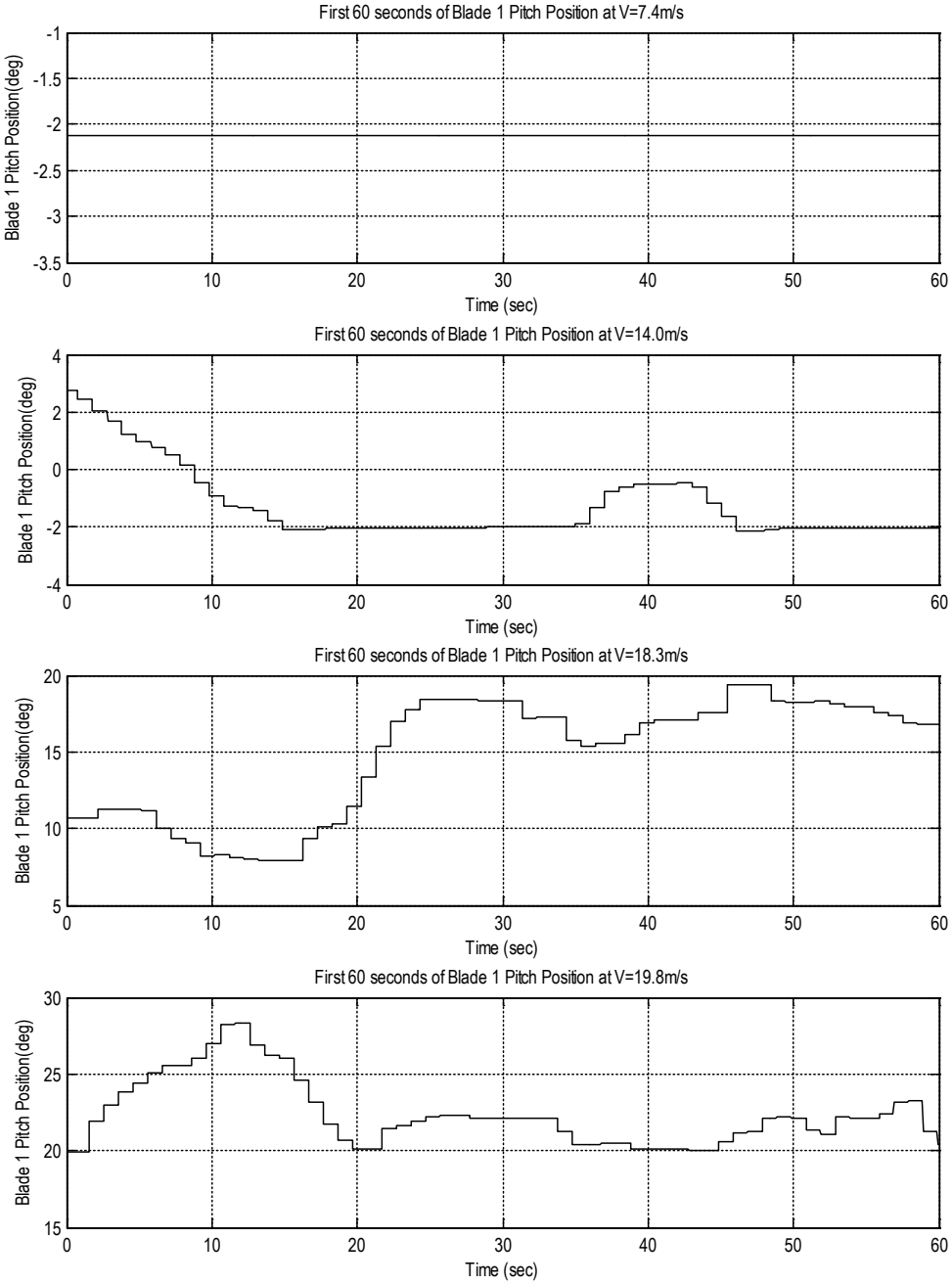


Figure 34. Time series for the first 60 seconds of blade 1 pitch position

Blade 2 Pitch Position

Turbulence Intensity	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-11	11-12	12-13	13-14	14-15	15-16	16-17	17-18	18-19	19-20	20-21	21-22	22-23	23-24	24-25	25-26
29-100%	1	1	8	1	1	1	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
27-29%	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
25-27%	0	1	1	0	1	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
23-25%	0	0	0	0	3	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
21-23%	0	1	0	4	1	1	0	2	5	1	1	1	0	1	0	0	0	0	0	0	0	0	0
19-21%	0	0	0	3	2	2	2	5	3	0	5	0	0	0	0	0	2	0	0	0	0	0	0
17-19%	0	0	0	3	4	0	3	2	8	3	2	5	1	3	2	2	6	3	0	0	0	0	0
15-17%	0	0	1	3	6	1	1	0	6	11	8	8	2	2	2	7	1	2	0	0	0	0	0
13-15%	0	0	1	7	0	2	3	2	2	5	9	10	2	1	2	4	2	4	3	3	0	0	0
11-13%	0	0	0	1	0	2	7	1	0	3	5	6	4	1	2	3	2	0	0	1	0	0	0
9-11%	0	0	0	2	6	6	5	1	0	1	1	2	4	4	1	1	0	1	0	0	0	0	0
7-9%	0	0	0	0	4	2	0	0	0	0	0	0	1	2	2	0	0	0	0	0	0	0	0
5-7%	0	0	0	0	0	2	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3-5%	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0-3%	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Wind Speed (m/s)

Total Files in Wind Speed Bin

	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-11	11-12	12-13	13-14	14-15	15-16	16-17	17-18	18-19	19-20	20-21	21-22	22-23	23-24	24-25	25-26
# bins with 4 TS	0	0	1	2	4	1	2	1	3	2	4	4	2	1	0	2	1	1	0	0	0	0	0

Wind Speed (m/s)

	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-11	11-12	12-13	13-14	14-15	15-16	16-17	17-18	18-19	19-20	20-21	21-22	22-23	23-24	24-25	25-26
#TS in WS bin	1	4	11	25	28	19	24	16	26	24	31	32	14	14	11	17	13	10	3	4	0	0	0

Wind Speed (m/s)

Figure 35. Capture matrix for blade 2 pitch position

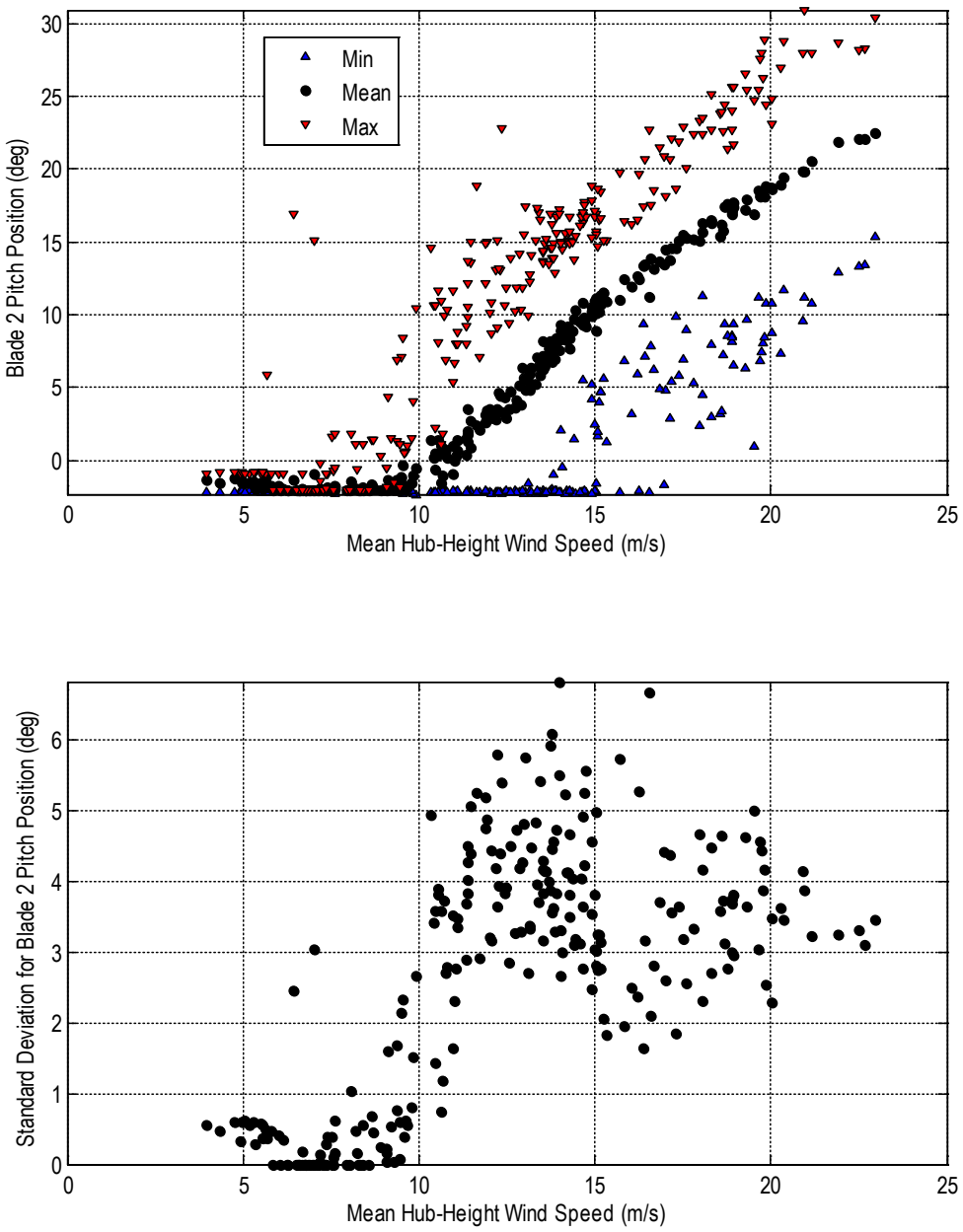


Figure 36. Scatterplot for blade 2 pitch position

Table 41. Binned Data for Blade 2 Pitch Position

Bin #	Bin WS Low	Bin WS High	Mean WS	# Files	Min of Minimums	Mean of Means	Max of Maximums
1	3.0	4.0	4.0	1	-2.13	-1.38	-0.97
2	4.0	5.0	4.8	4	-2.13	-1.37	-0.82
3	5.0	6.0	5.5	11	-2.15	-1.68	5.88
4	6.0	7.0	6.6	25	-2.21	-2.00	16.89
5	7.0	8.0	7.4	28	-2.26	-1.98	15.09
6	8.0	9.0	8.4	19	-2.11	-1.99	1.83
7	9.0	10.0	9.5	24	-2.31	-1.50	10.41
8	10.0	11.0	10.6	16	-2.19	0.21	14.59
9	11.0	12.0	11.4	26	-2.19	1.60	18.85
10	12.0	13.0	12.5	24	-2.25	4.12	22.79
11	13.0	14.0	13.5	31	-2.30	6.84	17.43
12	14.0	15.0	14.5	32	-2.25	9.34	18.81
13	15.0	16.0	15.3	14	-2.20	10.81	19.72
14	16.0	17.0	16.6	14	-2.14	13.11	22.65
15	17.0	18.0	17.5	11	2.40	14.85	23.29
16	18.0	19.0	18.6	17	2.99	16.63	25.61
17	19.0	20.0	19.6	13	1.02	17.99	28.86
18	20.0	21.0	20.4	10	7.36	19.24	30.95
19	21.0	22.0	21.4	3	10.79	20.99	28.69
20	22.0	23.0	22.8	4	13.36	22.30	30.40
21	23.0	24.0	0.0	0	0.00	0.00	0.00
22	24.0	25.0	0.0	0	0.00	0.00	0.00
23	25.0	26.0	0.0	0	0.00	0.00	0.00

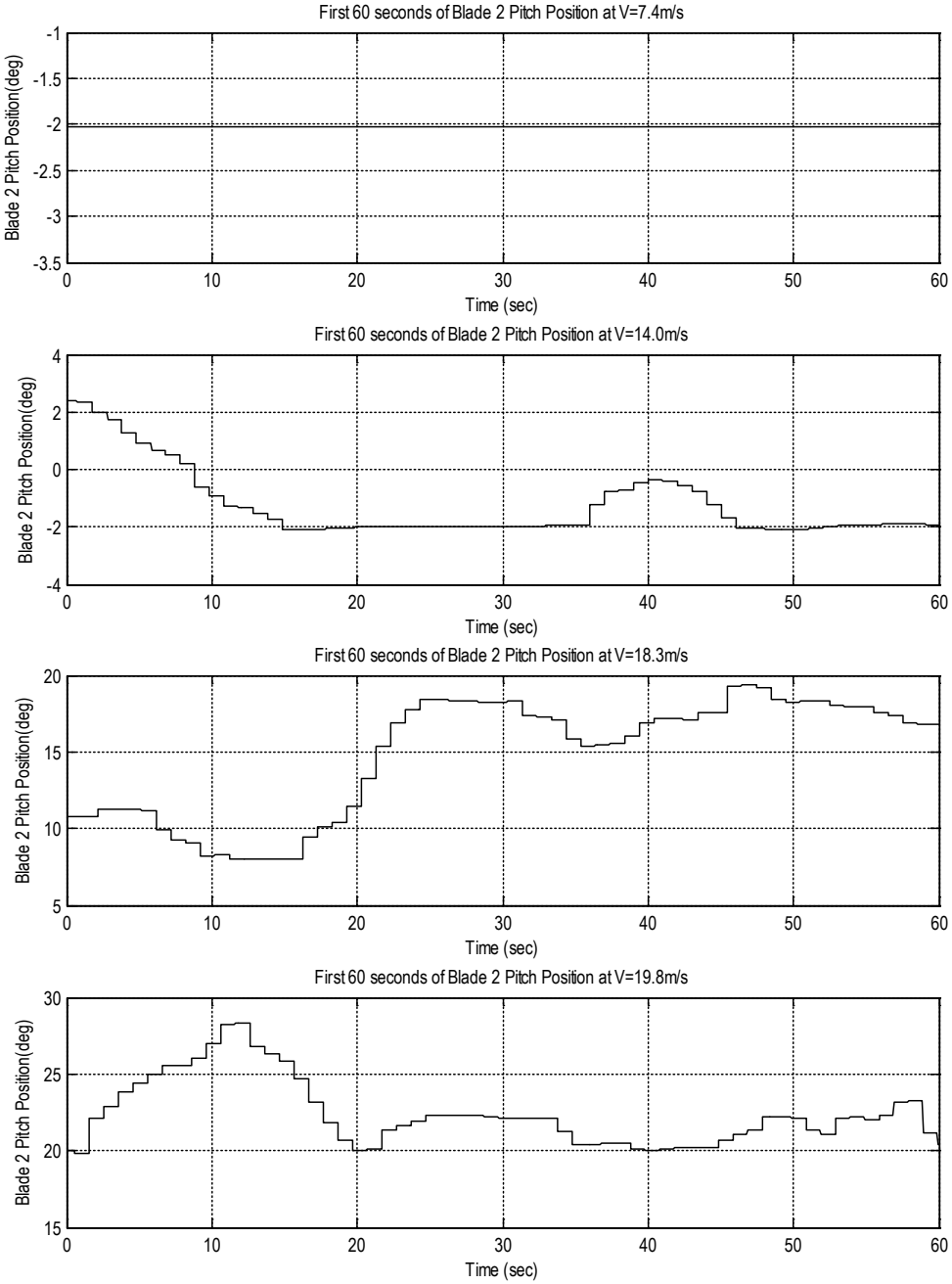


Figure 37. Time series for the first 60 seconds of blade 2 pitch position

Blade 3 Pitch Position

Turbulence Intensity	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-11	11-12	12-13	13-14	14-15	15-16	16-17	17-18	18-19	19-20	20-21	21-22	22-23	23-24	24-25	25-26
29-100%	1	1	8	1	1	1	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
27-29%	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
25-27%	0	1	1	0	1	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
23-25%	0	0	0	0	3	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
21-23%	0	1	0	4	1	1	0	2	5	1	1	1	0	1	0	0	0	0	0	0	0	0	0
19-21%	0	0	0	3	2	2	2	5	3	0	5	0	0	0	0	0	2	0	0	0	0	0	0
17-19%	0	0	0	3	4	0	3	2	8	3	2	5	1	3	2	2	6	3	0	0	0	0	0
15-17%	0	0	1	3	6	1	1	0	6	11	8	8	2	2	2	7	1	2	0	0	0	0	0
13-15%	0	0	1	7	0	2	3	2	2	5	9	10	2	1	2	4	2	4	3	3	0	0	0
11-13%	0	0	0	1	0	2	7	1	0	3	5	6	4	1	2	3	2	0	0	1	0	0	0
9-11%	0	0	0	2	6	6	5	1	0	1	1	2	4	4	1	1	0	1	0	0	0	0	0
7-9%	0	0	0	0	4	2	0	0	0	0	0	0	1	2	2	0	0	0	0	0	0	0	0
5-7%	0	0	0	0	0	2	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3-5%	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0-3%	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Wind Speed (m/s)

Total Files in Wind Speed Bin

	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-11	11-12	12-13	13-14	14-15	15-16	16-17	17-18	18-19	19-20	20-21	21-22	22-23	23-24	24-25	25-26
# bins with 4 TS	0	0	1	2	4	1	2	1	3	2	4	4	2	1	0	2	1	1	0	0	0	0	0

Wind Speed (m/s)

	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-11	11-12	12-13	13-14	14-15	15-16	16-17	17-18	18-19	19-20	20-21	21-22	22-23	23-24	24-25	25-26
#TS in WS bin	1	4	11	25	28	19	24	16	26	24	31	32	14	14	11	17	13	10	3	4	0	0	0

Wind Speed (m/s)

Figure 38. Capture matrix for blade 3 pitch position

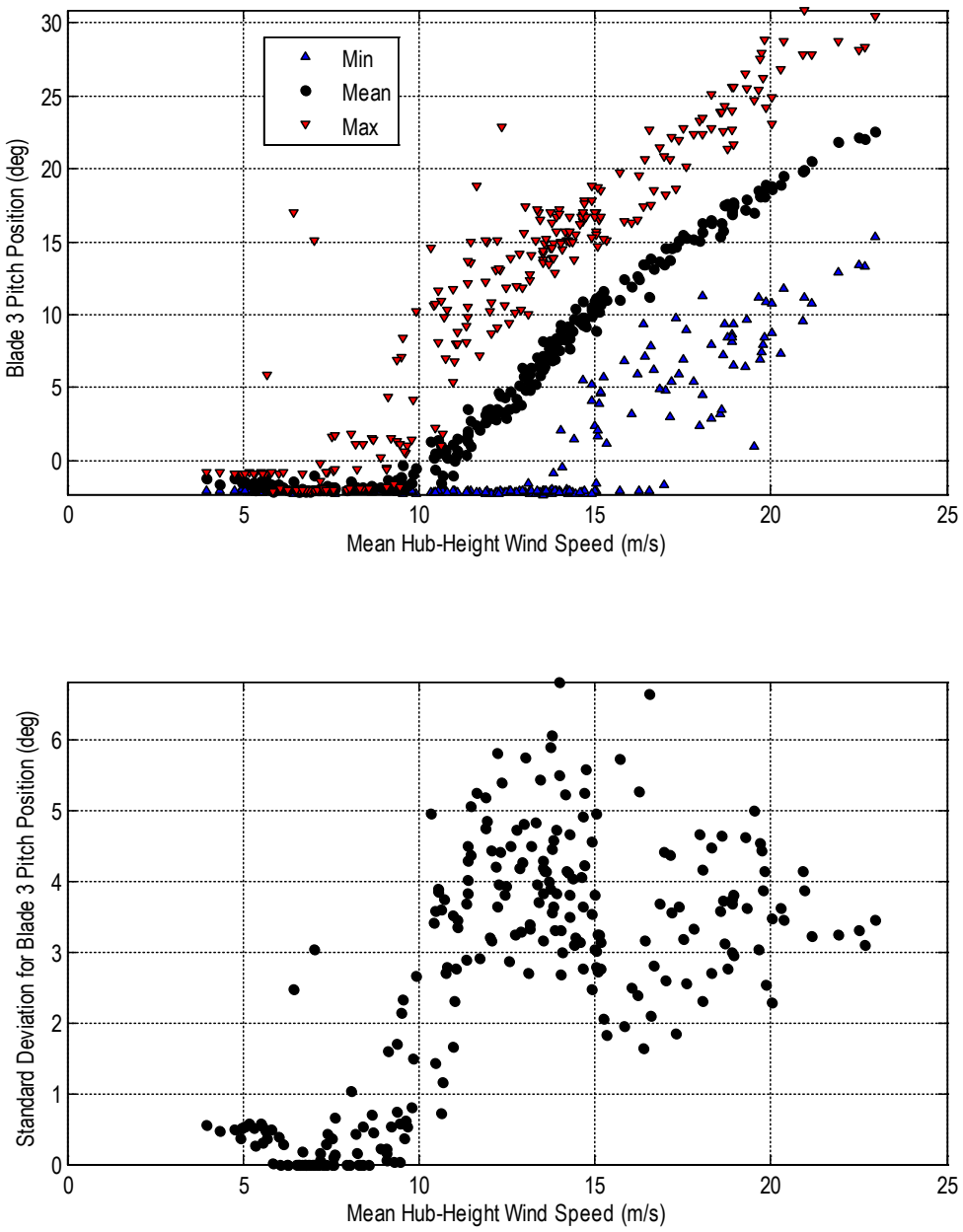


Figure 39. Scatterplot for blade 3 pitch position

Table 42. Binned Data for Blade 3 Pitch Position

Bin #	Bin WS Low	Bin WS High	Mean WS	# Files	Min of Minimums	Mean of Means	Max of Maximums
1	3.0	4.0	4.0	1	-2.04	-1.30	-0.89
2	4.0	5.0	4.8	4	-2.10	-1.37	-0.88
3	5.0	6.0	5.5	11	-2.15	-1.69	5.86
4	6.0	7.0	6.6	25	-2.23	-2.03	16.96
5	7.0	8.0	7.4	28	-2.26	-1.99	15.07
6	8.0	9.0	8.4	19	-2.11	-1.87	1.84
7	9.0	10.0	9.5	24	-2.31	-1.48	10.25
8	10.0	11.0	10.6	16	-2.20	0.21	14.60
9	11.0	12.0	11.4	26	-2.26	1.60	18.84
10	12.0	13.0	12.5	24	-2.24	4.13	22.83
11	13.0	14.0	13.5	31	-2.31	6.84	17.43
12	14.0	15.0	14.5	32	-2.25	9.34	18.79
13	15.0	16.0	15.3	14	-2.15	10.82	19.71
14	16.0	17.0	16.6	14	-2.10	13.11	22.65
15	17.0	18.0	17.5	11	2.41	14.85	23.30
16	18.0	19.0	18.6	17	2.91	16.63	25.59
17	19.0	20.0	19.6	13	1.00	17.99	28.82
18	20.0	21.0	20.4	10	7.37	19.24	30.91
19	21.0	22.0	21.4	3	10.77	20.99	28.69
20	22.0	23.0	22.8	4	13.37	22.30	30.41
21	23.0	24.0	0.0	0	0.00	0.00	0.00
22	24.0	25.0	0.0	0	0.00	0.00	0.00
23	25.0	26.0	0.0	0	0.00	0.00	0.00

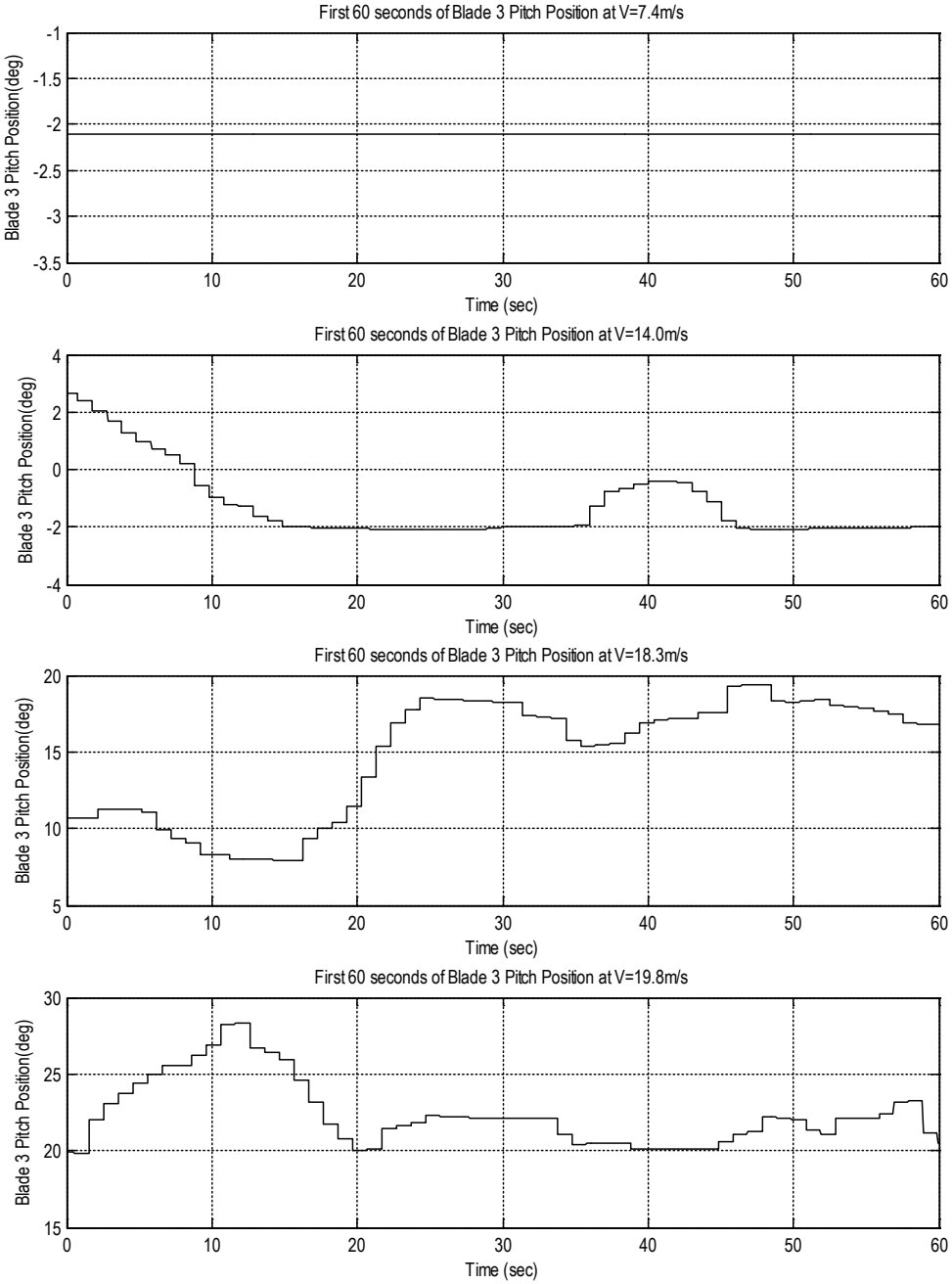


Figure 40. Time series for the first 60 seconds of blade 3 pitch position

Nacelle Yaw Angle

Turbulence Intensity	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-11	11-12	12-13	13-14	14-15	15-16	16-17	17-18	18-19	19-20	20-21	21-22	22-23	23-24	24-25	25-26
29-100%	1	1	8	1	1	1	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
27-29%	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
25-27%	0	1	1	0	1	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
23-25%	0	0	0	0	3	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
21-23%	0	1	0	4	1	1	0	2	5	1	1	1	0	1	0	0	0	0	0	0	0	0	0
19-21%	0	0	0	3	2	2	2	5	3	0	5	0	0	0	0	0	2	0	0	0	0	0	0
17-19%	0	0	0	3	4	0	3	2	8	3	2	5	1	3	2	2	6	3	0	0	0	0	0
15-17%	0	0	1	3	6	1	1	0	6	11	8	8	2	2	2	7	1	2	0	0	0	0	0
13-15%	0	0	1	7	0	2	3	2	2	5	9	10	2	1	2	4	2	4	3	3	0	0	0
11-13%	0	0	0	1	0	2	7	1	0	3	5	6	4	1	2	3	2	0	0	1	0	0	0
9-11%	0	0	0	2	6	6	5	1	0	1	1	2	4	4	1	1	0	1	0	0	0	0	0
7-9%	0	0	0	0	4	2	0	0	0	0	0	0	1	2	2	0	0	0	0	0	0	0	0
5-7%	0	0	0	0	0	2	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3-5%	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0-3%	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Wind Speed (m/s)

Total Files in Wind Speed Bin

	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-11	11-12	12-13	13-14	14-15	15-16	16-17	17-18	18-19	19-20	20-21	21-22	22-23	23-24	24-25	25-26
# bins with 4 TS	0	0	1	2	4	1	2	1	3	2	4	4	2	1	0	2	1	1	0	0	0	0	0

Wind Speed (m/s)

	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-11	11-12	12-13	13-14	14-15	15-16	16-17	17-18	18-19	19-20	20-21	21-22	22-23	23-24	24-25	25-26
#TS in WS bin	1	4	11	25	28	19	24	16	26	24	31	32	14	14	11	17	13	10	3	4	0	0	0

Wind Speed (m/s)

Figure 41. Capture matrix for nacelle yaw angle

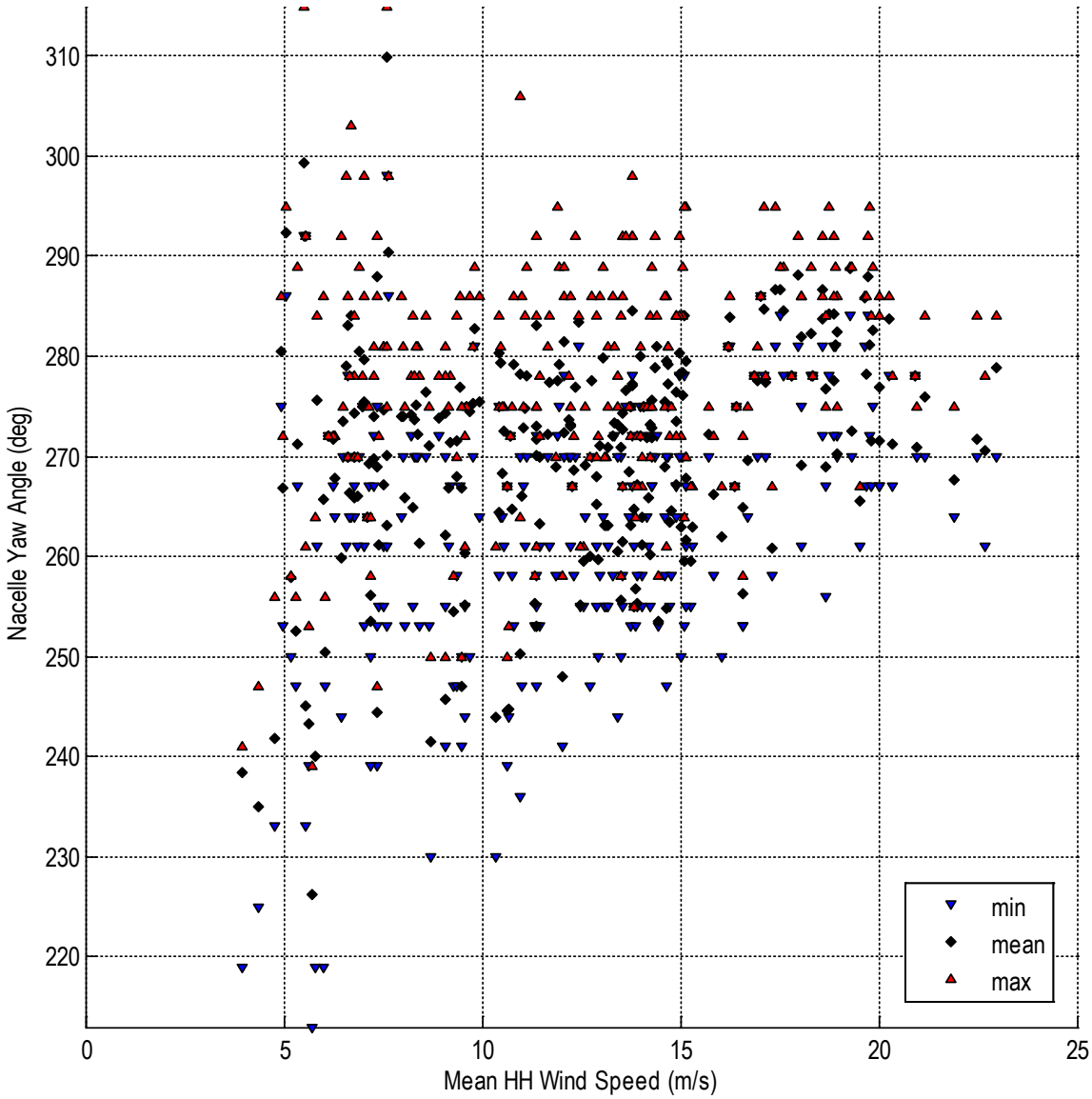


Figure 42. Vector average for nacelle yaw angle

Tower-Top Normal Acceleration

Turbulence Intensity	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-11	11-12	12-13	13-14	14-15	15-16	16-17	17-18	18-19	19-20	20-21	21-22	22-23	23-24	24-25	25-26
29-100%	1	1	8	1	1	1	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
27-29%	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
25-27%	0	1	1	0	1	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
23-25%	0	0	0	0	3	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
21-23%	0	1	0	4	1	1	0	2	5	1	1	1	0	1	0	0	0	0	0	0	0	0	0
19-21%	0	0	0	3	2	2	2	5	3	0	4	0	0	0	0	0	2	0	0	0	0	0	0
17-19%	0	0	0	3	4	0	3	2	8	3	2	5	0	3	2	2	6	3	0	0	0	0	0
15-17%	0	0	1	3	6	1	1	0	5	11	8	8	2	2	2	7	1	2	0	0	0	0	0
13-15%	0	0	1	7	0	2	3	2	2	5	9	7	2	1	2	4	2	4	3	3	0	0	0
11-13%	0	0	0	1	0	2	7	1	0	3	5	6	4	1	2	3	2	0	0	1	0	0	0
9-11%	0	0	0	2	6	4	5	1	0	1	1	2	4	4	1	1	0	1	0	0	0	0	0
7-9%	0	0	0	0	2	2	0	0	0	0	0	0	1	2	2	0	0	0	0	0	0	0	0
5-7%	0	0	0	0	0	2	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3-5%	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0-3%	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Wind Speed (m/s)

Total Files in Wind Speed Bin

	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-11	11-12	12-13	13-14	14-15	15-16	16-17	17-18	18-19	19-20	20-21	21-22	22-23	23-24	24-25	25-26
# bins with 4 TS	0	0	1	2	3	1	2	1	3	2	4	4	2	1	0	2	1	1	0	0	0	0	0

Wind Speed (m/s)

	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-11	11-12	12-13	13-14	14-15	15-16	16-17	17-18	18-19	19-20	20-21	21-22	22-23	23-24	24-25	25-26
#TS in WS bin	1	4	11	25	26	17	24	16	25	24	30	29	13	14	11	17	13	10	3	4	0	0	0

Wind Speed (m/s)

Figure 43. Capture matrix for tower-top normal acceleration

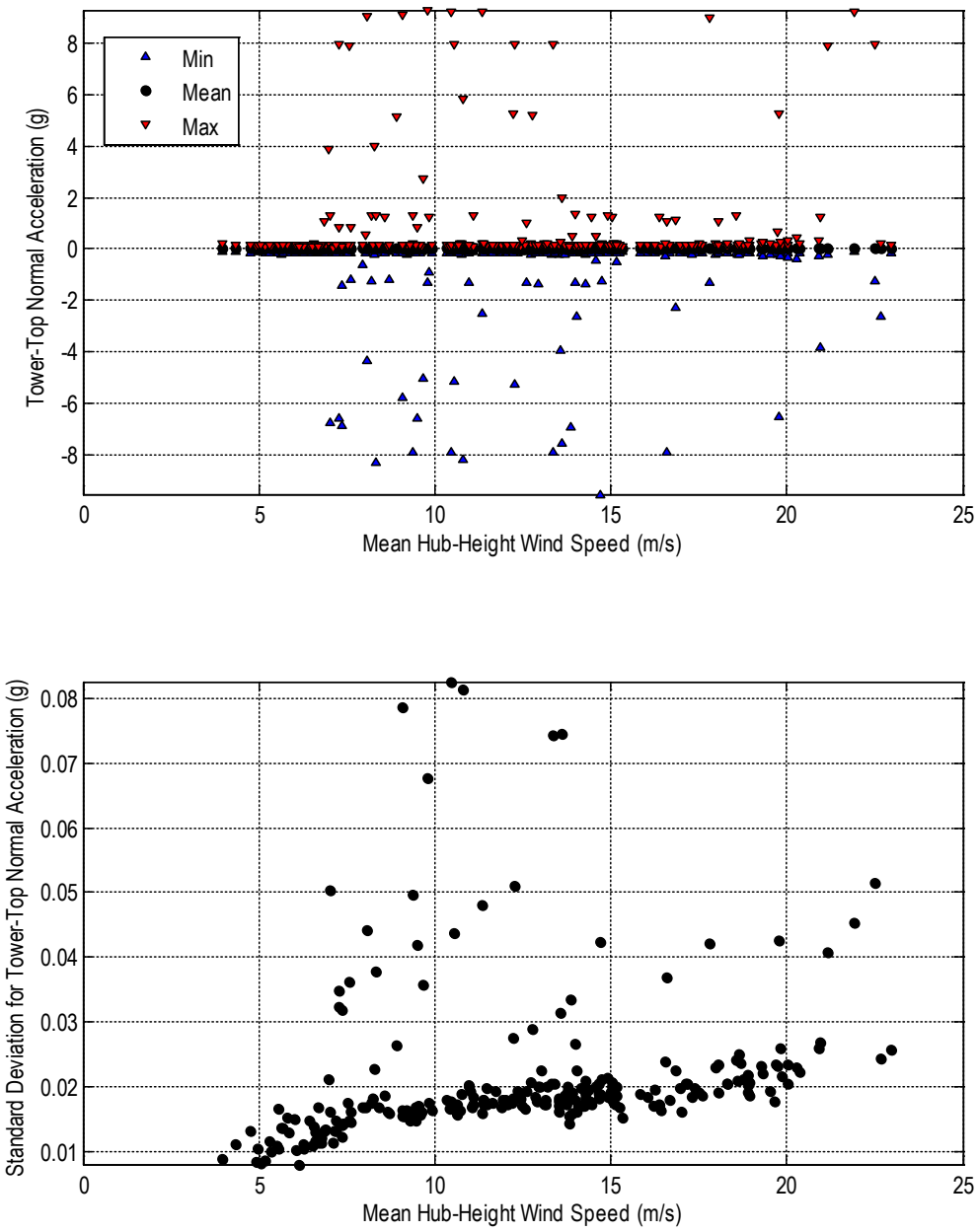


Figure 44. Scatterplot for tower-top normal acceleration

Table 43. Binned Data for Tower-Top Normal Acceleration

Bin #	Bin WS Low	Bin WS High	Mean WS	# Files	Min of Minimums	Mean of Means	Max of Maximums
1	3.0	4.0	4.0	1	-0.10	-0.00	0.20
2	4.0	5.0	4.8	4	-0.13	-0.00	0.15
3	5.0	6.0	5.5	11	-0.21	0.00	0.17
4	6.0	7.0	6.6	25	-0.15	-0.00	3.86
5	7.0	8.0	7.4	26	-6.87	0.00	7.91
6	8.0	9.0	8.4	17	-8.31	-0.00	9.04
7	9.0	10.0	9.5	24	-7.90	0.00	9.28
8	10.0	11.0	10.6	16	-8.19	0.00	9.20
9	11.0	12.0	11.4	25	-2.48	-0.00	9.22
10	12.0	13.0	12.5	24	-5.26	-0.00	7.91
11	13.0	14.0	13.5	30	-7.90	-0.00	7.93
12	14.0	15.0	14.5	29	-9.52	0.00	1.30
13	15.0	16.0	15.2	13	-0.52	-0.00	1.23
14	16.0	17.0	16.6	14	-7.89	0.00	1.26
15	17.0	18.0	17.5	11	-1.28	0.00	8.94
16	18.0	19.0	18.6	17	-0.21	0.00	1.30
17	19.0	20.0	19.6	13	-6.53	-0.00	5.26
18	20.0	21.0	20.4	10	-3.79	-0.00	1.24
19	21.0	22.0	21.4	3	-0.22	-0.00	9.20
20	22.0	23.0	22.8	4	-2.61	-0.00	7.93
21	23.0	24.0	0.0	0	0.00	0.00	0.00
22	24.0	25.0	0.0	0	0.00	0.00	0.00
23	25.0	26.0	0.0	0	0.00	0.00	0.00

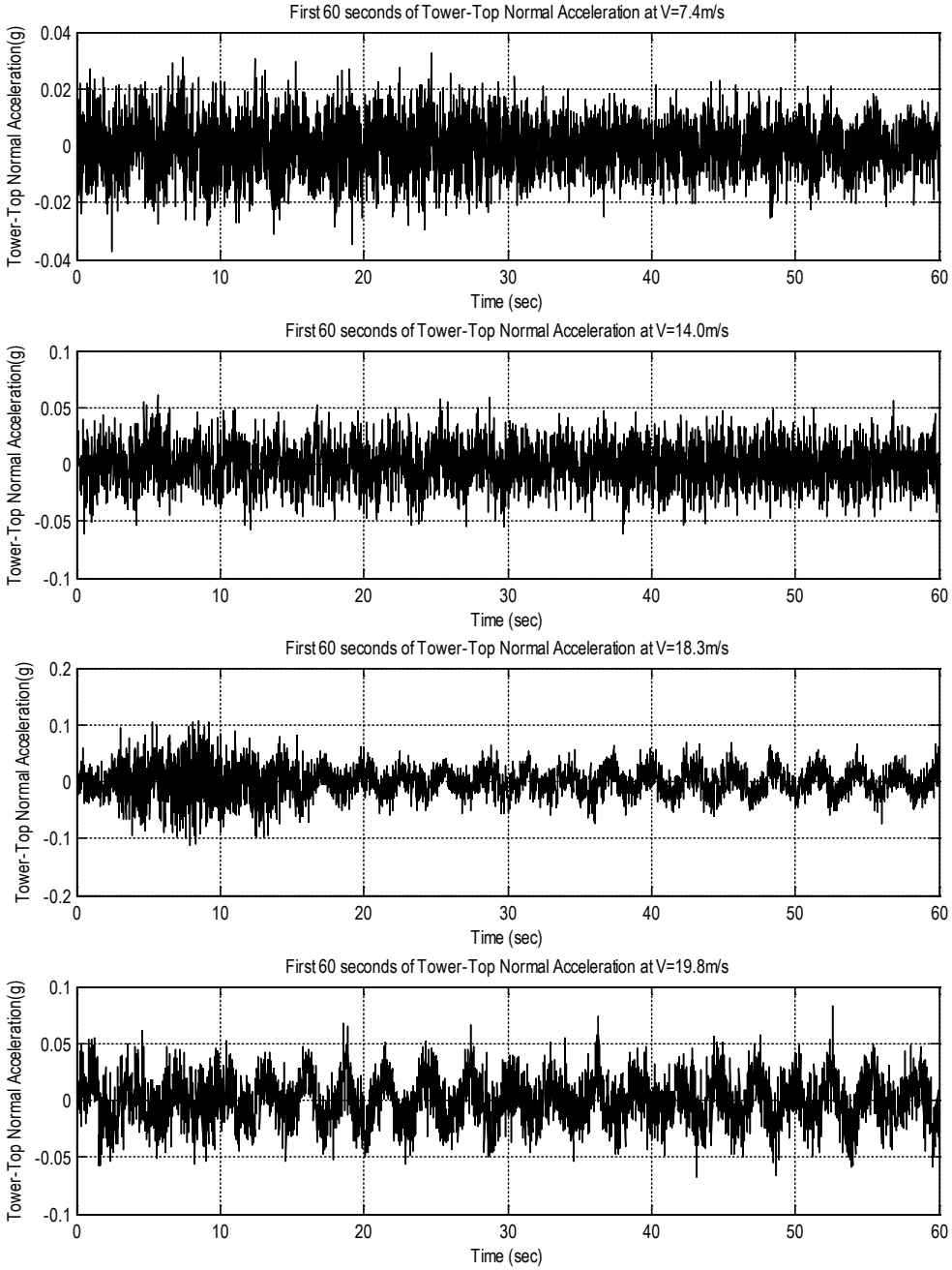


Figure 45. Time series for the first 60 seconds of tower-top normal acceleration

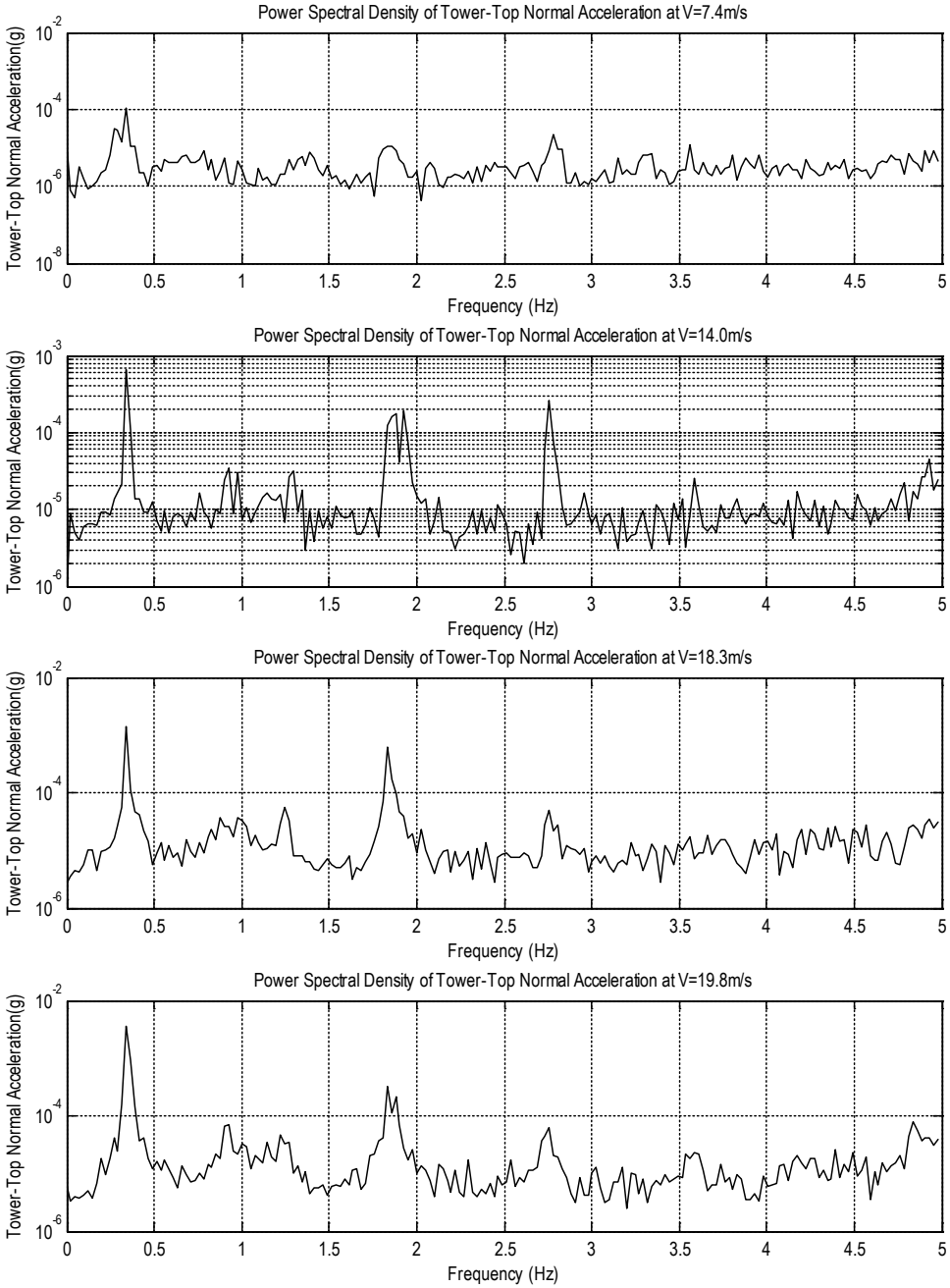


Figure 46. Power spectral density of tower-top normal acceleration

Tower-Top Lateral Acceleration

Turbulence Intensity	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-11	11-12	12-13	13-14	14-15	15-16	16-17	17-18	18-19	19-20	20-21	21-22	22-23	23-24	24-25	25-26
29-100%	1	1	8	1	1	1	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
27-29%	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
25-27%	0	1	1	0	1	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
23-25%	0	0	0	0	3	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
21-23%	0	1	0	4	1	1	0	2	5	1	1	1	0	1	0	0	0	0	0	0	0	0	0
19-21%	0	0	0	3	2	2	2	5	3	0	5	0	0	0	0	0	2	0	0	0	0	0	0
17-19%	0	0	0	3	4	0	3	2	8	3	1	5	1	3	2	2	4	3	0	0	0	0	0
15-17%	0	0	1	3	6	1	1	0	6	10	8	8	2	2	2	7	1	2	0	0	0	0	0
13-15%	0	0	1	7	0	2	3	2	2	5	9	10	2	1	2	4	2	4	3	3	0	0	0
11-13%	0	0	0	1	0	2	7	1	0	3	5	6	4	1	2	3	2	0	0	1	0	0	0
9-11%	0	0	0	2	6	6	5	1	0	1	1	2	4	4	1	1	0	1	0	0	0	0	0
7-9%	0	0	0	0	4	2	0	0	0	0	0	0	1	2	2	0	0	0	0	0	0	0	0
5-7%	0	0	0	0	0	2	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3-5%	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0-3%	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Wind Speed (m/s)

Total Files in Wind Speed Bin

	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-11	11-12	12-13	13-14	14-15	15-16	16-17	17-18	18-19	19-20	20-21	21-22	22-23	23-24	24-25	25-26
# bins with 4 TS	0	0	1	2	4	1	2	1	3	2	4	4	2	1	0	2	1	1	0	0	0	0	0

Wind Speed (m/s)

	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-11	11-12	12-13	13-14	14-15	15-16	16-17	17-18	18-19	19-20	20-21	21-22	22-23	23-24	24-25	25-26
#TS in WS bin	1	4	11	25	28	19	24	16	26	23	30	32	14	14	11	17	11	10	3	4	0	0	0

Wind Speed (m/s)

Figure 47. Capture matrix for tower-top lateral acceleration

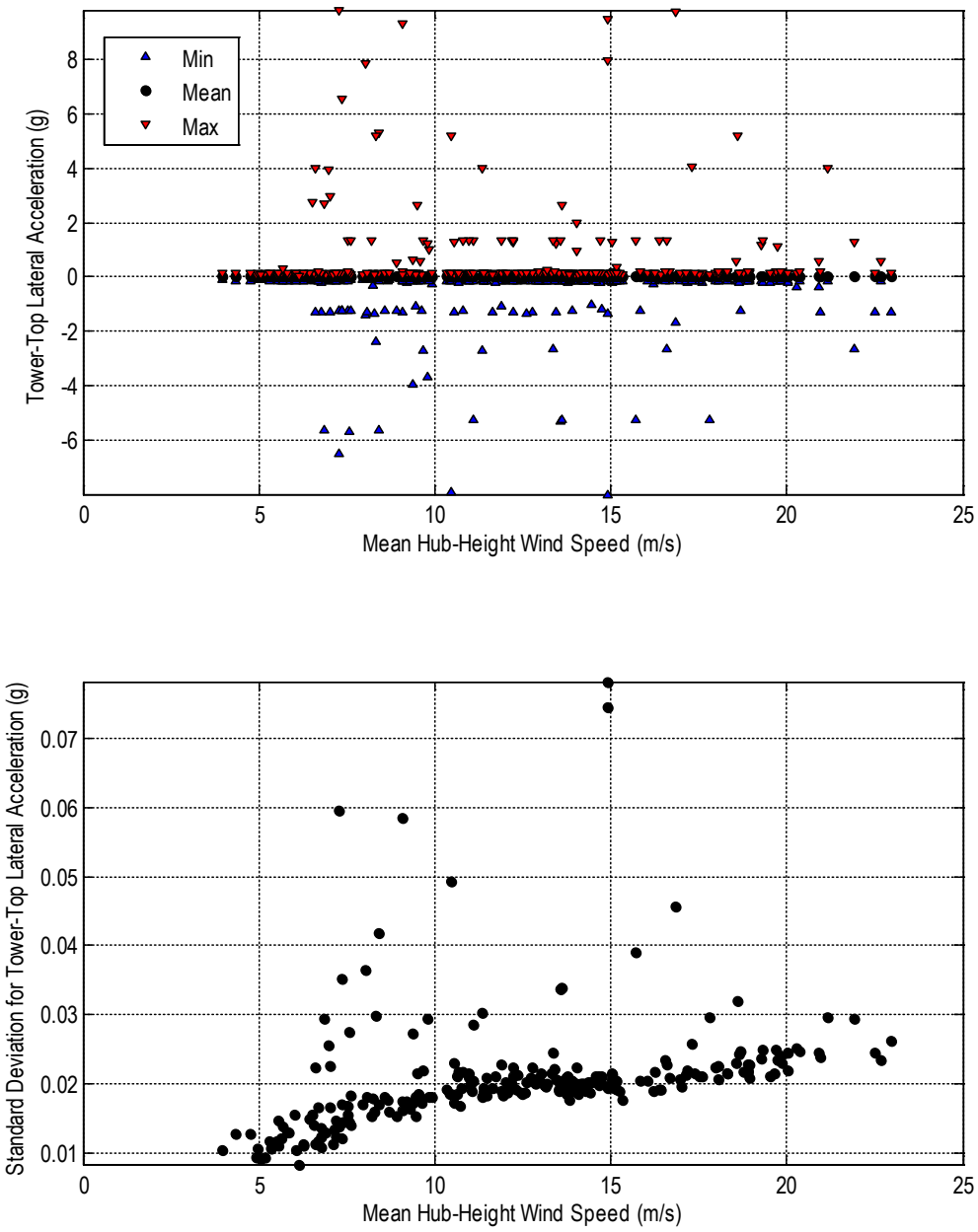


Figure 48. Scatterplot for tower-top lateral acceleration

Table 44. Binned Data for Tower-Top Lateral Acceleration

Bin #	Bin WS Low	Bin WS High	Mean WS	# Files	Min of Minimums	Mean of Means	Max of Maximums
1	3.0	4.0	4.0	1	-0.10	-0.00	0.11
2	4.0	5.0	4.8	4	-0.13	0.00	0.14
3	5.0	6.0	5.5	11	-0.13	0.00	0.27
4	6.0	7.0	6.6	25	-5.59	-0.00	3.97
5	7.0	8.0	7.4	28	-6.49	-0.00	9.81
6	8.0	9.0	8.4	19	-5.59	0.00	7.81
7	9.0	10.0	9.5	24	-3.93	0.00	9.29
8	10.0	11.0	10.6	16	-7.86	0.00	5.19
9	11.0	12.0	11.4	26	-5.25	0.00	3.96
10	12.0	13.0	12.5	23	-1.32	0.00	1.33
11	13.0	14.0	13.5	30	-5.26	0.00	2.61
12	14.0	15.0	14.5	32	-7.97	-0.00	9.47
13	15.0	16.0	15.3	14	-5.25	0.00	1.30
14	16.0	17.0	16.6	14	-2.64	0.00	9.70
15	17.0	18.0	17.5	11	-5.24	-0.00	4.04
16	18.0	19.0	18.6	17	-1.23	-0.00	5.20
17	19.0	20.0	19.6	11	-0.20	-0.00	1.33
18	20.0	21.0	20.4	10	-1.27	0.00	0.56
19	21.0	22.0	21.4	3	-2.65	-0.00	3.97
20	22.0	23.0	22.8	4	-1.30	0.00	0.54
21	23.0	24.0	0.0	0	0.00	0.00	0.00
22	24.0	25.0	0.0	0	0.00	0.00	0.00
23	25.0	26.0	0.0	0	0.00	0.00	0.00

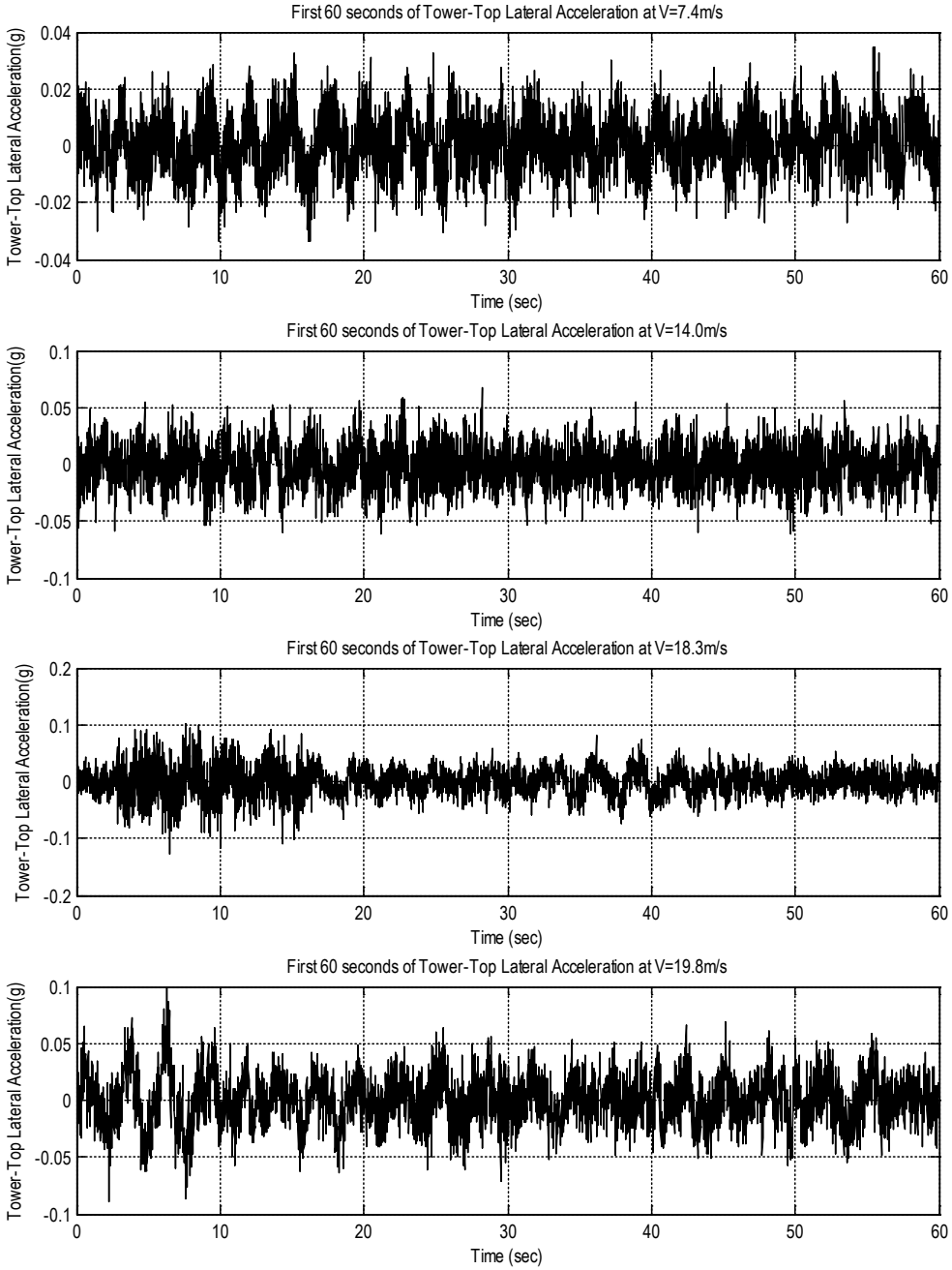


Figure 49. Time series for the first 60 seconds of tower-top lateral acceleration

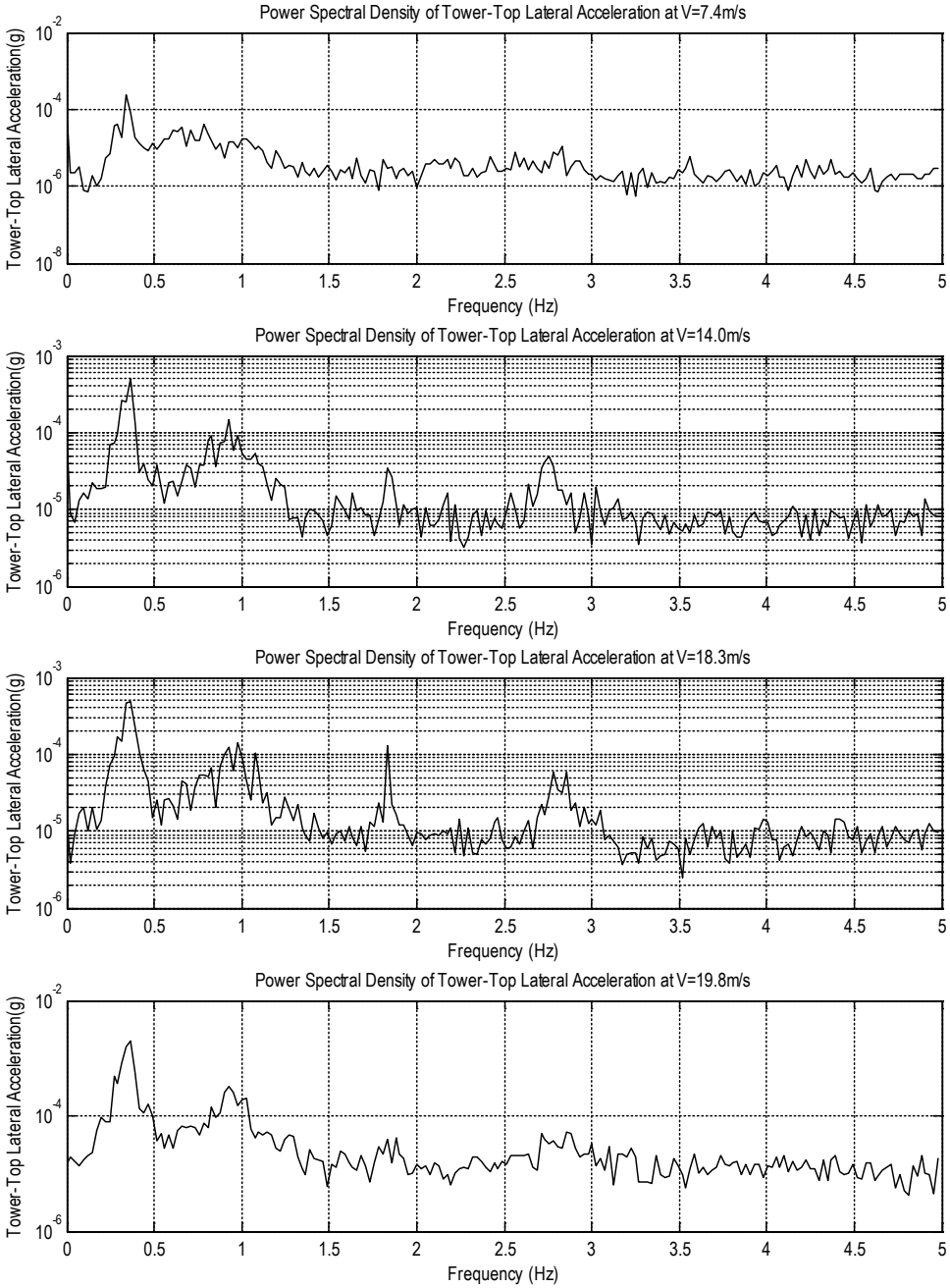


Figure 50. Power spectral density of tower-top lateral acceleration

Blade 1 Flap Bending

Turbulence Intensity	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-11	11-12	12-13	13-14	14-15	15-16	16-17	17-18	18-19	19-20	20-21	21-22	22-23	23-24	24-25	25-26
29-100%	1	1	8	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
27-29%	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
25-27%	0	1	1	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
23-25%	0	0	0	0	2	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
21-23%	0	1	0	4	1	1	0	1	4	1	1	1	0	1	0	0	0	0	0	0	0	0	0
19-21%	0	0	0	1	0	1	2	2	3	0	4	0	0	0	0	0	1	0	0	0	0	0	0
17-19%	0	0	0	2	3	0	1	1	3	3	0	2	0	2	0	1	2	1	0	0	0	0	0
15-17%	0	0	1	2	1	1	1	0	2	7	5	7	1	1	2	5	1	1	0	0	0	0	0
13-15%	0	0	1	4	0	1	1	1	1	2	6	8	1	1	1	3	1	2	0	1	0	0	0
11-13%	0	0	0	1	0	1	2	1	0	2	4	5	3	1	2	3	2	0	0	1	0	0	0
9-11%	0	0	0	1	3	3	3	1	0	1	1	1	4	3	1	1	0	1	0	0	0	0	0
7-9%	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0	0	0	0	0	0	0	0
5-7%	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3-5%	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0-3%	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Wind Speed (m/s)

Total Files in Wind Speed Bin

	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-11	11-12	12-13	13-14	14-15	15-16	16-17	17-18	18-19	19-20	20-21	21-22	22-23	23-24	24-25	25-26
# bins with 4 TS	0	0	1	2	0	0	0	0	1	1	4	3	1	0	0	1	0	0	0	0	0	0	0

Wind Speed (m/s)

	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-11	11-12	12-13	13-14	14-15	15-16	16-17	17-18	18-19	19-20	20-21	21-22	22-23	23-24	24-25	25-26
#TS in WS bin	1	4	11	17	12	10	12	10	14	16	21	24	10	10	7	13	7	5	0	2	0	0	0

Wind Speed (m/s)

Figure 51. Capture matrix for blade 1 flap bending

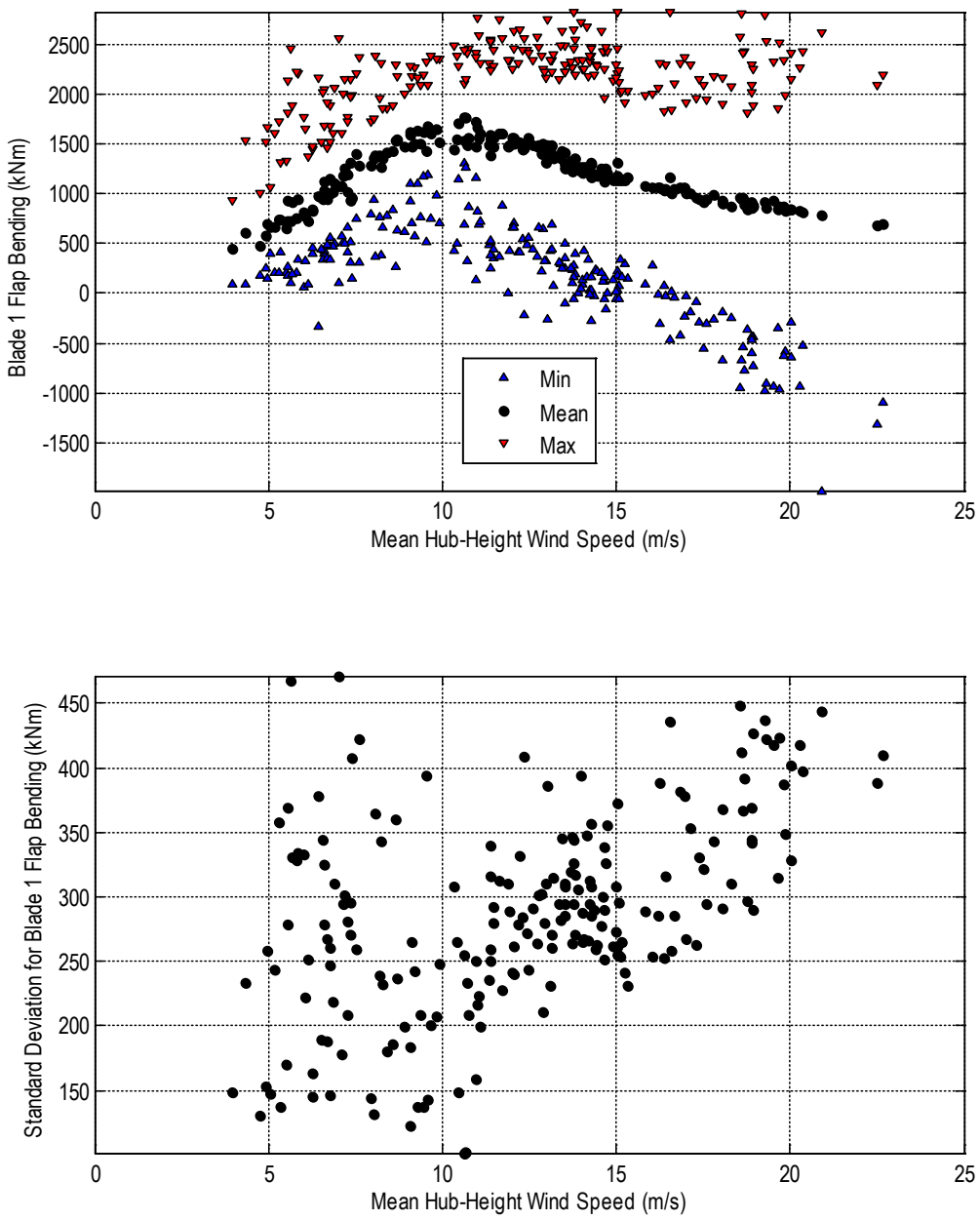


Figure 52. Scatterplot for blade 1 flap bending

Table 45. Binned Data for Blade 1 Flap Bending

Bin #	Bin WS Low	Bin WS High	Mean WS	# Files	Min of Minimums	Mean of Means	Max of Maximums
1	3.0	4.0	4.0	1	102.18	453.70	934.87
2	4.0	5.0	4.8	4	100.28	588.47	1,663.66
3	5.0	6.0	5.5	11	113.62	768.68	2,455.97
4	6.0	7.0	6.5	17	-324.48	954.60	2,155.97
5	7.0	8.0	7.4	12	106.51	1,163.35	2,552.83
6	8.0	9.0	8.4	10	268.28	1,411.67	2,381.82
7	9.0	10.0	9.4	12	516.82	1,563.62	2,379.22
8	10.0	11.0	10.6	10	137.27	1,598.81	2,478.26
9	11.0	12.0	11.4	14	6.85	1,536.73	2,758.26
10	12.0	13.0	12.5	16	-217.60	1,479.41	2,640.94
11	13.0	14.0	13.5	21	-249.37	1,338.34	2,824.99
12	14.0	15.0	14.4	24	-267.32	1,210.77	2,711.50
13	15.0	16.0	15.2	10	-48.04	1,155.72	2,819.53
14	16.0	17.0	16.5	10	-455.31	1,058.57	2,819.28
15	17.0	18.0	17.4	7	-550.73	963.81	2,296.99
16	18.0	19.0	18.6	13	-944.26	901.67	2,798.18
17	19.0	20.0	19.6	7	-976.86	872.61	2,786.56
18	20.0	21.0	20.3	5	-1,976.12	821.11	2,619.03
19	21.0	22.0	0.0	0	0.00	0.00	0.00
20	22.0	23.0	22.6	2	-1,306.22	692.32	2,191.29
21	23.0	24.0	0.0	0	0.00	0.00	0.00
22	24.0	25.0	0.0	0	0.00	0.00	0.00
23	25.0	26.0	0.0	0	0.00	0.00	0.00

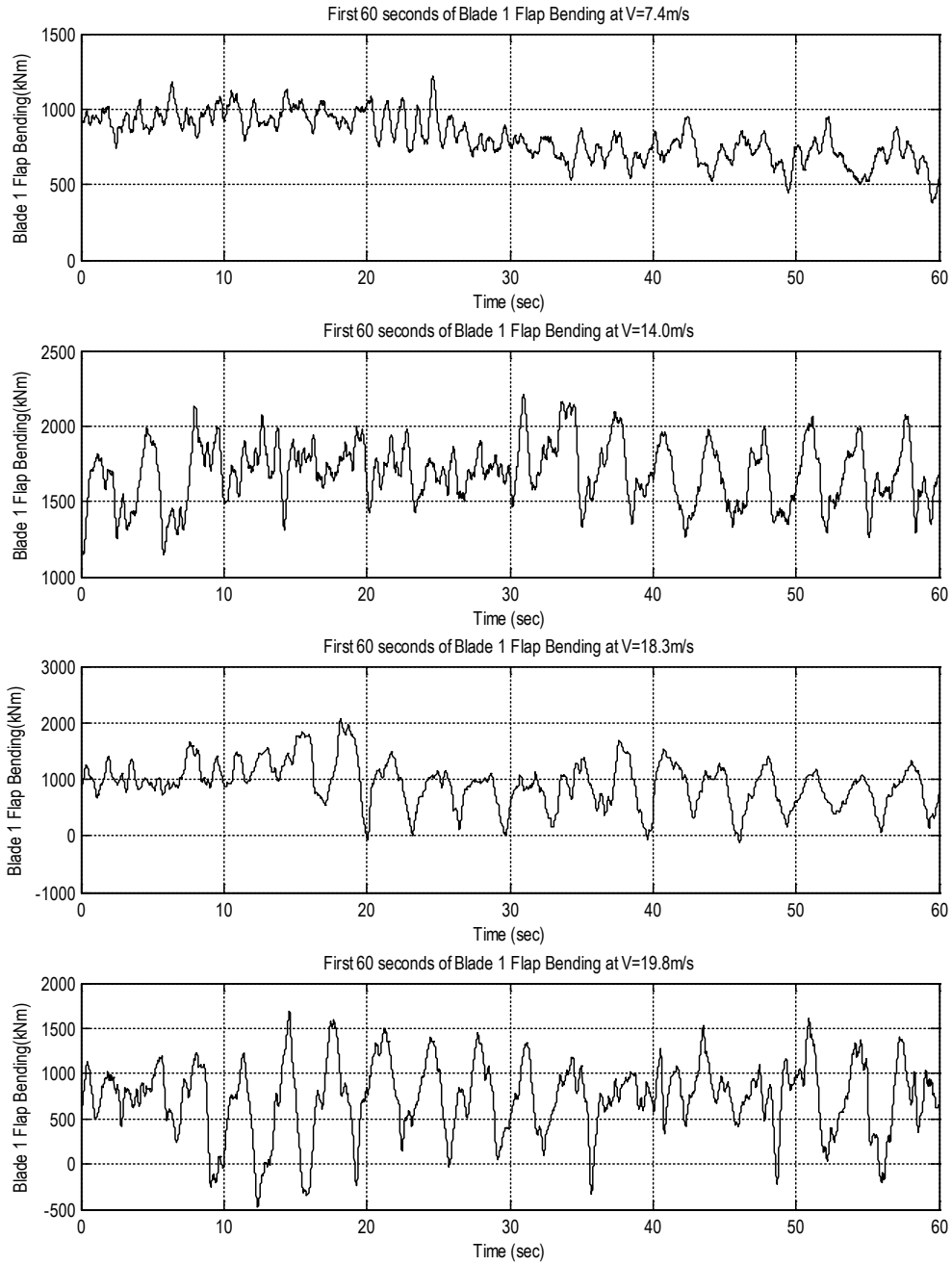


Figure 53. Time series for the first 60 seconds of blade 1 flap bending

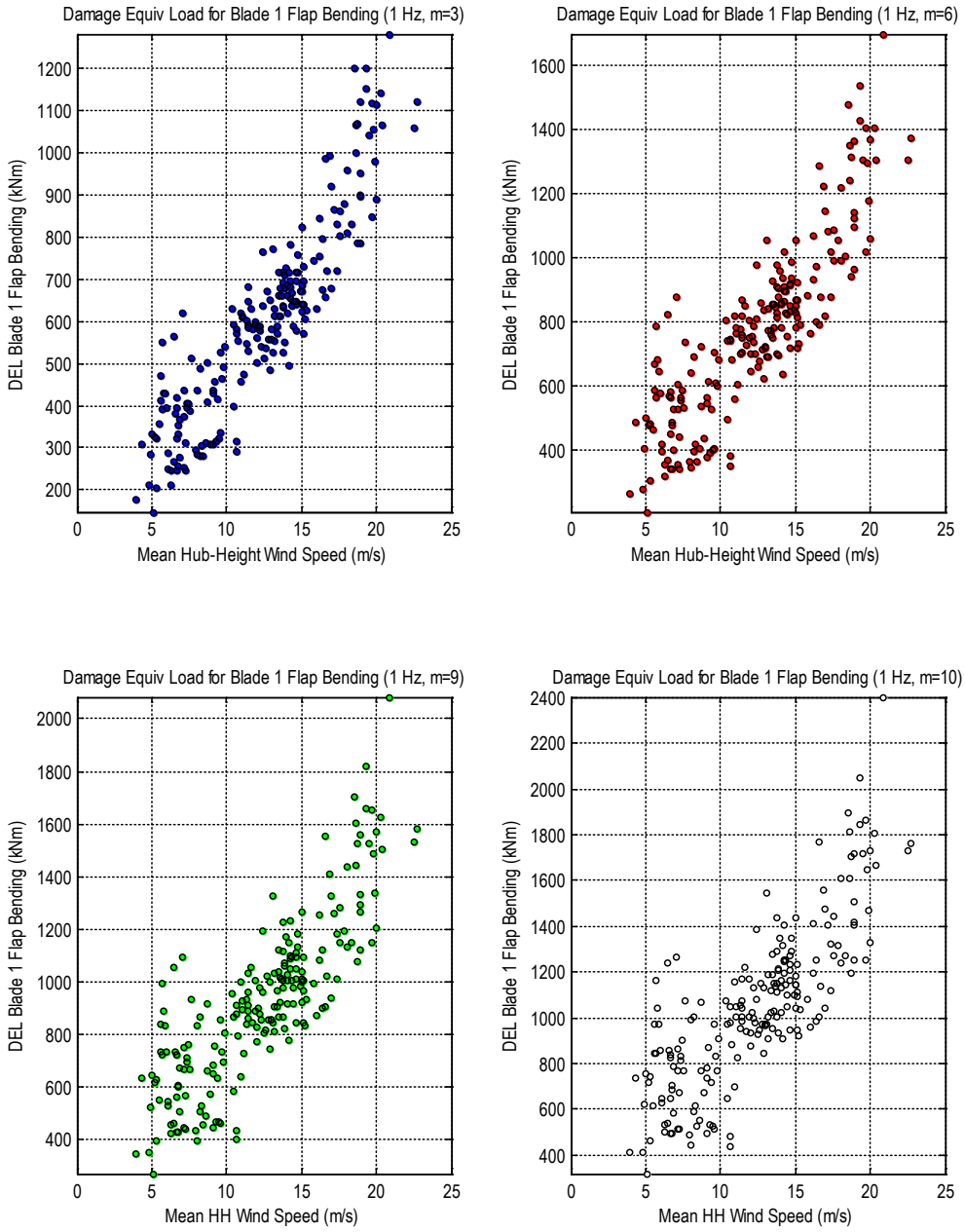


Figure 54. Damage equivalent load (DEL) (1 Hz, m=3, 6, 9, 10) for blade 1 flap bending

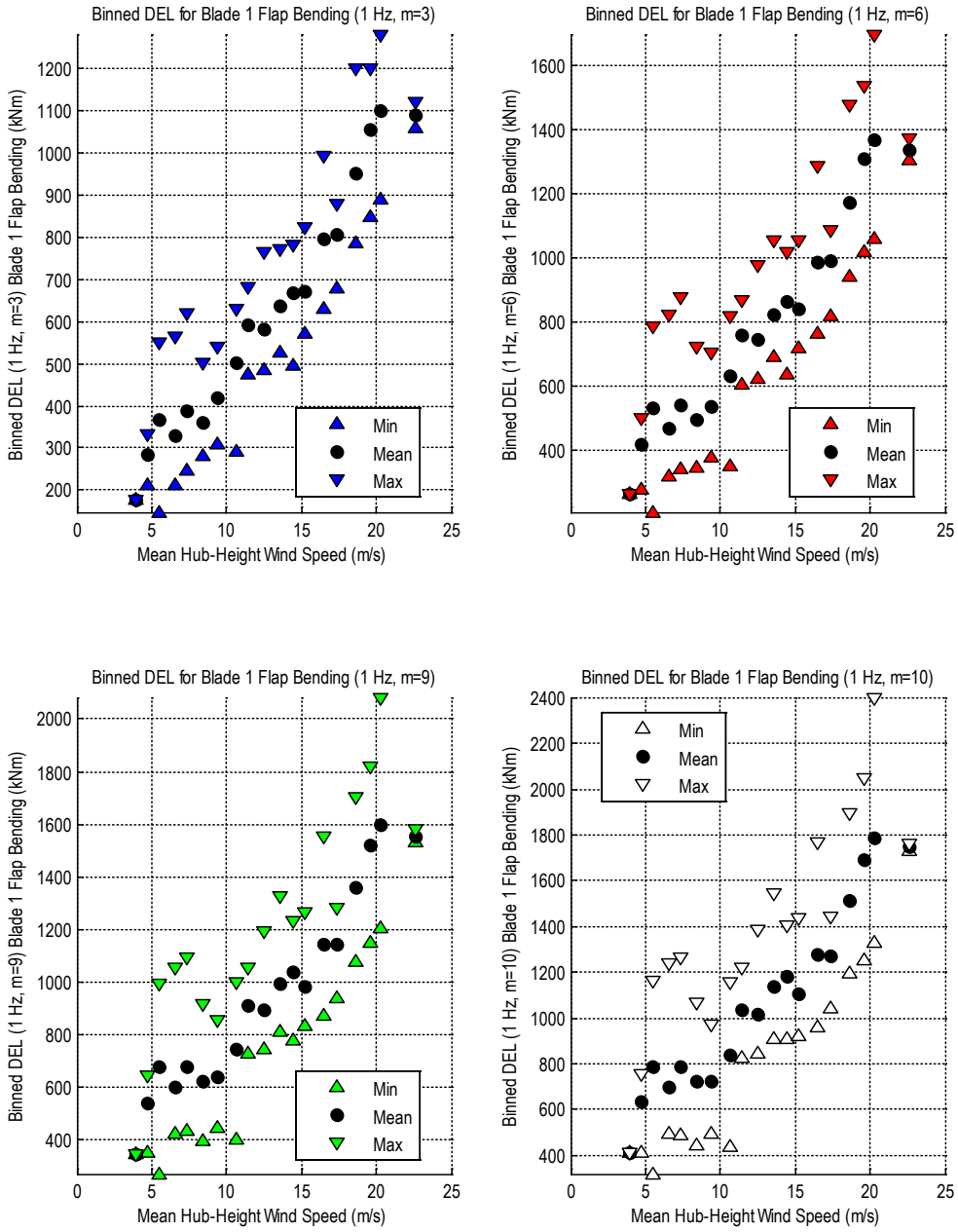


Figure 55. Binned DEL (1 Hz, m=3, 6, 9, 10) for blade 1 flap bending

Table 46. Binned Damage Equivalent Load (DEL) Data for Blade 1 Flap Bending

Bin #	Bin WS Low	Bin WS High	Mean WS	# Files	Min of Del (m=3)	Mean of Del (m=3)	Max of Del (m=3)	Min of Del (m=6)	Mean of Del (m=6)	Max of Del (m=6)	Min of Del (m=9)	Mean of Del (m=9)	Max of Del (m=9)
1	3.0	4.0	4.0	1	178.79	178.79	178.79	262.69	262.69	262.69	410.01	410.01	410.01
2	4.0	5.0	4.8	4	211.22	284.47	333.84	280.05	418.60	502.45	410.53	632.00	757.57
3	5.0	6.0	5.5	11	147.91	368.15	551.59	207.39	534.43	789.55	319.45	790.17	1,165.34
4	6.0	7.0	6.5	17	210.59	328.01	563.47	319.16	471.10	825.39	492.25	697.48	1,239.57
5	7.0	8.0	7.4	12	246.67	386.79	619.80	342.51	541.52	880.53	485.13	789.51	1,263.47
6	8.0	9.0	8.4	10	279.20	360.72	500.83	344.81	496.36	722.73	441.52	723.41	1,069.89
7	9.0	10.0	9.4	12	308.60	420.28	539.39	379.07	535.68	704.01	496.88	721.11	972.98
8	10.0	11.0	10.6	10	292.33	501.32	630.17	349.87	632.76	819.12	440.33	837.95	1,154.60
9	11.0	12.0	11.4	14	474.76	591.87	683.00	606.75	762.39	871.48	827.37	1,035.24	1,221.47
10	12.0	13.0	12.5	16	484.41	581.46	765.39	623.70	746.25	979.12	842.85	1,019.47	1,385.57
11	13.0	14.0	13.5	21	526.54	635.00	770.95	690.57	825.06	1,055.65	907.90	1,135.75	1,545.89
12	14.0	15.0	14.4	24	495.63	667.81	781.18	635.49	864.69	1,018.92	906.20	1,184.93	1,407.34
13	15.0	16.0	15.2	10	572.59	670.30	823.58	717.98	840.38	1,055.19	919.12	1,104.00	1,439.66
14	16.0	17.0	16.5	10	629.41	797.09	991.61	764.03	987.03	1,290.04	961.44	1,275.00	1,766.99
15	17.0	18.0	17.4	7	676.60	804.90	879.11	820.81	991.50	1,087.95	1,039.36	1,273.53	1,440.68
16	18.0	19.0	18.6	13	783.99	951.29	1,199.69	944.09	1,173.42	1,478.75	1,197.81	1,510.94	1,895.50
17	19.0	20.0	19.6	7	848.89	1,056.11	1,199.84	1,017.94	1,310.52	1,538.38	1,252.37	1,691.42	2,047.54
18	20.0	21.0	20.3	5	888.85	1,097.95	1,280.82	1,062.56	1,369.22	1,699.82	1,326.38	1,787.20	2,402.10
19	21.0	22.0	0.0	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
20	22.0	23.0	22.6	2	1,058.63	1,089.59	1,120.55	1,305.10	1,338.85	1,372.60	1,733.22	1,747.36	1,761.51
21	23.0	24.0	0.0	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
22	24.0	25.0	0.0	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
23	25.0	26.0	0.0	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

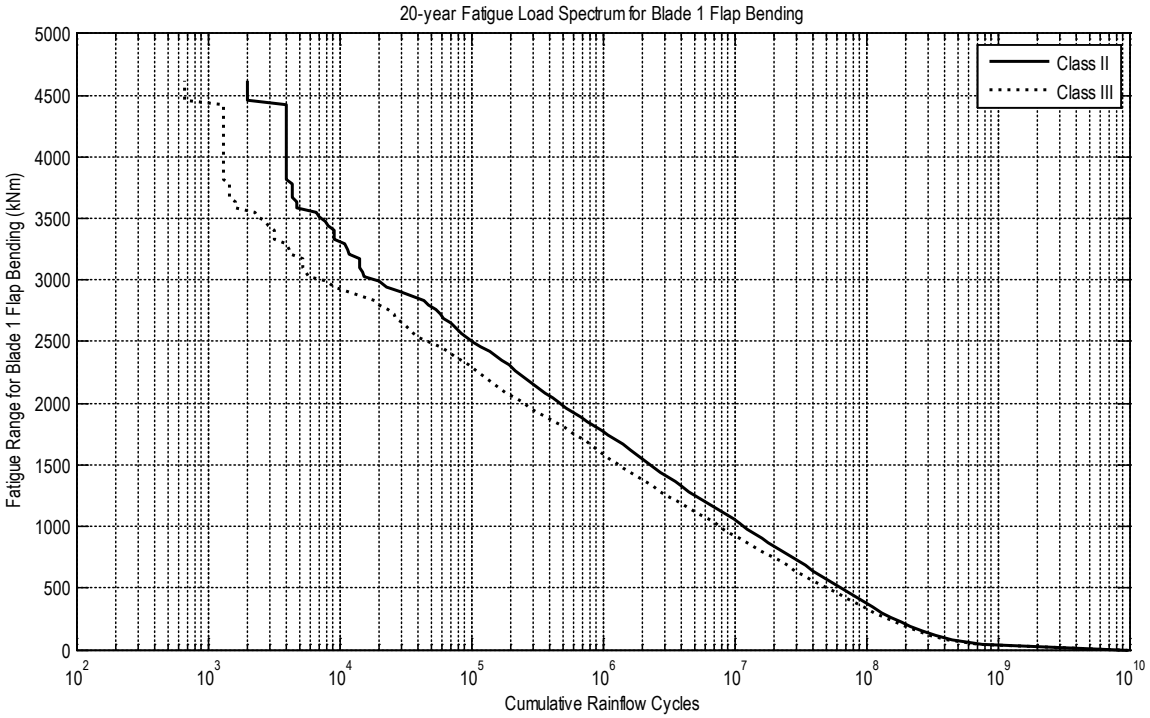


Figure 56. Twenty-year fatigue load spectrum for blade 1 flap bending

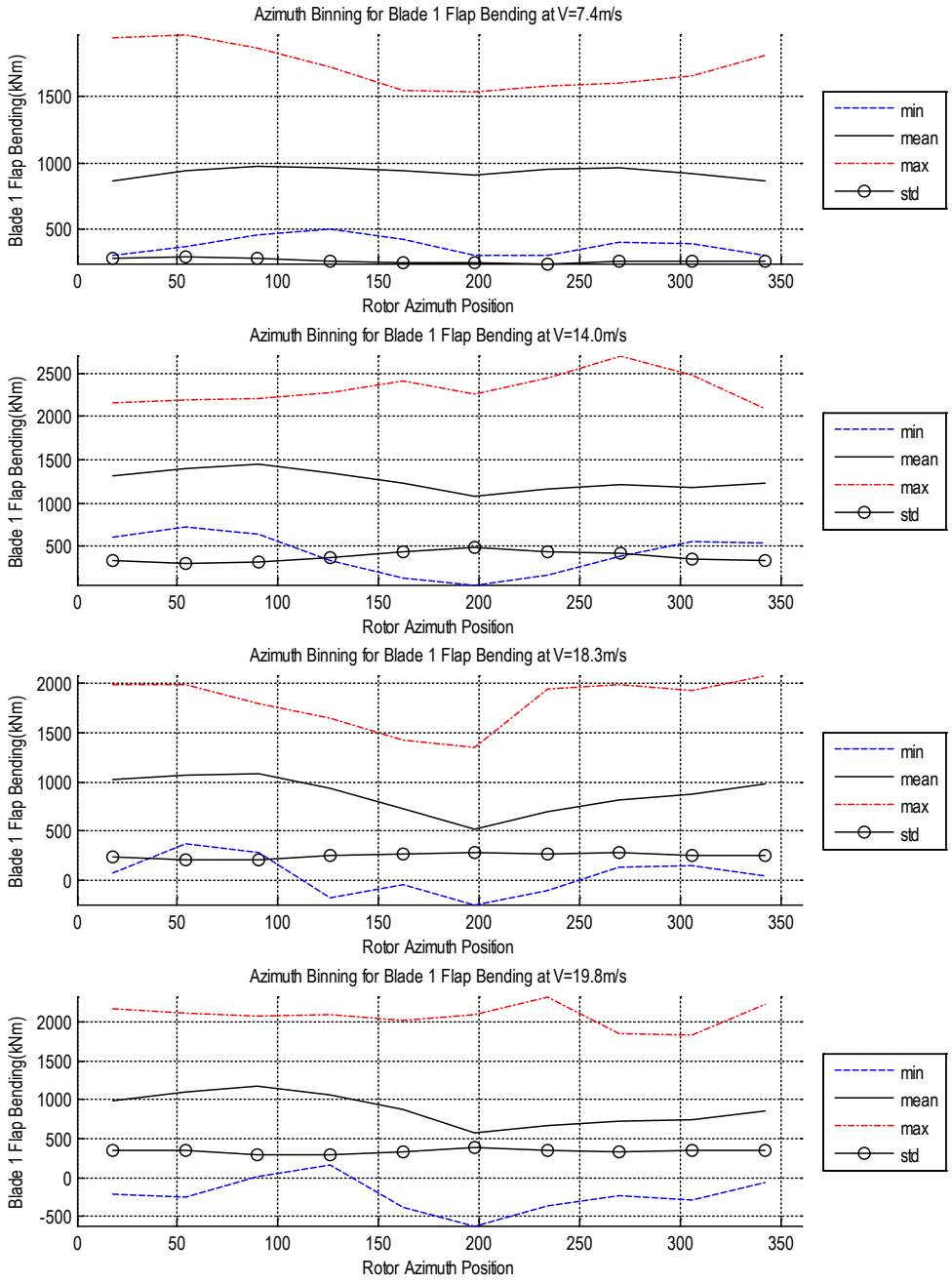


Figure 57. Azimuth binning for blade 1 flap bending

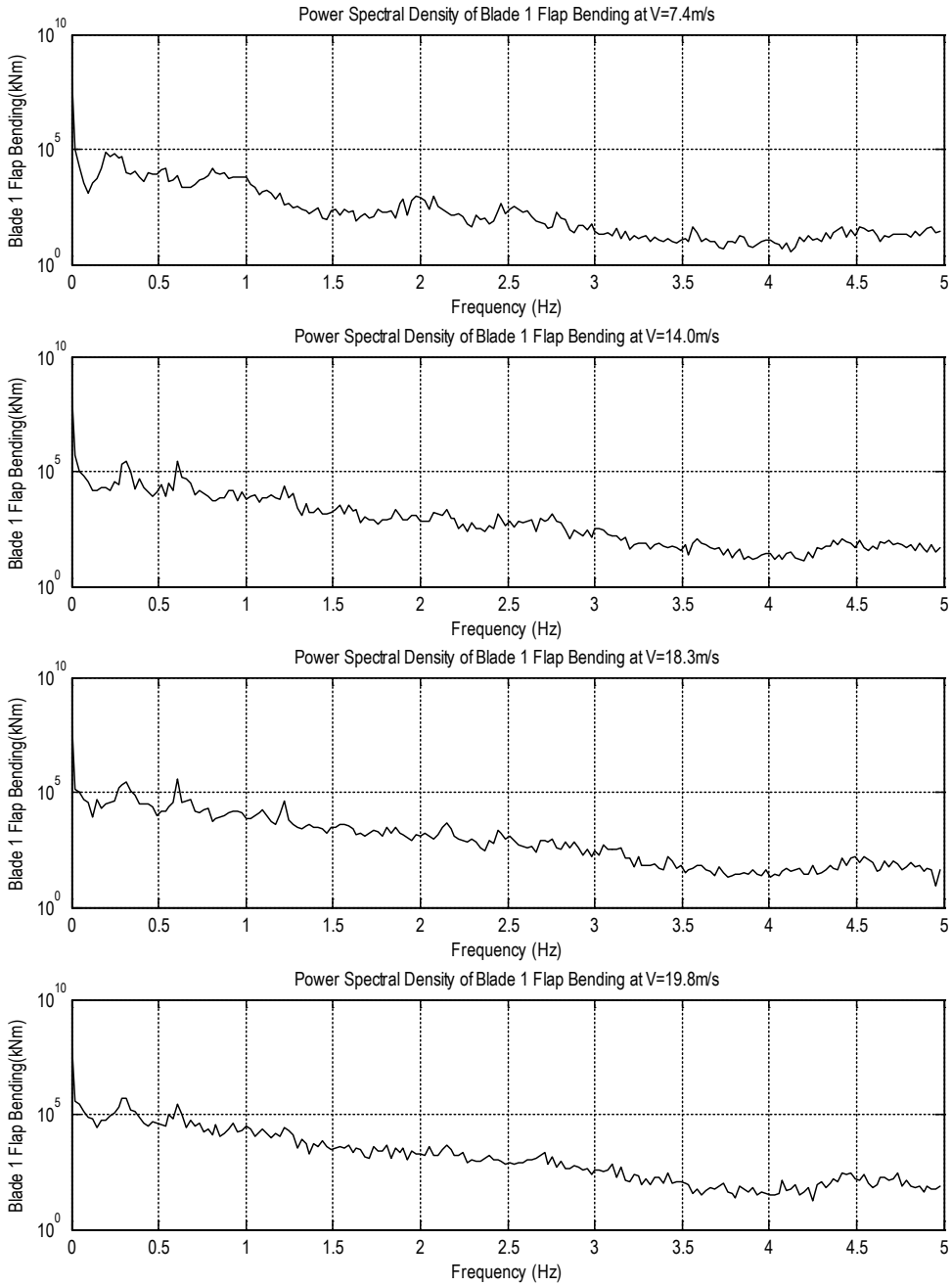


Figure 58. Power spectral density of blade 1 flap bending

Blade 1 Leadlag Bending

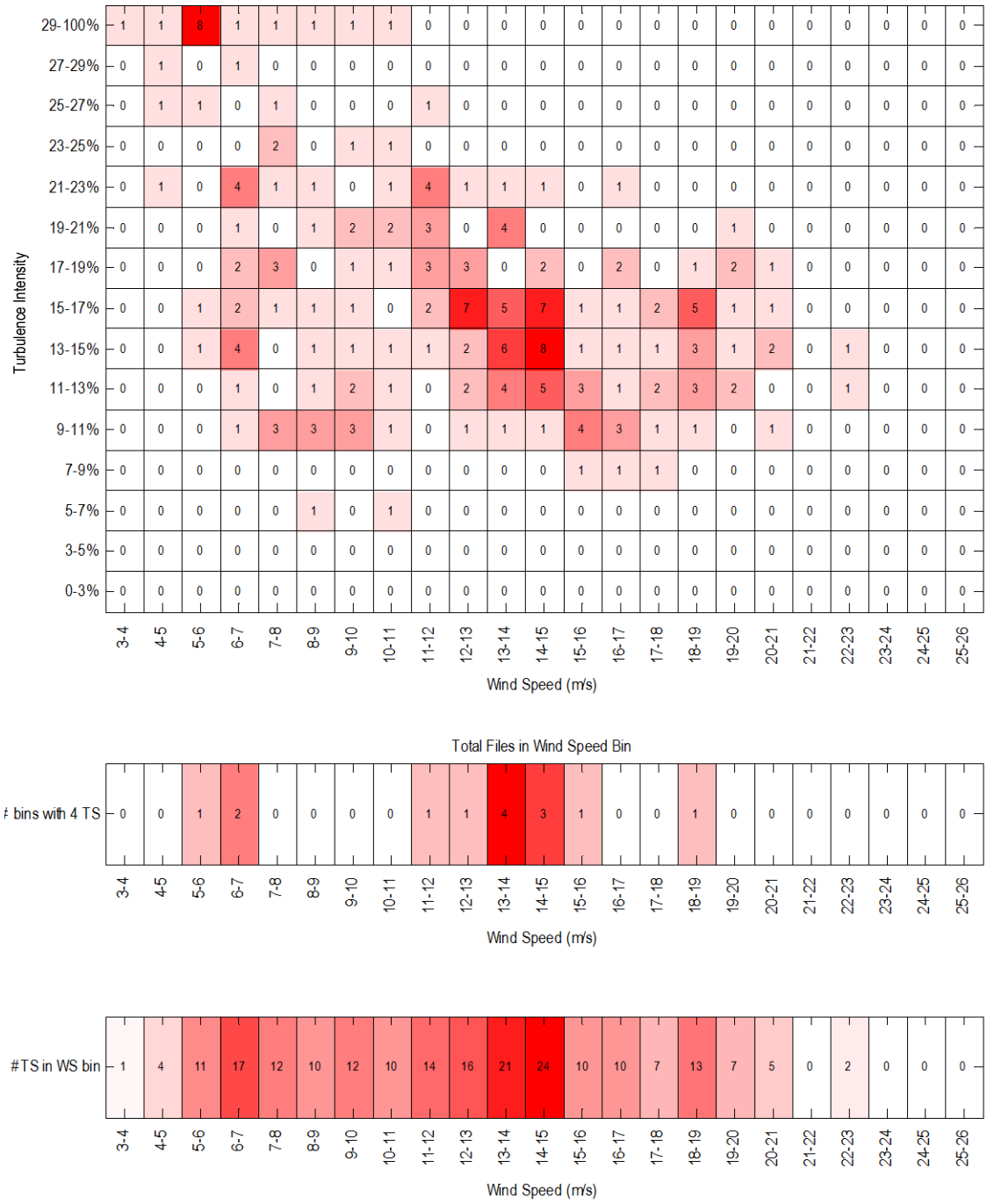


Figure 59. Capture matrix for blade 1 leadlag bending

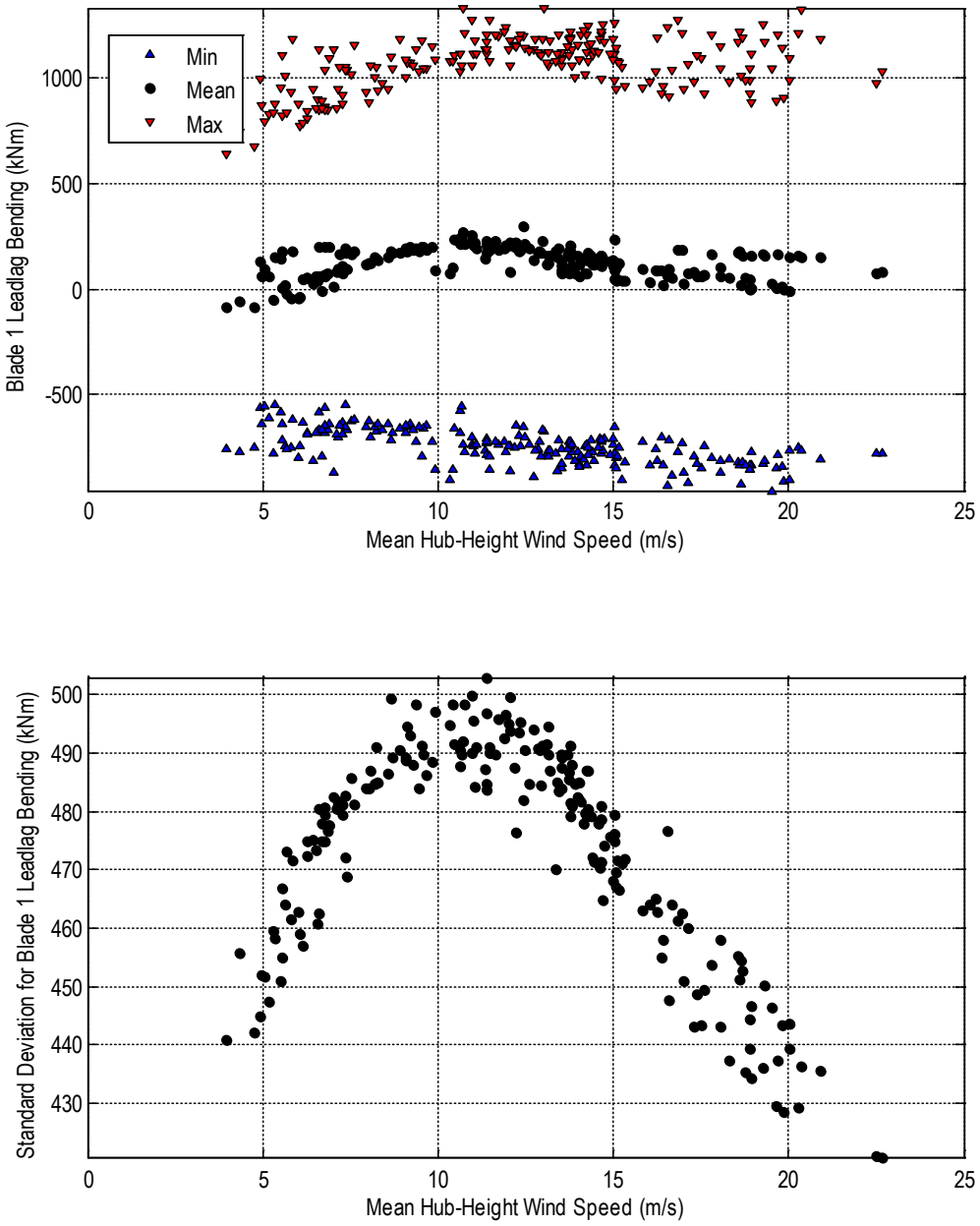


Figure 60. Scatterplot for blade 1 leadlag bending

Table 47. Binned Data for Blade 1 Leadlag Bending

Bin #	Bin WS Low	Bin WS High	Mean WS	# Files	Min of Minimums	Mean of Means	Max of Maximums
1	3.0	4.0	4.0	1	-753.36	-83.86	636.35
2	4.0	5.0	4.8	4	-767.34	13.54	992.06
3	5.0	6.0	5.5	11	-774.85	64.53	1,184.77
4	6.0	7.0	6.5	17	-810.33	65.99	1,137.95
5	7.0	8.0	7.4	12	-865.58	122.07	1,154.58
6	8.0	9.0	8.4	9	-713.46	149.90	1,183.86
7	9.0	10.0	9.4	12	-854.78	182.12	1,176.56
8	10.0	11.0	10.6	10	-901.60	207.55	1,329.01
9	11.0	12.0	11.4	14	-853.02	199.14	1,274.90
10	12.0	13.0	12.5	15	-888.11	192.47	1,206.00
11	13.0	14.0	13.5	20	-857.27	134.76	1,217.10
12	14.0	15.0	14.4	24	-837.90	129.37	1,252.52
13	15.0	16.0	15.2	10	-902.57	87.43	1,261.17
14	16.0	17.0	16.5	10	-931.56	91.13	1,272.30
15	17.0	18.0	17.4	7	-915.32	76.50	1,204.69
16	18.0	19.0	18.6	13	-920.76	78.31	1,220.67
17	19.0	20.0	19.6	7	-954.02	75.37	1,253.16
18	20.0	21.0	20.3	5	-903.10	122.26	1,321.16
19	21.0	22.0	0.0	0	0.00	0.00	0.00
20	22.0	23.0	22.6	2	-778.01	76.80	1,028.39
21	23.0	24.0	0.0	0	0.00	0.00	0.00
22	24.0	25.0	0.0	0	0.00	0.00	0.00
23	25.0	26.0	0.0	0	0.00	0.00	0.00

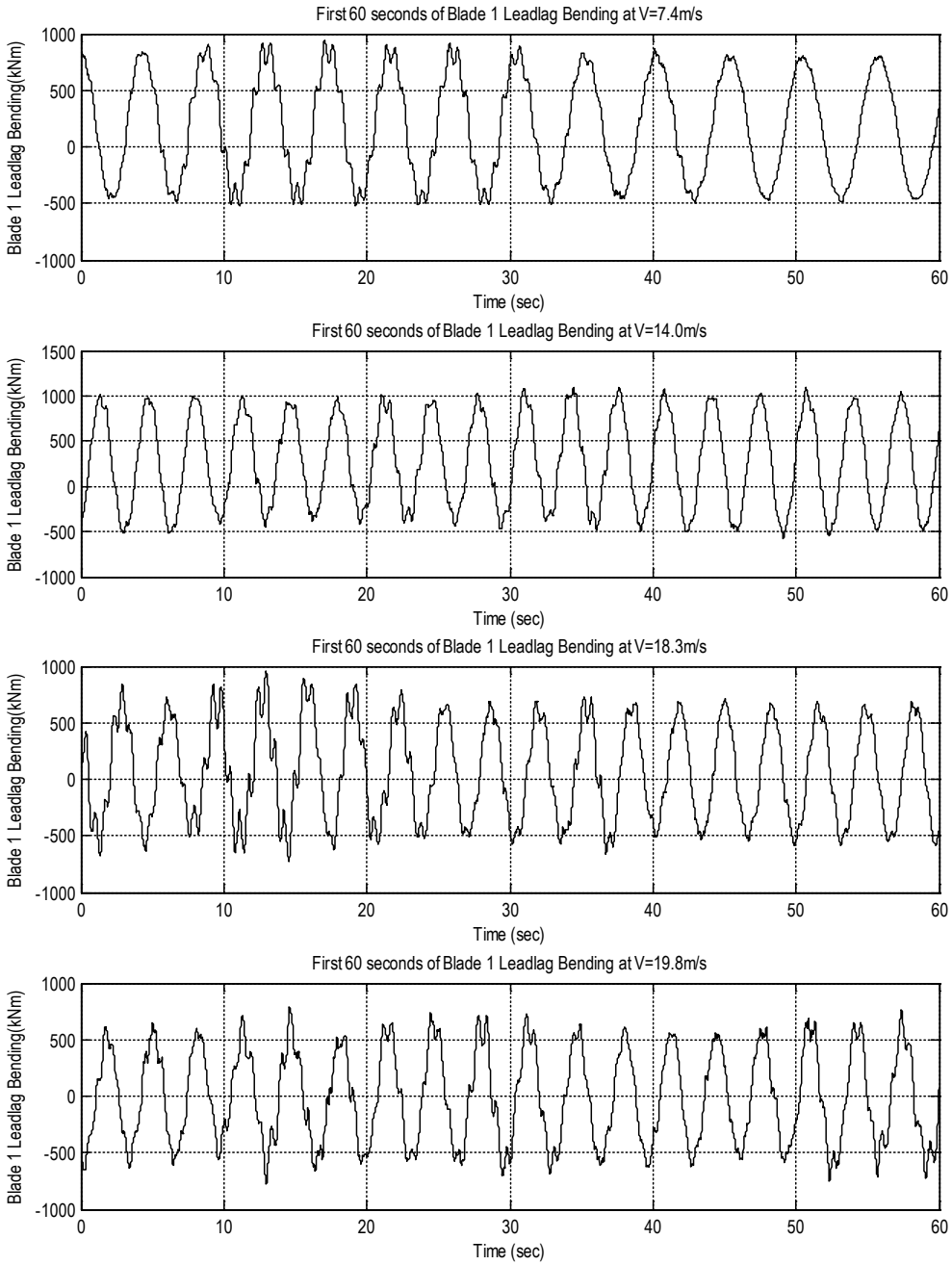


Figure 61. Time series for the first 60 seconds of blade 1 leadlag bending

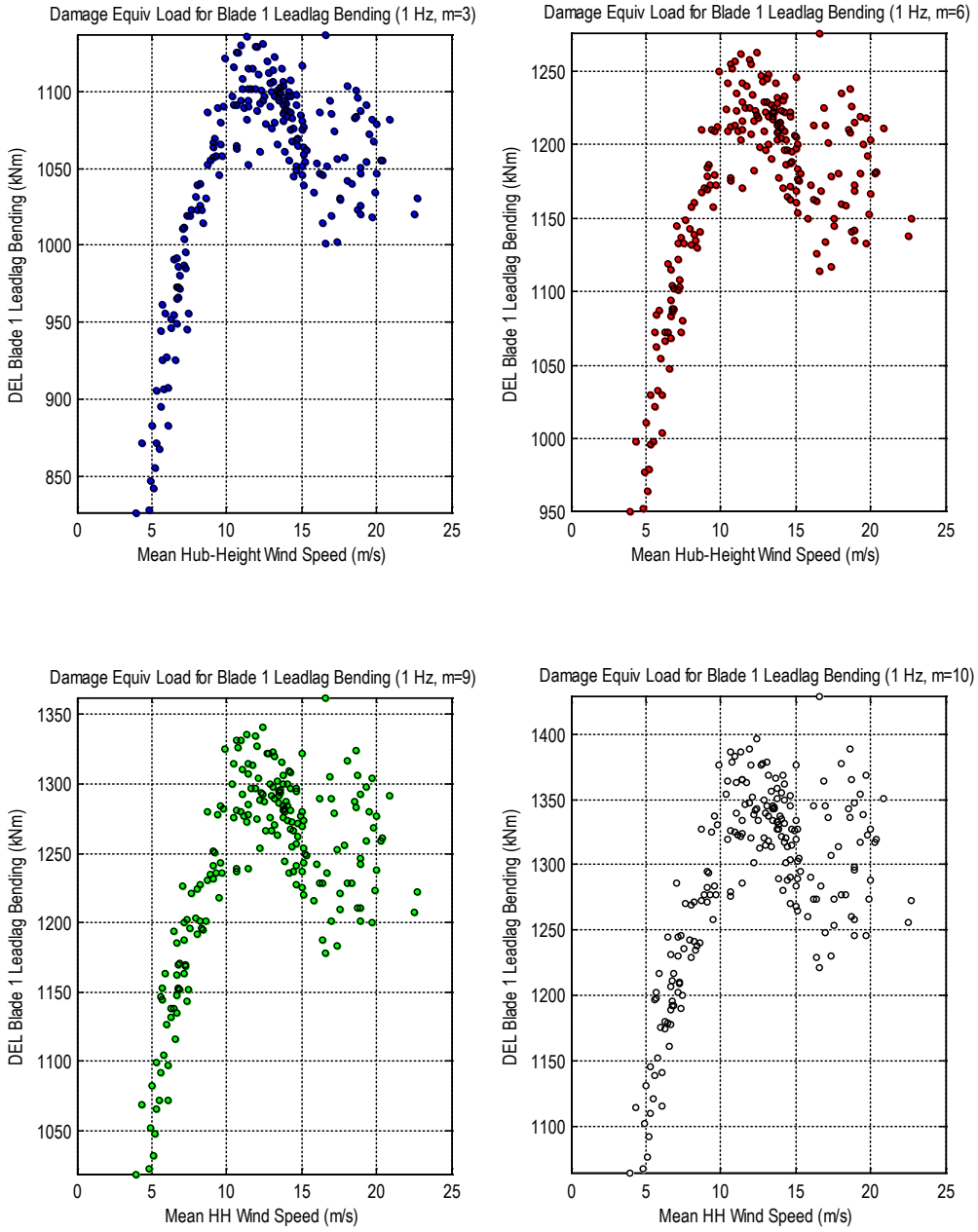


Figure 62. DEL (1 Hz, m=3, 6, 9, 10) for blade 1 leadlag bending

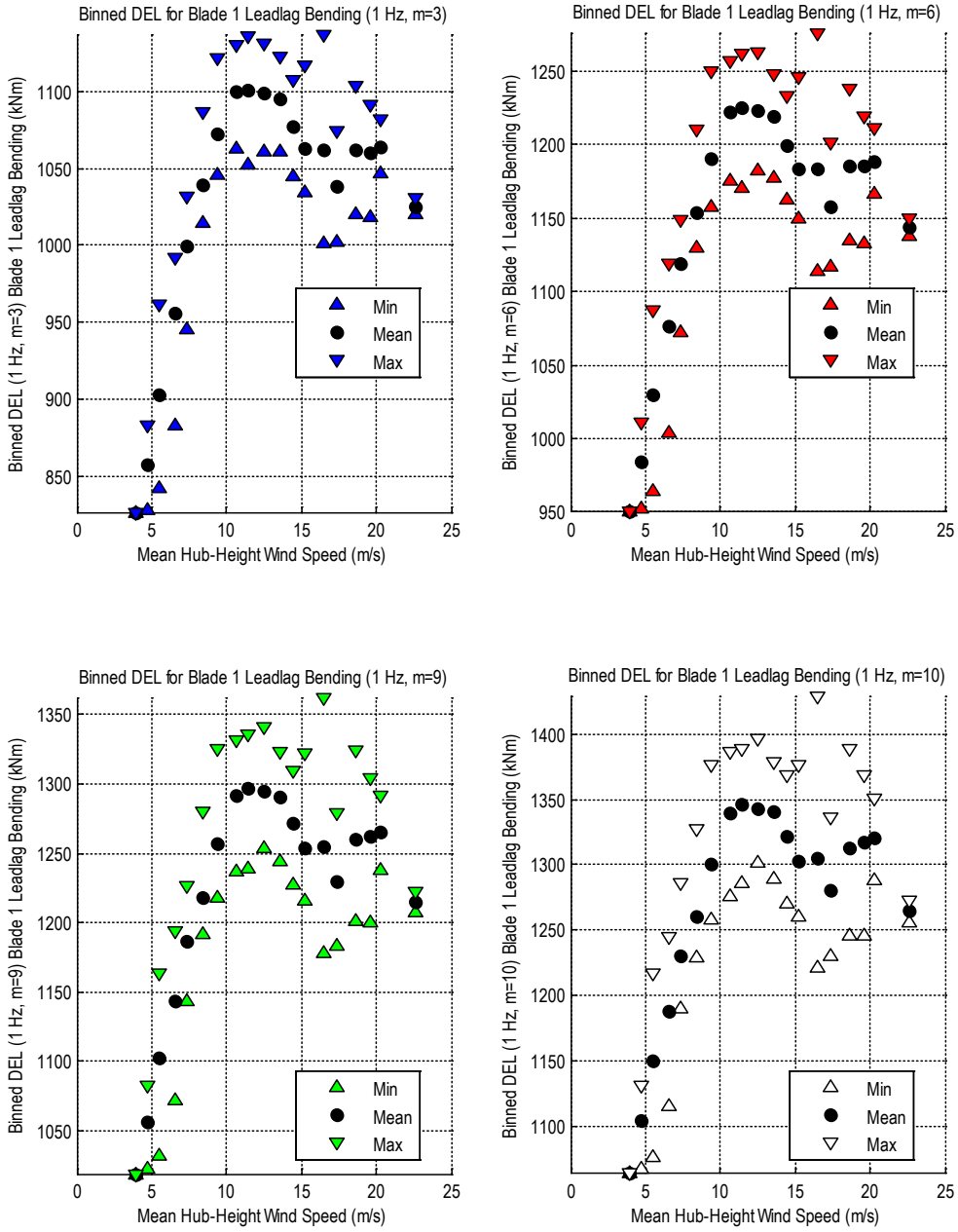


Figure 63. Binned DEL (1 Hz, m=3, 6, 9, 10) for blade 1 leadlag bending

Table 48. Binned DEL Data for Blade 1 Leadlag Bending

Bin #	Bin WS Low	Bin WS High	Mean WS	# Files	Min of Del (m=3)	Mean of Del (m=3)	Max of Del (m=3)	Min of Del (m=6)	Mean of Del (m=6)	Max of Del (m=6)	Min of Del (m=9)	Mean of Del (m=9)	Max of Del (m=9)
1	3.0	4.0	4.0	1	826.44	826.44	826.44	949.87	949.87	949.87	1,063.53	1,063.53	1,063.53
2	4.0	5.0	4.8	4	828.11	857.41	882.81	952.74	984.50	1,010.39	1,067.25	1,103.74	1,130.93
3	5.0	6.0	5.5	11	841.67	902.77	961.08	964.40	1,029.74	1,086.80	1,076.03	1,150.08	1,217.39
4	6.0	7.0	6.5	17	882.72	955.47	991.68	1,004.37	1,076.26	1,119.42	1,115.16	1,187.38	1,244.36
5	7.0	8.0	7.4	12	945.41	999.09	1031.39	1,072.40	1,118.82	1,148.25	1,189.99	1,230.63	1,286.03
6	8.0	9.0	8.4	10	1,014.24	1,038.96	1,086.53	1,129.61	1,154.10	1,210.03	1,228.91	1,260.04	1,327.19
7	9.0	10.0	9.4	12	1,045.99	1,072.33	1,121.76	1,157.17	1,190.12	1,249.82	1,257.91	1,300.76	1,376.70
8	10.0	11.0	10.6	10	1,062.73	1,099.82	1,130.18	1,175.31	1,221.69	1,257.05	1,276.55	1,339.44	1,386.56
9	11.0	12.0	11.4	14	1,052.05	1,101.30	1,135.55	1,170.94	1,224.88	1,262.01	1,286.23	1,346.60	1,388.55
10	12.0	13.0	12.5	16	1,060.61	1,099.27	1,131.51	1,182.38	1,222.66	1,262.69	1,302.05	1,343.43	1,396.40
11	13.0	14.0	13.5	21	1,060.82	1,095.55	1,123.07	1,177.73	1,218.67	1,247.64	1,289.70	1,340.17	1,378.74
12	14.0	15.0	14.4	24	1,044.72	1,077.46	1,107.37	1,163.02	1,199.42	1,233.17	1,270.24	1,321.63	1,368.31
13	15.0	16.0	15.2	10	1,034.73	1,063.40	1,117.10	1,150.04	1,183.06	1,245.71	1,260.07	1,302.31	1,375.95
14	16.0	17.0	16.5	10	1,001.76	1,061.88	1,137.35	1,113.82	1,183.01	1,275.14	1,221.07	1,305.43	1,428.28
15	17.0	18.0	17.4	7	1,002.70	1,038.72	1,074.53	1,116.60	1,157.73	1,200.85	1,230.84	1,280.44	1,336.23
16	18.0	19.0	18.6	13	1,020.16	1,061.81	1,103.82	1,134.40	1,185.34	1,237.56	1,246.31	1,313.17	1,389.02
17	19.0	20.0	19.6	7	1,018.30	1,060.17	1,091.42	1,132.88	1,185.20	1,219.29	1,245.90	1,317.31	1,368.60
18	20.0	21.0	20.3	5	1,046.89	1,063.78	1,081.54	1,166.53	1,188.65	1,211.34	1,287.87	1,320.49	1,350.49
19	21.0	22.0	0.0	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
20	22.0	23.0	22.6	2	1,020.50	1,025.43	1,030.36	1,137.73	1,143.80	1,149.88	1,255.98	1,264.44	1,272.91
21	23.0	24.0	0.0	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
22	24.0	25.0	0.0	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
23	25.0	26.0	0.0	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

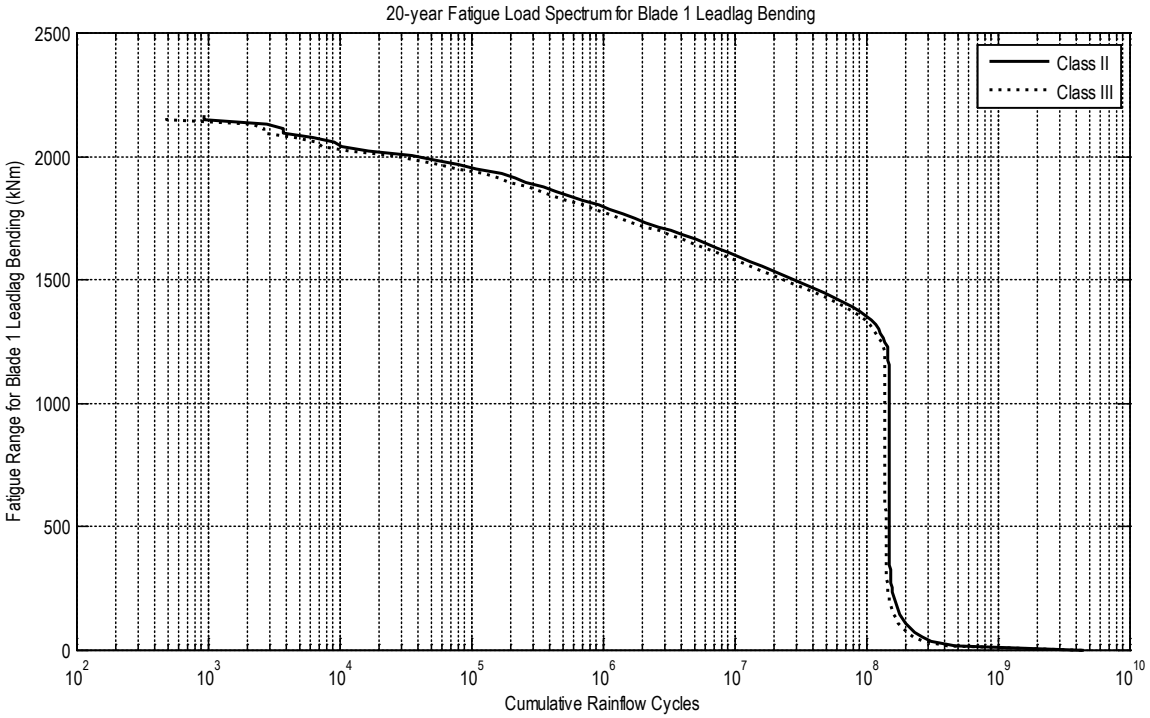


Figure 64. Twenty-year fatigue load spectrum for blade 1 leadlag bending

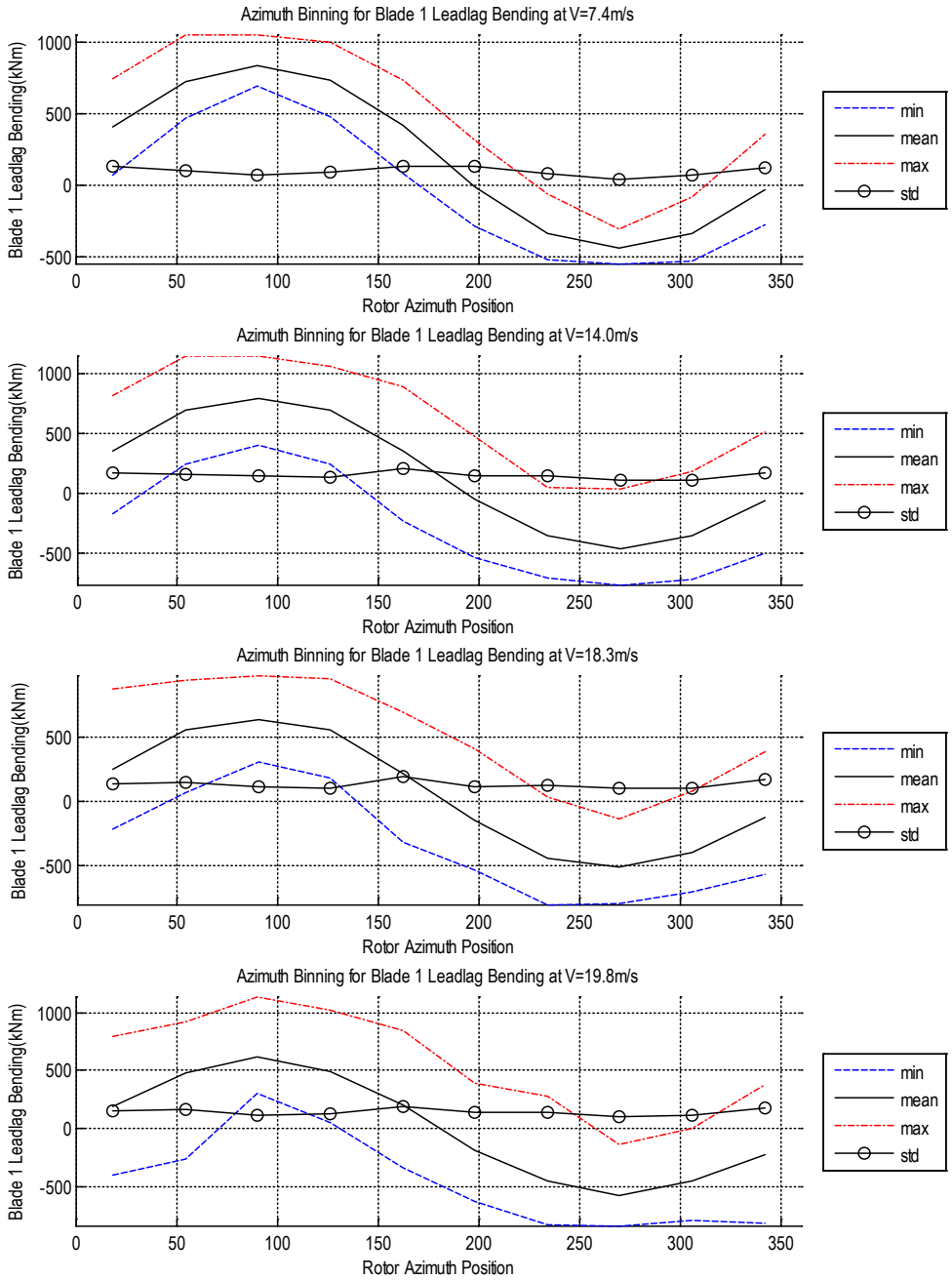


Figure 65. Azimuth binning for blade 1 leadlag bending

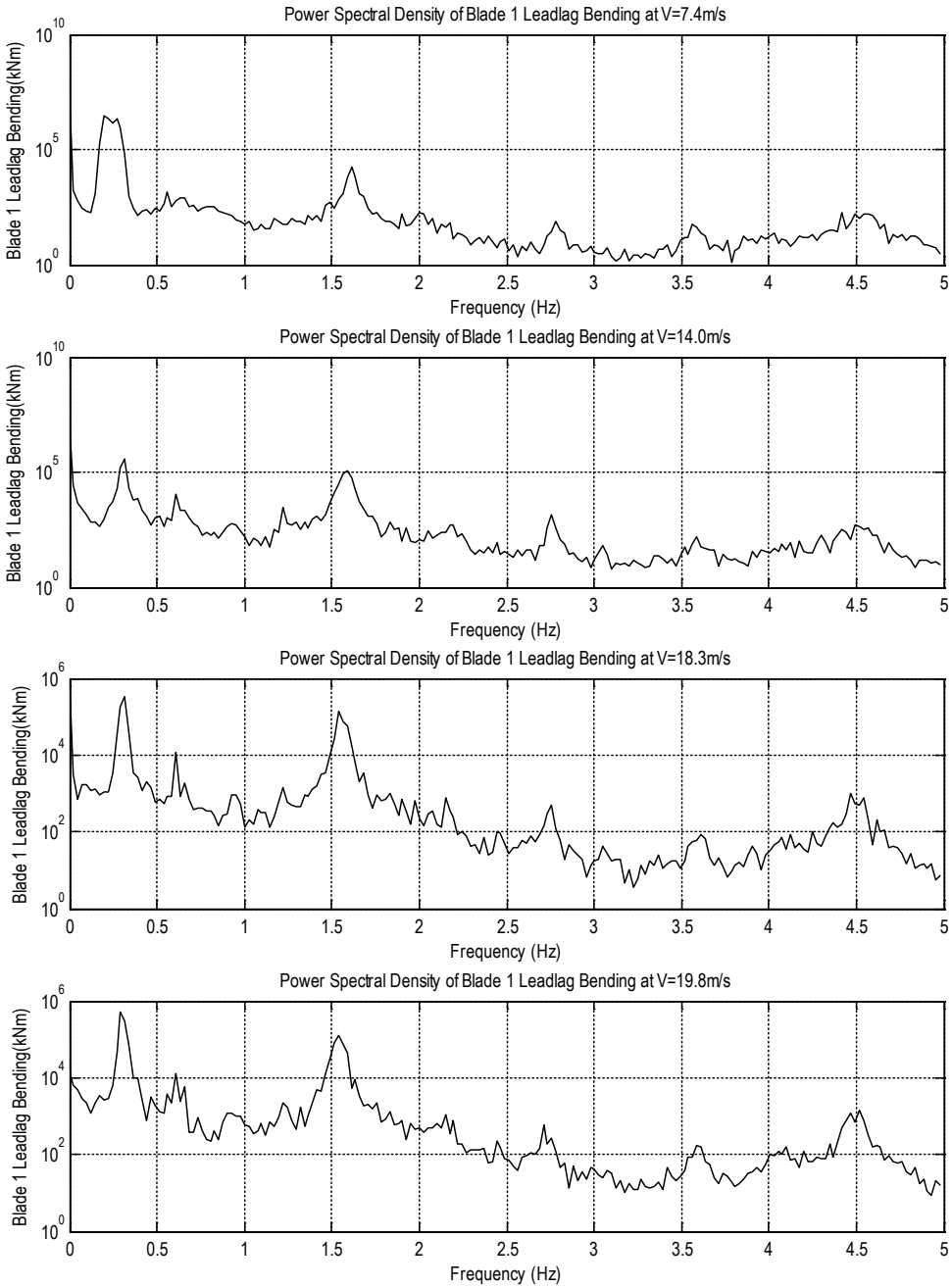


Figure 66. Power spectral density of blade 1 leadlag bending

Blade 2 Flap Bending

Turbulence Intensity	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-11	11-12	12-13	13-14	14-15	15-16	16-17	17-18	18-19	19-20	20-21	21-22	22-23	23-24	24-25	25-26
29-100%	1	1	8	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
27-29%	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
25-27%	0	1	1	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
23-25%	0	0	0	0	2	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
21-23%	0	1	0	4	0	1	0	1	4	1	1	1	0	1	0	0	0	0	0	0	0	0	0
19-21%	0	0	0	1	0	1	2	2	3	0	4	0	0	0	0	0	1	0	0	0	0	0	0
17-19%	0	0	0	2	3	0	1	1	4	3	0	2	1	2	1	1	2	0	0	0	0	0	0
15-17%	0	0	1	2	3	1	1	0	3	7	7	7	1	1	2	5	1	1	0	0	0	0	0
13-15%	0	0	1	4	0	1	1	1	1	2	6	8	1	1	1	3	1	2	0	1	0	0	0
11-13%	0	0	0	1	0	1	2	1	0	2	3	5	3	1	2	3	2	0	0	1	0	0	0
9-11%	0	0	0	1	3	3	4	1	0	1	1	1	4	3	1	1	0	1	0	0	0	0	0
7-9%	0	0	0	0	2	1	0	0	0	0	0	0	1	1	1	0	0	0	0	0	0	0	0
5-7%	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3-5%	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0-3%	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Wind Speed (m/s)

Total Files in Wind Speed Bin

	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-11	11-12	12-13	13-14	14-15	15-16	16-17	17-18	18-19	19-20	20-21	21-22	22-23	23-24	24-25	25-26
# bins with 4 TS	0	0	1	2	0	0	1	0	2	1	3	3	1	0	0	1	0	0	0	0	0	0	0

Wind Speed (m/s)

	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-11	11-12	12-13	13-14	14-15	15-16	16-17	17-18	18-19	19-20	20-21	21-22	22-23	23-24	24-25	25-26
#TS in WS bin	1	4	11	17	15	11	13	10	16	16	22	24	11	10	8	13	7	4	0	2	0	0	0

Wind Speed (m/s)

Figure 67. Capture matrix for blade 2 flap bending

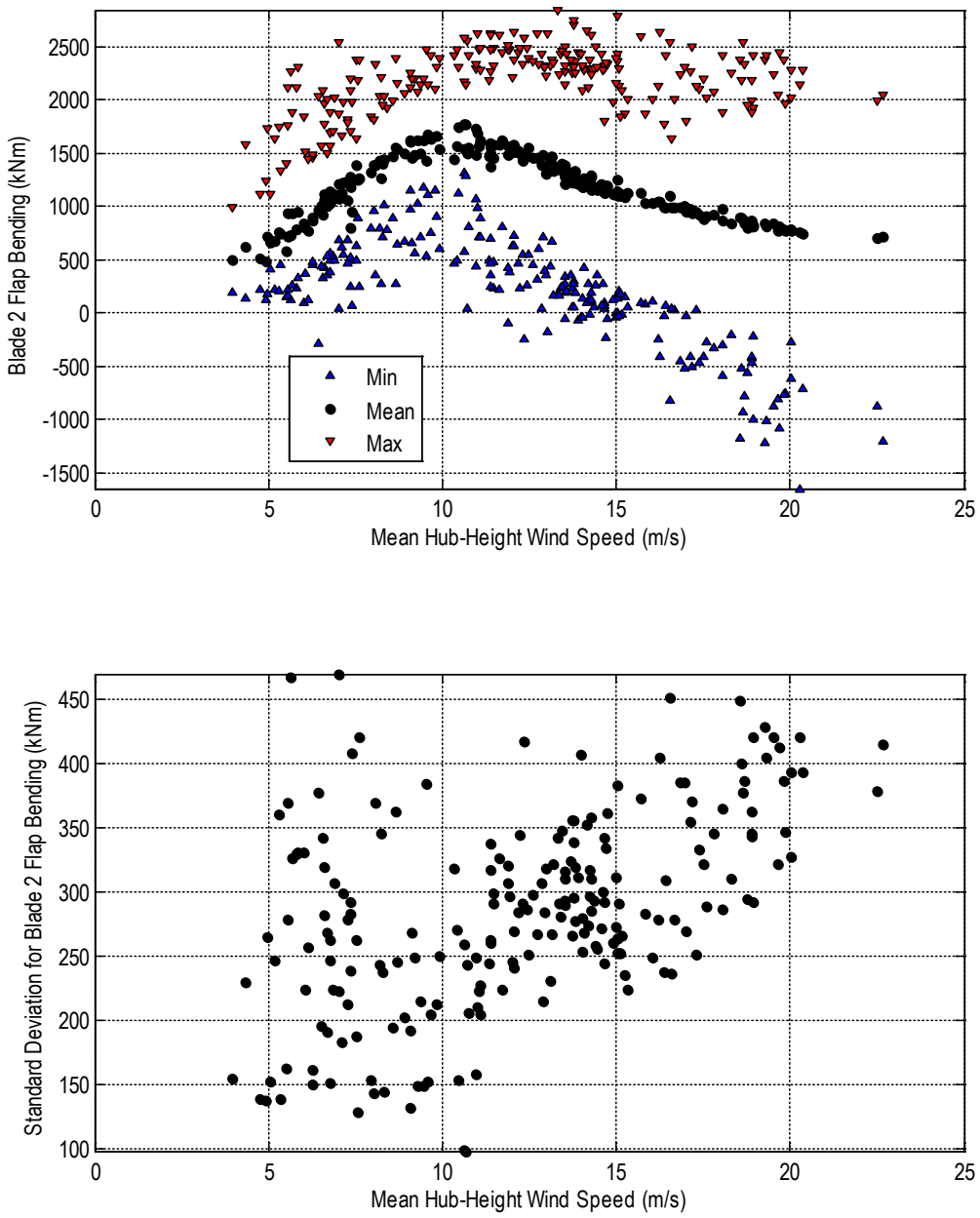


Figure 68. Scatterplot for blade 2 flap bending

Table 49. Binned Data for Blade 2 Flap Bending

Bin #	Bin WS Low	Bin WS High	Mean WS	# Files	Min of Minimums	Mean of Means	Max of Maximums
1	3.0	4.0	4.0	1	194.72	491.17	995.02
2	4.0	5.0	4.8	4	132.81	578.23	1,726.31
3	5.0	6.0	5.5	11	121.76	771.16	2,310.20
4	6.0	7.0	6.5	17	-285.62	979.70	2,081.91
5	7.0	8.0	7.4	15	51.06	1,173.23	2,532.92
6	8.0	9.0	8.4	10	279.96	1,434.87	2,383.40
7	9.0	10.0	9.4	12	533.11	1,568.96	2,468.15
8	10.0	11.0	10.6	10	48.40	1,607.92	2,582.10
9	11.0	12.0	11.4	16	-97.89	1,547.20	2,622.83
10	12.0	13.0	12.5	15	-238.47	1,469.60	2,633.41
11	13.0	14.0	13.6	20	-64.87	1,311.56	2,845.00
12	14.0	15.0	14.4	24	-233.40	1,189.97	2,644.77
13	15.0	16.0	15.2	11	-29.06	1,120.07	2,785.06
14	16.0	17.0	16.5	10	-810.42	1,017.25	2,632.56
15	17.0	18.0	17.4	8	-507.90	928.45	2,497.23
16	18.0	19.0	18.6	13	-1,171.89	855.03	2,535.71
17	19.0	20.0	19.6	7	-1,217.29	805.85	2,440.66
18	20.0	21.0	20.2	4	-1,644.91	764.92	2,277.19
19	21.0	22.0	0.0	0	0.00	0.00	0.00
20	22.0	23.0	22.6	2	-1,197.47	707.75	2,041.19
21	23.0	24.0	0.0	0	0.00	0.00	0.00
22	24.0	25.0	0.0	0	0.00	0.00	0.00
23	25.0	26.0	0.0	0	0.00	0.00	0.00

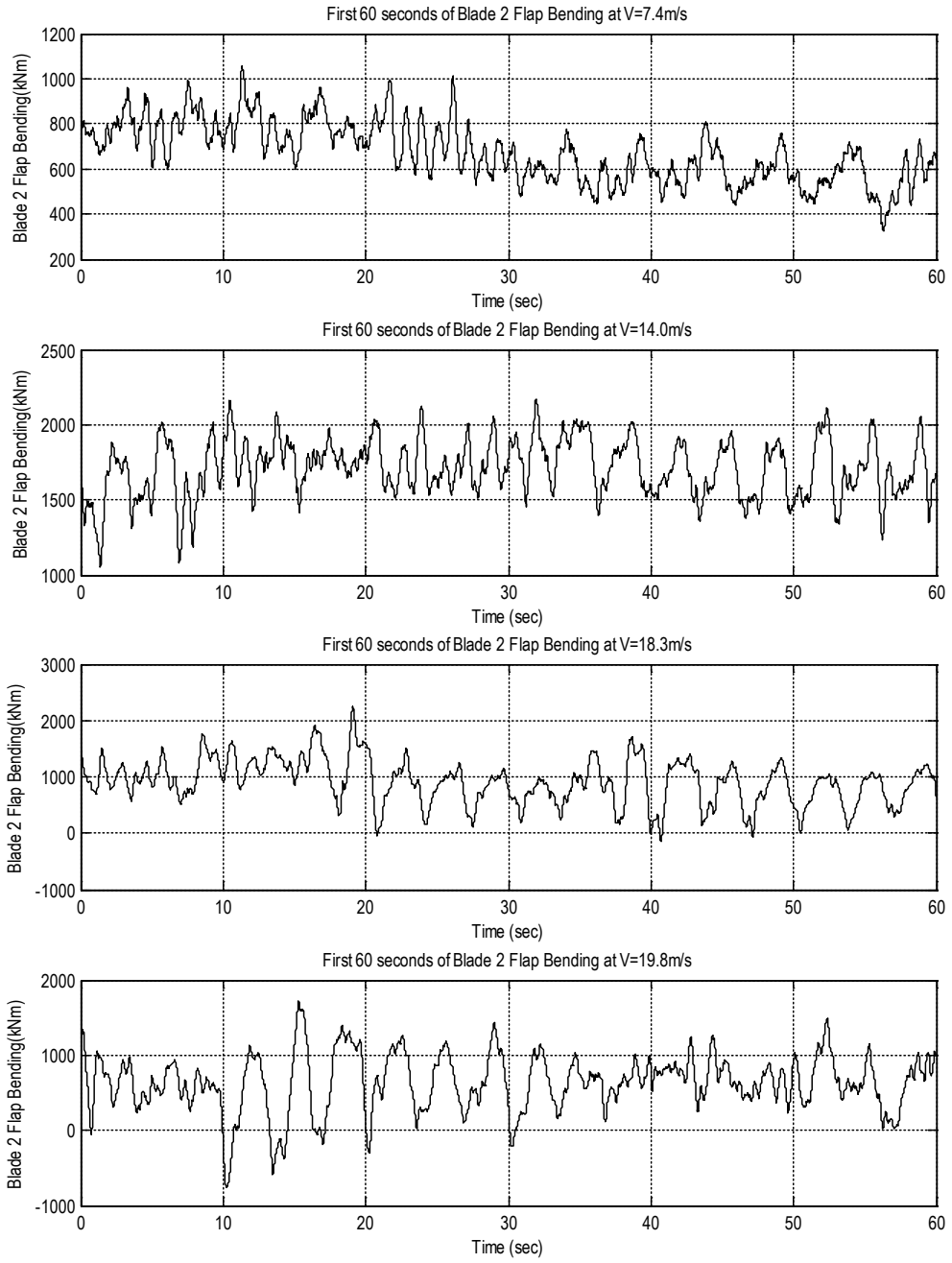


Figure 69. Time series for the first 60 seconds of blade 2 flap bending

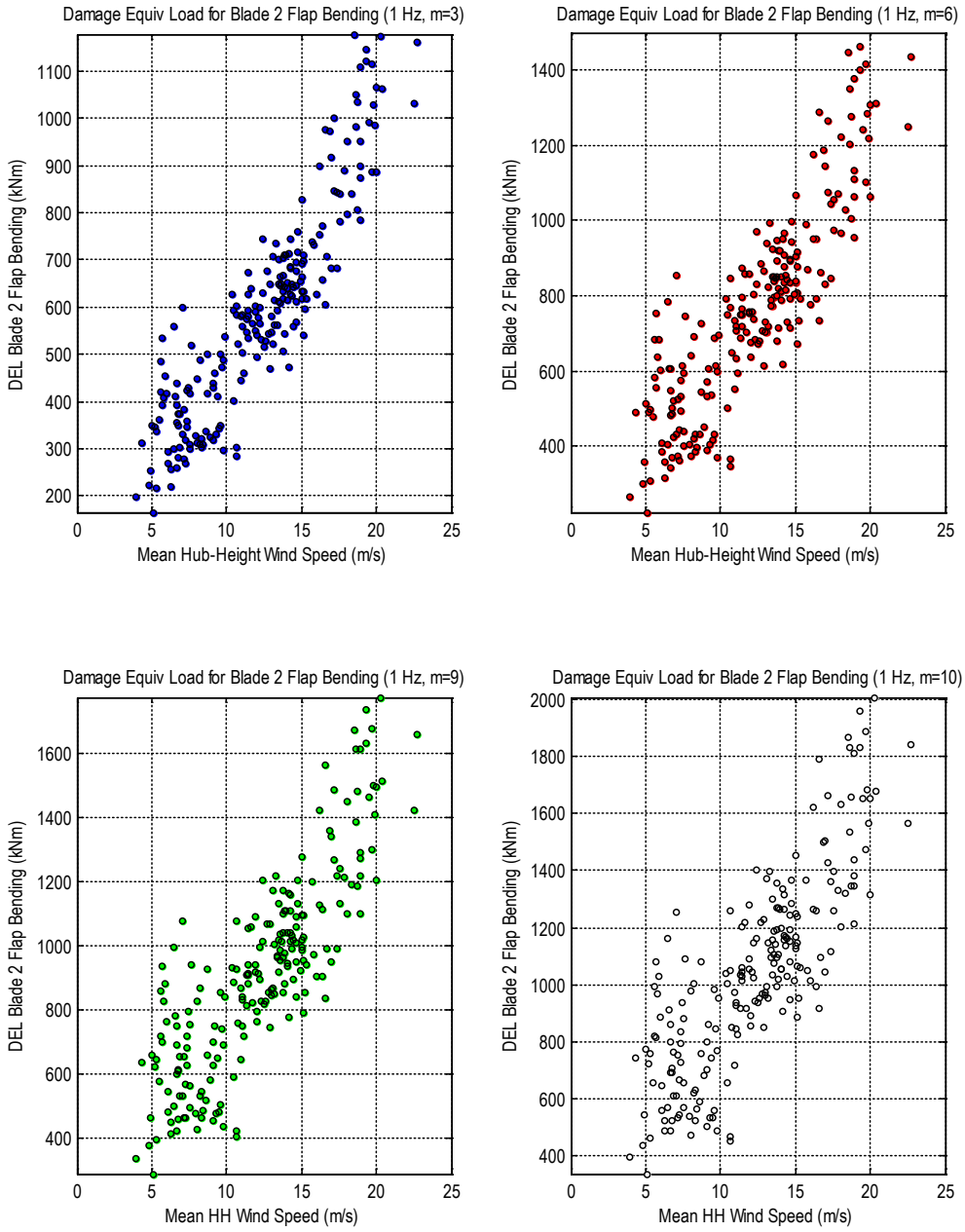


Figure 70. DEL (1 Hz, m=3, 6, 9, 10) for blade 2 flap bending

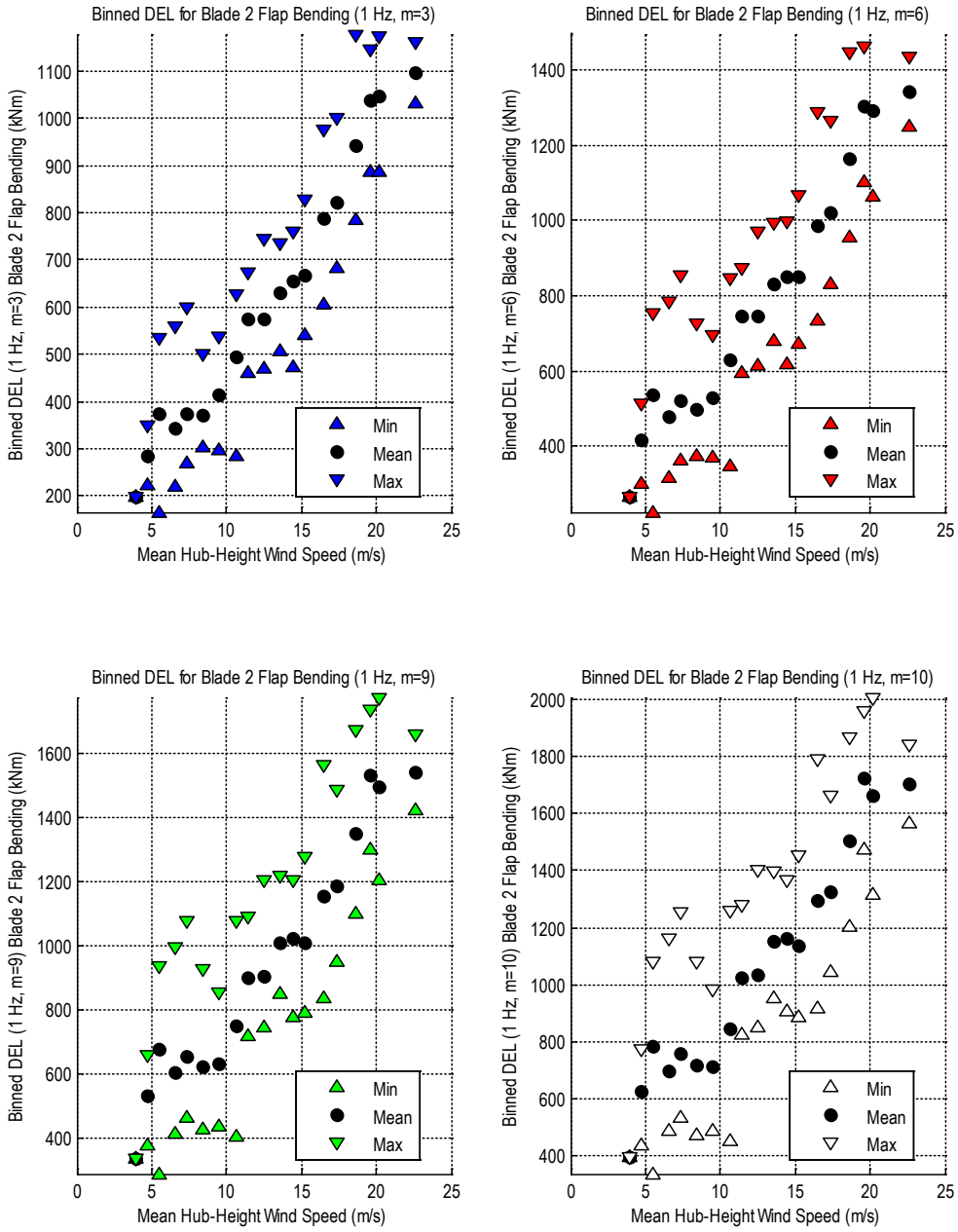


Figure 71. Binned DEL (1 Hz, m=3, 6, 9, 10) for blade 2 flap bending

Table 50. Binned DEL Data for Blade 2 Flap Bending

Bin #	Bin WS Low	Bin WS High	Mean WS	# Files	Min of Del (m=3)	Mean of Del (m=3)	Max of Del (m=3)	Min of Del (m=6)	Mean of Del (m=6)	Max of Del (m=6)	Min of Del (m=9)	Mean of Del (m=9)	Max of Del (m=9)
1	3.0	4.0	4.0	1	198.34	198.34	198.34	265.10	265.10	265.10	394.93	394.93	394.93
2	4.0	5.0	4.8	4	223.65	284.56	348.46	299.26	415.02	514.66	439.88	625.36	772.01
3	5.0	6.0	5.5	11	165.67	374.75	535.36	225.15	536.31	753.06	338.69	786.61	1,079.44
4	6.0	7.0	6.5	17	218.67	344.36	559.22	316.91	480.07	785.82	488.60	699.59	1,160.34
5	7.0	8.0	7.4	15	268.78	373.99	600.49	364.15	519.99	855.91	533.60	759.60	1,251.46
6	8.0	9.0	8.4	11	301.83	370.04	500.66	374.08	500.01	728.65	473.57	719.06	1,082.19
7	9.0	10.0	9.5	13	297.45	413.60	537.27	371.13	527.81	696.17	490.66	714.33	984.54
8	10.0	11.0	10.6	10	284.57	494.31	625.79	348.41	631.21	845.84	452.75	847.57	1,258.61
9	11.0	12.0	11.4	16	459.71	574.12	672.35	594.11	745.99	875.50	823.67	1,024.79	1,278.75
10	12.0	13.0	12.5	16	470.11	574.94	744.38	616.25	747.73	972.37	850.98	1,035.10	1,401.62
11	13.0	14.0	13.5	22	506.45	630.08	736.56	681.00	829.77	994.45	951.92	1,153.97	1,398.16
12	14.0	15.0	14.4	24	473.69	654.39	759.28	619.18	849.50	998.08	908.35	1,161.42	1,368.09
13	15.0	16.0	15.2	11	541.83	668.33	828.67	673.11	852.18	1,067.39	887.65	1,138.08	1,452.20
14	16.0	17.0	16.5	10	607.01	788.91	976.11	735.63	987.22	1,288.65	915.51	1,294.66	1,787.21
15	17.0	18.0	17.4	8	682.23	821.35	1,002.42	833.00	1,020.45	1,266.08	1,046.46	1,325.01	1,662.36
16	18.0	19.0	18.6	13	784.94	942.86	1,178.43	957.07	1,165.25	1,445.38	1,204.47	1,505.75	1,867.50
17	19.0	20.0	19.6	7	885.15	1,039.46	1,146.23	1,101.64	1,304.00	1,464.19	1,470.20	1,720.63	1,957.85
18	20.0	21.0	20.2	4	885.50	1,047.14	1,173.04	1,062.70	1,293.99	1,495.72	1,316.36	1,661.46	2,005.34
19	21.0	22.0	0.0	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
20	22.0	23.0	22.6	2	1,031.38	1,096.66	1,161.95	1,248.58	1,342.19	1,435.80	1,562.75	1701.07	1,839.40
21	23.0	24.0	0.0	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
22	24.0	25.0	0.0	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
23	25.0	26.0	0.0	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

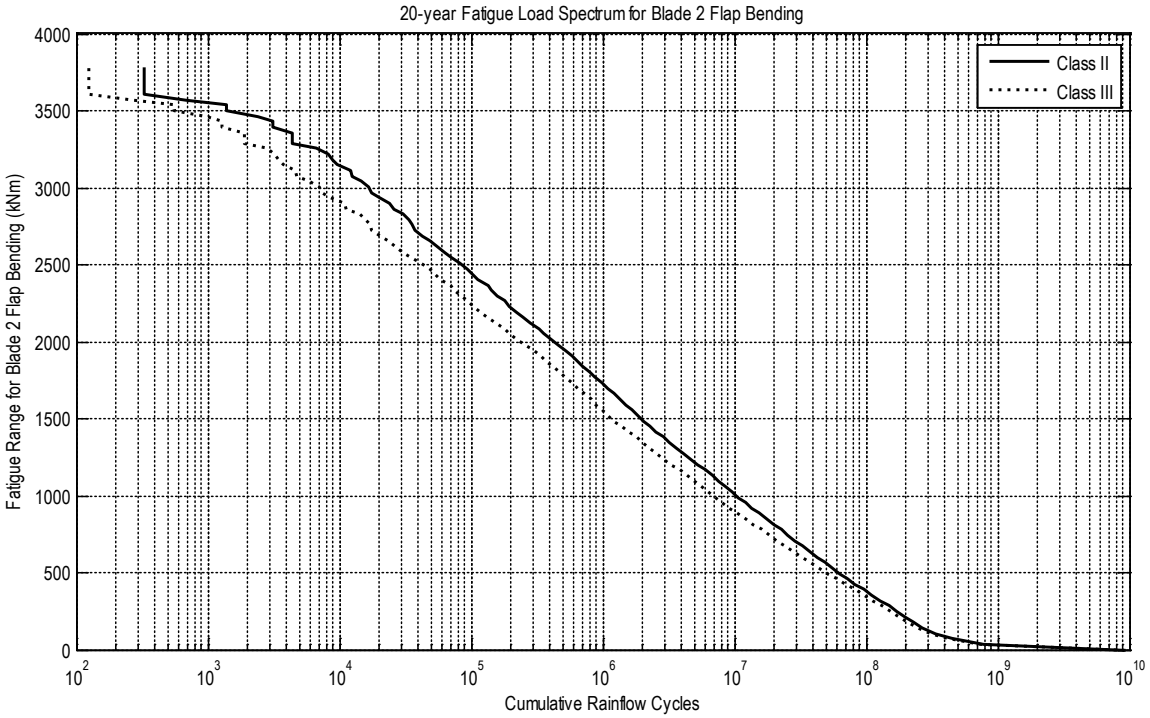


Figure 72. Twenty-year fatigue load spectrum for blade 2 flap bending

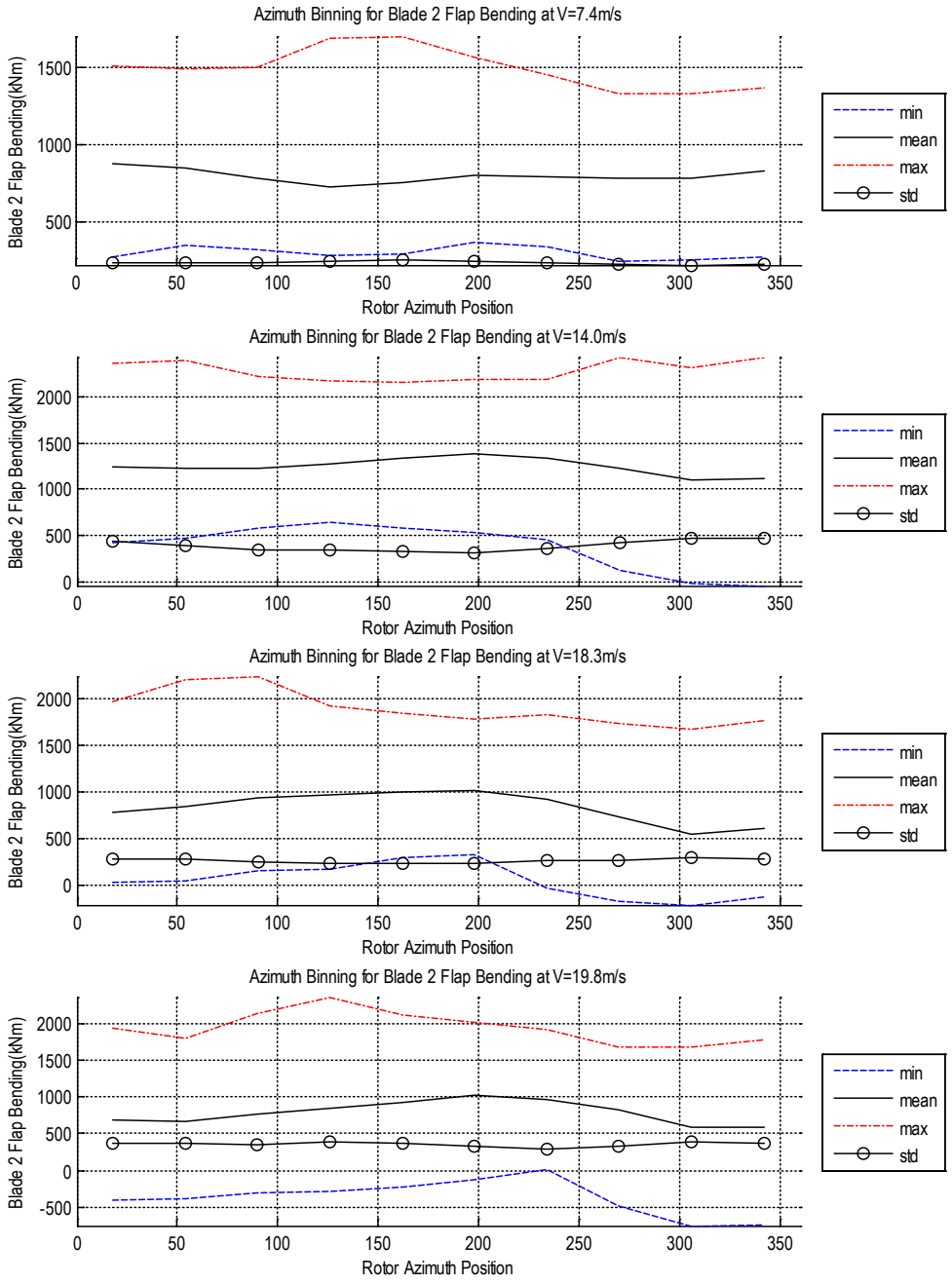


Figure 73. Azimuth binning for blade 2 flap bending

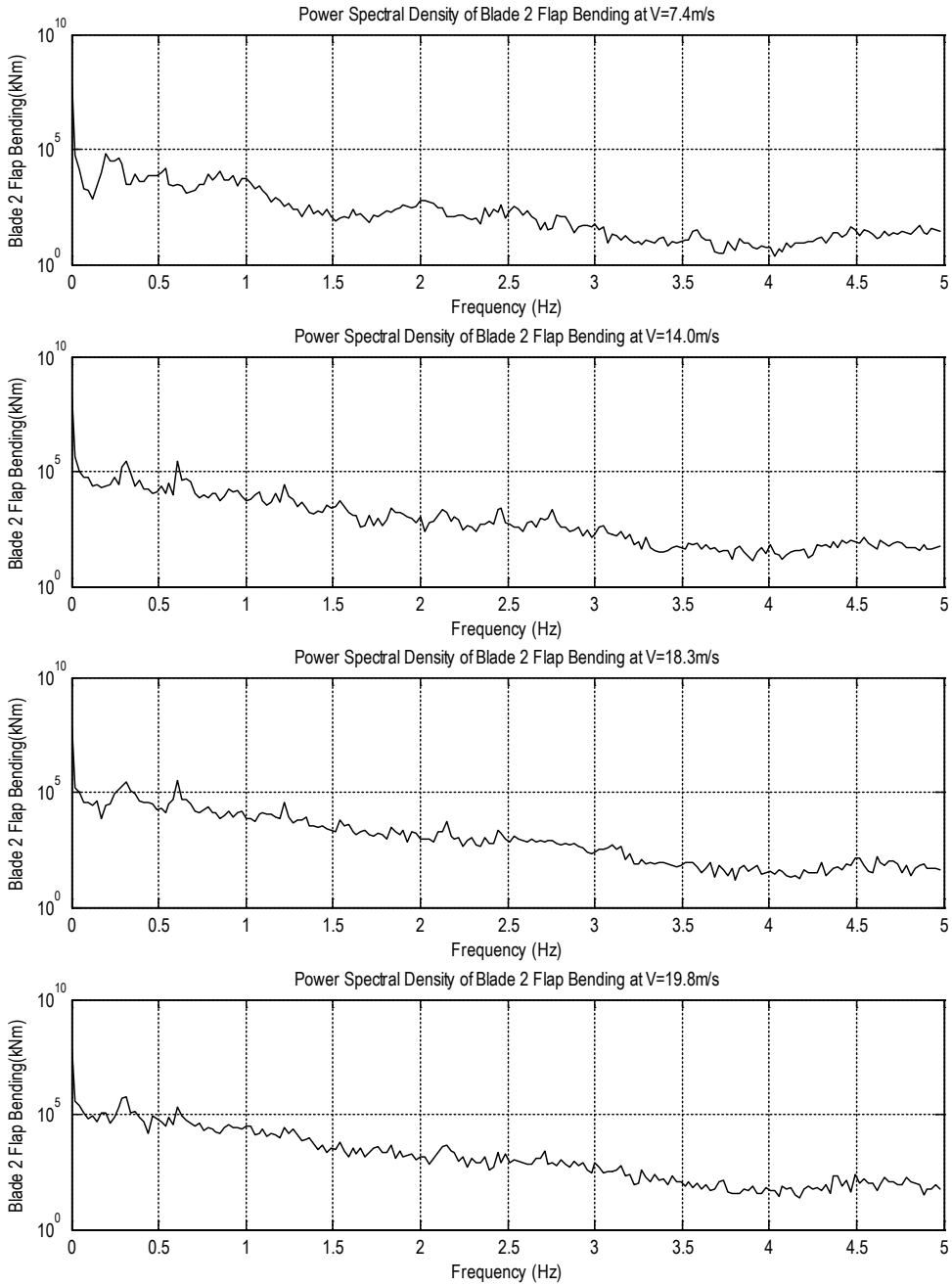


Figure 74. Power spectral density of blade 2 flap bending

Blade 2 Leadlag Bending

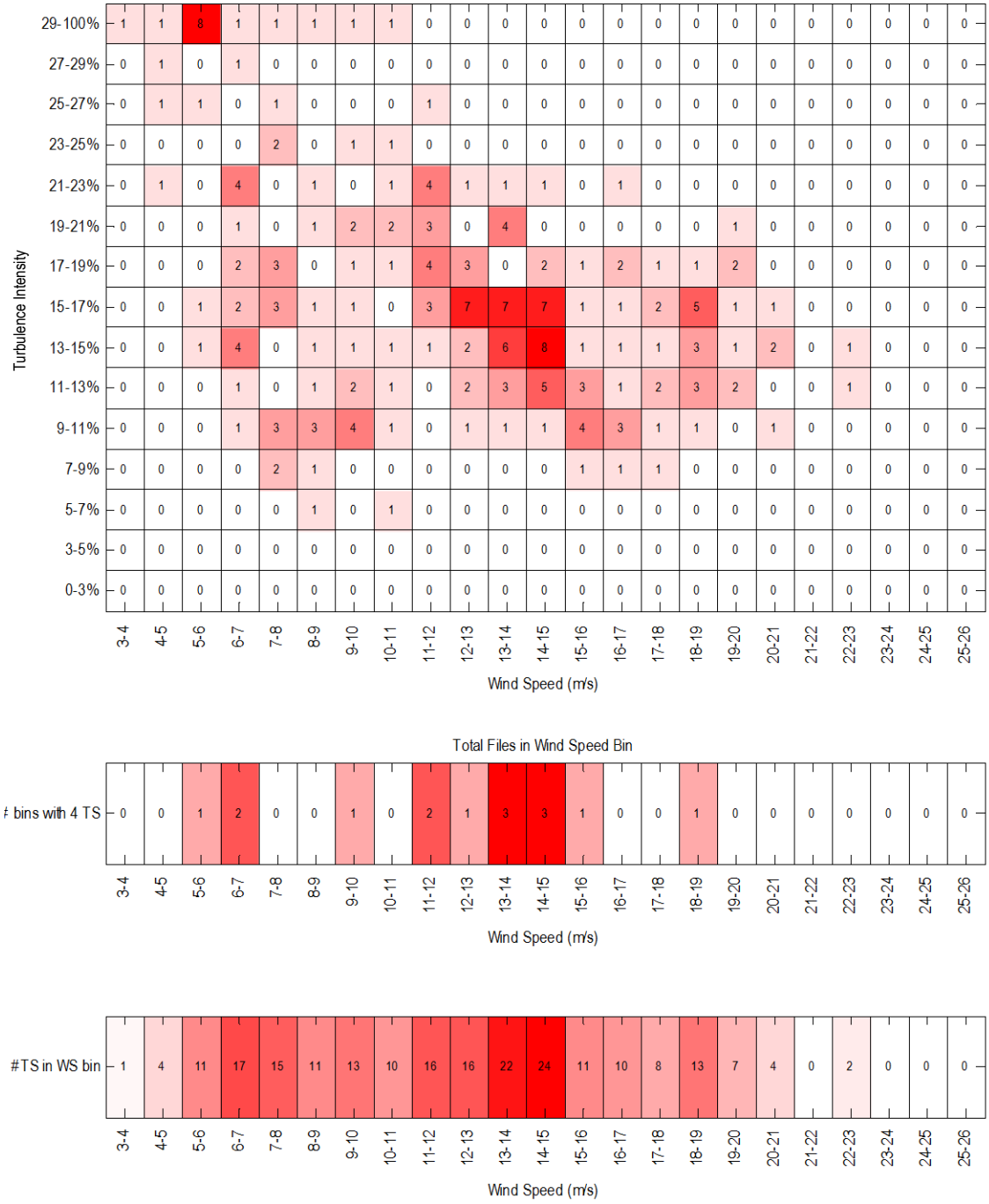


Figure 75. Capture matrix for blade 2 leadlag bending

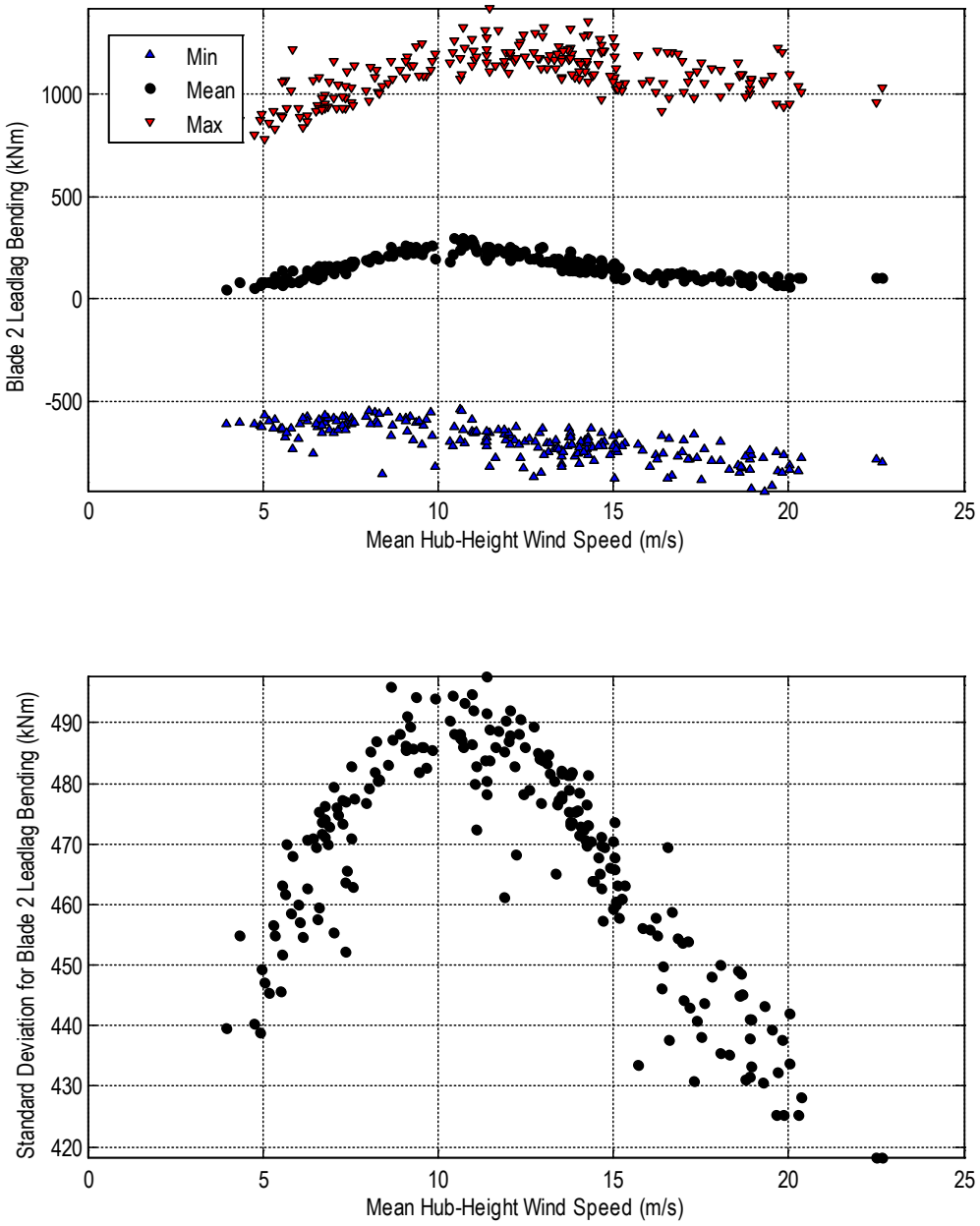


Figure 76. Scatterplot for blade 2 leadlag bending

Table 51. Binned Data for Blade 2 Leadlag Bending

Bin #	Bin WS Low	Bin WS High	Mean WS	# Files	Min of Minimums	Mean of Means	Max of Maximums
1	3.0	4.0	4.0	1	-608.01	47.80	791.10
2	4.0	5.0	4.8	4	-622.04	70.53	899.45
3	5.0	6.0	5.5	11	-733.10	94.93	1,217.56
4	6.0	7.0	6.5	17	-754.18	128.96	1,079.48
5	7.0	8.0	7.4	15	-648.73	158.78	1,156.93
6	8.0	9.0	8.4	10	-666.80	209.38	1,159.68
7	9.0	10.0	9.4	12	-814.11	237.76	1,247.94
8	10.0	11.0	10.6	10	-717.51	262.12	1,324.13
9	11.0	12.0	11.4	16	-820.69	235.32	1,422.31
10	12.0	13.0	12.5	15	-865.35	218.92	1,288.61
11	13.0	14.0	13.6	20	-815.81	174.46	1,316.71
12	14.0	15.0	14.4	24	-801.96	156.12	1,351.46
13	15.0	16.0	15.2	11	-874.89	124.32	1,228.60
14	16.0	17.0	16.5	10	-875.29	114.97	1,211.81
15	17.0	18.0	17.4	8	-881.16	103.99	1,154.79
16	18.0	19.0	18.6	13	-924.28	93.92	1,152.68
17	19.0	20.0	19.6	7	-936.19	87.02	1,224.55
18	20.0	21.0	20.2	4	-842.60	92.42	1,094.23
19	21.0	22.0	0.0	0	0.00	0.00	0.00
20	22.0	23.0	22.6	2	-796.84	101.12	1,031.32
21	23.0	24.0	0.0	0	0.00	0.00	0.00
22	24.0	25.0	0.0	0	0.00	0.00	0.00
23	25.0	26.0	0.0	0	0.00	0.00	0.00

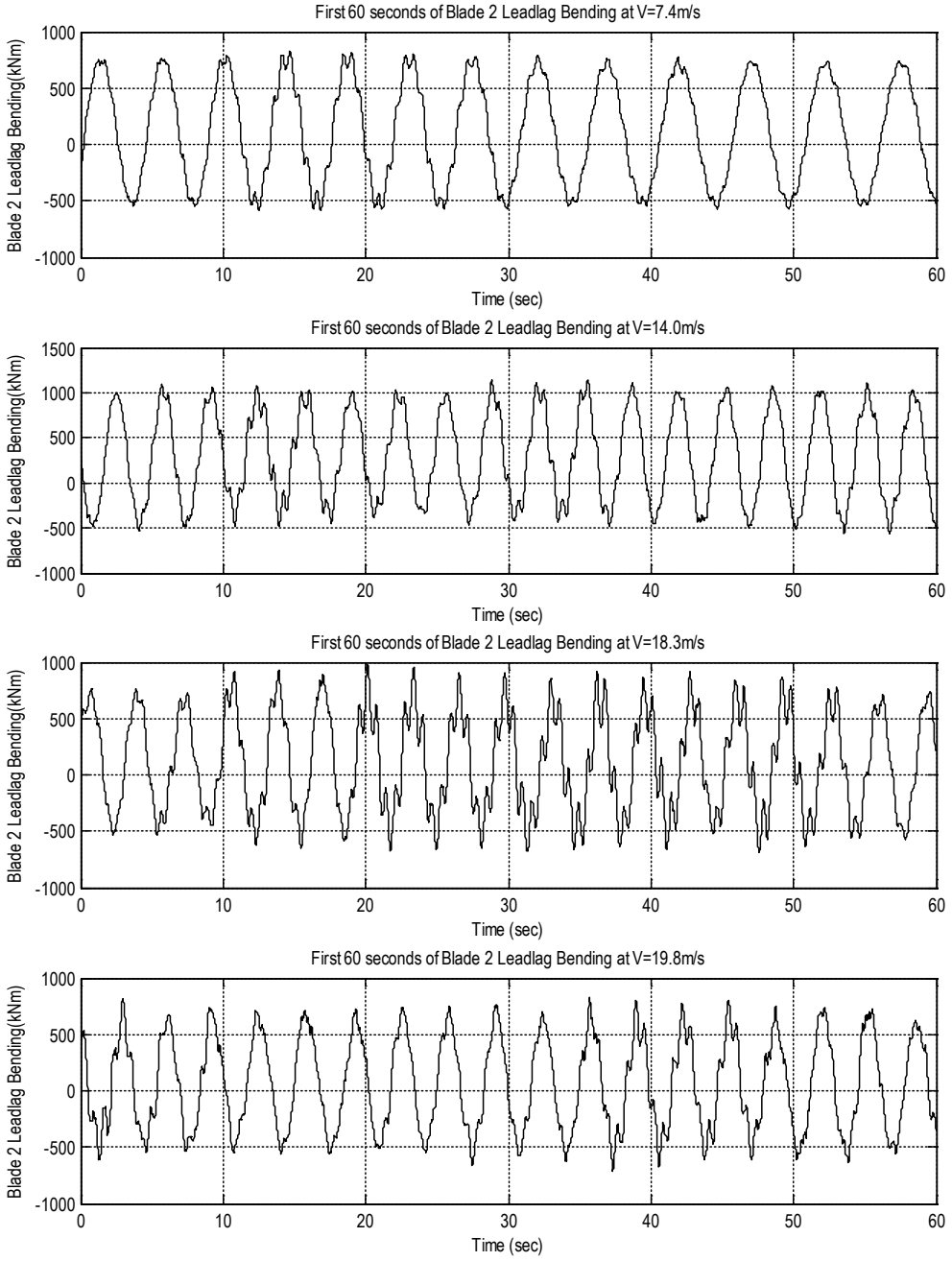


Figure 77. Time series for the first 60 seconds of blade 2 leadlag bending

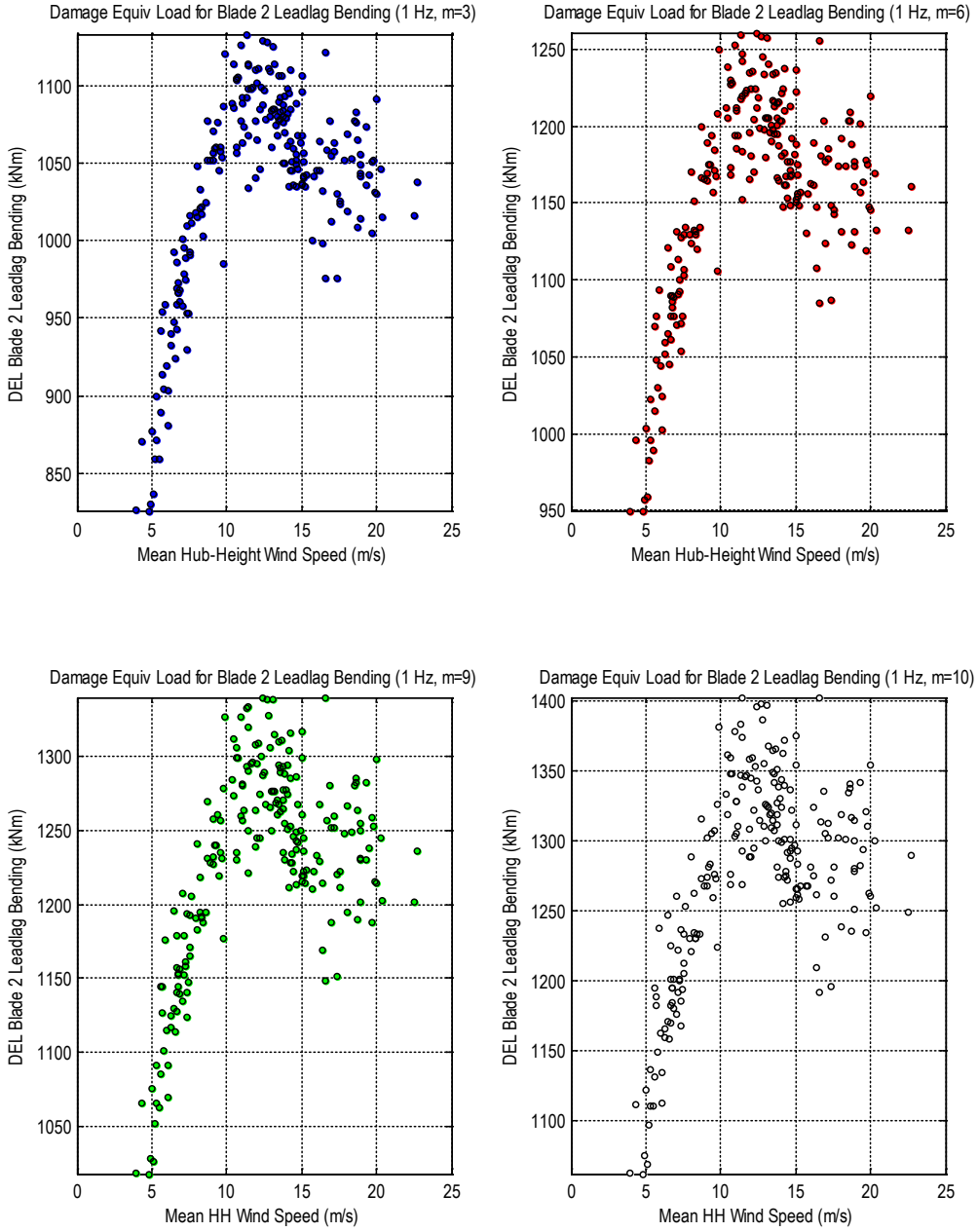


Figure 78. DEL (1 Hz, m=3, 6, 9, 10) for blade 2 leadlag bending

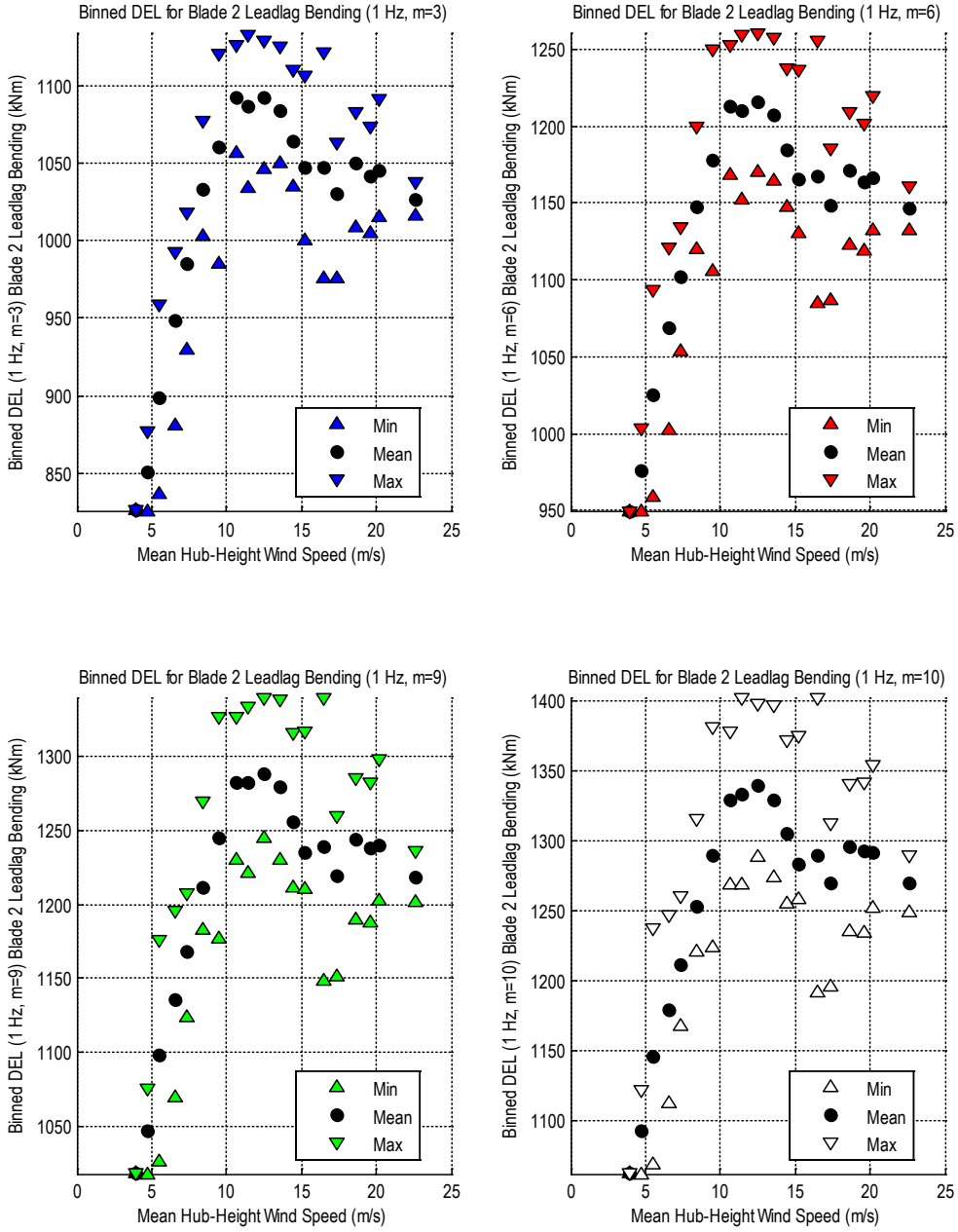


Figure 79. Binned DEL (1 Hz, m=3, 6, 9, 10) for blade 2 leadlag bending

Table 52. Binned DEL Data for Blade 2 Leadlag Bending

Bin #	Bin WS Low	Bin WS High	Mean WS	# Files	Min of Del (m=3)	Mean of Del (m=3)	Max of Del (m=3)	Min of Del (m=6)	Mean of Del (m=6)	Max of Del (m=6)	Min of Del (m=9)	Mean of Del (m=9)	Max of Del (m=9)
1	3.0	4.0	4.0	1	826.20	826.20	826.20	949.63	949.63	949.63	1,063.16	1,063.16	1,063.16
2	4.0	5.0	4.8	4	824.87	850.75	877.41	948.75	976.22	1,003.78	1,062.13	1,092.72	1,122.46
3	5.0	6.0	5.5	11	836.49	898.89	958.67	958.38	1,025.50	1,093.62	1,069.18	1,146.08	1,237.37
4	6.0	7.0	6.5	17	881.12	948.84	992.21	1,002.32	1,068.80	1,120.75	1,112.44	1,179.08	1,246.84
5	7.0	8.0	7.4	15	929.75	984.70	1,018.08	1,054.10	1,102.29	1,134.58	1,168.27	1,211.37	1,260.32
6	8.0	9.0	8.4	11	1,003.03	1,033.09	1,077.61	1,120.42	1,147.87	1,199.92	1,220.66	1,253.70	1,315.92
7	9.0	10.0	9.5	13	985.37	1,060.23	1,120.52	1,105.79	1,177.91	1,249.93	1,224.32	1,289.37	1,381.07
8	10.0	11.0	10.6	10	1,056.12	1,092.11	1,126.23	1,168.26	1,213.01	1,252.92	1,269.38	1,329.53	1,378.15
9	11.0	12.0	11.4	16	1,033.75	1,086.98	1,133.07	1,152.03	1,210.37	1,259.43	1,268.53	1,333.13	1,402.72
10	12.0	13.0	12.5	16	1,046.13	1,091.93	1,128.42	1,170.82	1,215.72	1,260.10	1,288.26	1,339.25	1,397.53
11	13.0	14.0	13.5	22	1,049.62	1,084.12	1,124.68	1,164.81	1,207.03	1,257.36	1,274.07	1,329.78	1,397.28
12	14.0	15.0	14.4	24	1,034.56	1,063.97	1,110.32	1,147.66	1,184.41	1,238.08	1,255.06	1,305.36	1,371.51
13	15.0	16.0	15.2	11	1,000.14	1,047.27	1,106.55	1,130.16	1,165.79	1,236.75	1,258.55	1,282.98	1,374.81
14	16.0	17.0	16.5	10	975.80	1,047.28	1,121.49	1,085.22	1,167.22	1,255.90	1,191.58	1,290.04	1,402.39
15	17.0	18.0	17.4	8	975.94	1,030.02	1,063.02	1,086.83	1,148.23	1,185.70	1,195.50	1,269.82	1,312.17
16	18.0	19.0	18.6	13	1,008.90	1,050.26	1,082.86	1,122.56	1,171.48	1,209.10	1,235.75	1,296.11	1,340.73
17	19.0	20.0	19.6	7	1,004.47	1,041.50	1,073.41	1,119.42	1,163.34	1,201.58	1,234.93	1,292.34	1,341.98
18	20.0	21.0	20.2	4	1,014.92	1,045.49	1,091.25	1,132.07	1,166.71	1,219.38	1,252.72	1,292.00	1,354.05
19	21.0	22.0	0.0	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
20	22.0	23.0	22.6	2	1,015.95	1,026.83	1,037.70	1,132.21	1,146.38	1,160.56	1,249.17	1,269.49	1,289.81
21	23.0	24.0	0.0	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
22	24.0	25.0	0.0	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
23	25.0	26.0	0.0	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

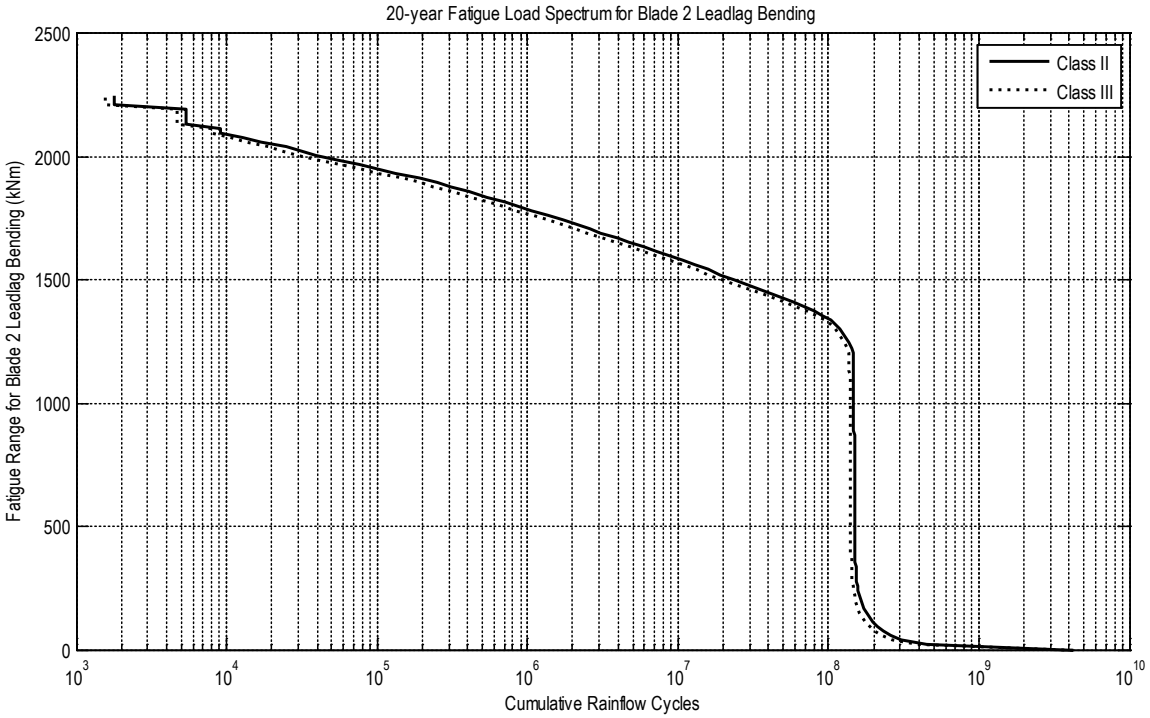


Figure 80. Twenty-year fatigue load spectrum for blade 2 leadlag bending

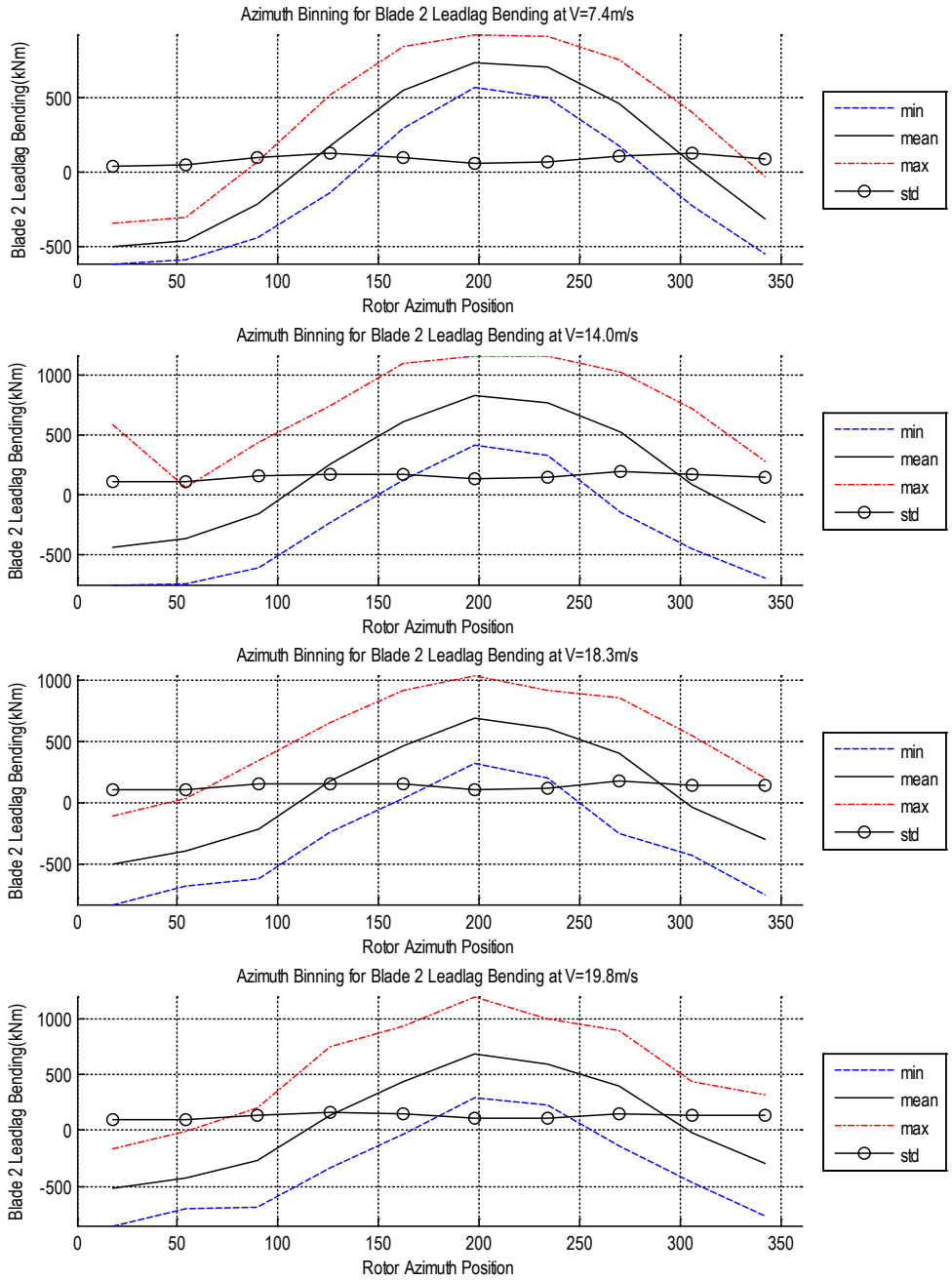


Figure 81. Azimuth binning for blade 2 leadlag bending

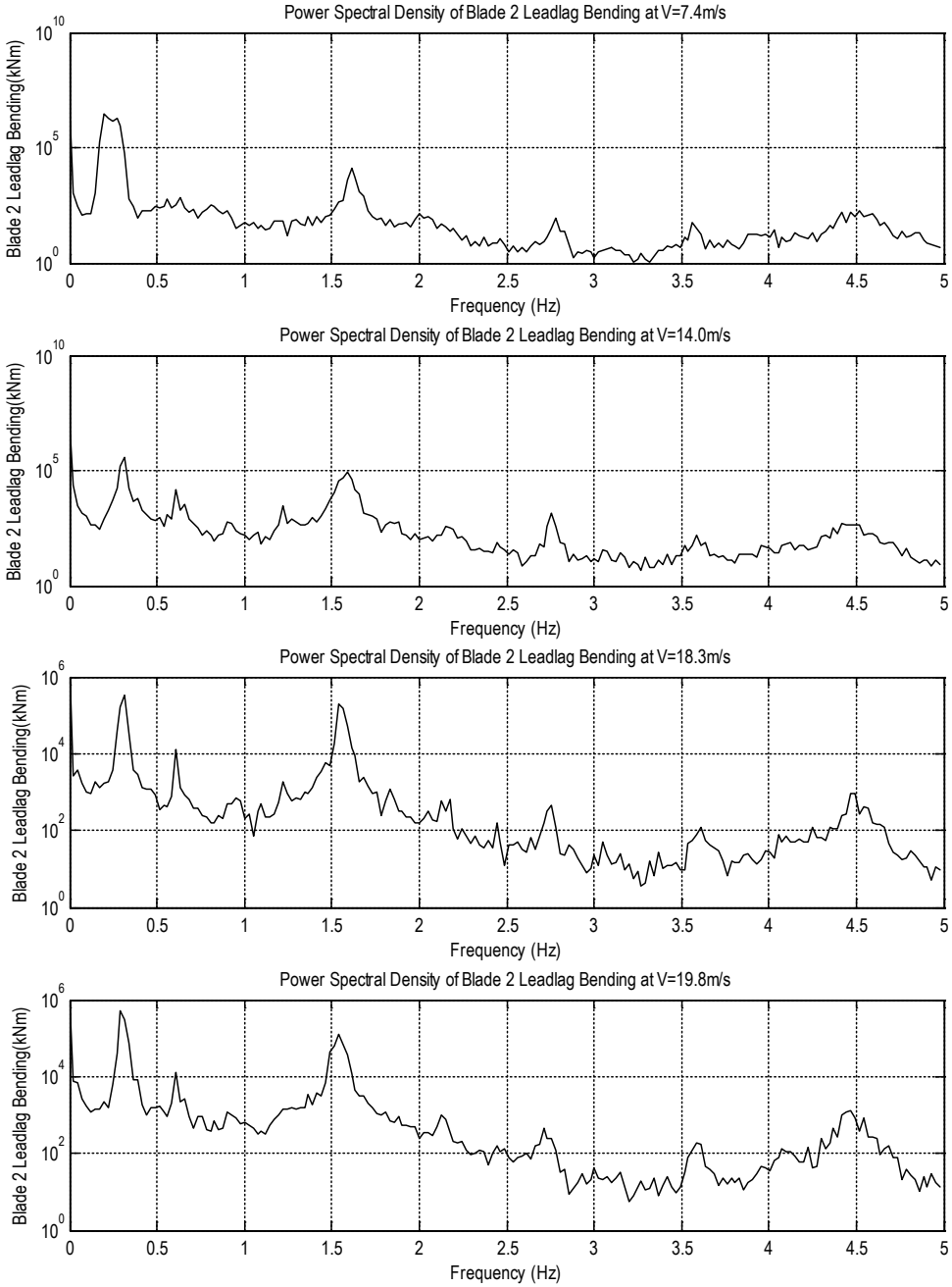


Figure 82. Power spectral density of blade 2 leadlag bending

Blade 3 Flap Bending

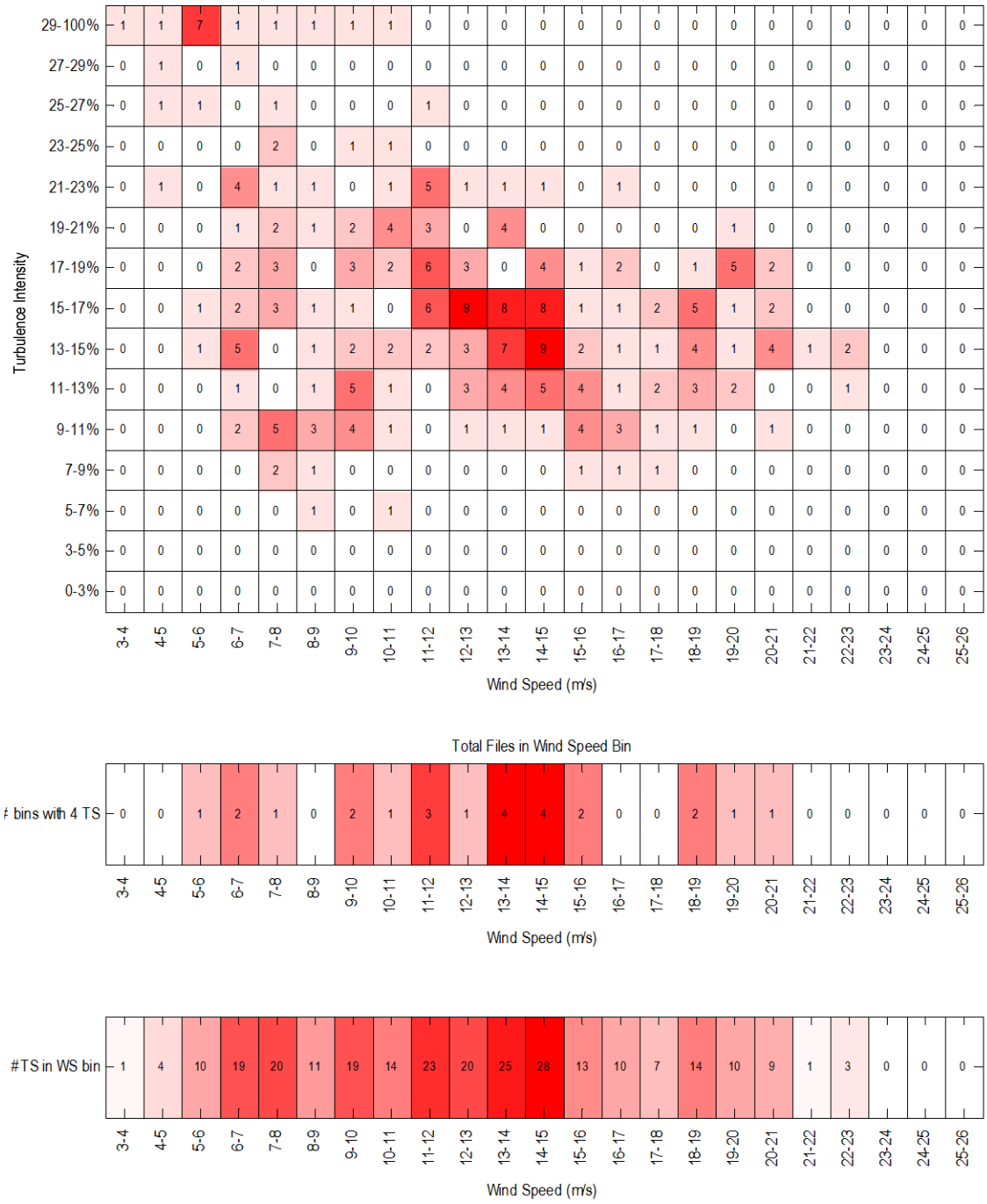


Figure 83. Capture matrix for blade 3 flap bending

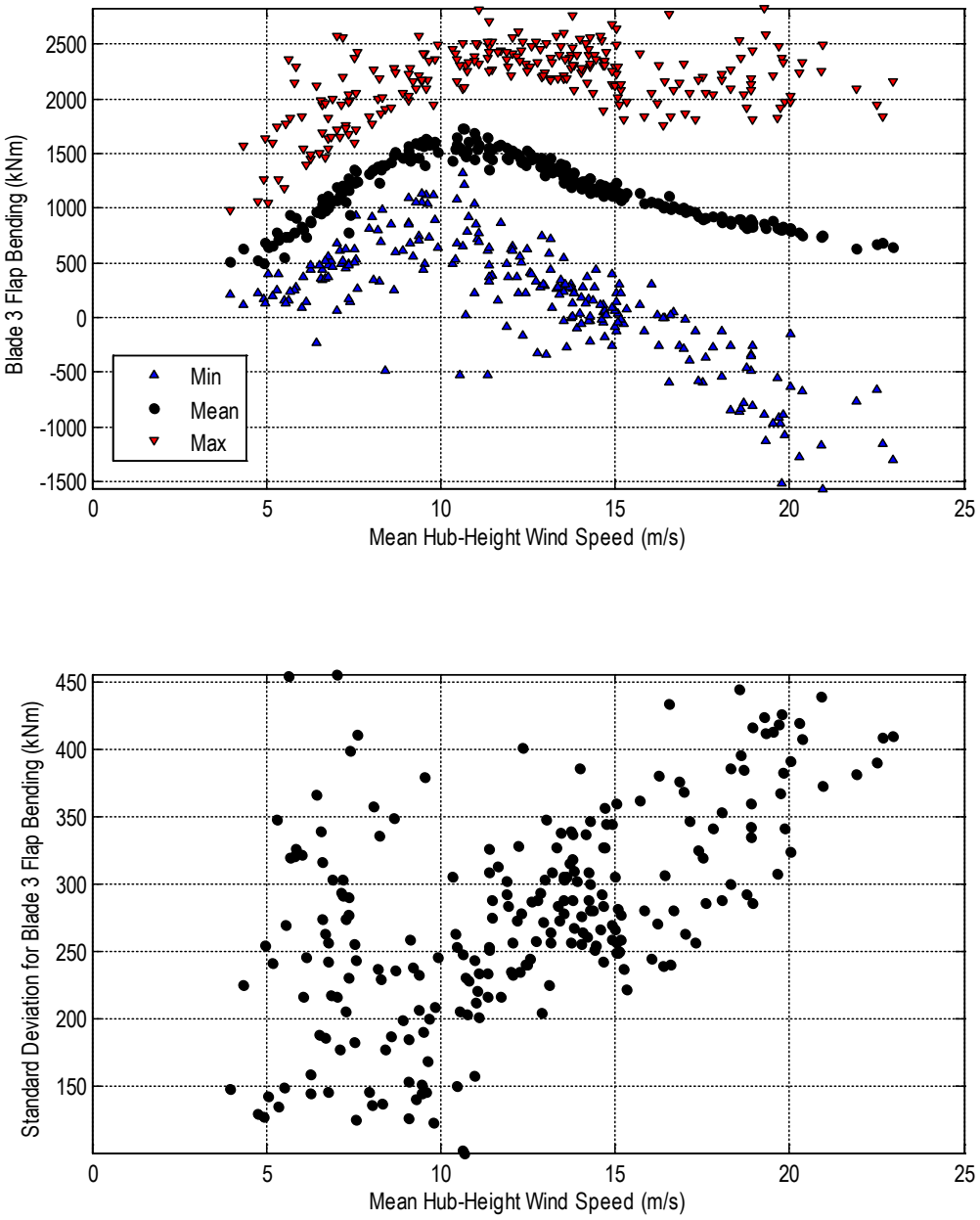


Figure 84. Scatterplot for blade 3 flap bending

Table 53. Binned Data for Blade 3 Flap Bending

Bin #	Bin WS Low	Bin WS High	Mean WS	# Files	Min of Minimums	Mean of Means	Max of Maximums
1	3.0	4.0	4.0	1	214.88	506.17	978.65
2	4.0	5.0	4.8	4	125.23	583.64	1,630.30
3	5.0	6.0	5.5	10	128.22	743.47	2,357.58
4	6.0	7.0	6.5	19	-233.71	955.69	2,115.82
5	7.0	8.0	7.3	20	61.57	1,164.62	2,566.86
6	8.0	9.0	8.4	11	-479.02	1,392.52	2,280.36
7	9.0	10.0	9.5	19	443.85	1,544.30	2,576.19
8	10.0	11.0	10.6	14	-527.49	1,578.21	2,497.10
9	11.0	12.0	11.4	23	-527.49	1,530.03	2,816.42
10	12.0	13.0	12.5	20	-318.09	1,444.97	2,605.98
11	13.0	14.0	13.5	25	-335.81	1,319.32	2,760.67
12	14.0	15.0	14.5	28	-251.49	1,186.59	2,676.38
13	15.0	16.0	15.3	13	-118.29	1,117.64	2,632.46
14	16.0	17.0	16.5	10	-582.76	1,028.20	2,773.84
15	17.0	18.0	17.4	7	-583.69	938.27	2,197.43
16	18.0	19.0	18.6	14	-855.72	865.20	2,530.37
17	19.0	20.0	19.6	10	-1,516.41	825.57	2,830.99
18	20.0	21.0	20.4	9	-1,559.22	772.17	2,492.41
19	21.0	22.0	21.9	1	-760.23	633.24	2,084.29
20	22.0	23.0	22.7	3	-1,300.90	666.10	2,158.09
21	23.0	24.0	0.0	0	0.00	0.00	0.00
22	24.0	25.0	0.0	0	0.00	0.00	0.00
23	25.0	26.0	0.0	0	0.00	0.00	0.00

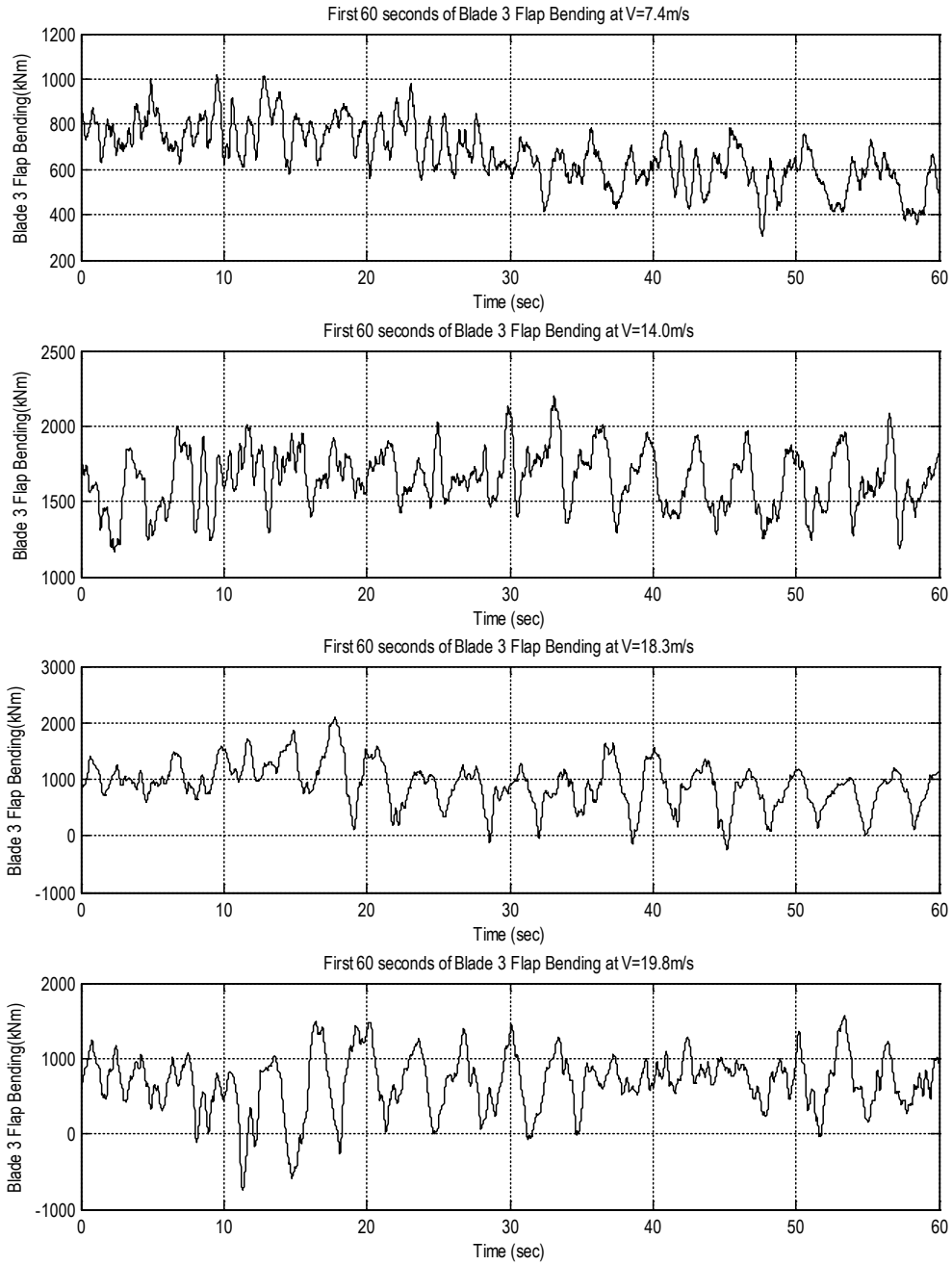


Figure 85. Time series for the first 60 seconds of blade 3 flap bending

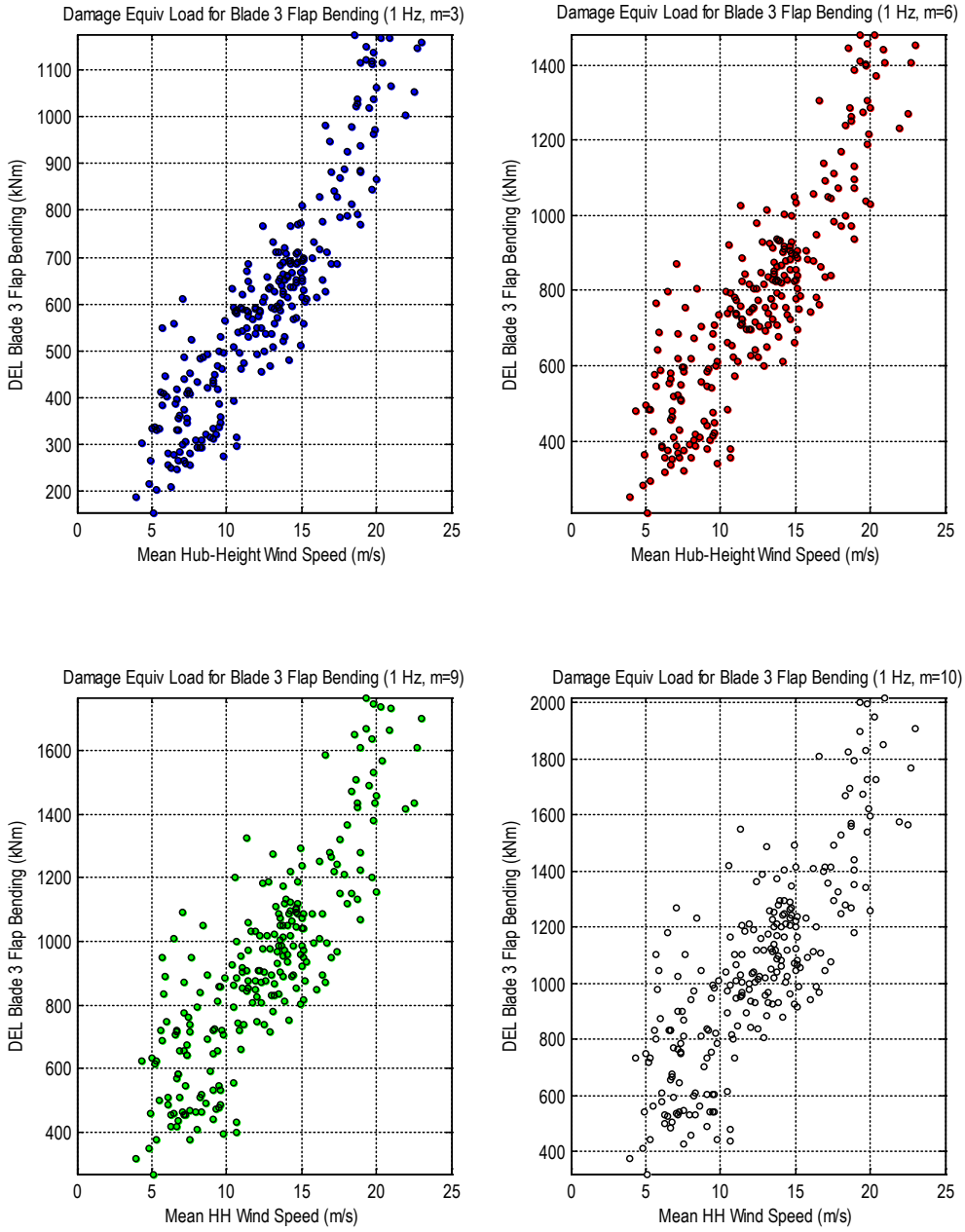


Figure 86. DEL (1 Hz, m=3, 6, 9, 10) for blade 3 flap bending

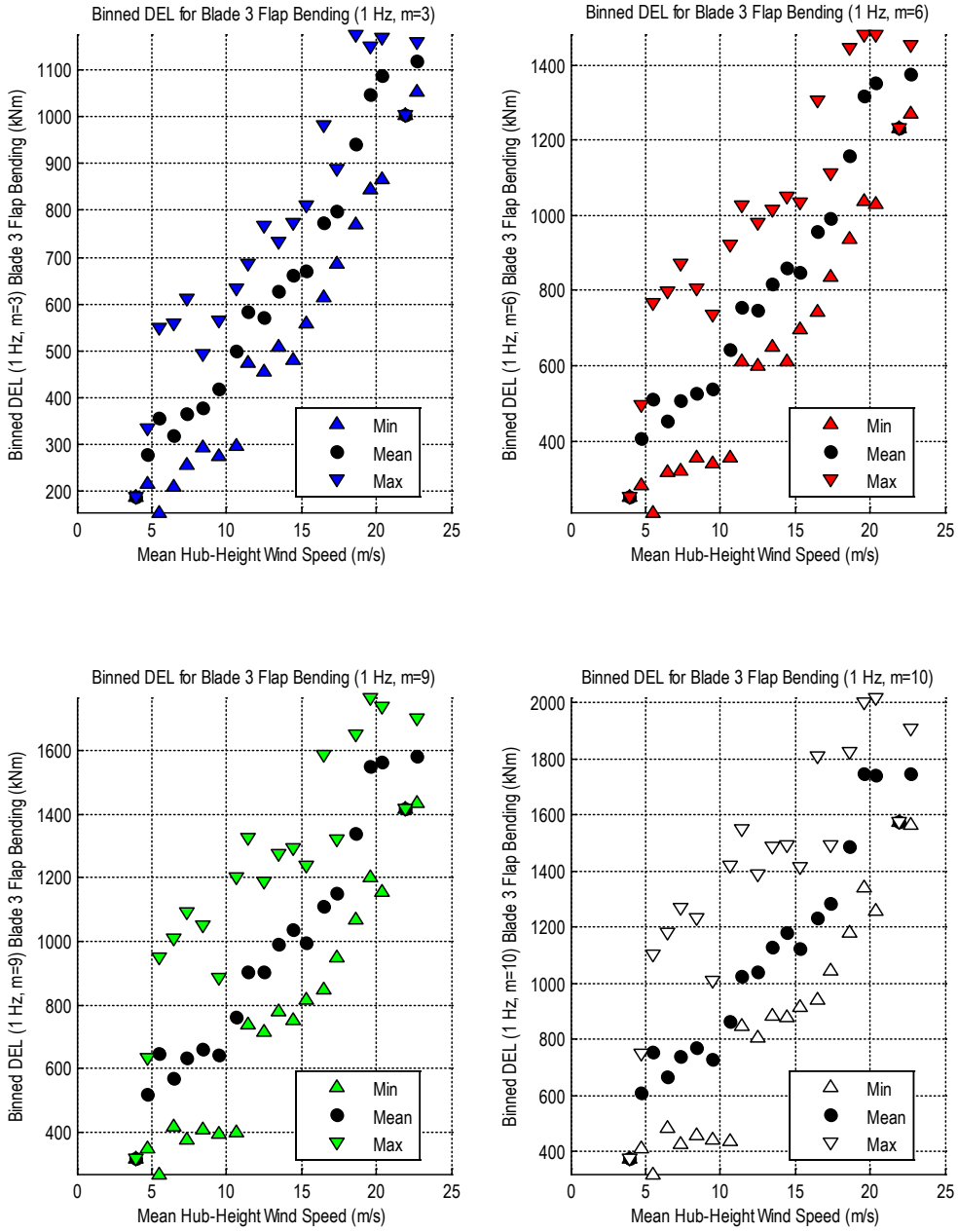


Figure 87. Binned DEL (1 Hz, m=3, 6, 9, 10) for blade 3 flap bending

Table 54. Binned DEL Data for Blade 3 Flap Bending

Bin #	Bin WS Low	Bin WS High	Mean WS	# Files	Min of Del (m=3)	Mean of Del (m=3)	Max of Del (m=3)	Min of Del (m=6)	Mean of Del (m=6)	Max of Del (m=6)	Min of Del (m=9)	Mean of Del (m=9)	Max of Del (m=9)
1	3.0	4.0	4.0	1	186.72	186.72	186.72	250.37	250.37	250.37	376.50	376.50	376.50
2	4.0	5.0	4.8	4	215.40	279.69	333.21	282.37	405.48	494.41	410.41	608.16	746.39
3	5.0	6.0	5.5	10	155.28	356.12	548.19	211.14	512.58	767.27	319.62	754.10	1,104.18
4	6.0	7.0	6.5	19	210.74	319.77	559.14	317.54	452.77	797.10	484.88	666.56	1,180.44
5	7.0	8.0	7.3	20	256.45	366.35	612.36	321.84	507.58	872.19	428.44	736.98	1,266.57
6	8.0	9.0	8.4	11	293.53	376.99	492.90	356.41	526.54	805.05	455.22	768.68	1,232.02
7	9.0	10.0	9.5	19	273.67	417.22	563.60	340.01	536.66	735.77	442.13	728.80	1,008.98
8	10.0	11.0	10.6	14	297.98	498.07	631.68	354.93	642.87	921.50	437.87	862.94	1,419.13
9	11.0	12.0	11.4	23	473.20	581.89	685.67	610.40	753.78	1,026.87	847.53	1,026.23	1,552.49
10	12.0	13.0	12.5	20	456.32	571.49	766.00	601.85	747.03	979.38	808.46	1,037.53	1,391.04
11	13.0	14.0	13.5	25	507.62	626.17	733.22	651.83	818.72	1,013.46	882.16	1,129.68	1,489.74
12	14.0	15.0	14.5	28	480.16	660.11	772.77	613.81	859.87	1,051.70	876.42	1,182.77	1,494.19
13	15.0	16.0	15.3	13	558.70	670.64	810.15	697.09	847.43	1,036.19	913.39	1,121.20	1,414.08
14	16.0	17.0	16.5	10	614.26	773.76	982.03	745.06	957.37	1,303.76	939.78	1,234.50	1,812.06
15	17.0	18.0	17.4	7	686.57	798.45	888.85	834.91	991.52	1,112.56	1,047.80	1,286.82	1,492.51
16	18.0	19.0	18.6	14	769.78	939.94	1,176.58	937.56	1,158.73	1,443.24	1,181.82	1,487.76	1,825.11
17	19.0	20.0	19.6	10	845.42	1,048.34	1,148.91	1,036.52	1,317.19	1,481.68	1,340.04	1,746.50	2,003.63
18	20.0	21.0	20.4	9	867.93	1,088.61	1,169.19	1,031.82	1,350.70	1,480.87	1,260.26	1,741.87	2,020.75
19	21.0	22.0	21.9	1	1,003.50	1,003.50	1,003.50	1,231.25	1,231.25	1,231.25	1,573.86	1,573.86	1,573.86
20	22.0	23.0	22.7	3	1,053.70	1,119.83	1,159.57	1,271.10	1,376.47	1,452.41	1,566.44	1,747.85	1,906.80
21	23.0	24.0	0.0	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
22	24.0	25.0	0.0	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
23	25.0	26.0	0.0	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

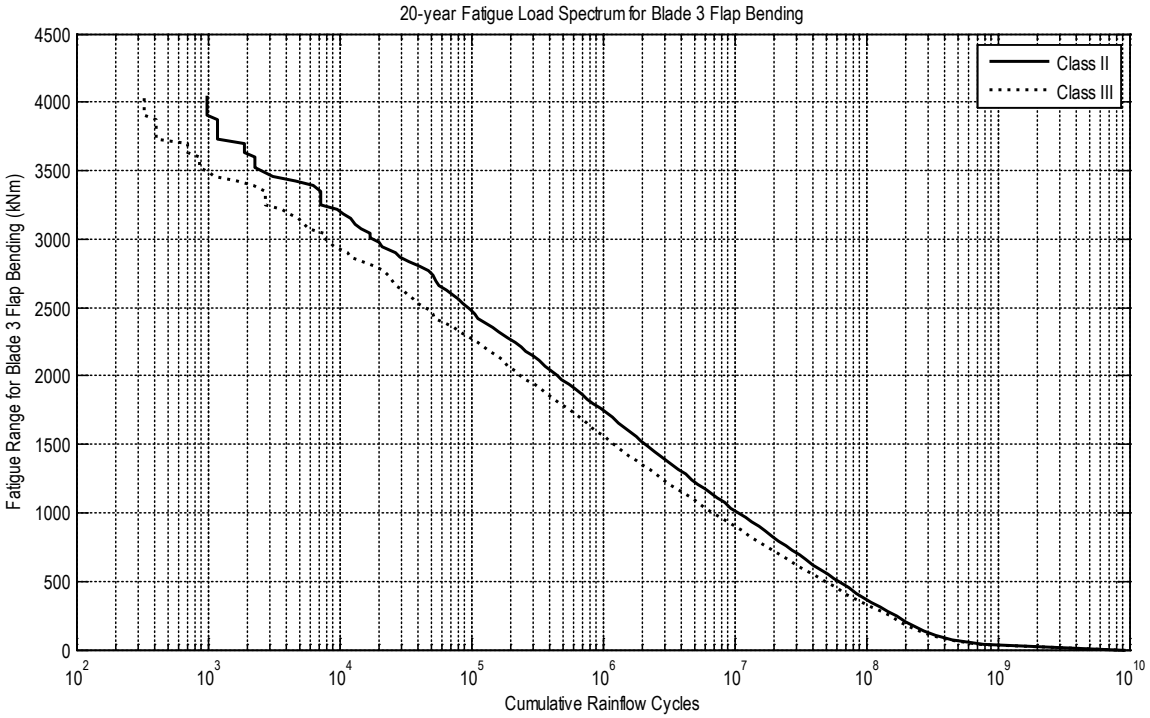


Figure 88. Twenty-year fatigue load spectrum for blade 3 flap bending

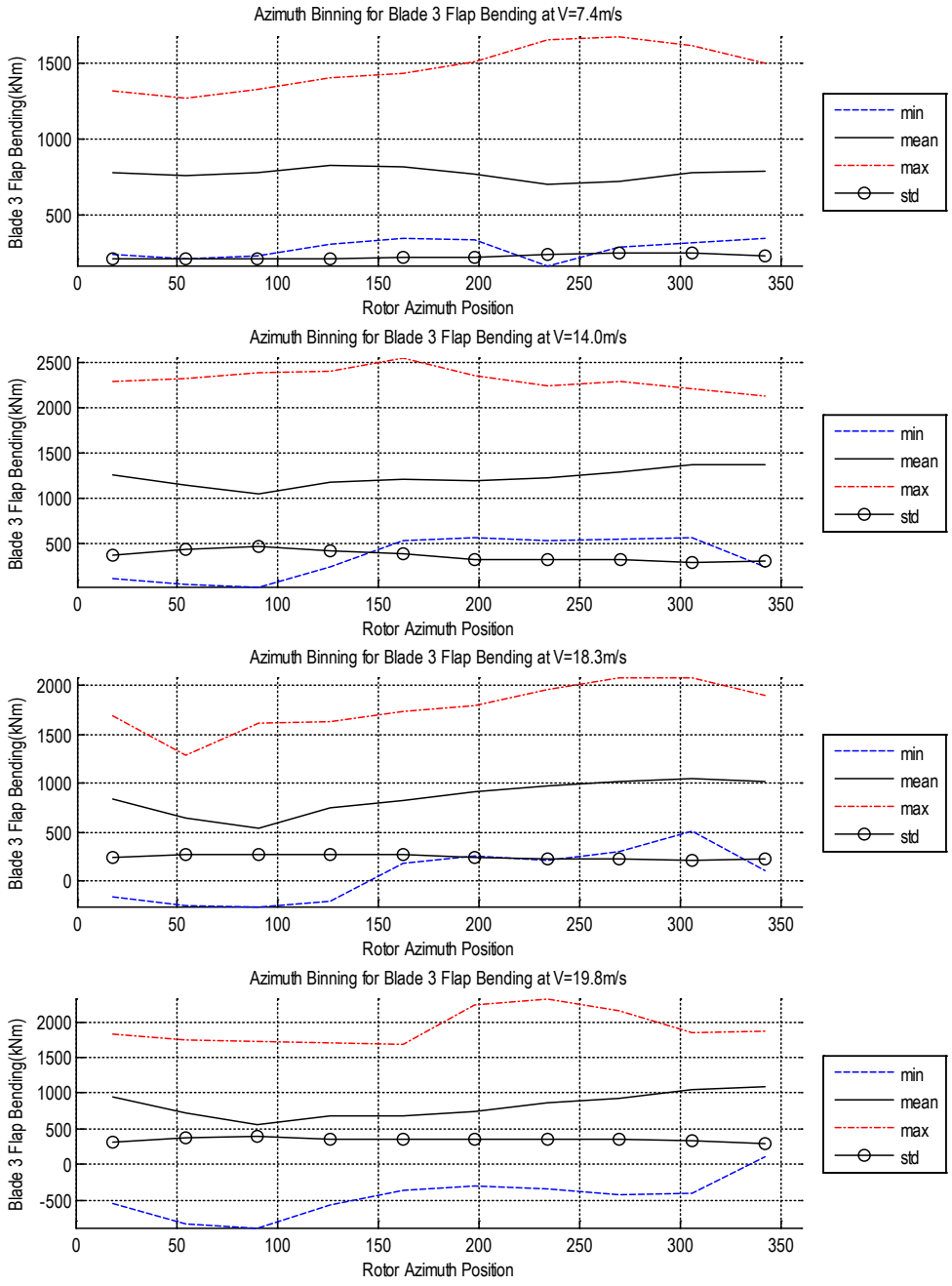


Figure 89. Azimuth binning for blade 3 flap bending

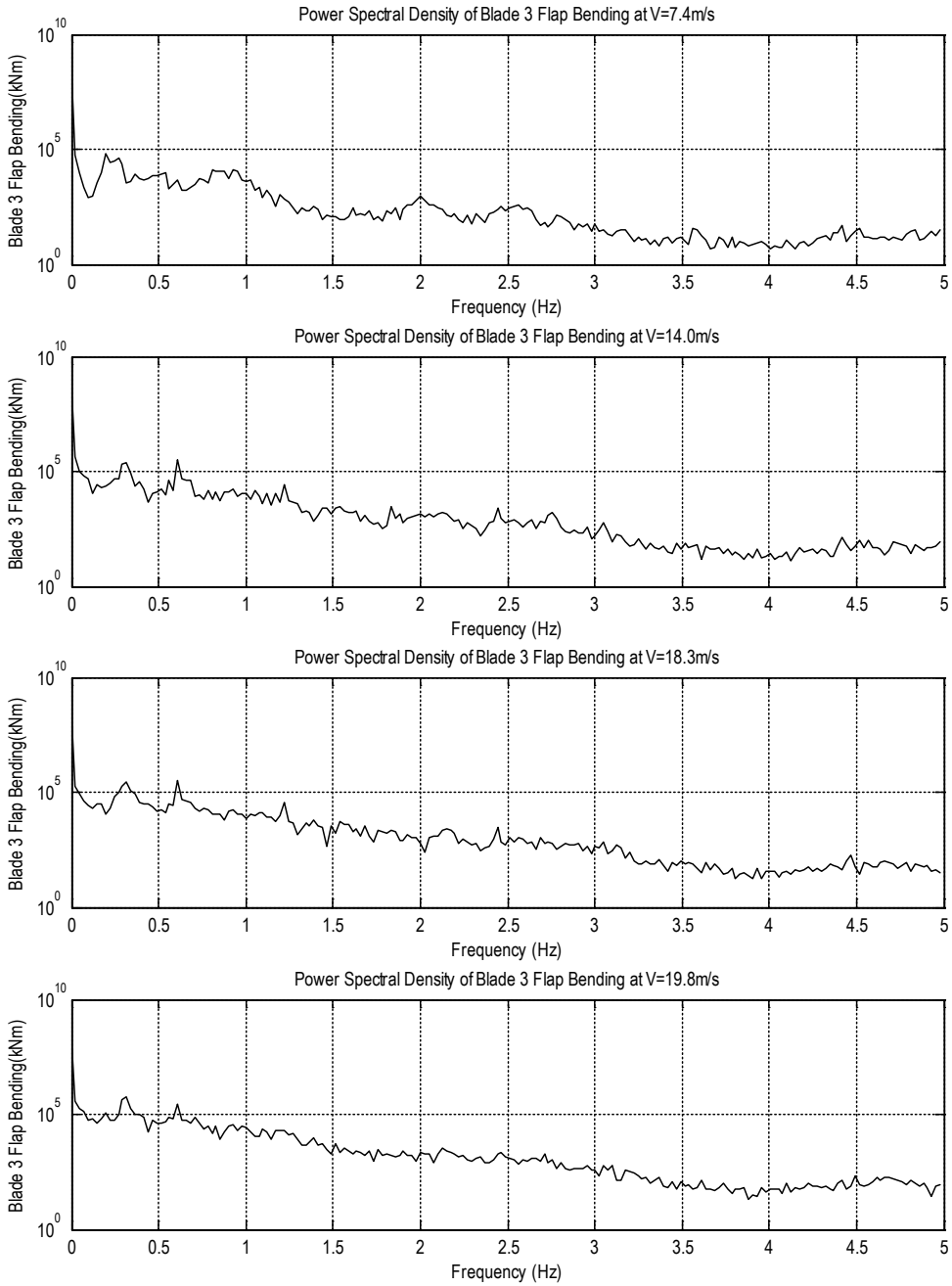


Figure 90. Power spectral density of blade 3 flap bending

Blade 3 Leadlag Bending

Turbulence Intensity	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-11	11-12	12-13	13-14	14-15	15-16	16-17	17-18	18-19	19-20	20-21	21-22	22-23	23-24	24-25	25-26
29-100%	1	1	7	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
27-29%	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
25-27%	0	1	1	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
23-25%	0	0	0	0	2	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
21-23%	0	1	0	4	1	1	0	1	5	1	1	1	0	1	0	0	0	0	0	0	0	0	0
19-21%	0	0	0	1	2	1	2	4	3	0	4	0	0	0	0	0	1	0	0	0	0	0	0
17-19%	0	0	0	2	3	0	3	2	6	3	0	4	1	2	0	1	5	2	0	0	0	0	0
15-17%	0	0	1	2	3	1	1	0	6	9	8	8	1	1	2	5	1	2	0	0	0	0	0
13-15%	0	0	1	5	0	1	2	2	2	3	7	9	2	1	1	4	1	4	1	2	0	0	0
11-13%	0	0	0	1	0	1	5	1	0	3	4	5	4	1	2	3	2	0	0	1	0	0	0
9-11%	0	0	0	2	5	3	4	1	0	1	1	1	4	3	1	1	0	1	0	0	0	0	0
7-9%	0	0	0	0	2	1	0	0	0	0	0	0	1	1	1	0	0	0	0	0	0	0	0
5-7%	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3-5%	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0-3%	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Wind Speed (m/s)

Total Files in Wind Speed Bin

	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-11	11-12	12-13	13-14	14-15	15-16	16-17	17-18	18-19	19-20	20-21	21-22	22-23	23-24	24-25	25-26
# bins with 4 TS	0	0	1	2	1	0	2	1	3	1	4	4	2	0	0	2	1	1	0	0	0	0	0

Wind Speed (m/s)

	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-11	11-12	12-13	13-14	14-15	15-16	16-17	17-18	18-19	19-20	20-21	21-22	22-23	23-24	24-25	25-26
#TS in WS bin	1	4	10	19	20	11	19	14	23	20	25	28	13	10	7	14	10	9	1	3	0	0	0

Wind Speed (m/s)

Figure 91. Capture matrix for blade 3 leadlag bending

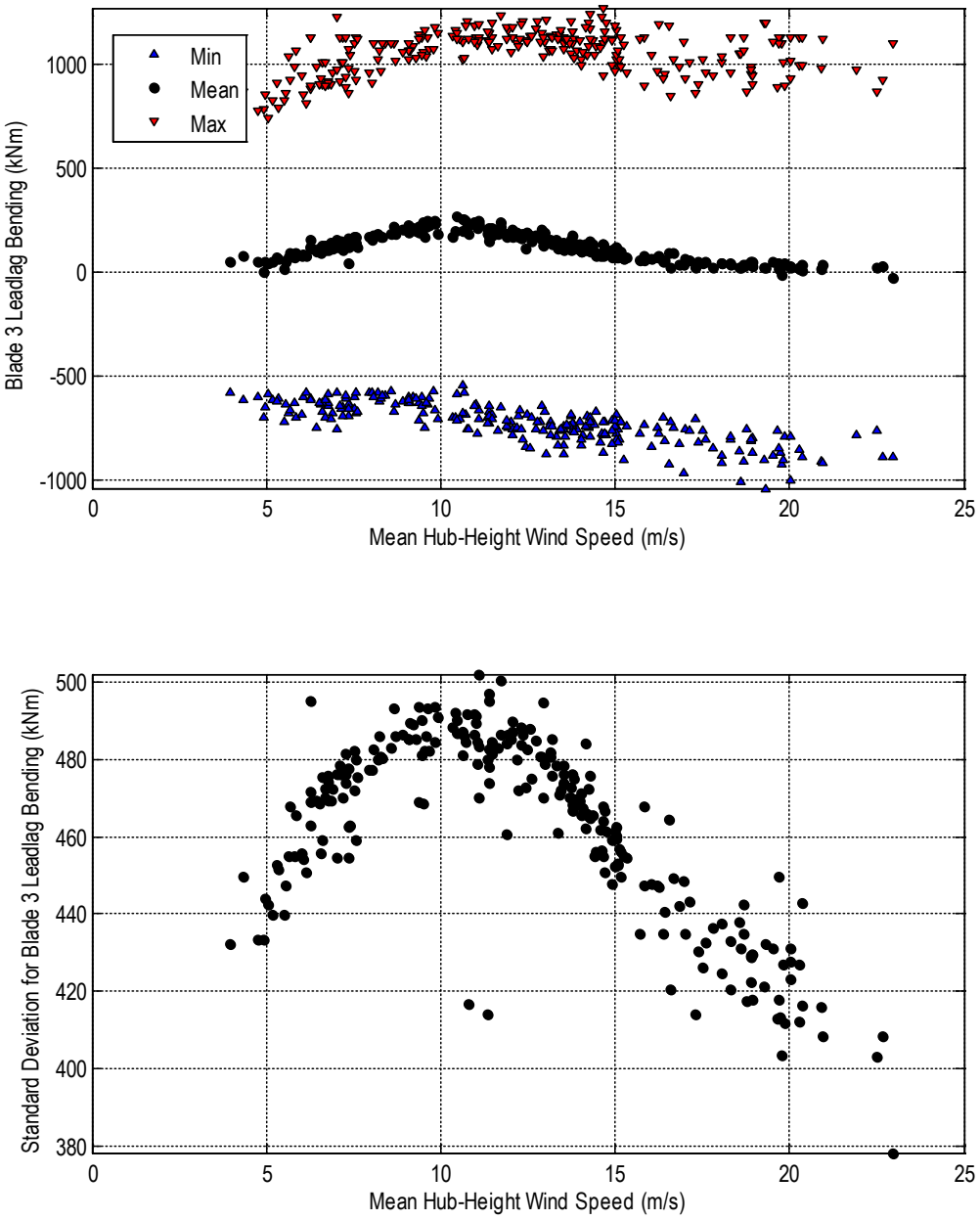


Figure 92. Scatterplot for blade 3 leadlag bending

Table 55. Binned Data for Blade 3 Leadlag Bending

Bin #	Bin WS Low	Bin WS High	Mean WS	# Files	Min of Minimums	Mean of Means	Max of Maximums
1	3.0	4.0	4.0	1	-576.47	50.25	758.02
2	4.0	5.0	4.8	4	-696.20	46.09	867.38
3	5.0	6.0	5.5	10	-715.70	62.73	1,059.66
4	6.0	7.0	6.5	19	-746.38	111.98	1,122.30
5	7.0	8.0	7.3	20	-748.50	134.79	1,221.23
6	8.0	9.0	8.4	10	-666.14	182.24	1,099.80
7	9.0	10.0	9.5	17	-742.35	214.18	1,173.11
8	10.0	11.0	10.6	12	-751.88	227.12	1,202.89
9	11.0	12.0	11.4	23	-771.93	203.87	1,227.65
10	12.0	13.0	12.5	18	-843.22	171.25	1,203.45
11	13.0	14.0	13.5	22	-872.95	133.63	1,201.68
12	14.0	15.0	14.5	27	-860.08	106.74	1,269.08
13	15.0	16.0	15.3	13	-899.61	79.07	1,157.34
14	16.0	17.0	16.5	10	-961.47	59.34	1,187.14
15	17.0	18.0	17.4	7	-842.69	43.87	1,019.94
16	18.0	19.0	18.6	14	-1,001.77	36.50	1,122.30
17	19.0	20.0	19.6	10	-1,035.62	27.37	1,197.23
18	20.0	21.0	20.4	9	-1,000.04	23.88	1,122.30
19	21.0	22.0	0.0	0	0.00	0.00	0.00
20	22.0	23.0	22.7	3	-886.98	7.33	1,094.63
21	23.0	24.0	0.0	0	0.00	0.00	0.00
22	24.0	25.0	0.0	0	0.00	0.00	0.00
23	25.0	26.0	0.0	0	0.00	0.00	0.00

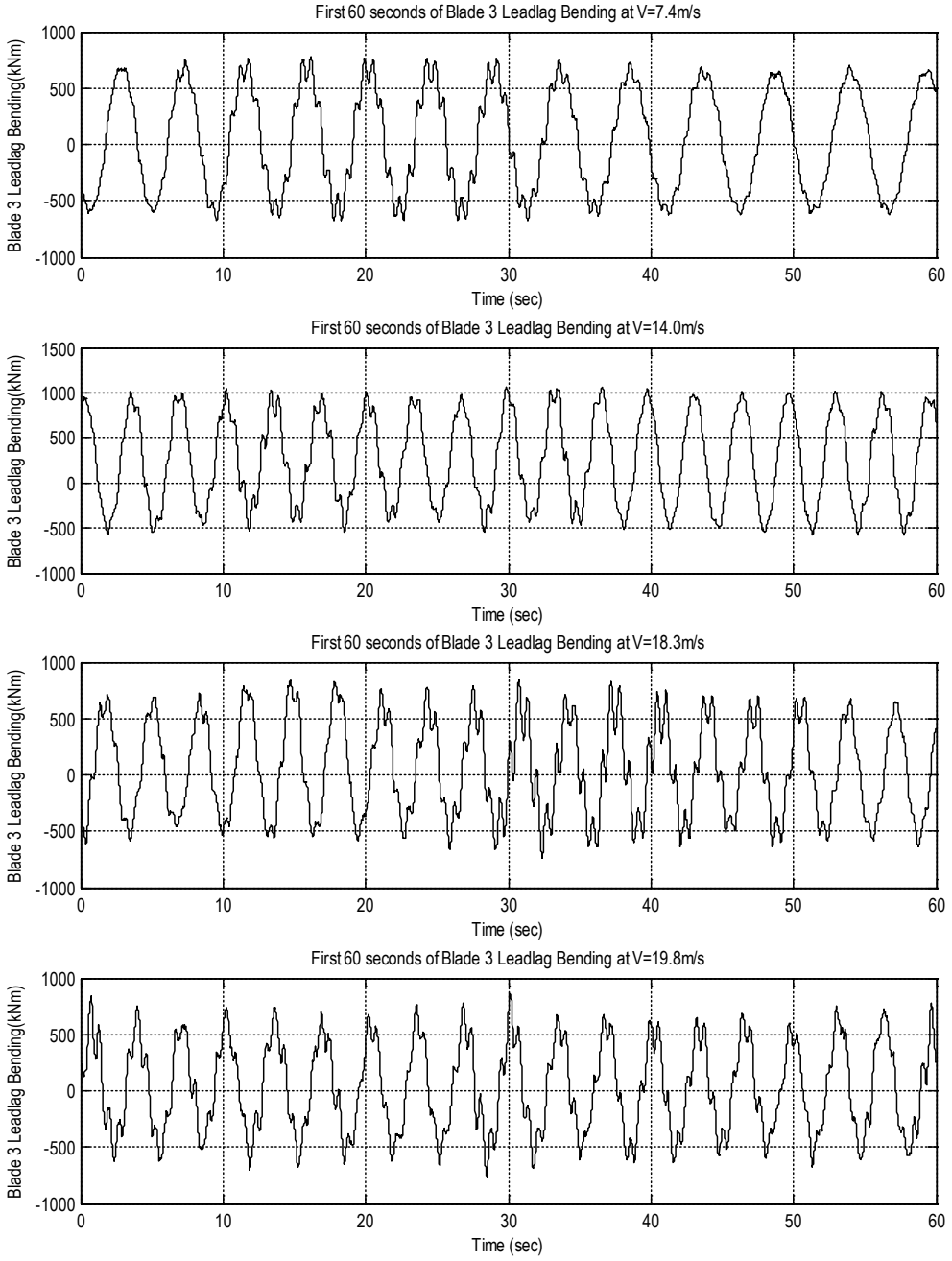


Figure 93. Time series for the first 60 seconds of blade 3 leadlag bending

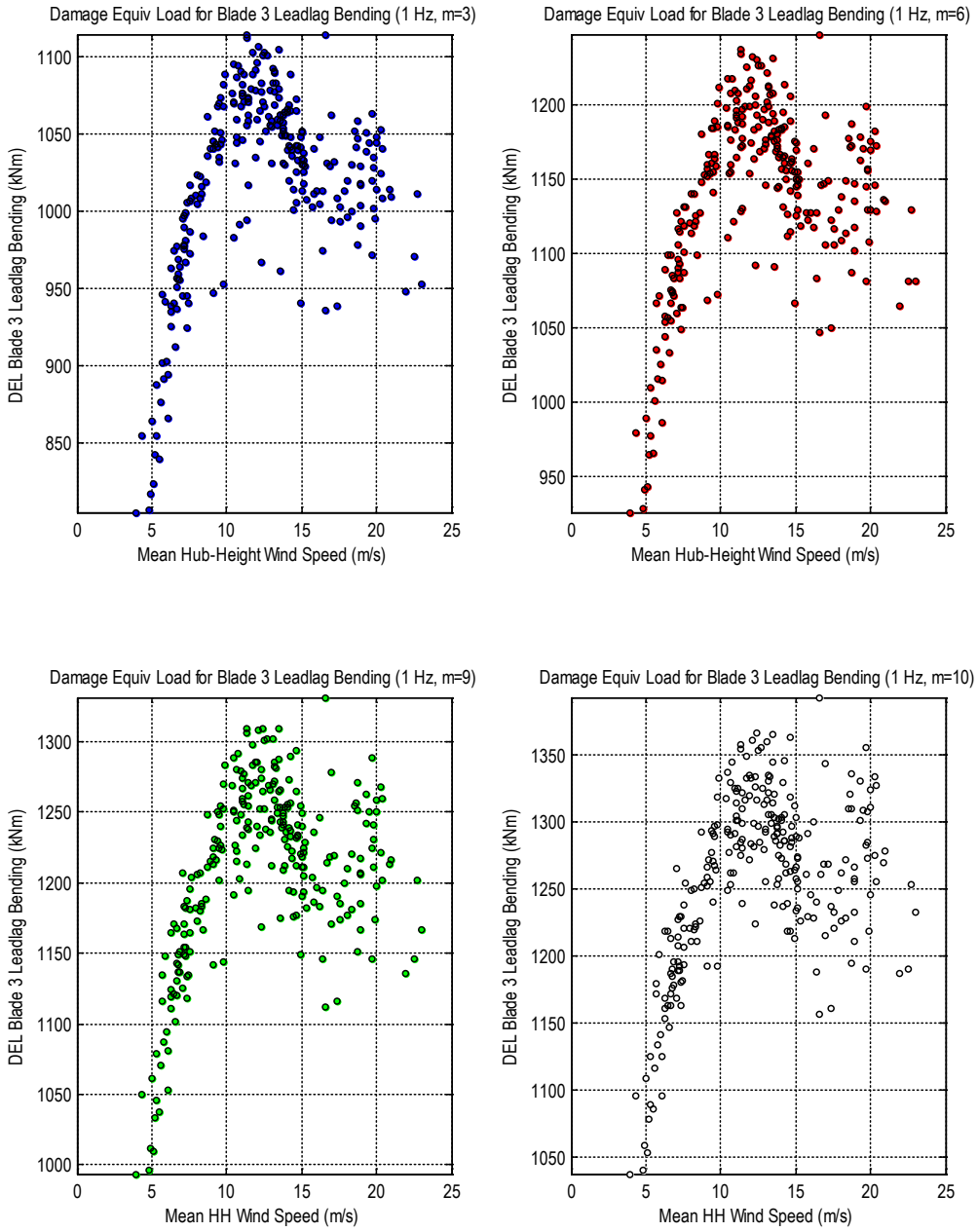


Figure 94. DEL (1 Hz, m=3, 6, 9, 10) for blade 3 leadlag bending

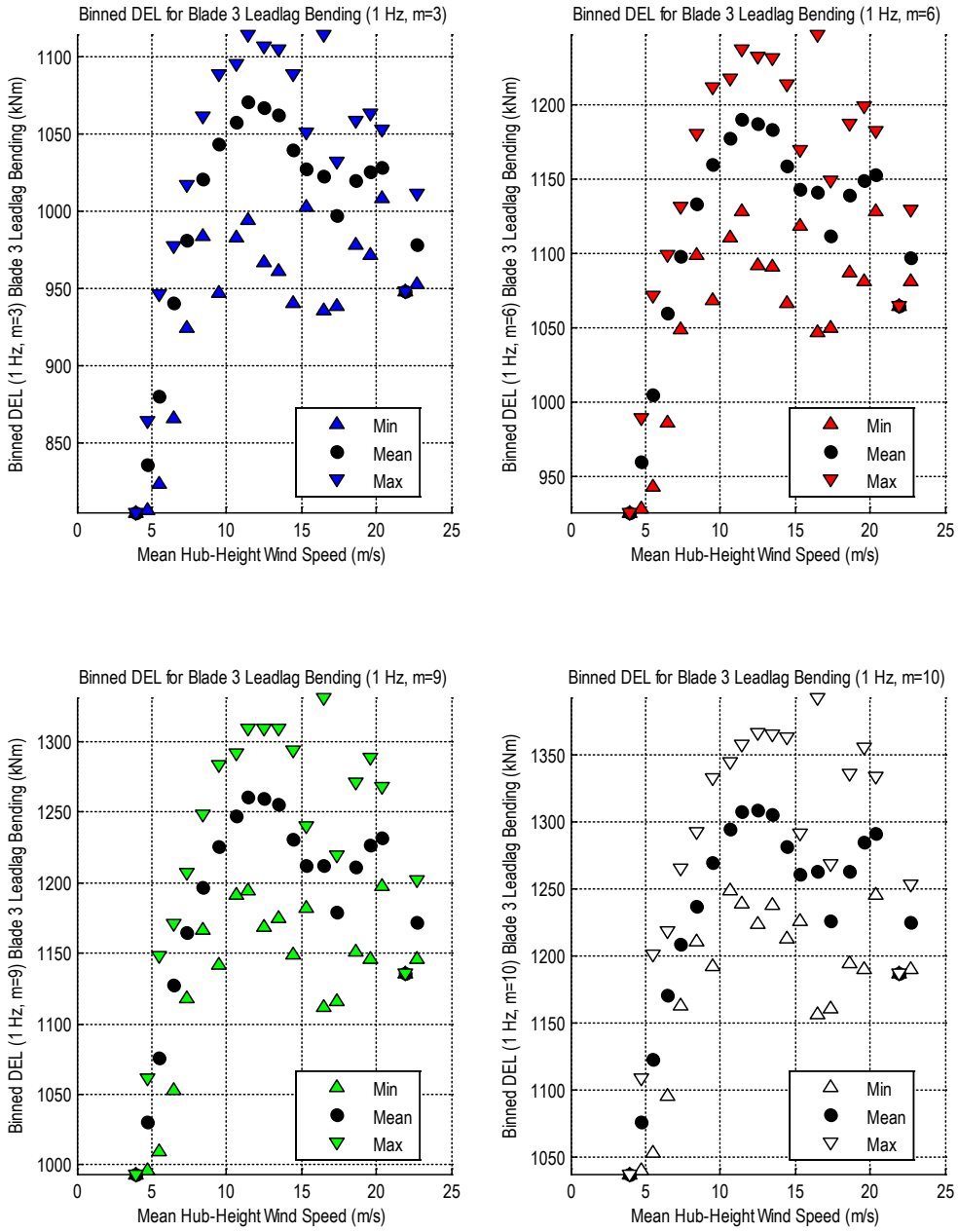


Figure 95. Binned DEL (1 Hz, m=3, 6, 9, 10) for blade 3 leadlag bending

Table 56. Binned DEL Data for Blade 3 Leadlag Bending

Bin #	Bin WS Low	Bin WS High	Mean WS	# Files	Min of Del (m=3)	Mean of Del (m=3)	Max of Del (m=3)	Min of Del (m=6)	Mean of Del (m=6)	Max of Del (m=6)	Min of Del (m=9)	Mean of Del (m=9)	Max of Del (m=9)
1	3.0	4.0	4.0	1	805.44	805.44	805.44	926.03	926.03	926.03	1,037.24	1,037.24	1,037.24
2	4.0	5.0	4.8	4	807.04	835.88	863.97	928.39	959.74	989.46	1,039.90	1,075.64	1,108.81
3	5.0	6.0	5.5	10	823.38	880.72	945.96	943.33	1,005.28	1,071.72	1,052.64	1,123.13	1,201.17
4	6.0	7.0	6.5	19	866.45	941.13	977.40	986.21	1,060.48	1,099.80	1,095.47	1,170.96	1,218.46
5	7.0	8.0	7.3	20	924.86	981.29	1,017.25	1,048.83	1,098.44	1,131.90	1,162.81	1,208.16	1,265.01
6	8.0	9.0	8.4	11	984.37	1,020.79	1,061.05	1,099.79	1,133.75	1,180.55	1,210.84	1,237.34	1,292.50
7	9.0	10.0	9.5	19	946.87	1,043.47	1,088.64	1,068.84	1,159.90	1,211.81	1,192.17	1,269.97	1,332.69
8	10.0	11.0	10.6	14	982.67	1,057.91	1,095.22	1,111.37	1,177.81	1,218.26	1,248.38	1,294.59	1,344.68
9	11.0	12.0	11.4	23	994.62	1,070.53	1,114.65	1,129.09	1,190.72	1,238.11	1,238.72	1,307.95	1,357.92
10	12.0	13.0	12.5	20	967.56	1,066.84	1,106.83	1,091.99	1,188.05	1,233.09	1,224.10	1,308.72	1,366.30
11	13.0	14.0	13.5	25	961.85	1,062.10	1,104.29	1,091.53	1,183.44	1,231.97	1,238.02	1,305.36	1,364.84
12	14.0	15.0	14.5	28	941.04	1,039.50	1,088.48	1,067.18	1,159.00	1,213.98	1,212.59	1,281.17	1,362.82
13	15.0	16.0	15.3	13	1,003.19	1,027.04	1,050.64	1,118.63	1,143.58	1,169.84	1,226.00	1,261.18	1,291.34
14	16.0	17.0	16.5	10	935.79	1,022.82	1,114.40	1,047.03	1,141.15	1,248.07	1,156.12	1,262.51	1,393.07
15	17.0	18.0	17.4	7	938.44	997.63	1,031.70	1,050.63	1,111.89	1,149.54	1,161.03	1,226.23	1,268.19
16	18.0	19.0	18.6	14	978.73	1,020.25	1,058.17	1,088.01	1,139.15	1,187.79	1,194.14	1,262.92	1,335.45
17	19.0	20.0	19.6	10	972.28	1,025.10	1,063.51	1,081.96	1,149.05	1,199.18	1,190.13	1,285.25	1,355.85
18	20.0	21.0	20.4	9	1,008.25	1,028.64	1,053.00	1,128.46	1,153.19	1,183.10	1,245.46	1,291.01	1,333.75
19	21.0	22.0	21.9	1	948.07	948.07	948.07	1,064.64	1,064.64	1,064.64	1,186.81	1,186.81	1,186.81
20	22.0	23.0	22.7	3	953.30	978.57	1,011.40	1,081.20	1,097.66	1,129.95	1,190.36	1,225.30	1,253.00
21	23.0	24.0	0.0	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
22	24.0	25.0	0.0	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
23	25.0	26.0	0.0	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

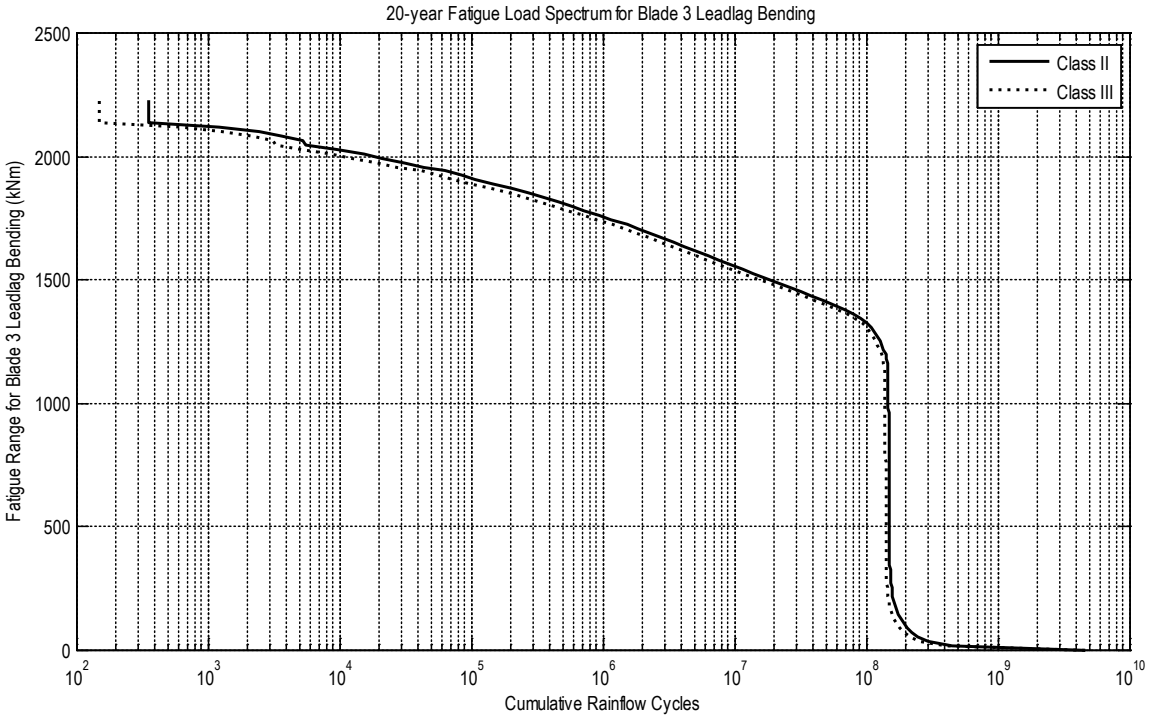


Figure 96. Twenty-year fatigue load spectrum for blade 3 leadlag bending

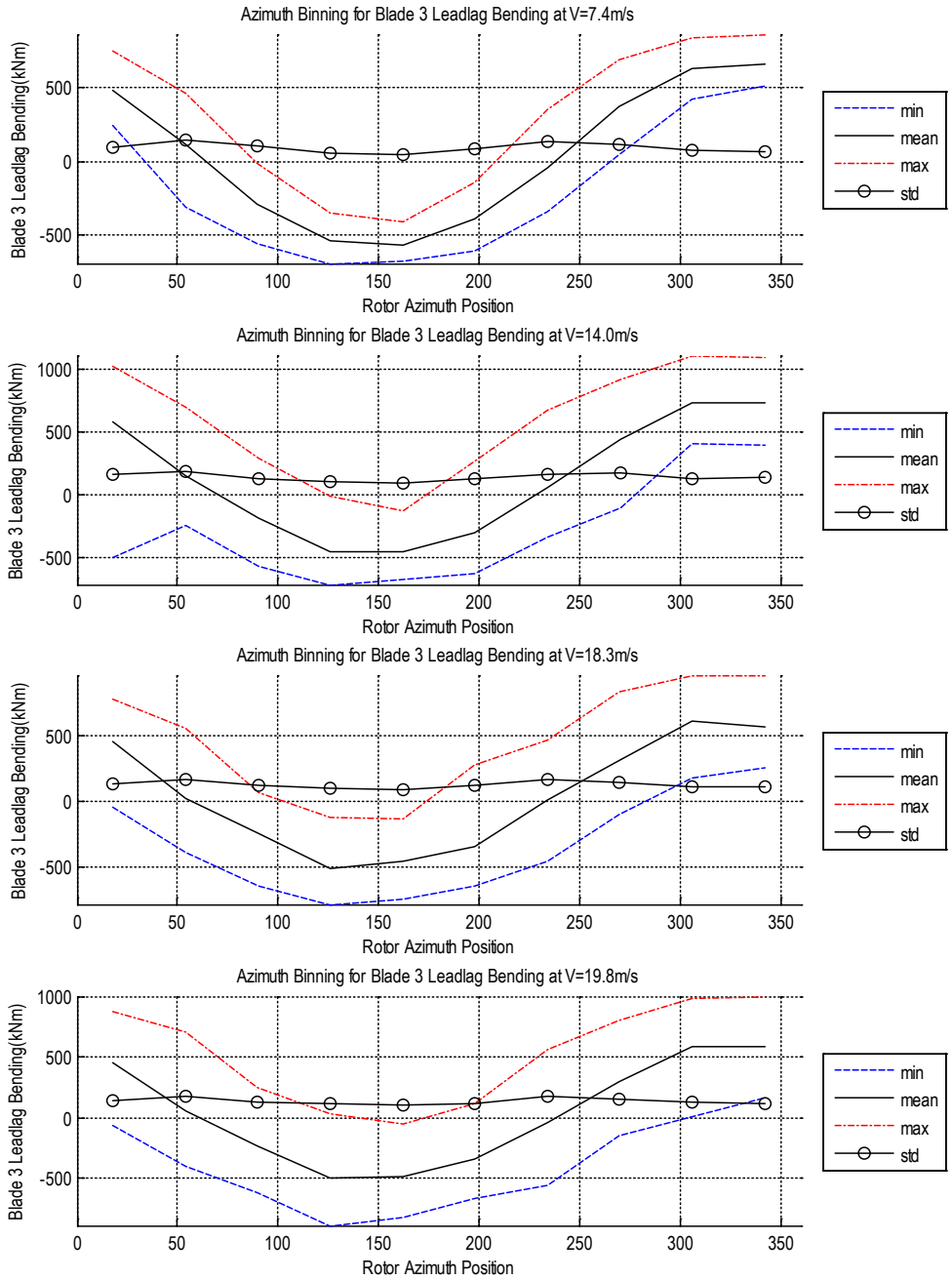


Figure 97. Azimuth binning for blade 3 leadlag bending

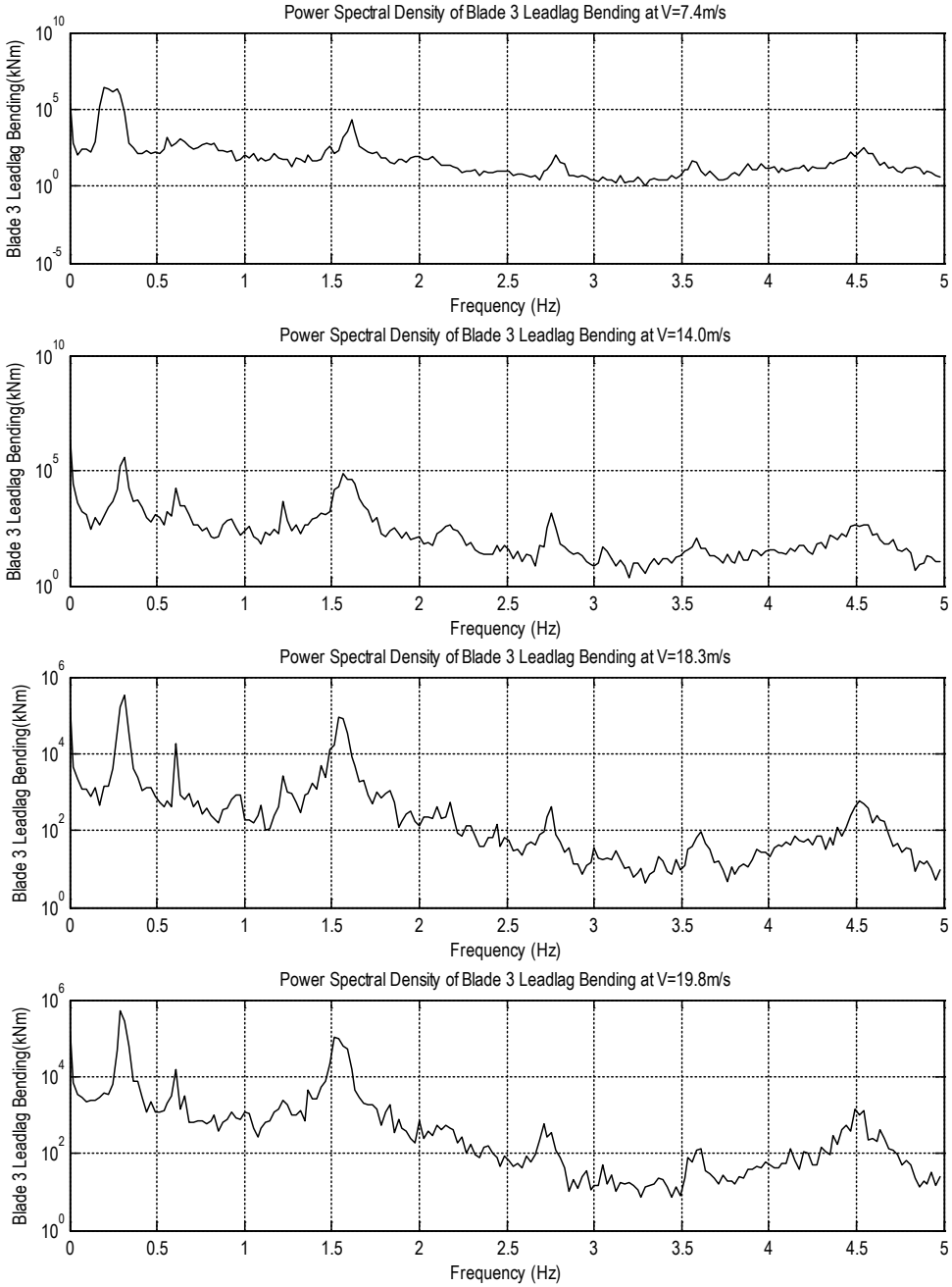


Figure 98. Power spectral density of blade 3 leadlag bending

Main Shaft Bending 0

Turbulence Intensity	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-11	11-12	12-13	13-14	14-15	15-16	16-17	17-18	18-19	19-20	20-21	21-22	22-23	23-24	24-25	25-26
29-100%	1	1	6	1	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
27-29%	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
25-27%	0	1	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
23-25%	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
21-23%	0	1	0	4	0	1	0	1	1	0	1	1	0	1	0	0	0	0	0	0	0	0	0
19-21%	0	0	0	1	0	0	0	1	2	0	1	0	0	0	0	0	0	0	0	0	0	0	0
17-19%	0	0	0	1	1	0	0	0	0	3	0	0	0	1	1	1	1	0	0	0	0	0	0
15-17%	0	0	1	1	0	0	0	0	0	2	3	5	0	0	1	1	1	0	0	0	0	0	0
13-15%	0	0	1	0	0	0	1	0	0	1	0	3	1	0	0	1	0	0	0	0	0	0	0
11-13%	0	0	0	1	0	0	0	0	0	1	2	4	1	0	2	2	0	0	0	0	0	0	0
9-11%	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	1	0	0	0	0	0	0	0
7-9%	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5-7%	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3-5%	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0-3%	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Wind Speed (m/s)

Total Files in Wind Speed Bin

	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-11	11-12	12-13	13-14	14-15	15-16	16-17	17-18	18-19	19-20	20-21	21-22	22-23	23-24	24-25	25-26
# bins with 4 TS	0	0	1	1	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0

Wind Speed (m/s)

	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-11	11-12	12-13	13-14	14-15	15-16	16-17	17-18	18-19	19-20	20-21	21-22	22-23	23-24	24-25	25-26
#TS in WS bin	1	4	9	10	3	1	2	4	3	8	7	13	2	3	4	6	2	0	0	0	0	0	0

Wind Speed (m/s)

Figure 99. Capture matrix for main shaft bending 0

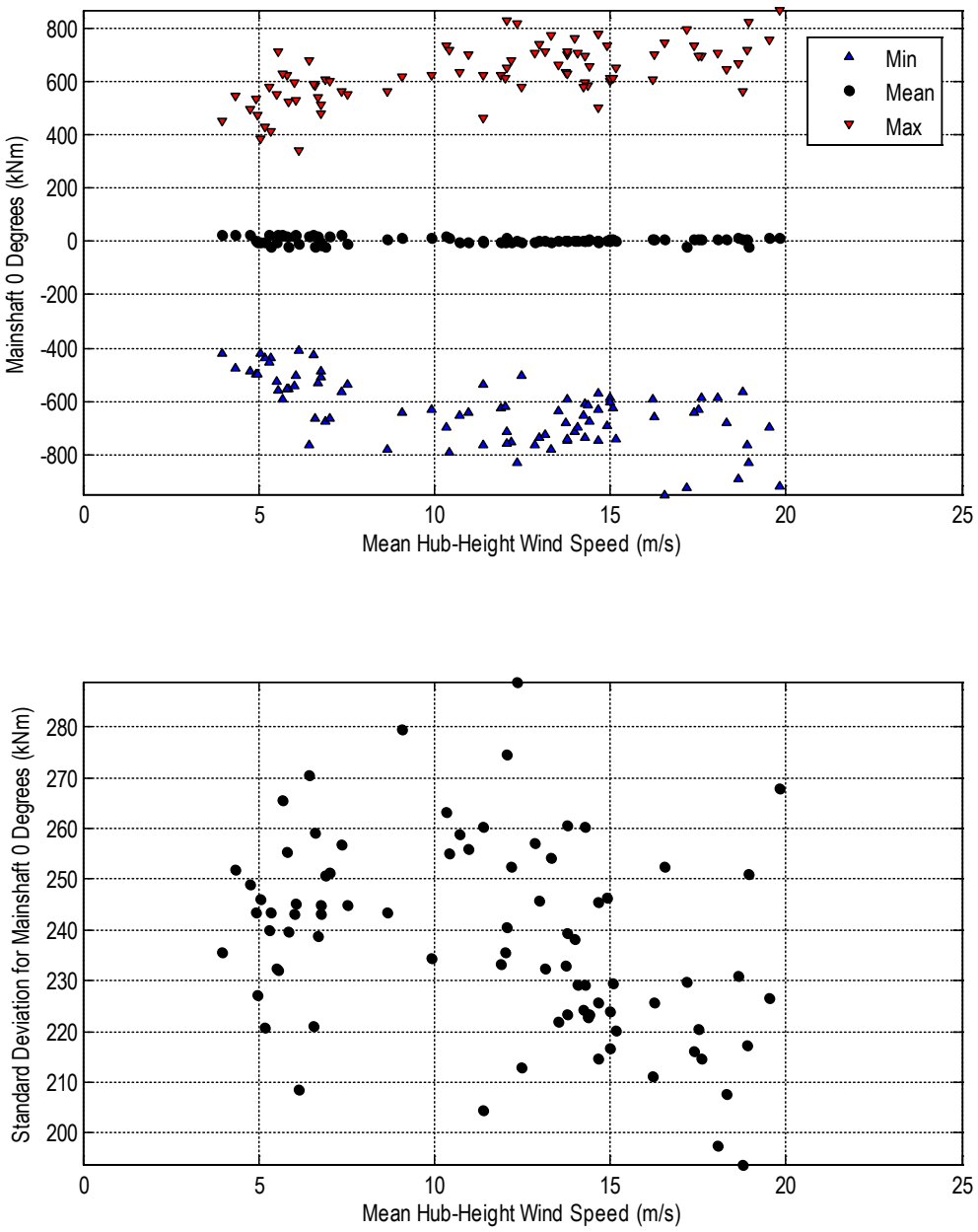


Figure 100. Scatterplot for main shaft bending 0

Table 57. Binned Data for Main Shaft Bending 0

Bin #	Bin WS Low	Bin WS High	Mean WS	# Files	Min of Minimums	Mean of Means	Max of Maximums
1	3.0	4.0	4.0	1	-419.62	22.57	452.34
2	4.0	5.0	4.8	4	-495.97	12.50	546.46
3	5.0	6.0	5.5	9	-589.37	5.25	708.78
4	6.0	7.0	6.5	10	-762.01	4.09	675.61
5	7.0	8.0	7.3	3	-661.75	11.30	600.15
6	8.0	9.0	8.7	1	-778.09	5.15	561.43
7	9.0	10.0	9.5	2	-641.43	12.32	624.99
8	10.0	11.0	10.6	4	-790.64	6.47	733.04
9	11.0	12.0	11.6	3	-760.36	-1.44	625.15
10	12.0	13.0	12.4	8	-828.99	0.64	825.45
11	13.0	14.0	13.6	7	-778.03	1.38	771.15
12	14.0	15.0	14.5	13	-746.17	3.05	778.51
13	15.0	16.0	15.1	2	-738.59	5.17	647.97
14	16.0	17.0	16.3	3	-948.08	7.46	745.24
15	17.0	18.0	17.4	4	-921.30	0.61	796.44
16	18.0	19.0	18.6	6	-890.07	4.31	821.98
17	19.0	20.0	19.7	2	-916.19	14.48	869.30
18	20.0	21.0	0.0	0	0.00	0.00	0.00
19	21.0	22.0	0.0	0	0.00	0.00	0.00
20	22.0	23.0	0.0	0	0.00	0.00	0.00
21	23.0	24.0	0.0	0	0.00	0.00	0.00
22	24.0	25.0	0.0	0	0.00	0.00	0.00
23	25.0	26.0	0.0	0	0.00	0.00	0.00

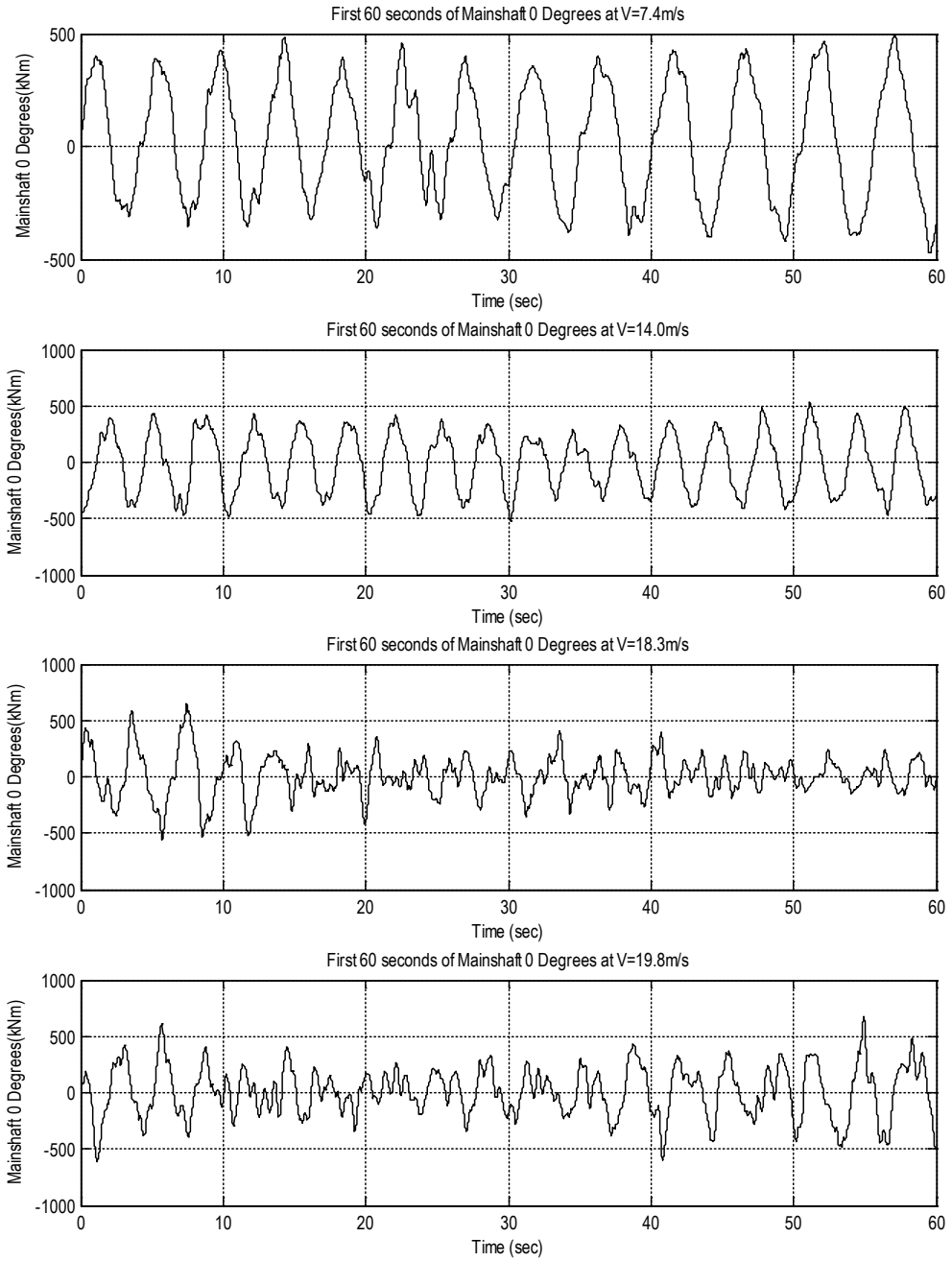


Figure 101. Time series for the first 60 seconds of main shaft bending 0

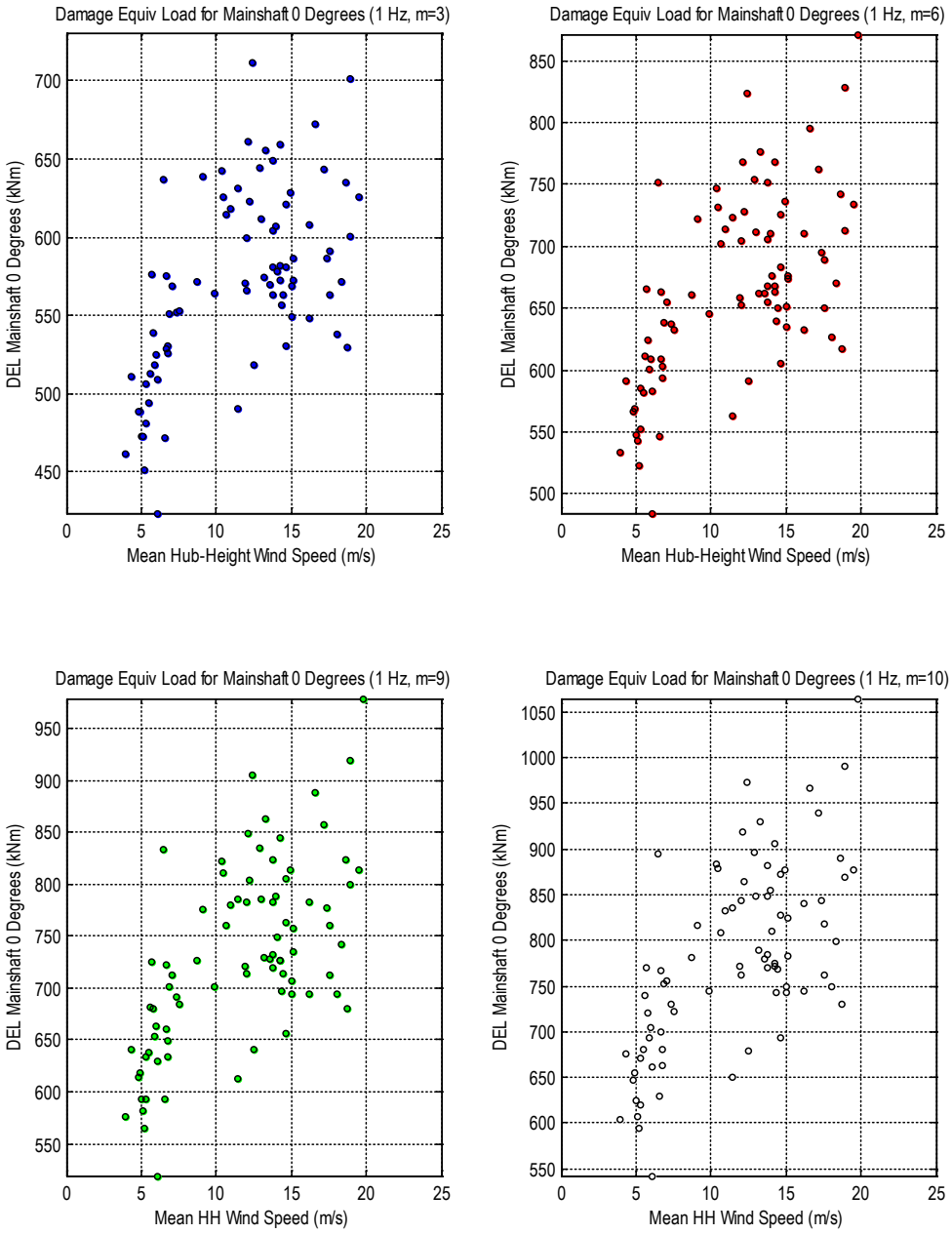


Figure 102. DEL (1 Hz, m=3, 6, 9, 10) for main shaft bending 0

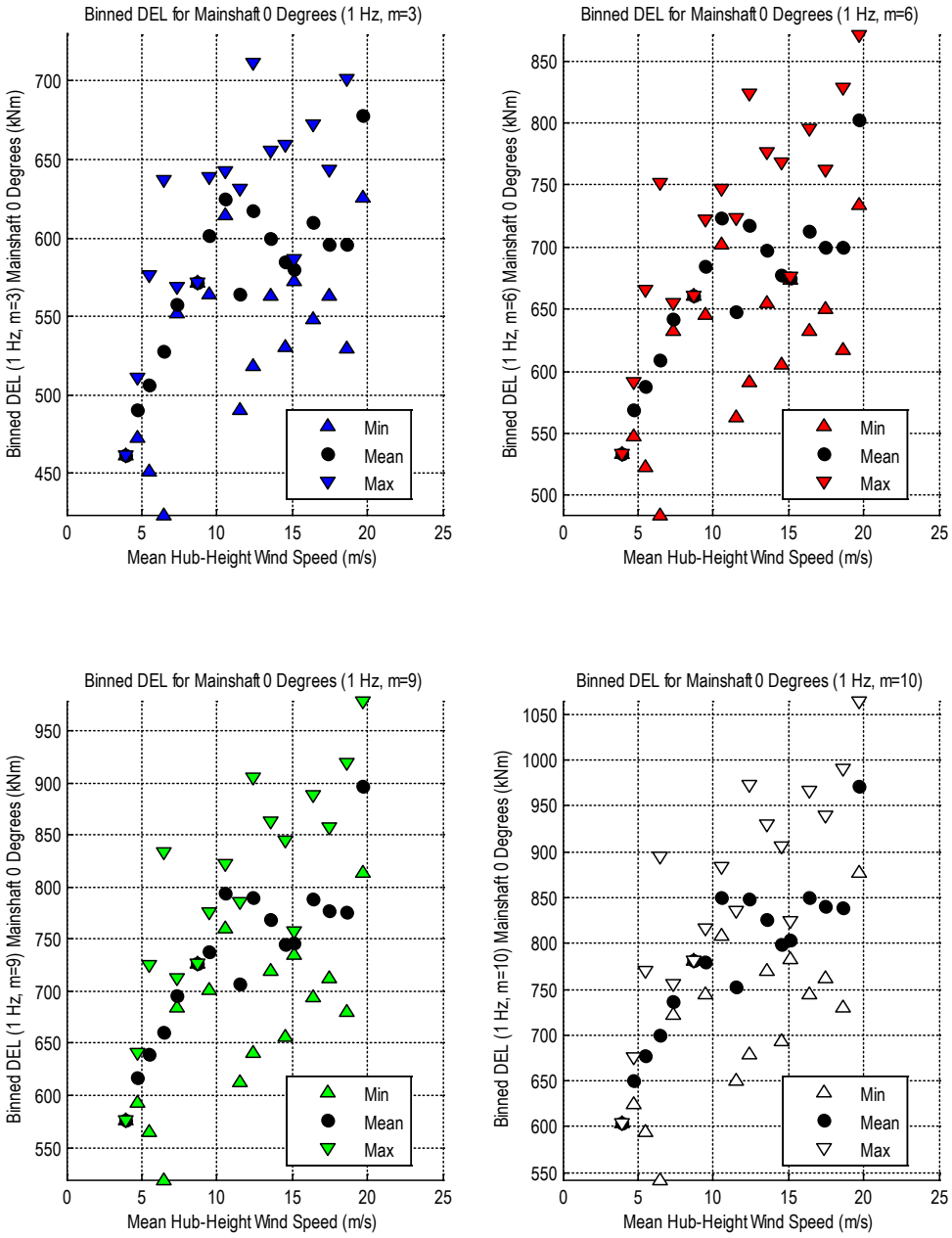


Figure 103. Binned DEL (1 Hz, m=3, 6, 9, 10) for main shaft bending 0

Table 58. Binned DEL Data for Main Shaft Bending 0

Bin #	Bin WS Low	Bin WS High	Mean WS	# Files	Min of Del (m=3)	Mean of Del (m=3)	Max of Del (m=3)	Min of Del (m=6)	Mean of Del (m=6)	Max of Del (m=6)	Min of Del (m=9)	Mean of Del (m=9)	Max of Del (m=9)
1	3.0	4.0	4.0	1	461.75	461.75	461.75	533.78	533.78	533.78	604.45	604.45	604.45
2	4.0	5.0	4.8	4	472.97	490.26	510.90	547.26	568.73	591.75	625.33	650.52	676.32
3	5.0	6.0	5.5	9	451.66	505.94	576.22	522.58	587.20	665.14	594.10	677.58	770.76
4	6.0	7.0	6.5	10	423.84	527.79	636.45	484.43	608.28	751.95	542.24	699.45	894.90
5	7.0	8.0	7.3	3	551.89	558.01	569.13	632.62	641.85	655.39	722.22	736.12	755.67
6	8.0	9.0	8.7	1	571.39	571.39	571.39	660.91	660.91	660.91	780.69	780.69	780.69
7	9.0	10.0	9.5	2	564.40	601.41	638.42	645.44	683.77	722.10	745.10	780.36	815.62
8	10.0	11.0	10.6	4	614.53	625.09	642.01	701.49	723.32	747.09	807.79	850.32	883.06
9	11.0	12.0	11.6	3	490.37	564.30	631.66	563.38	648.23	723.13	650.25	752.43	835.77
10	12.0	13.0	12.4	8	518.26	616.97	711.13	591.35	716.81	823.73	679.35	848.23	972.92
11	13.0	14.0	13.6	7	563.02	599.64	655.64	654.77	697.16	776.55	770.07	825.95	929.38
12	14.0	15.0	14.5	13	530.52	584.48	658.80	605.55	677.82	768.15	693.58	799.27	905.33
13	15.0	16.0	15.1	2	572.70	579.72	586.74	674.22	675.36	676.50	782.76	803.33	823.89
14	16.0	17.0	16.3	3	547.98	609.61	672.52	632.69	712.64	794.76	743.65	850.06	966.35
15	17.0	18.0	17.4	4	563.08	595.92	642.96	650.66	699.16	761.63	761.83	840.80	939.53
16	18.0	19.0	18.6	6	530.07	596.03	701.23	617.14	699.45	827.67	729.33	838.14	990.95
17	19.0	20.0	19.7	2	625.51	677.57	729.64	733.82	802.55	871.28	877.72	971.33	1,064.95
18	20.0	21.0	0.0	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
19	21.0	22.0	0.0	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
20	22.0	23.0	0.0	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
21	23.0	24.0	0.0	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
22	24.0	25.0	0.0	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
23	25.0	26.0	0.0	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

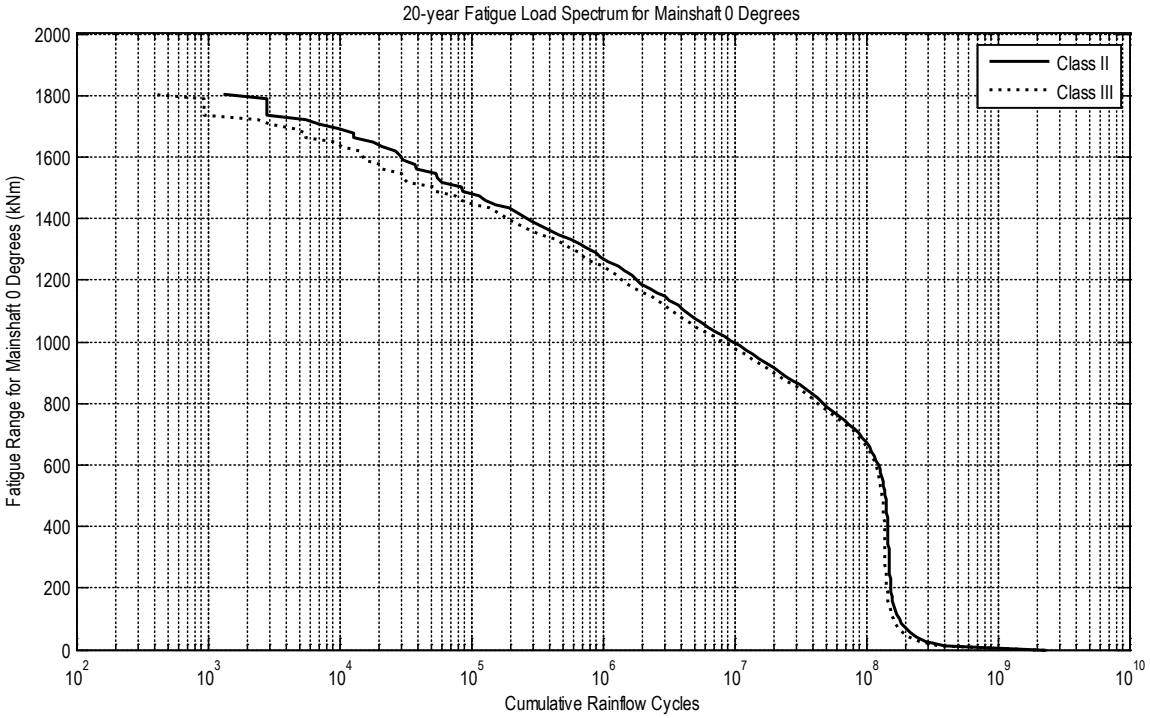


Figure 104. Twenty-year fatigue load spectrum for main shaft bending 0

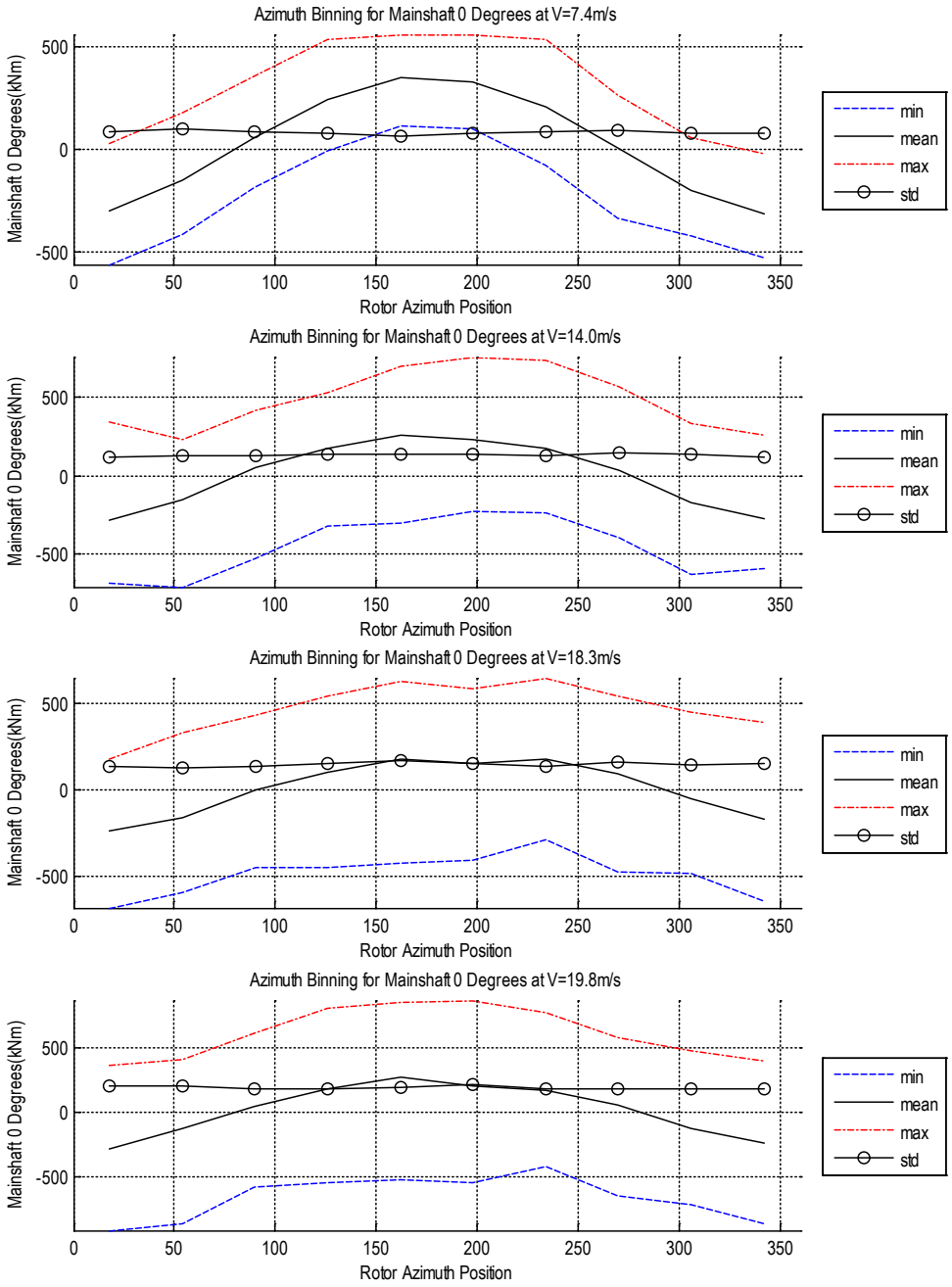


Figure 105. Azimuth binning for main shaft bending 0

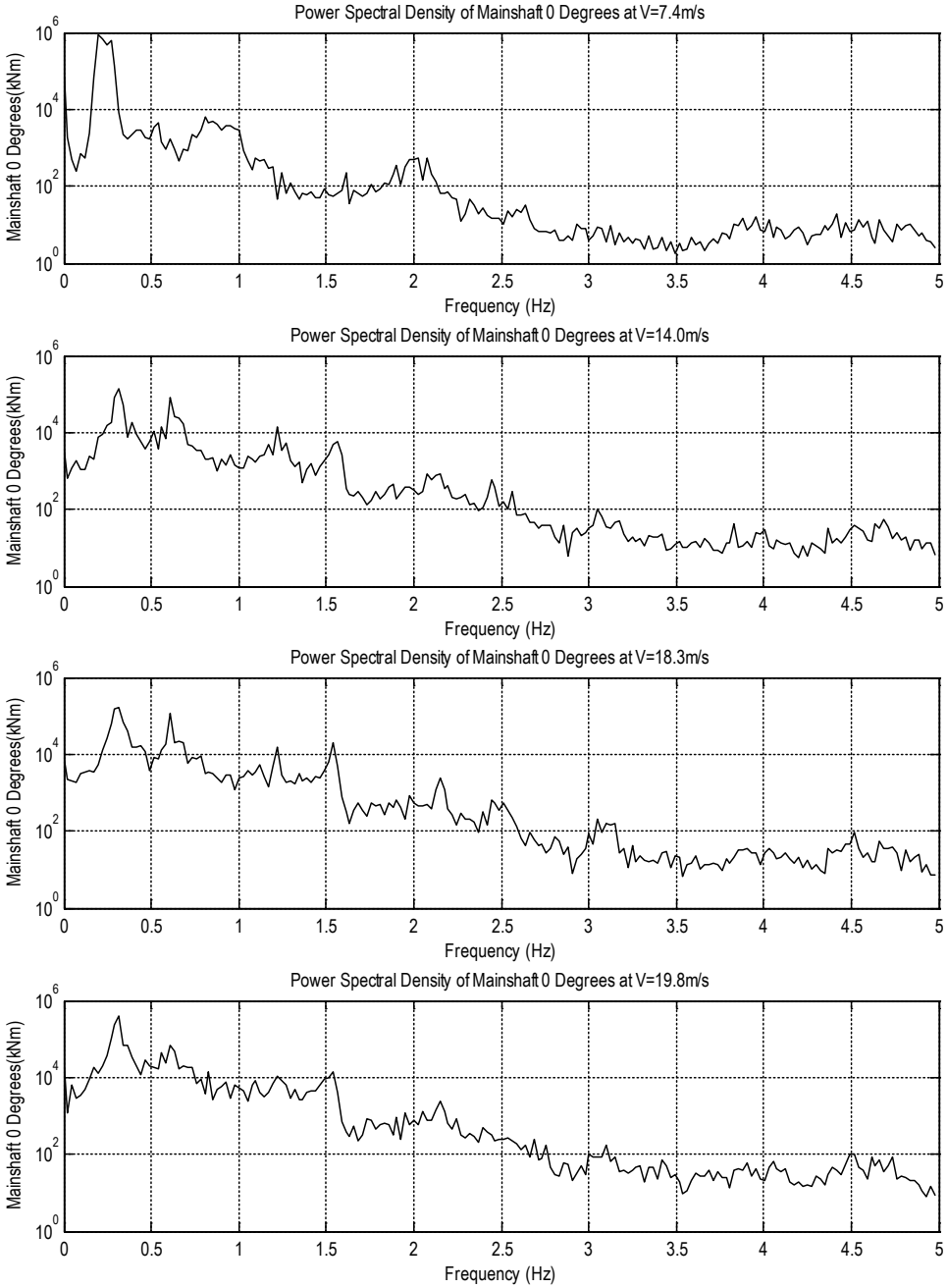


Figure 106. Power spectral density of main shaft bending 0

Main Shaft Bending 90

Turbulence Intensity	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-11	11-12	12-13	13-14	14-15	15-16	16-17	17-18	18-19	19-20	20-21	21-22	22-23	23-24	24-25	25-26
29-100%	1	1	6	1	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
27-29%	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
25-27%	0	1	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
23-25%	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
21-23%	0	1	0	4	0	1	0	1	1	0	1	1	0	1	0	0	0	0	0	0	0	0	0
19-21%	0	0	0	1	0	0	0	1	2	0	1	0	0	0	0	0	0	0	0	0	0	0	0
17-19%	0	0	0	1	1	0	0	0	0	3	0	0	0	1	1	1	1	0	0	0	0	0	0
15-17%	0	0	1	1	0	0	0	0	0	2	3	5	0	0	1	1	1	0	0	0	0	0	0
13-15%	0	0	1	0	0	0	1	0	0	1	0	3	1	0	0	1	0	0	0	0	0	0	0
11-13%	0	0	0	1	0	0	0	0	0	1	2	4	1	0	2	2	0	0	0	0	0	0	0
9-11%	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	1	0	0	0	0	0	0	0
7-9%	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5-7%	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3-5%	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0-3%	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Wind Speed (m/s)

Total Files in Wind Speed Bin

	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-11	11-12	12-13	13-14	14-15	15-16	16-17	17-18	18-19	19-20	20-21	21-22	22-23	23-24	24-25	25-26
# bins with 4 TS	0	0	1	1	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0

Wind Speed (m/s)

	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-11	11-12	12-13	13-14	14-15	15-16	16-17	17-18	18-19	19-20	20-21	21-22	22-23	23-24	24-25	25-26
#TS in WS bin	1	4	9	10	3	1	2	4	3	8	7	13	2	3	4	6	2	0	0	0	0	0	0

Wind Speed (m/s)

Figure 107. Capture matrix for main shaft bending 90

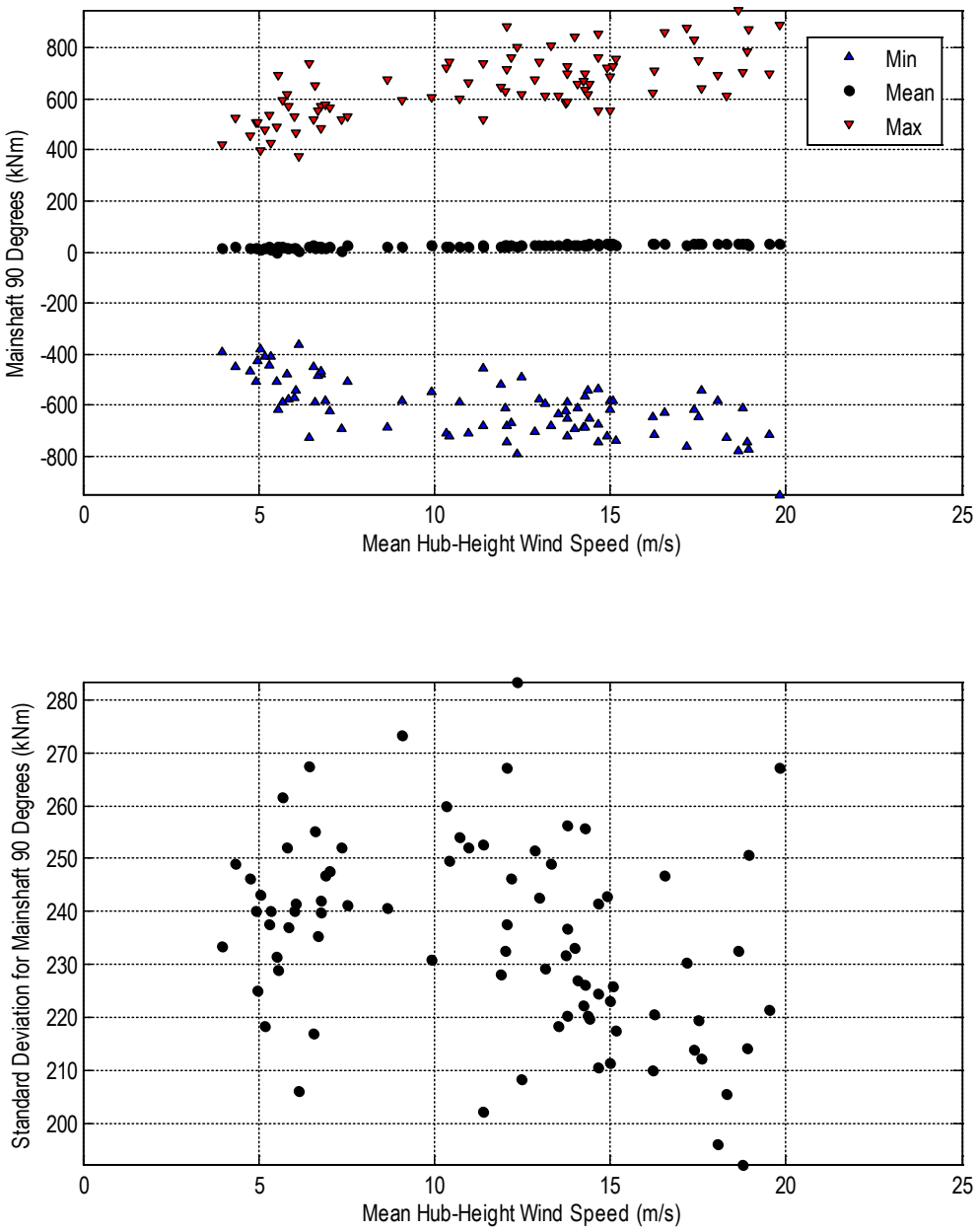


Figure 108. Scatterplot for main shaft bending 90

Table 59. Binned Data for Main Shaft Bending 90

Bin #	Bin WS Low	Bin WS High	Mean WS	# Files	Min of Minimums	Mean of Means	Max of Maximums
1	3.0	4.0	4.0	1	-391.26	14.29	420.62
2	4.0	5.0	4.8	4	-504.91	15.84	524.55
3	5.0	6.0	5.5	9	-614.11	12.25	694.07
4	6.0	7.0	6.5	10	-724.61	17.70	740.08
5	7.0	8.0	7.3	3	-689.21	15.65	565.04
6	8.0	9.0	8.7	1	-684.05	18.03	672.27
7	9.0	10.0	9.5	2	-578.47	21.83	605.77
8	10.0	11.0	10.6	4	-721.68	20.32	741.82
9	11.0	12.0	11.6	3	-677.05	23.24	739.16
10	12.0	13.0	12.4	8	-792.06	24.28	880.33
11	13.0	14.0	13.6	7	-720.22	26.71	806.07
12	14.0	15.0	14.5	13	-740.92	28.36	853.50
13	15.0	16.0	15.1	2	-738.57	29.73	753.81
14	16.0	17.0	16.3	3	-715.72	30.23	856.37
15	17.0	18.0	17.4	4	-759.76	30.60	878.91
16	18.0	19.0	18.6	6	-780.53	31.48	948.90
17	19.0	20.0	19.7	2	-948.46	32.12	888.78
18	20.0	21.0	0.0	0	0.00	0.00	0.00
19	21.0	22.0	0.0	0	0.00	0.00	0.00
20	22.0	23.0	0.0	0	0.00	0.00	0.00
21	23.0	24.0	0.0	0	0.00	0.00	0.00
22	24.0	25.0	0.0	0	0.00	0.00	0.00
23	25.0	26.0	0.0	0	0.00	0.00	0.00

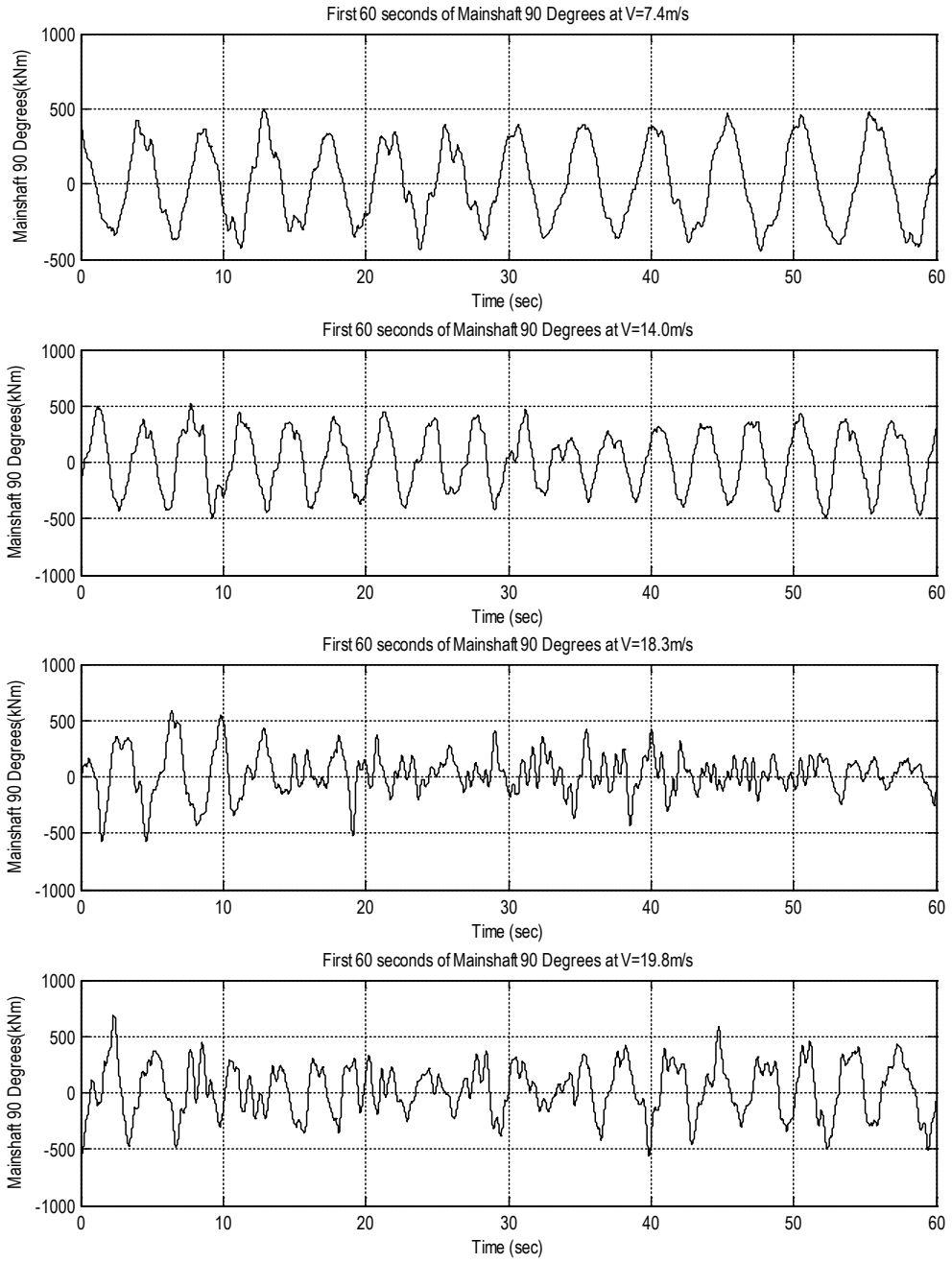


Figure 109. Time series for the first 60 seconds of main shaft bending 90

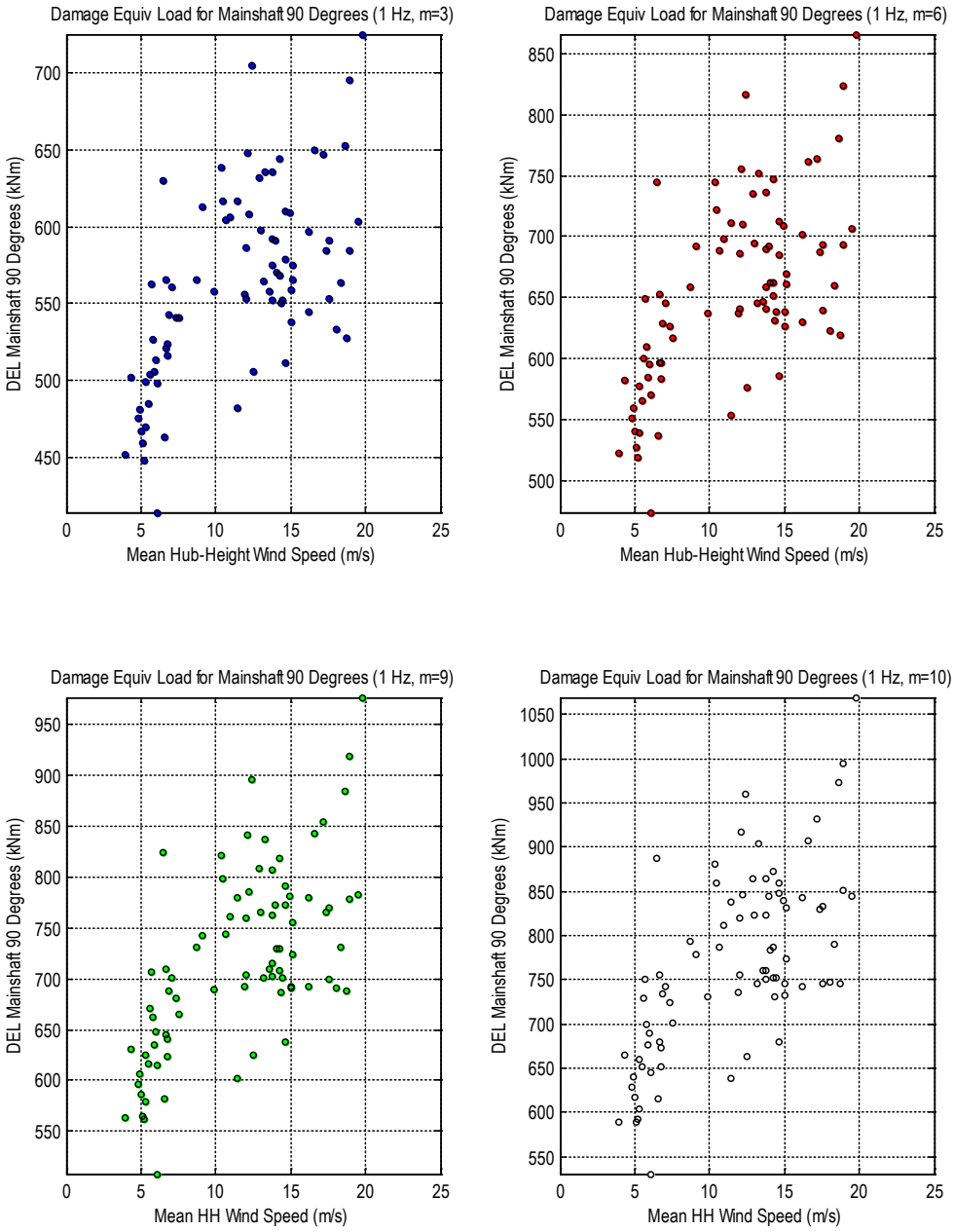


Figure 110. DEL (1 Hz, m=3, 6, 9, 10) for main shaft bending 90

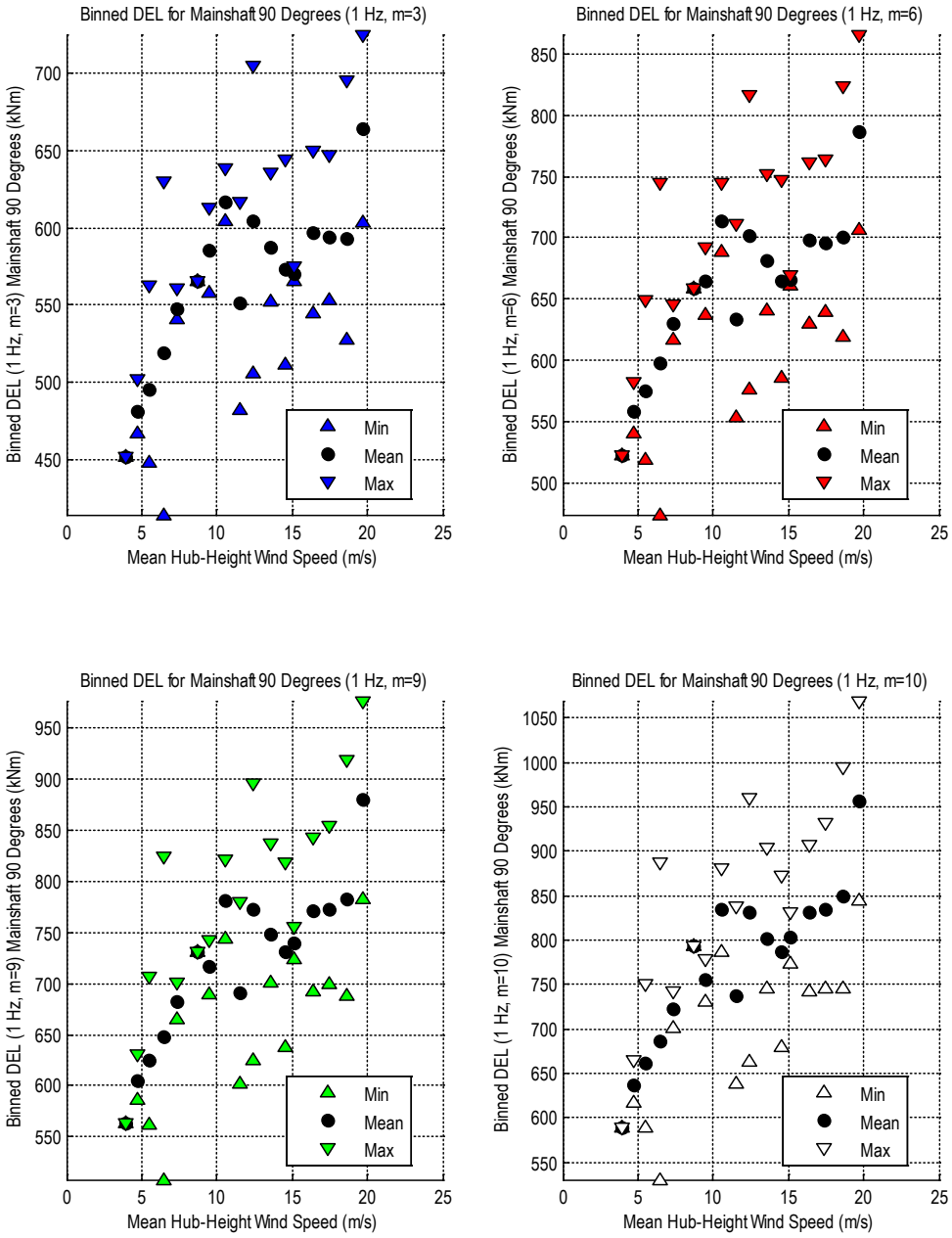


Figure 111. Binned DEL (1 Hz, m=3, 6, 9, 10) for main shaft bending 90

Table 60. Binned DEL Data for Main Shaft Bending 90

Bin #	Bin WS Low	Bin WS High	Mean WS	# Files	Min of Del (m=3)	Mean of Del (m=3)	Max of Del (m=3)	Min of Del (m=6)	Mean of Del (m=6)	Max of Del (m=6)	Min of Del (m=9)	Mean of Del (m=9)	Max of Del (m=9)
1	3.0	4.0	4.0	1	451.68	451.68	451.68	521.80	521.80	521.80	589.91	589.91	589.91
2	4.0	5.0	4.8	4	467.14	481.58	502.43	540.78	558.38	582.00	617.45	637.71	665.32
3	5.0	6.0	5.5	9	447.90	495.81	563.04	518.92	574.43	649.02	589.42	661.56	750.30
4	6.0	7.0	6.5	10	414.56	518.82	630.19	473.84	597.65	744.67	530.71	686.24	887.39
5	7.0	8.0	7.3	3	540.52	547.50	560.66	616.58	629.32	645.30	700.46	722.50	742.58
6	8.0	9.0	8.7	1	565.77	565.77	565.77	658.82	658.82	658.82	793.82	793.82	793.82
7	9.0	10.0	9.5	2	557.57	585.17	612.77	636.79	664.40	692.02	731.44	755.39	779.35
8	10.0	11.0	10.6	4	603.97	616.38	638.16	688.15	713.03	744.88	786.65	834.89	881.42
9	11.0	12.0	11.6	3	481.83	551.29	616.34	553.34	633.79	710.85	638.26	737.18	837.54
10	12.0	13.0	12.4	8	506.19	604.56	704.70	576.57	701.88	816.07	663.40	831.03	959.44
11	13.0	14.0	13.6	7	552.35	587.62	635.79	640.66	681.34	752.06	745.33	801.09	903.87
12	14.0	15.0	14.5	13	511.65	573.27	644.14	586.05	664.59	746.93	678.98	786.64	873.14
13	15.0	16.0	15.1	2	565.48	570.17	574.86	661.37	665.16	668.94	774.14	802.57	831.00
14	16.0	17.0	16.3	3	544.64	597.07	650.21	630.30	697.56	760.84	742.95	831.12	907.73
15	17.0	18.0	17.4	4	553.26	593.92	647.00	639.56	696.06	763.72	746.31	835.32	931.74
16	18.0	19.0	18.6	6	527.81	592.91	695.14	619.08	699.94	823.95	745.72	850.01	993.59
17	19.0	20.0	19.7	2	603.09	664.08	725.08	706.68	786.35	866.02	845.15	957.17	1,069.19
18	20.0	21.0	0.0	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
19	21.0	22.0	0.0	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
20	22.0	23.0	0.0	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
21	23.0	24.0	0.0	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
22	24.0	25.0	0.0	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
23	25.0	26.0	0.0	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

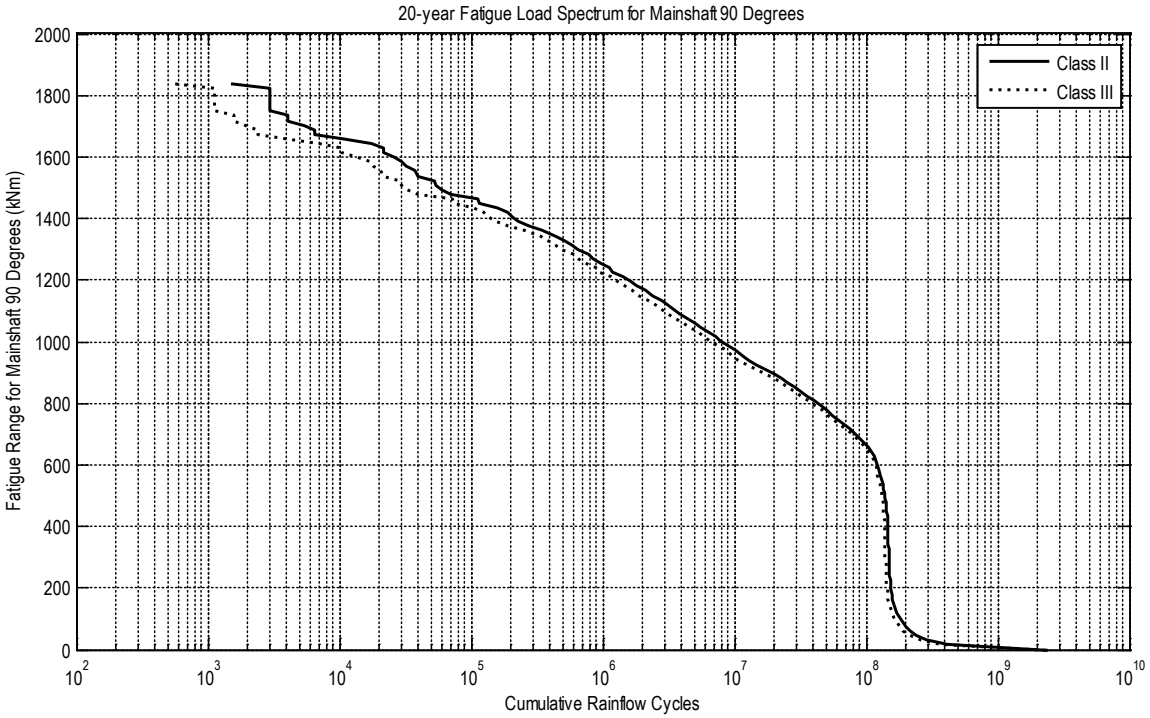


Figure 112. Twenty-year fatigue load spectrum for main shaft bending 90

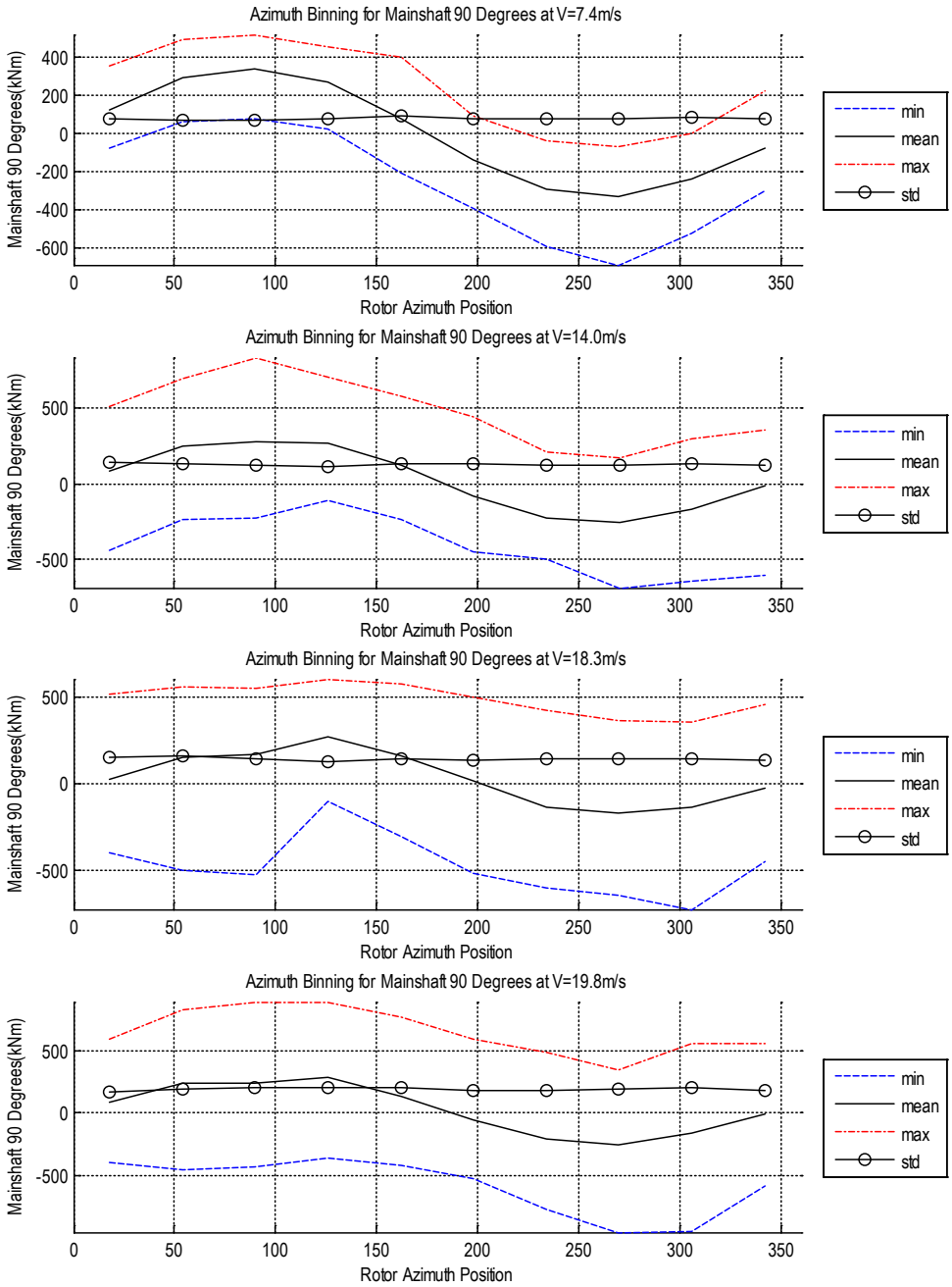


Figure 113. Azimuth binning for main shaft bending 90

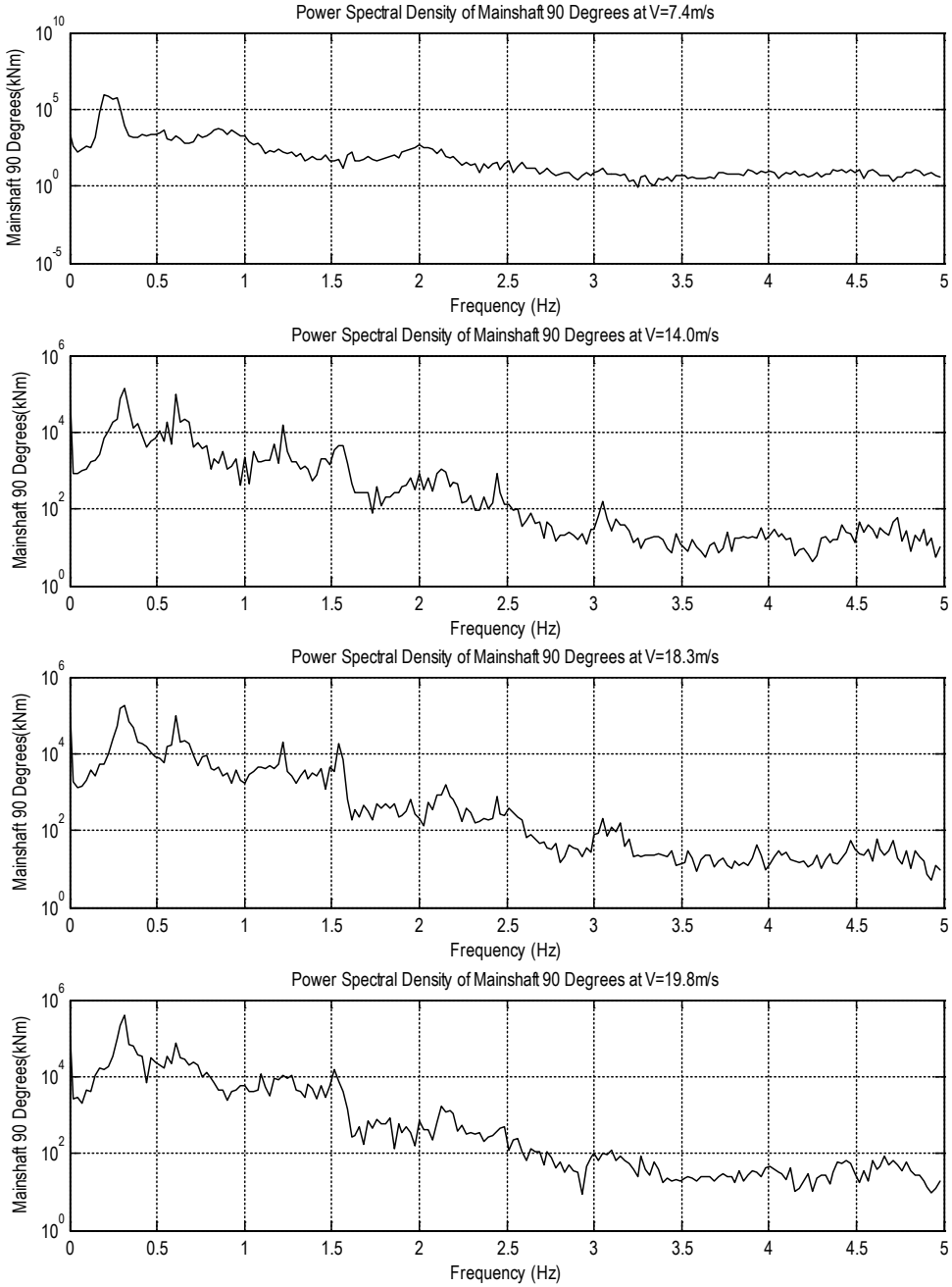


Figure 114. Power spectral density of main shaft bending 90

Main Shaft Torque

Turbulence Intensity	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-11	11-12	12-13	13-14	14-15	15-16	16-17	17-18	18-19	19-20	20-21	21-22	22-23	23-24	24-25	25-26
29-100%	1	1	7	1	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
27-29%	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
25-27%	0	1	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
23-25%	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
21-23%	0	1	0	4	0	1	0	1	2	0	1	1	0	1	0	0	0	0	0	0	0	0	0
19-21%	0	0	0	1	0	0	0	1	2	0	1	0	0	0	0	0	0	0	0	0	0	0	0
17-19%	0	0	0	1	1	0	0	0	0	3	0	0	0	1	1	1	1	0	0	0	0	0	0
15-17%	0	0	1	1	0	0	0	0	0	2	3	5	0	0	2	1	1	0	0	0	0	0	0
13-15%	0	0	1	1	0	0	1	0	0	1	0	3	1	0	0	1	0	0	0	0	0	0	0
11-13%	0	0	0	1	0	0	0	0	0	1	2	4	1	0	2	2	0	0	0	0	0	0	0
9-11%	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	1	0	0	0	0	0	0	0
7-9%	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5-7%	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3-5%	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0-3%	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Wind Speed (m/s)

Total Files in Wind Speed Bin

	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-11	11-12	12-13	13-14	14-15	15-16	16-17	17-18	18-19	19-20	20-21	21-22	22-23	23-24	24-25	25-26
# bins with 4 TS	0	0	1	1	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0

Wind Speed (m/s)

	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-11	11-12	12-13	13-14	14-15	15-16	16-17	17-18	18-19	19-20	20-21	21-22	22-23	23-24	24-25	25-26
#TS in WS bin	1	4	10	11	3	1	2	4	4	8	7	13	2	3	5	6	2	0	0	0	0	0	0

Wind Speed (m/s)

Figure 115. Capture matrix for main shaft torque

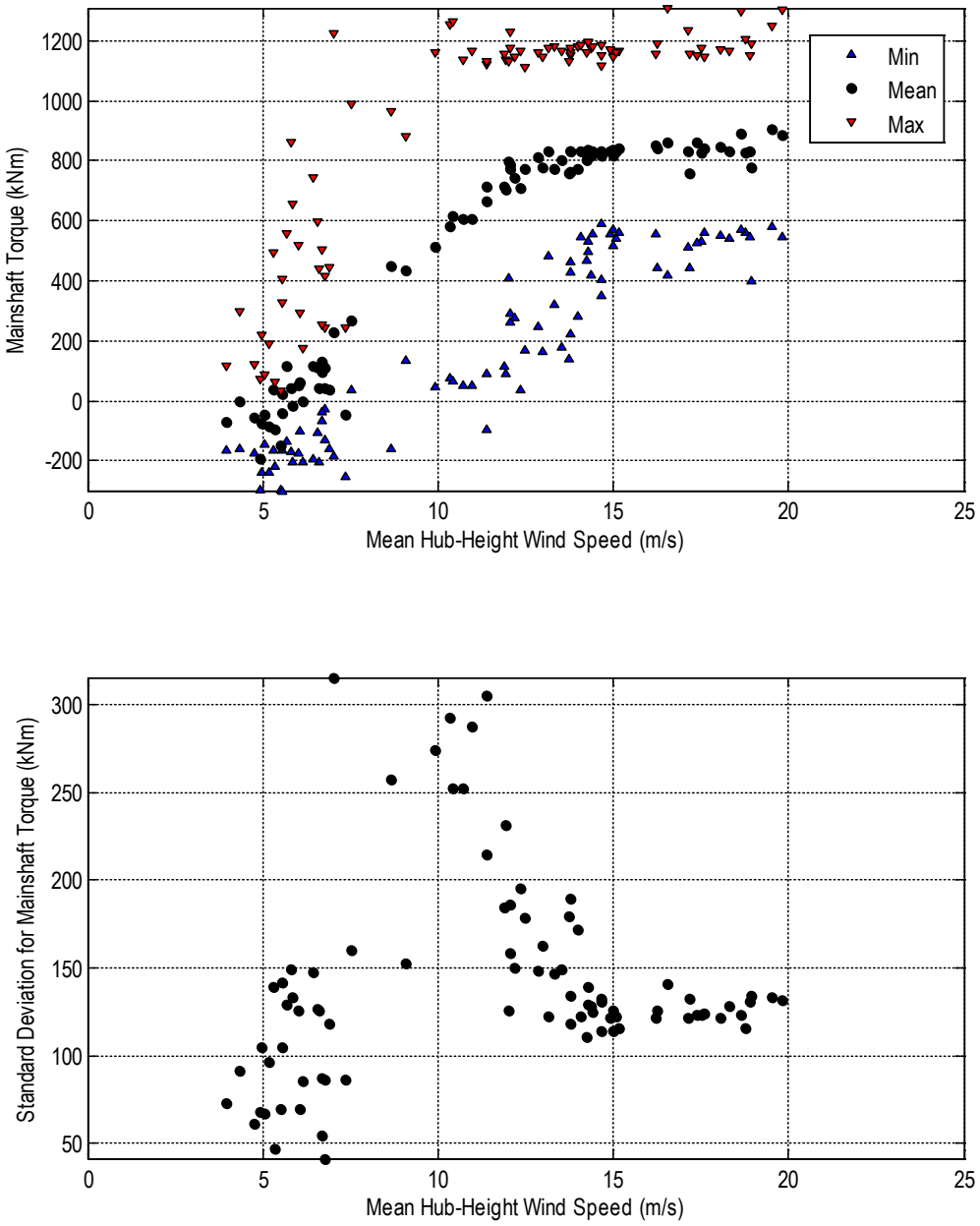


Figure 116. Scatterplot for main shaft torque

Table 61. Binned Data for Main Shaft Torque

Bin #	Bin WS Low	Bin WS High	Mean WS	# Files	Min of Minimums	Mean of Means	Max of Maximums
1	3.0	4.0	4.0	1	-163.83	-70.60	113.00
2	4.0	5.0	4.8	4	-297.59	-81.19	295.53
3	5.0	6.0	5.5	10	-299.33	-22.06	860.62
4	6.0	7.0	6.5	11	-201.51	71.79	743.70
5	7.0	8.0	7.3	3	-251.20	151.00	1,225.76
6	8.0	9.0	8.7	1	-160.51	447.27	965.45
7	9.0	10.0	9.5	2	45.66	473.86	1,158.36
8	10.0	11.0	10.6	4	49.68	600.92	1,264.56
9	11.0	12.0	11.7	4	-96.95	698.45	1,157.72
10	12.0	13.0	12.4	8	36.35	772.23	1,227.08
11	13.0	14.0	13.6	7	138.15	799.15	1,180.11
12	14.0	15.0	14.5	13	281.78	820.86	1,197.06
13	15.0	16.0	15.1	2	541.05	837.33	1,166.29
14	16.0	17.0	16.3	3	418.39	850.52	1,310.35
15	17.0	18.0	17.4	5	445.63	824.25	1,232.10
16	18.0	19.0	18.6	6	398.15	835.33	1,298.37
17	19.0	20.0	19.7	2	548.99	896.87	1,300.80
18	20.0	21.0	0.0	0	0.00	0.00	0.00
19	21.0	22.0	0.0	0	0.00	0.00	0.00
20	22.0	23.0	0.0	0	0.00	0.00	0.00
21	23.0	24.0	0.0	0	0.00	0.00	0.00
22	24.0	25.0	0.0	0	0.00	0.00	0.00
23	25.0	26.0	0.0	0	0.00	0.00	0.00

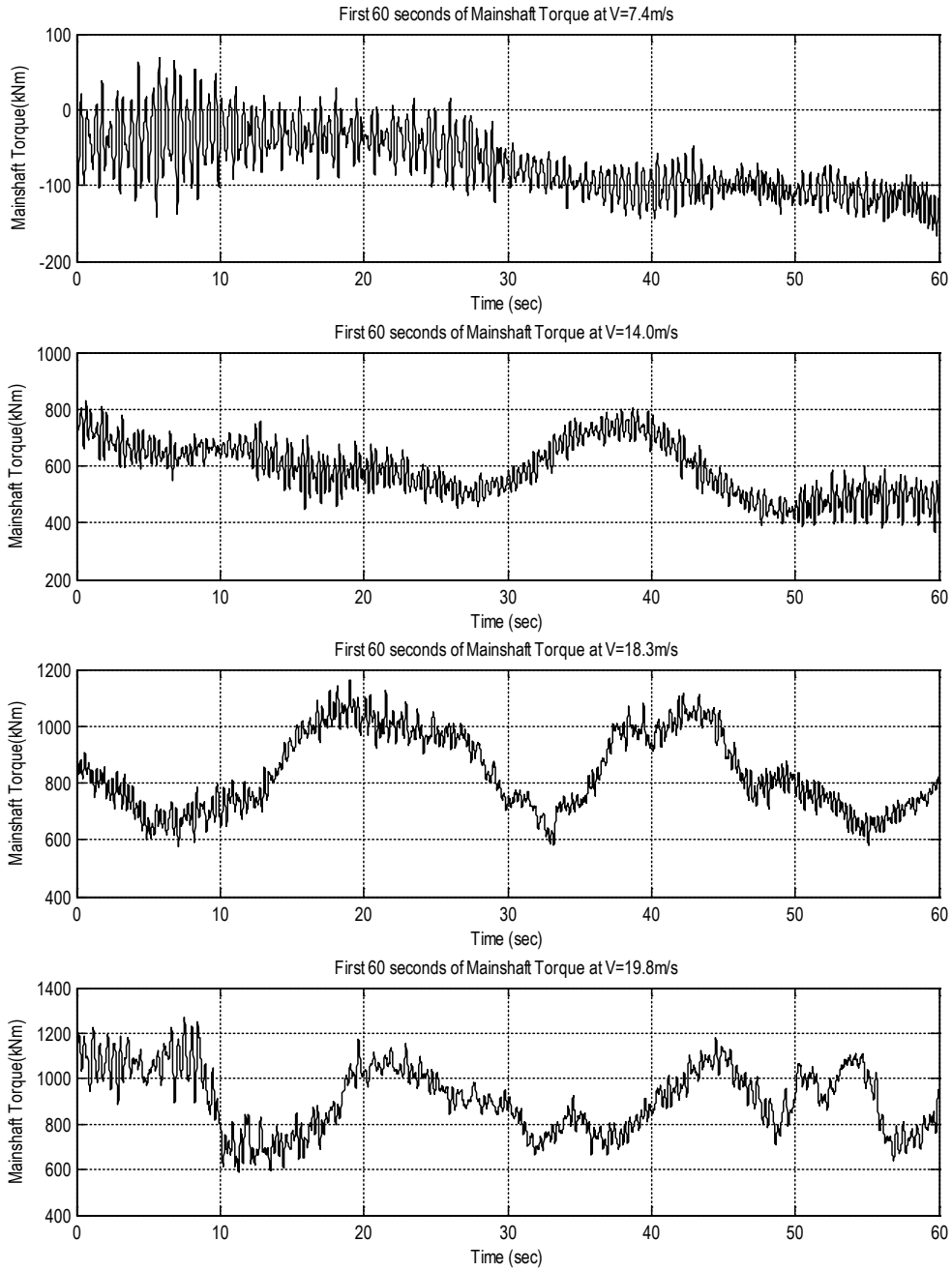


Figure 117. Time series for first 60 seconds of main shaft torque

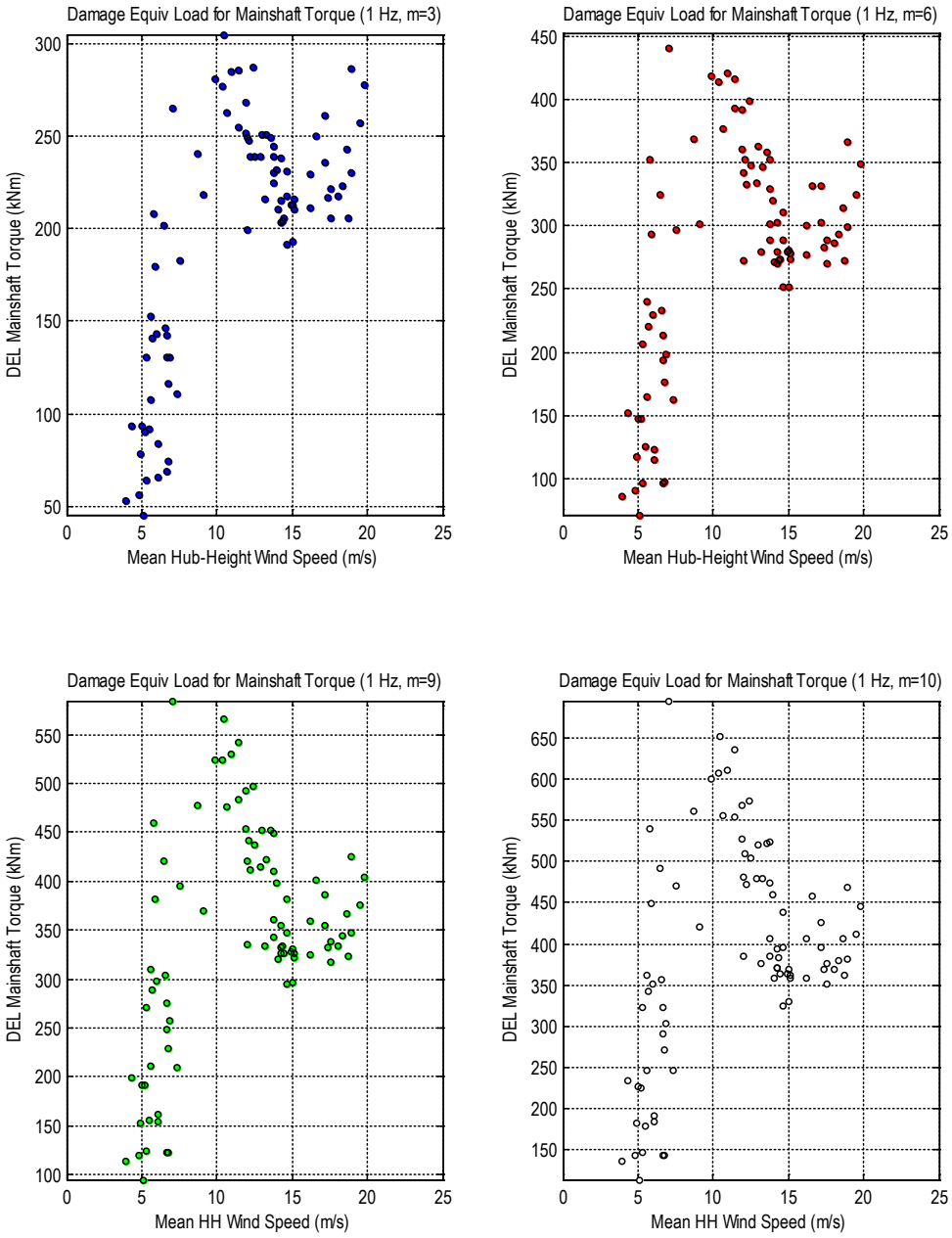


Figure 118. DEL (1 Hz, m=3, 6, 9, 10) for main shaft torque

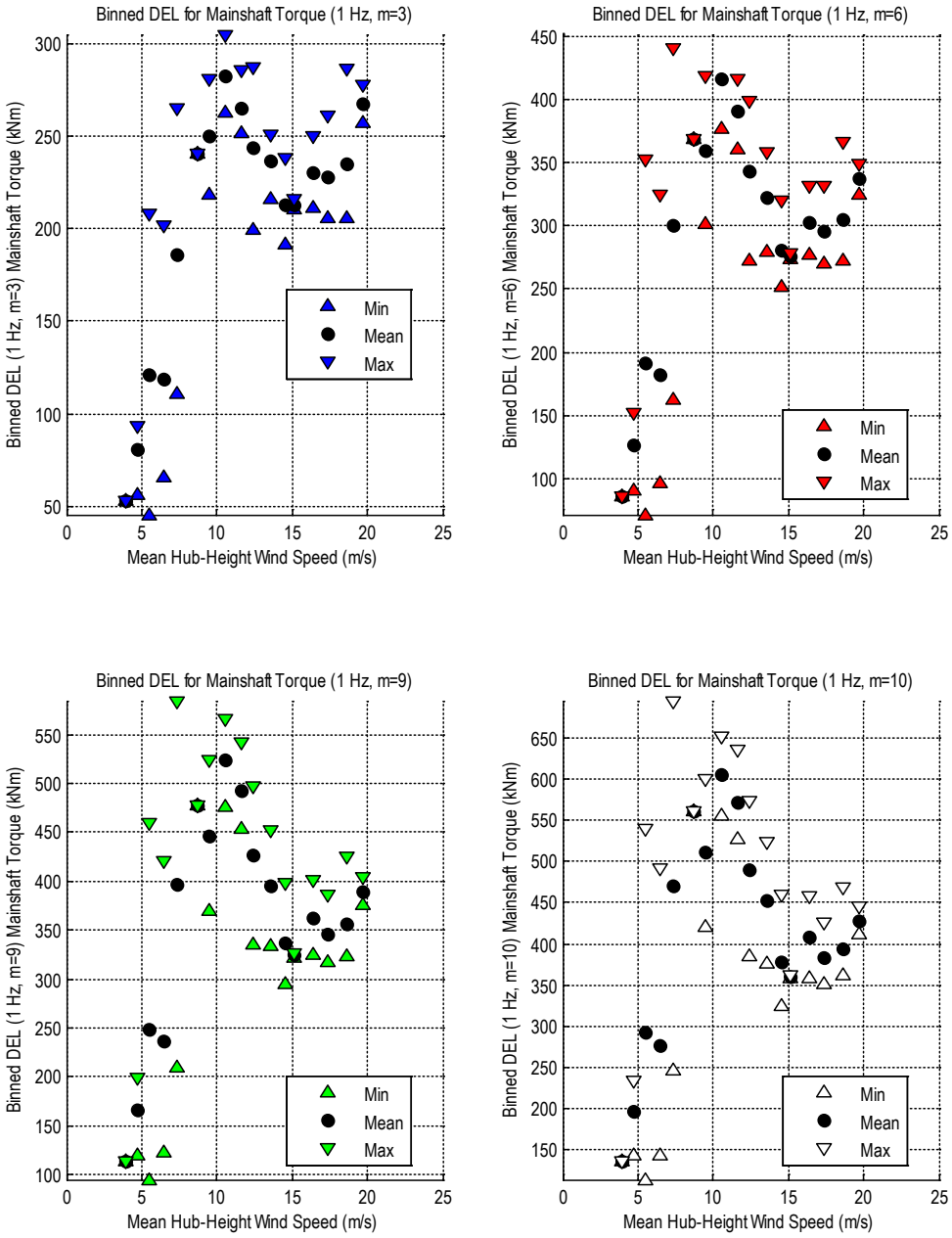


Figure 119. Binned DEL (1 Hz, m=3, 6, 9, 10) for main shaft torque

Table 62. Binned DEL Data for Main Shaft Torque

Bin #	Bin WS Low	Bin WS High	Mean WS	# Files	Min of Del (m=3)	Mean of Del (m=3)	Max of Del (m=3)	Min of Del (m=6)	Mean of Del (m=6)	Max of Del (m=6)	Min of Del (m=9)	Mean of Del (m=9)	Max of Del (m=9)
1	3.0	4.0	4.0	1	52.92	52.92	52.92	85.43	85.43	85.43	136.23	136.23	136.23
2	4.0	5.0	4.8	4	56.43	80.43	93.51	90.42	126.65	152.29	143.80	196.75	233.15
3	5.0	6.0	5.5	10	45.51	121.02	208.39	71.40	191.87	352.57	113.71	292.73	540.08
4	6.0	7.0	6.5	11	65.70	118.43	201.85	95.79	181.85	324.71	142.55	277.36	491.95
5	7.0	8.0	7.3	3	110.52	186.05	265.18	162.35	299.89	440.49	245.92	470.50	695.42
6	8.0	9.0	8.7	1	240.28	240.28	240.28	369.07	369.07	369.07	561.53	561.53	561.53
7	9.0	10.0	9.5	2	218.24	249.66	281.08	301.19	360.03	418.87	420.40	510.51	600.63
8	10.0	11.0	10.6	4	262.74	282.38	304.90	376.83	416.02	451.77	554.90	605.92	650.97
9	11.0	12.0	11.7	4	251.19	264.90	285.38	360.47	390.34	416.20	527.71	571.41	636.53
10	12.0	13.0	12.4	8	199.35	243.79	286.92	272.37	342.97	399.39	385.77	490.83	574.24
11	13.0	14.0	13.6	7	215.91	236.25	250.87	280.01	322.54	358.76	376.23	452.45	523.21
12	14.0	15.0	14.5	13	191.54	212.88	237.85	251.74	281.16	320.47	325.35	378.74	460.47
13	15.0	16.0	15.1	2	210.01	213.09	216.16	273.84	276.31	278.79	358.73	360.20	361.67
14	16.0	17.0	16.3	3	211.33	230.23	249.73	277.06	303.24	332.21	358.80	407.46	457.31
15	17.0	18.0	17.4	5	205.92	228.15	260.77	270.58	295.40	332.03	351.18	383.45	426.04
16	18.0	19.0	18.6	6	205.84	234.56	286.62	273.12	305.51	366.46	361.23	394.54	469.21
17	19.0	20.0	19.7	2	257.14	267.33	277.51	325.13	337.26	349.40	411.66	428.27	444.88
18	20.0	21.0	0.0	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
19	21.0	22.0	0.0	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
20	22.0	23.0	0.0	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
21	23.0	24.0	0.0	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
22	24.0	25.0	0.0	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
23	25.0	26.0	0.0	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

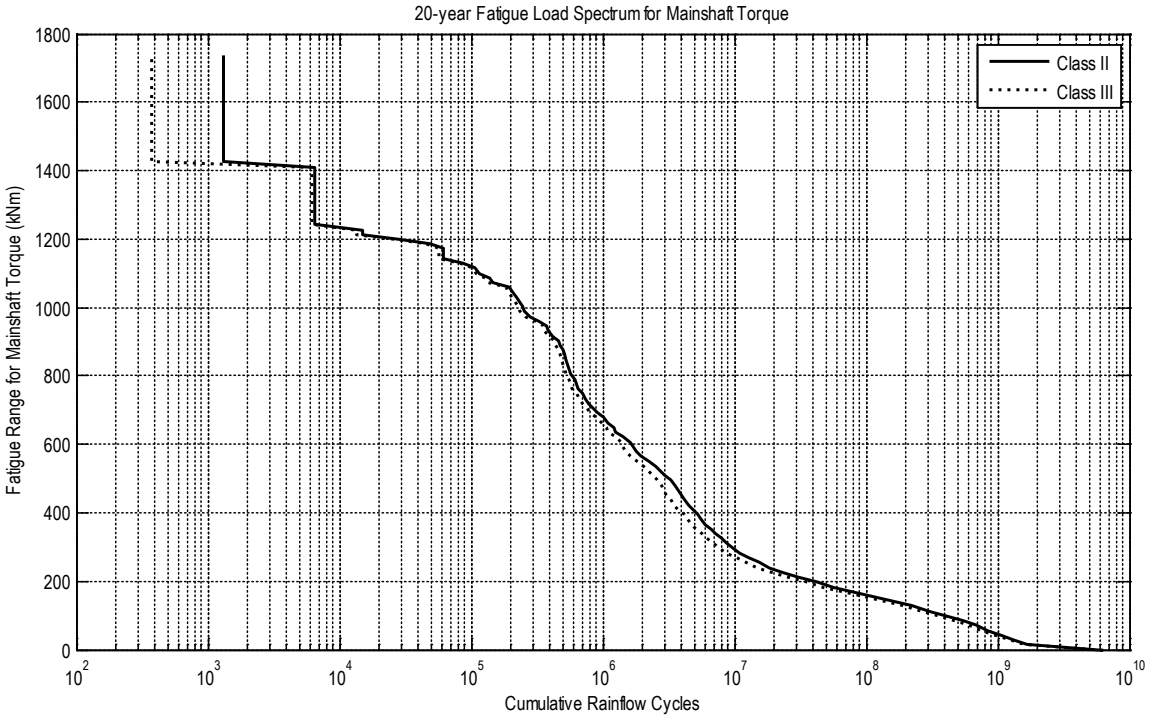


Figure 120. Twenty-year fatigue load spectrum for main shaft torque

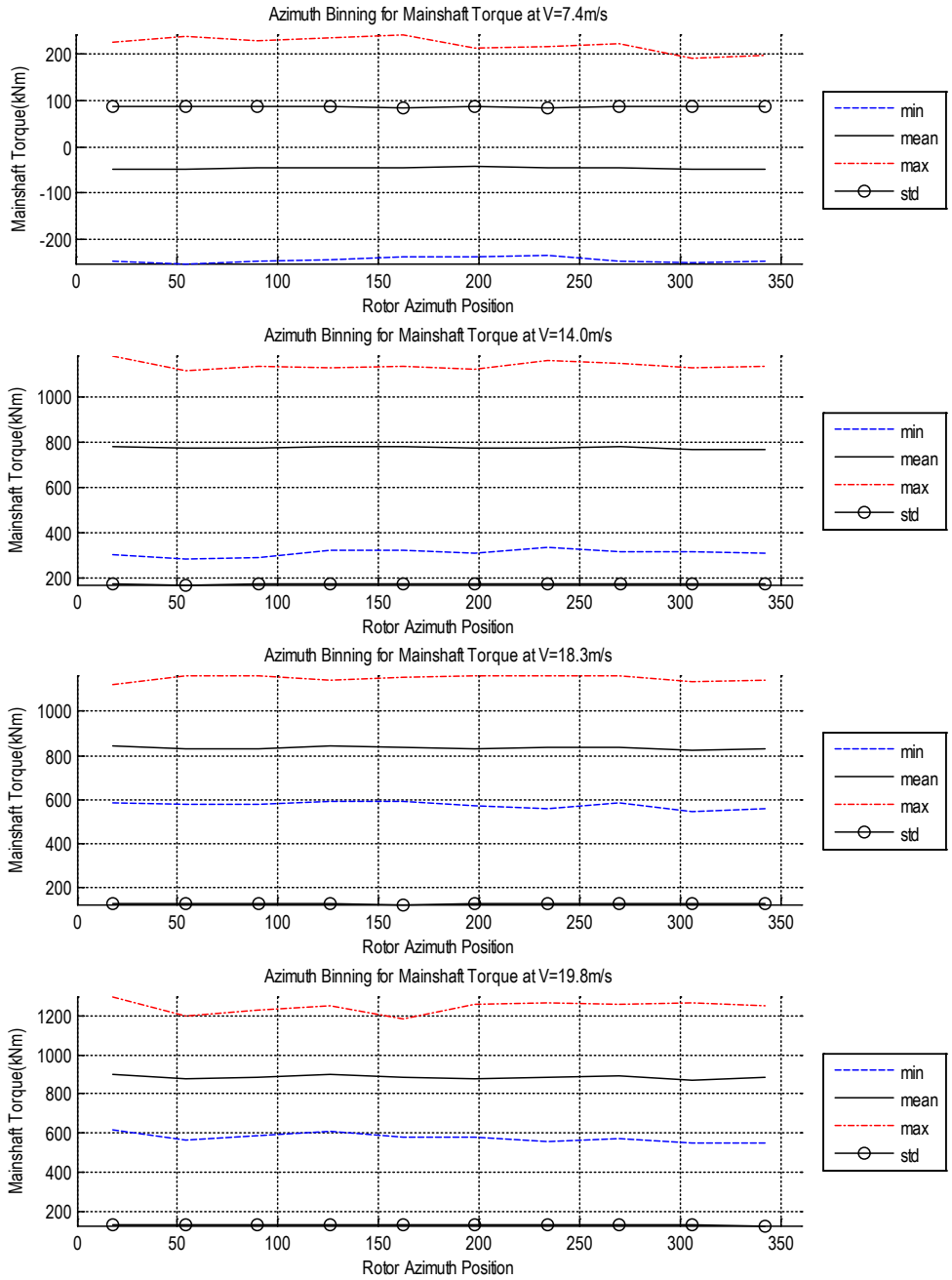


Figure 121. Azimuth binning for main shaft torque

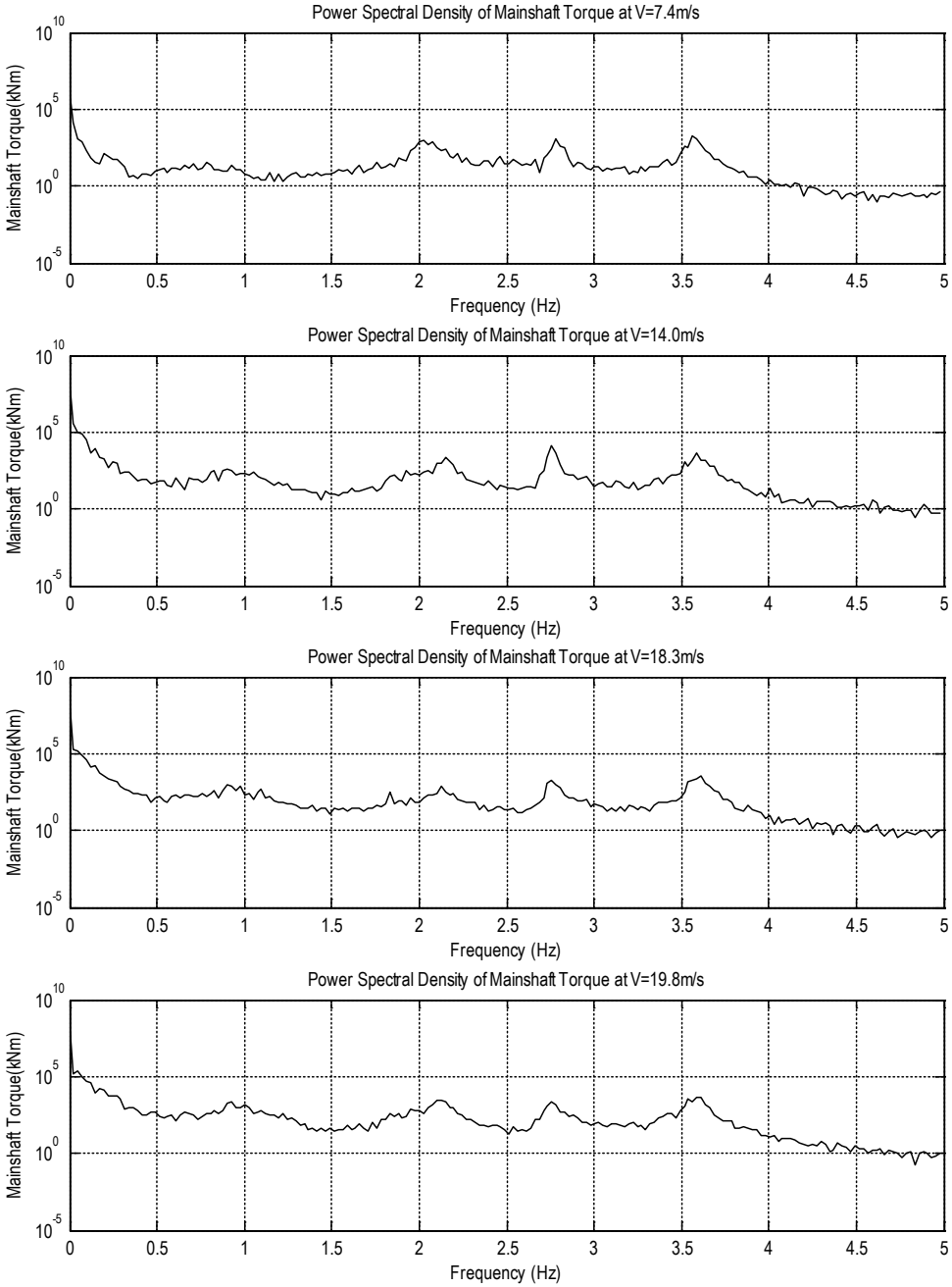


Figure 122. Power spectral density of main shaft torque

Tower-Top Normal Bending

Turbulence Intensity	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-11	11-12	12-13	13-14	14-15	15-16	16-17	17-18	18-19	19-20	20-21	21-22	22-23	23-24	24-25	25-26
29-100%	1	1	8	1	1	0	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
27-29%	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
25-27%	0	1	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
23-25%	0	0	0	0	2	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
21-23%	0	1	0	4	0	1	0	2	5	0	1	1	0	1	0	0	0	0	0	0	0	0	0
19-21%	0	0	0	1	2	2	2	3	3	0	2	0	0	0	0	0	0	0	0	0	0	0	0
17-19%	0	0	0	1	1	0	0	1	4	3	0	3	0	3	1	2	1	2	0	0	0	0	0
15-17%	0	0	1	1	0	1	1	0	2	3	5	6	0	0	2	2	1	2	0	0	0	0	0
13-15%	0	0	1	3	0	2	1	2	2	3	5	5	2	1	2	2	2	2	0	0	0	0	0
11-13%	0	0	0	1	0	0	3	0	0	3	3	6	2	1	2	3	2	0	0	0	0	0	0
9-11%	0	0	0	2	2	0	3	0	0	1	1	2	4	2	1	1	0	1	0	0	0	0	0
7-9%	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
5-7%	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3-5%	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0-3%	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Wind Speed (m/s)

Total Files in Wind Speed Bin

	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-11	11-12	12-13	13-14	14-15	15-16	16-17	17-18	18-19	19-20	20-21	21-22	22-23	23-24	24-25	25-26
# bins with 4 TS	0	0	1	1	0	0	0	0	2	0	2	3	1	0	0	0	0	0	0	0	0	0	0

Wind Speed (m/s)

	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-11	11-12	12-13	13-14	14-15	15-16	16-17	17-18	18-19	19-20	20-21	21-22	22-23	23-24	24-25	25-26
#TS in WS bin	1	4	11	15	9	6	13	10	16	13	17	23	9	8	8	10	6	7	0	0	0	0	0

Wind Speed (m/s)

Figure 123. Capture matrix for tower-top normal bending

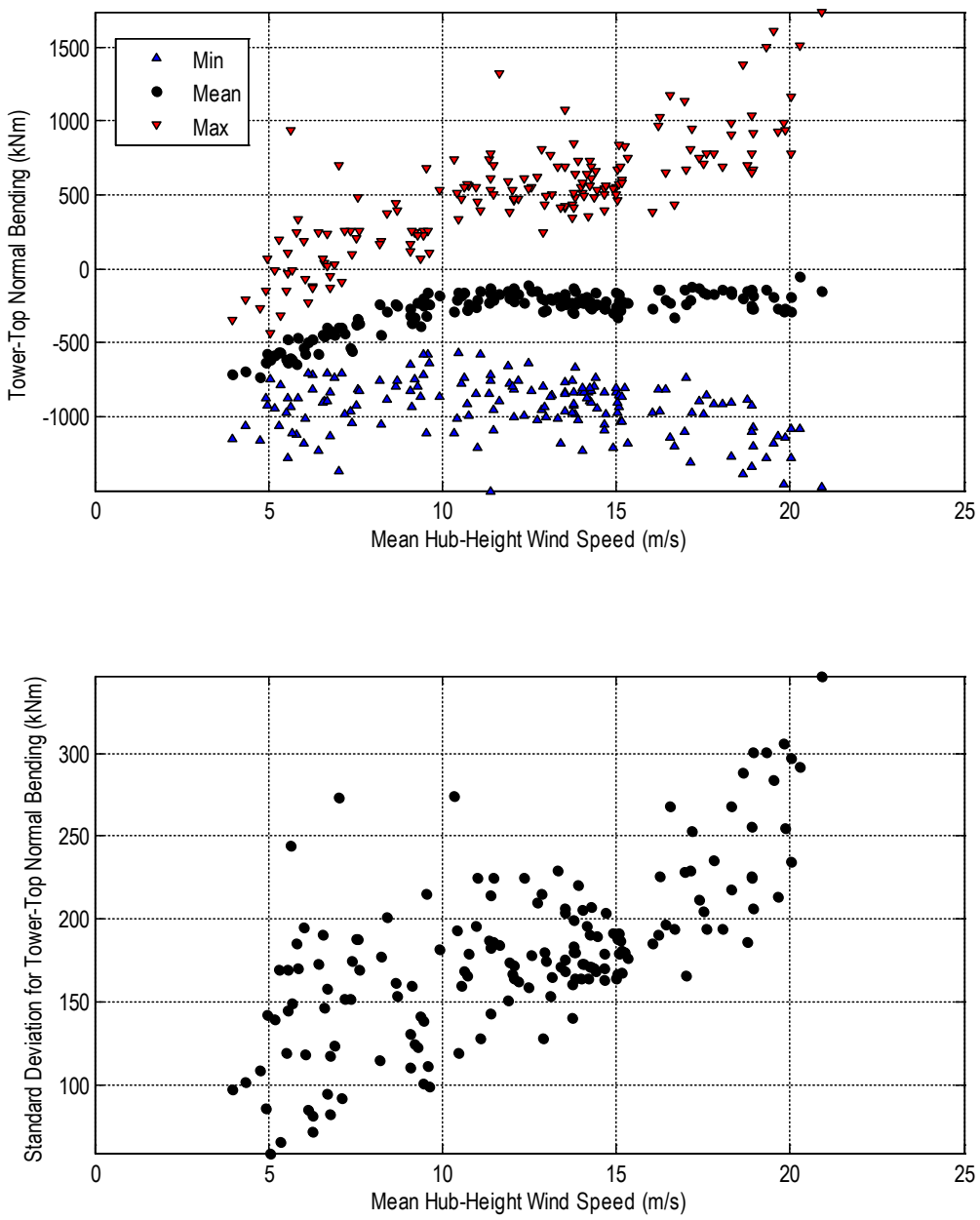


Figure 124. Scatterplot for tower-top normal bending

Table 63. Binned Data for Tower-Top Normal Bending

Bin #	Bin WS Low	Bin WS High	Mean WS	# Files	Min of Minimums	Mean of Means	Max of Maximums
1	3.0	4.0	4.0	1	-1,149.02	-716.28	-350.83
2	4.0	5.0	4.8	4	-1,162.59	-660.82	68.41
3	5.0	6.0	5.5	11	-1,281.65	-583.43	937.82
4	6.0	7.0	6.4	15	-1,230.48	-476.05	243.51
5	7.0	8.0	7.3	9	-1,369.73	-424.89	696.37
6	8.0	9.0	8.4	6	-1,051.03	-285.59	441.34
7	9.0	10.0	9.4	13	-1,109.53	-277.42	679.54
8	10.0	11.0	10.6	10	-1,107.21	-211.04	735.18
9	11.0	12.0	11.4	16	-1,499.59	-181.79	1,320.04
10	12.0	13.0	12.5	13	-1,024.09	-195.90	803.47
11	13.0	14.0	13.6	17	-1,182.11	-222.13	1,066.83
12	14.0	15.0	14.4	23	-1,225.21	-231.04	722.32
13	15.0	16.0	15.1	9	-1,177.88	-242.16	835.63
14	16.0	17.0	16.5	8	-1,199.30	-203.89	1,170.32
15	17.0	18.0	17.4	8	-1,303.56	-173.17	944.11
16	18.0	19.0	18.7	10	-1,384.30	-194.29	1,380.01
17	19.0	20.0	19.6	6	-1,450.50	-217.58	1,602.27
18	20.0	21.0	20.4	7	-1,478.13	-155.51	1,737.26
19	21.0	22.0	0.0	0	0.00	0.00	0.00
20	22.0	23.0	0.0	0	0.00	0.00	0.00
21	23.0	24.0	0.0	0	0.00	0.00	0.00
22	24.0	25.0	0.0	0	0.00	0.00	0.00
23	25.0	26.0	0.0	0	0.00	0.00	0.00

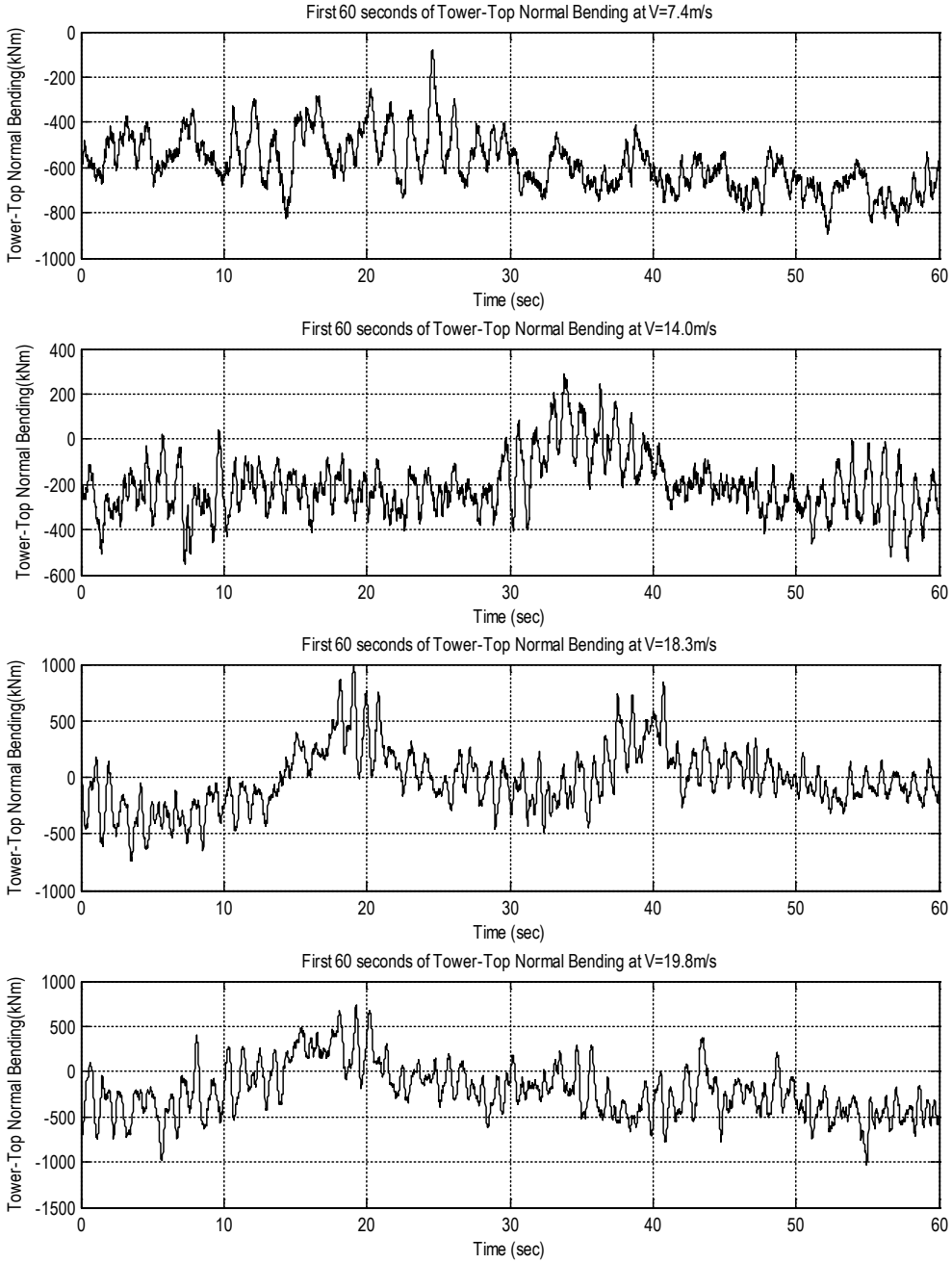


Figure 125. Time series for the first 60 seconds of tower-top normal bending

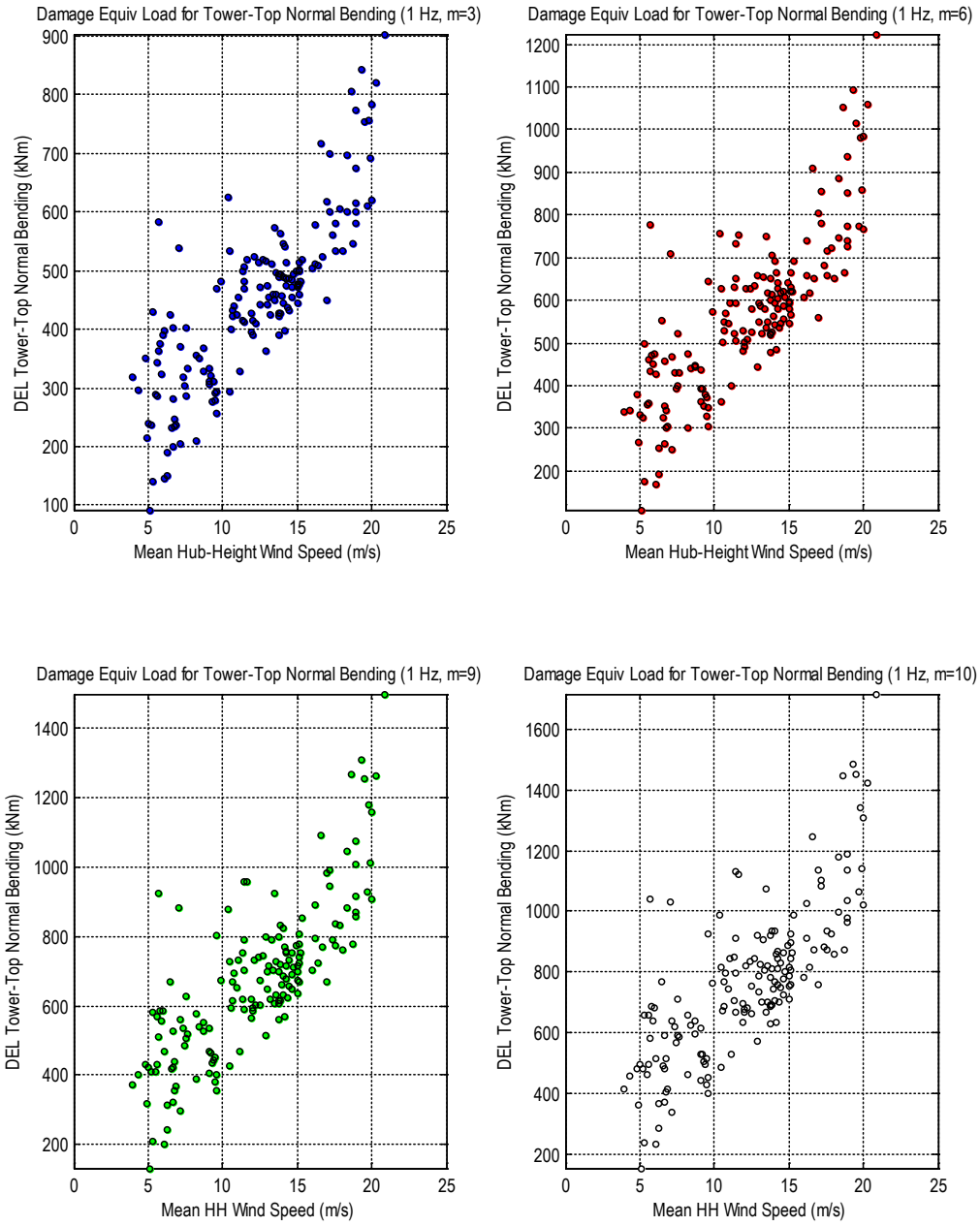


Figure 126. DEL (1 Hz, m=3, 6, 9, 10) for tower-top normal bending

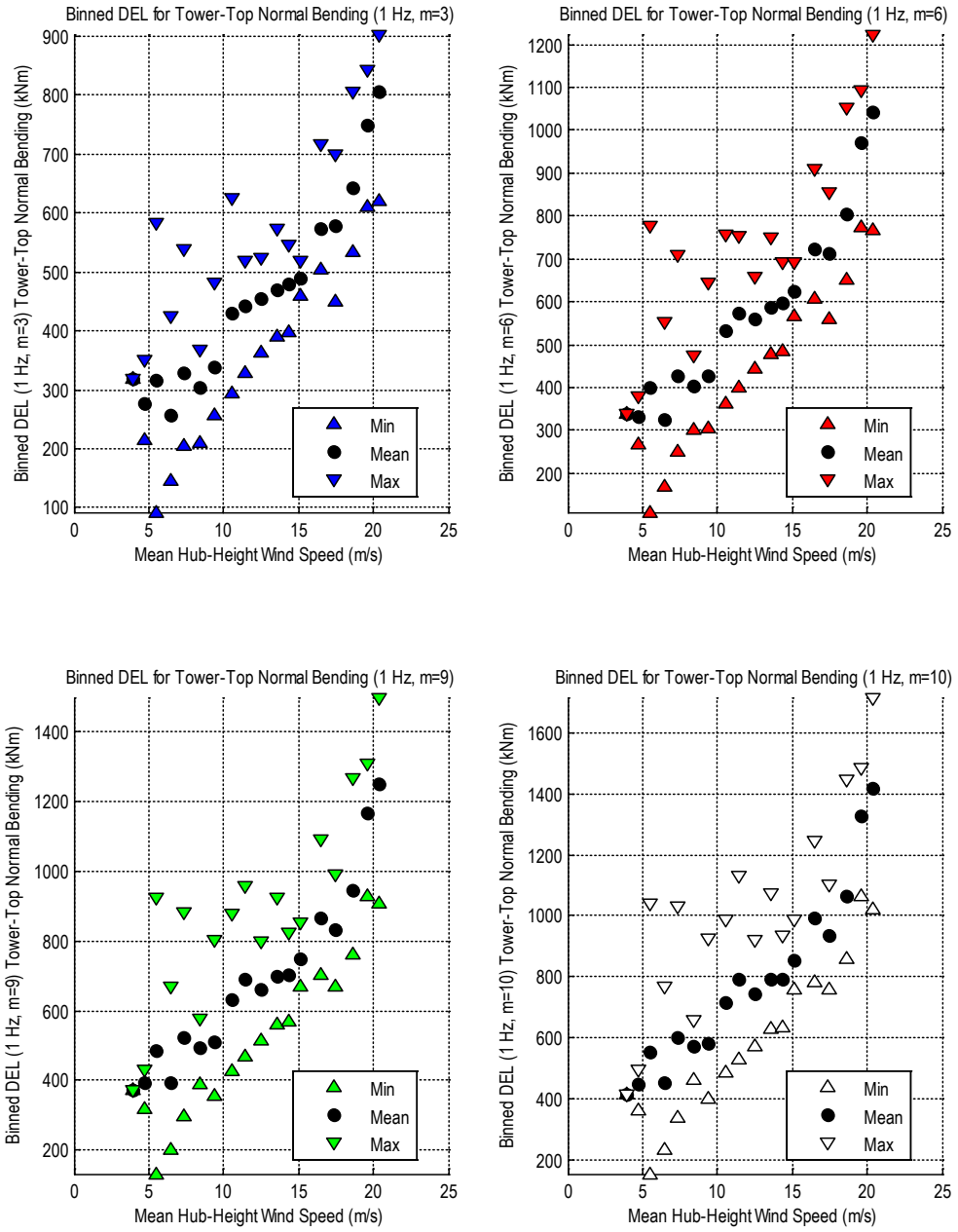


Figure 127. Binned DEL (1 Hz, m=3, 6, 9, 10) for tower-top normal bending

Table 64. Binned DEL Data for Tower-Top Normal Bending

Bin #	Bin WS Low	Bin WS High	Mean WS	# Files	Min of Del (m=3)	Mean of Del (m=3)	Max of Del (m=3)	Min of Del (m=6)	Mean of Del (m=6)	Max of Del (m=6)	Min of Del (m=9)	Mean of Del (m=9)	Max of Del (m=9)
1	3.0	4.0	4.0	1	319.55	319.55	319.55	338.47	338.47	338.47	413.72	413.72	413.72
2	4.0	5.0	4.8	4	215.95	275.74	350.51	268.76	331.54	381.14	362.81	449.28	497.01
3	5.0	6.0	5.5	11	92.56	315.09	582.96	109.58	401.48	777.36	152.84	552.86	1,037.97
4	6.0	7.0	6.4	15	145.08	258.15	424.37	170.31	324.40	552.41	232.73	450.82	766.64
5	7.0	8.0	7.3	9	204.63	329.58	538.63	251.07	428.46	708.30	335.33	601.54	1,030.49
6	8.0	9.0	8.4	6	210.38	303.97	368.04	303.16	402.45	473.28	459.89	572.61	655.16
7	9.0	10.0	9.4	13	256.53	338.95	482.87	306.24	426.53	645.51	399.60	578.86	927.31
8	10.0	11.0	10.6	10	293.65	430.02	625.63	360.99	533.09	755.67	485.27	712.82	986.75
9	11.0	12.0	11.4	16	329.18	442.55	518.43	400.64	572.29	753.30	526.95	791.47	1,130.21
10	12.0	13.0	12.5	13	362.93	455.83	523.77	442.66	560.91	659.64	573.72	745.25	918.74
11	13.0	14.0	13.6	17	390.59	470.71	574.32	476.83	587.89	751.04	630.50	791.20	1,072.33
12	14.0	15.0	14.4	23	397.72	480.07	546.84	485.85	595.59	691.19	635.56	789.71	935.13
13	15.0	16.0	15.1	9	459.61	488.55	518.38	565.98	622.89	692.63	758.05	853.42	985.77
14	16.0	17.0	16.5	8	505.05	573.02	717.41	607.22	723.86	910.32	782.61	989.97	1,245.01
15	17.0	18.0	17.4	8	450.15	579.27	699.17	560.61	712.34	856.84	759.88	935.82	1,101.98
16	18.0	19.0	18.7	10	534.96	643.06	806.53	651.86	802.83	1,050.63	857.21	1,065.20	1,447.78
17	19.0	20.0	19.6	6	609.86	749.75	842.42	772.44	969.10	1,092.84	1,063.22	1,327.31	1,485.24
18	20.0	21.0	20.4	7	620.33	805.43	903.27	768.34	1,042.90	1,223.88	1,021.50	1,416.92	1,717.06
19	21.0	22.0	0.0	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
20	22.0	23.0	0.0	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
21	23.0	24.0	0.0	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
22	24.0	25.0	0.0	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
23	25.0	26.0	0.0	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

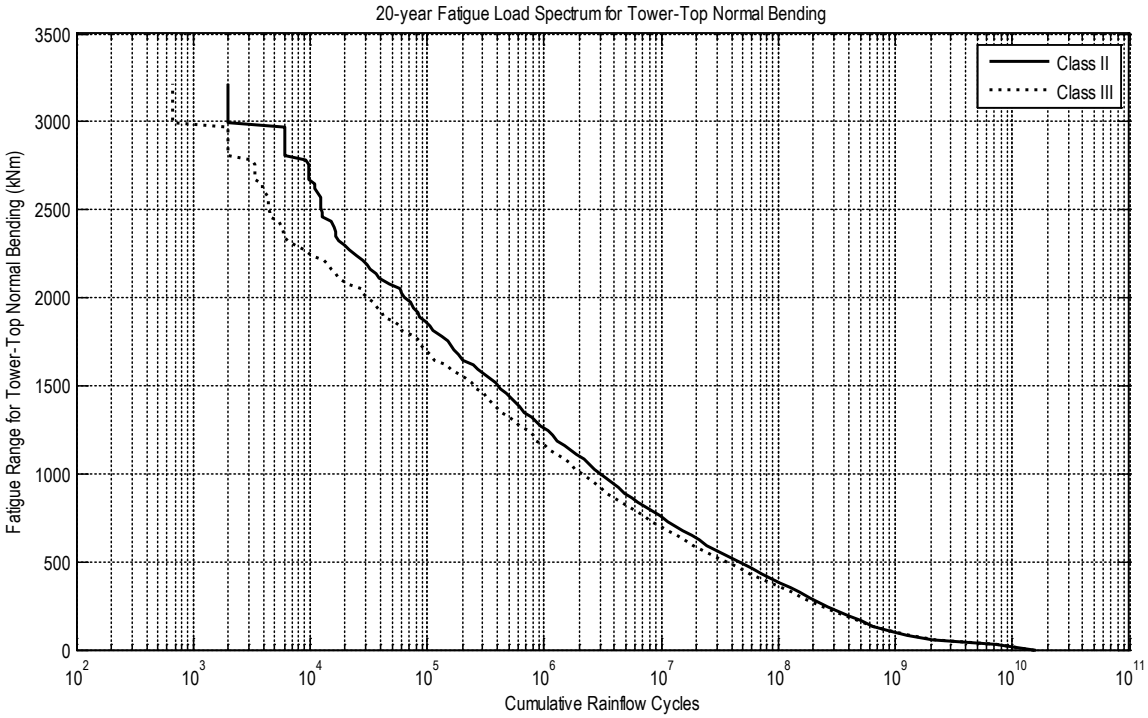


Figure 128. Twenty-year fatigue load spectrum for tower-top normal bending

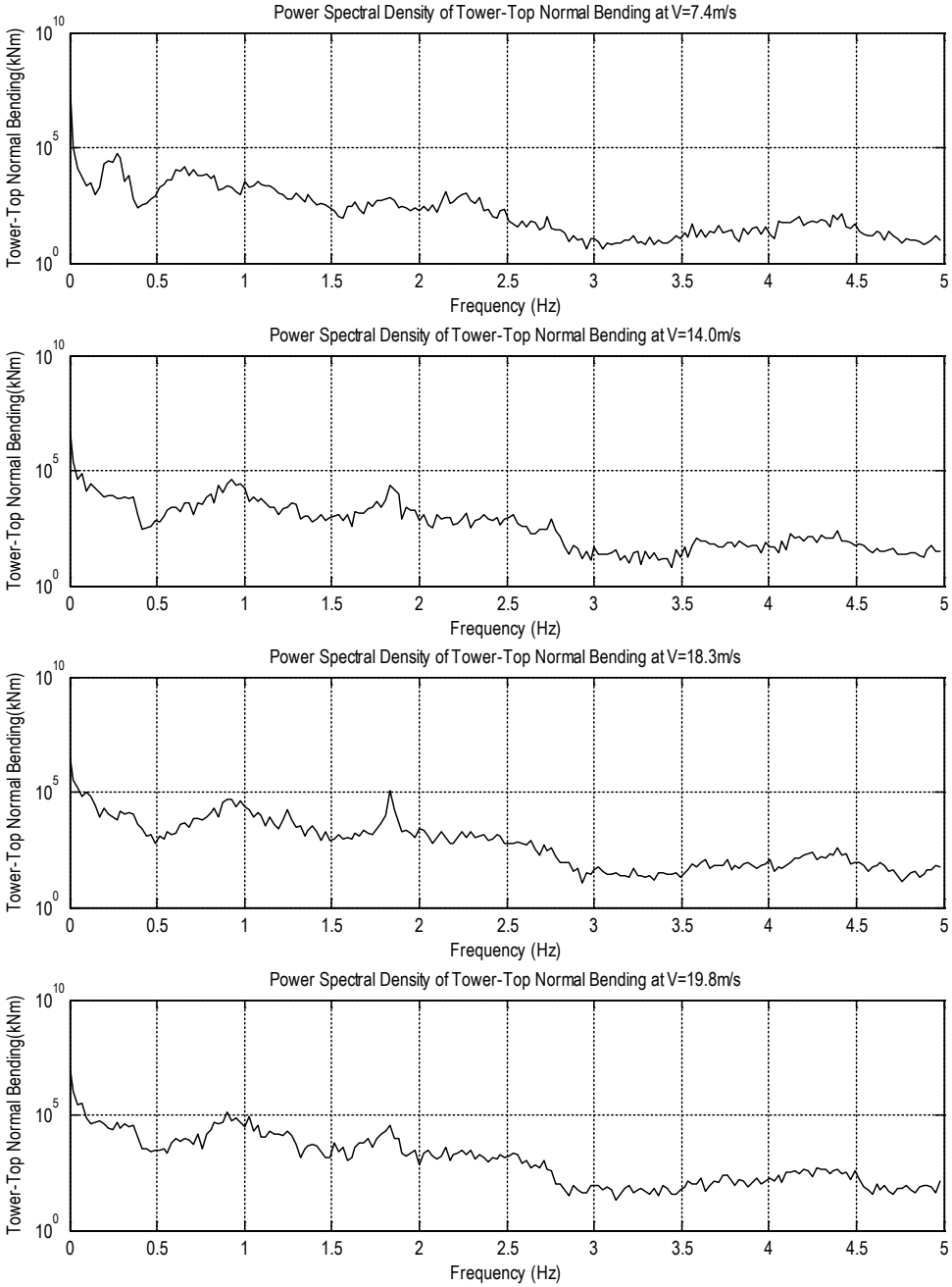


Figure 129. Power spectral density of tower-top normal bending

Tower-Top Lateral Bending

Turbulence Intensity	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-11	11-12	12-13	13-14	14-15	15-16	16-17	17-18	18-19	19-20	20-21	21-22	22-23	23-24	24-25	25-26
29-100%	1	1	8	1	1	0	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
27-29%	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
25-27%	0	1	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
23-25%	0	0	0	0	2	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
21-23%	0	1	0	4	0	1	0	1	4	0	1	1	0	1	0	0	0	0	0	0	0	0	0
19-21%	0	0	0	1	2	2	2	3	3	0	4	0	0	0	0	0	0	0	0	0	0	0	0
17-19%	0	0	0	1	1	0	0	1	4	3	0	3	0	3	1	1	1	2	0	0	0	0	0
15-17%	0	0	1	1	0	1	1	0	0	3	5	6	2	0	2	2	1	2	0	0	0	0	0
13-15%	0	0	1	3	0	0	1	2	2	1	5	5	2	1	2	2	2	0	0	0	0	0	0
11-13%	0	0	0	0	0	0	3	0	0	3	3	6	2	1	2	3	2	0	0	0	0	0	0
9-11%	0	0	0	2	2	0	3	0	0	1	1	2	4	2	1	1	0	1	0	0	0	0	0
7-9%	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
5-7%	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3-5%	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0-3%	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Wind Speed (m/s)

Total Files in Wind Speed Bin

	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-11	11-12	12-13	13-14	14-15	15-16	16-17	17-18	18-19	19-20	20-21	21-22	22-23	23-24	24-25	25-26
# bins with 4 TS	0	0	1	1	0	0	0	0	2	0	3	3	1	0	0	0	0	0	0	0	0	0	0

Wind Speed (m/s)

	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-11	11-12	12-13	13-14	14-15	15-16	16-17	17-18	18-19	19-20	20-21	21-22	22-23	23-24	24-25	25-26
#TS in WS bin	1	4	11	14	9	4	13	9	13	11	19	23	11	8	8	9	6	5	0	0	0	0	0

Wind Speed (m/s)

Figure 130. Capture matrix for tower-top lateral bending

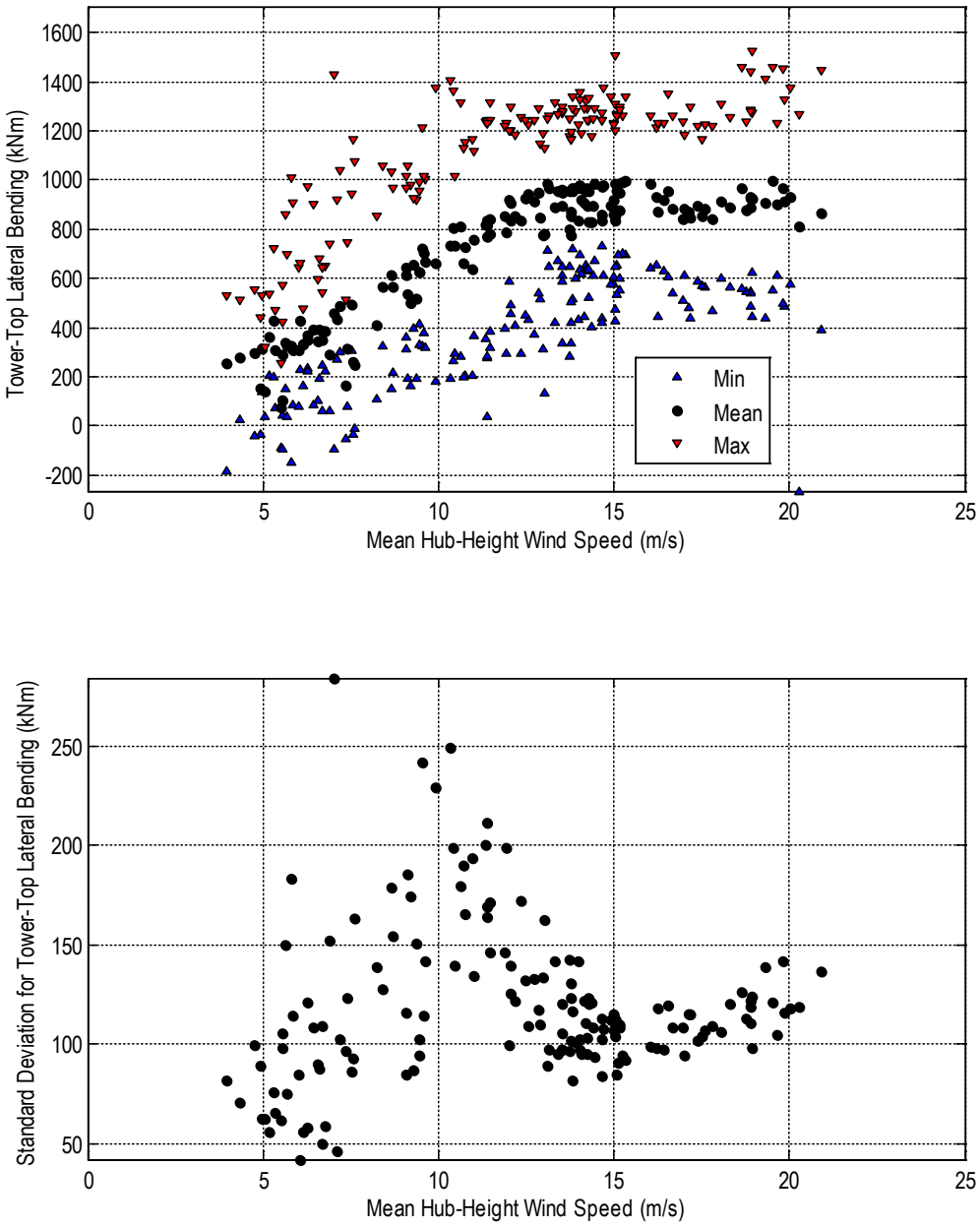


Figure 131. Scatterplot for tower-top lateral bending

Table 65. Binned Data for Tower-Top Lateral Bending

Bin #	Bin WS Low	Bin WS High	Mean WS	# Files	Min of Minimums	Mean of Means	Max of Maximums
1	3.0	4.0	4.0	1	-184.53	255.38	530.89
2	4.0	5.0	4.8	4	-39.03	260.29	551.35
3	5.0	6.0	5.5	11	-148.78	272.90	1,006.87
4	6.0	7.0	6.4	14	59.15	359.12	973.37
5	7.0	8.0	7.3	9	-94.89	365.01	1,427.84
6	8.0	9.0	8.5	4	107.92	539.89	1,055.76
7	9.0	10.0	9.4	13	164.80	630.17	1,374.08
8	10.0	11.0	10.6	9	194.09	738.89	1,402.28
9	11.0	12.0	11.4	13	40.70	804.49	1,311.24
10	12.0	13.0	12.5	11	296.39	881.64	1,298.65
11	13.0	14.0	13.5	19	132.95	905.48	1,337.91
12	14.0	15.0	14.4	23	406.13	917.22	1,372.41
13	15.0	16.0	15.1	11	427.10	921.73	1,506.65
14	16.0	17.0	16.5	8	447.65	902.78	1,348.78
15	17.0	18.0	17.4	8	442.36	863.49	1,700.37
16	18.0	19.0	18.7	9	446.12	914.63	1,522.32
17	19.0	20.0	19.6	6	439.45	930.73	1,455.81
18	20.0	21.0	20.5	5	-264.34	854.58	1,443.12
19	21.0	22.0	0.0	0	0.00	0.00	0.00
20	22.0	23.0	0.0	0	0.00	0.00	0.00
21	23.0	24.0	0.0	0	0.00	0.00	0.00
22	24.0	25.0	0.0	0	0.00	0.00	0.00
23	25.0	26.0	0.0	0	0.00	0.00	0.00

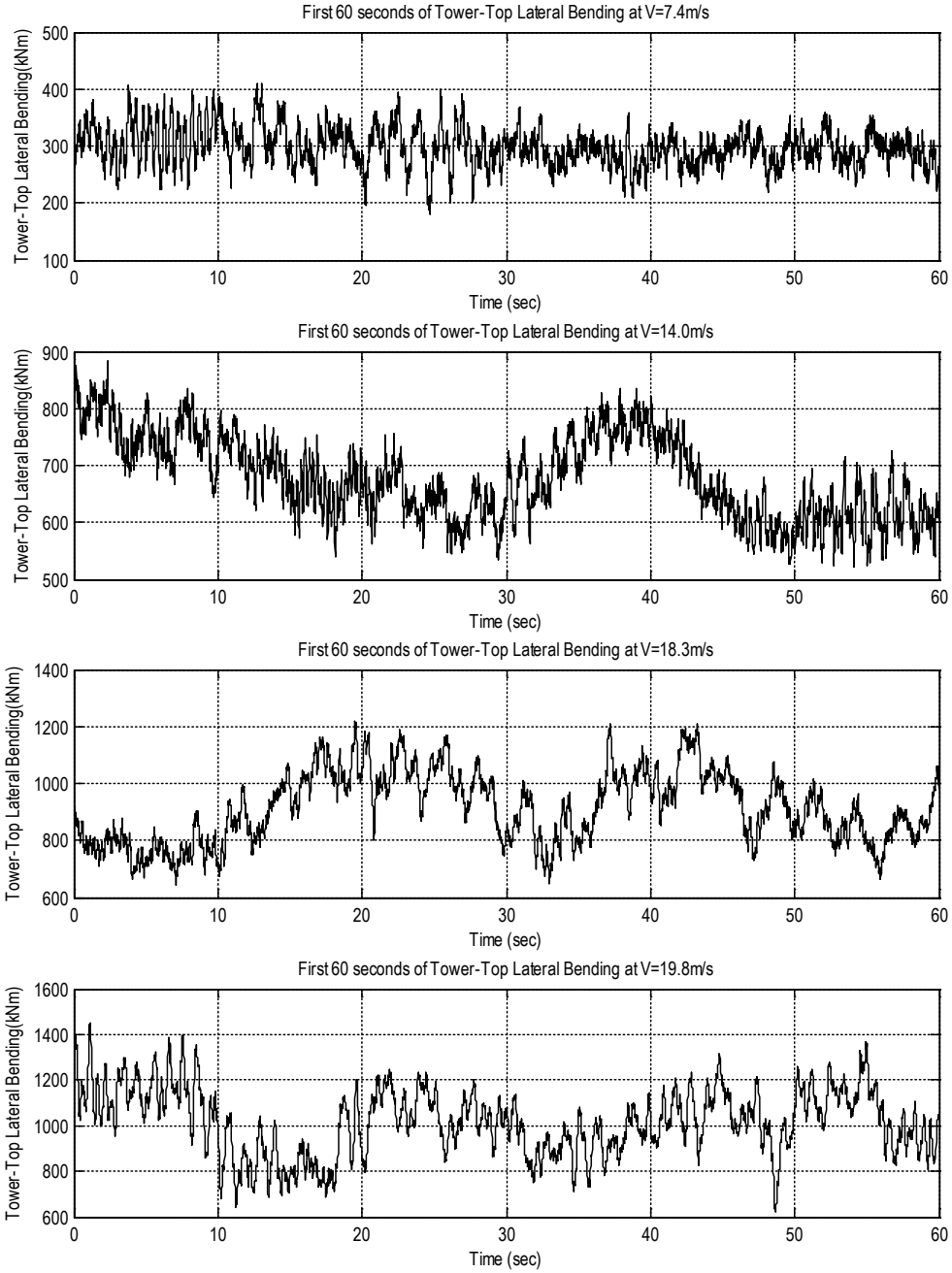


Figure 132. Time series for the first 60 seconds of tower-top lateral bending

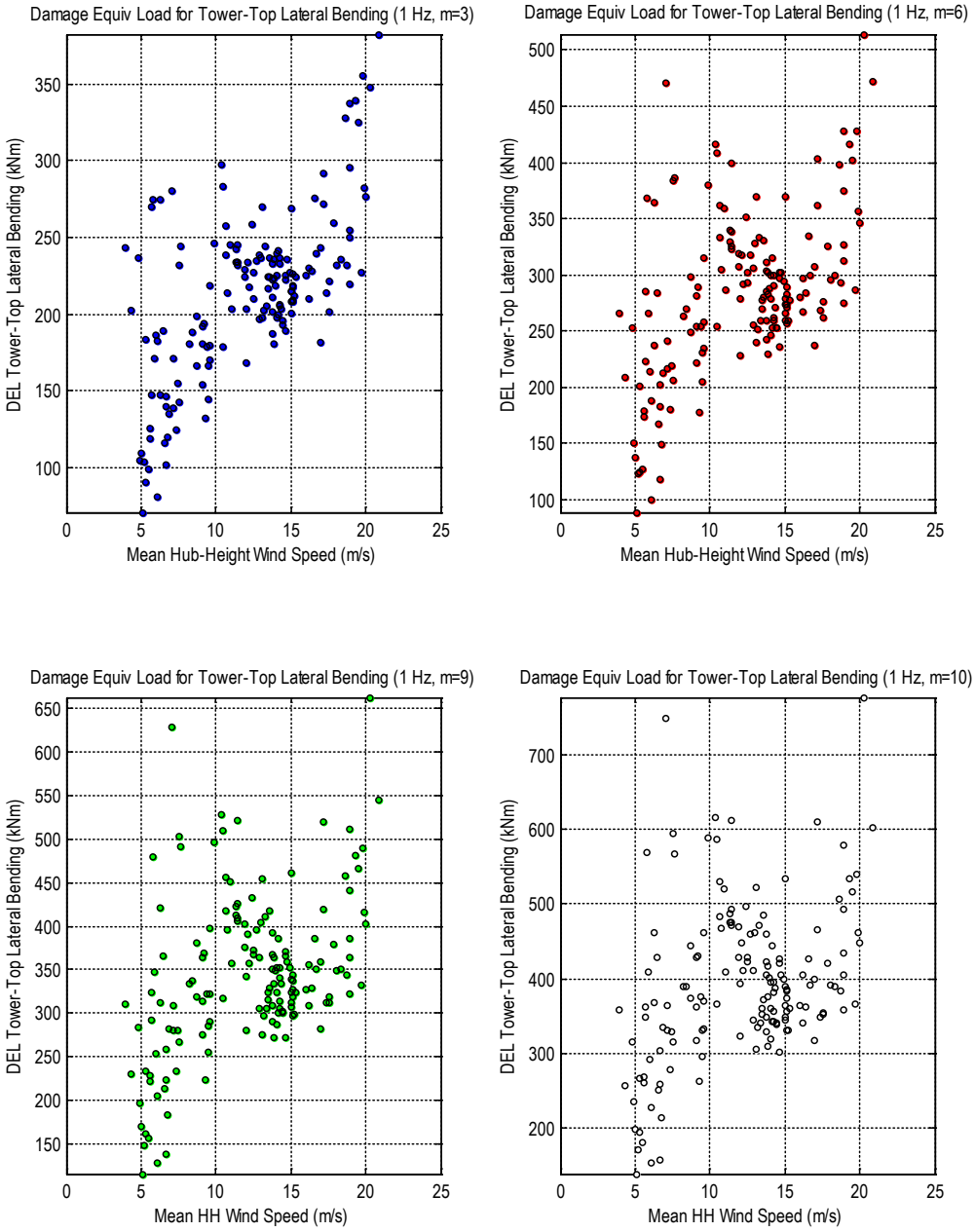


Figure 133. DEL (1 Hz, m=3, 6, 9, 10) for tower-top lateral bending

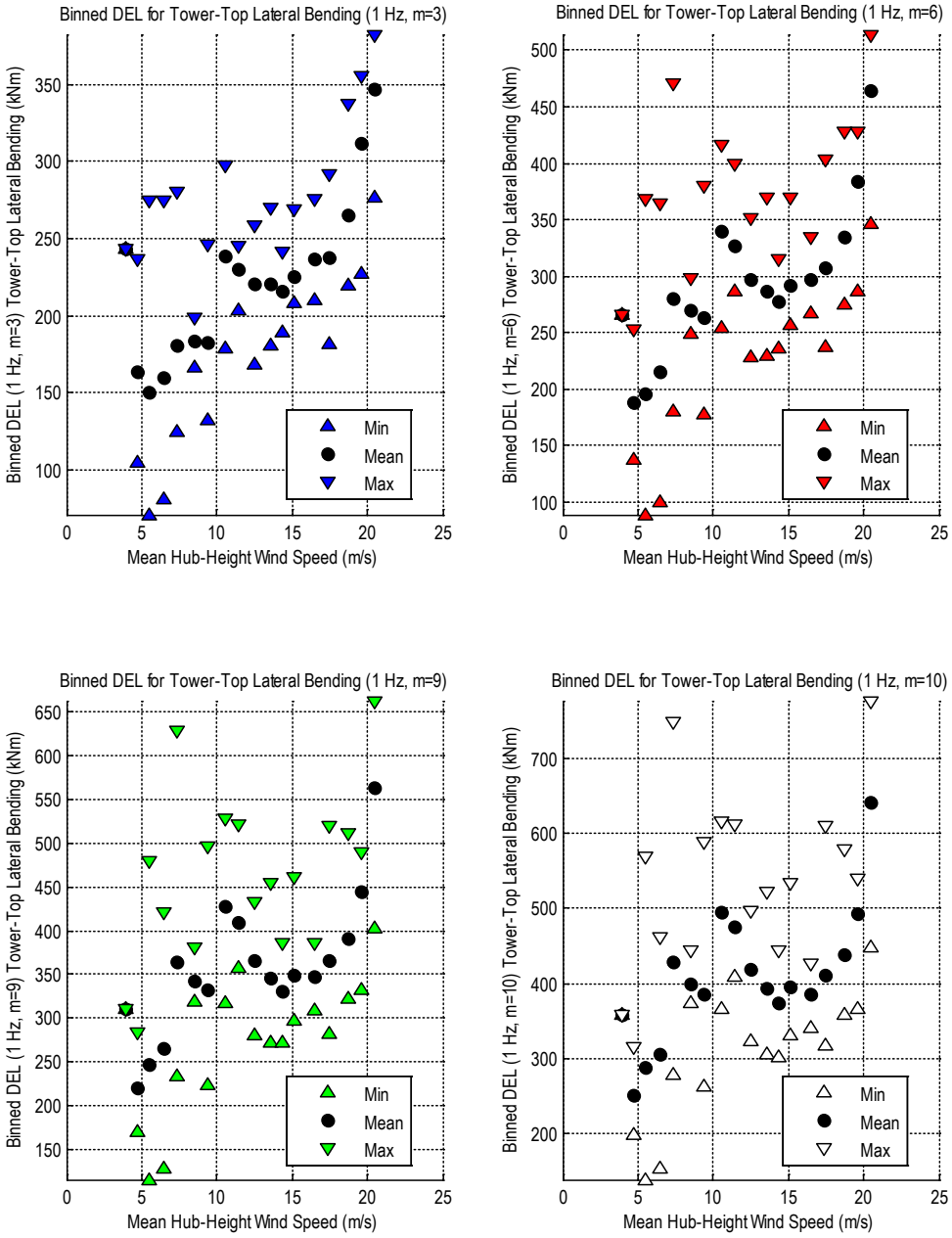


Figure 134. Binned DEL (1 Hz, m=3, 6, 9, 10) for tower-top lateral bending

Table 66. Binned DEL Data for Tower-Top Lateral Bending

Bin #	Bin WS Low	Bin WS High	Mean WS	# Files	Min of Del (m=3)	Mean of Del (m=3)	Max of Del (m=3)	Min of Del (m=6)	Mean of Del (m=6)	Max of Del (m=6)	Min of Del (m=9)	Mean of Del (m=9)	Max of Del (m=9)
1	3.0	4.0	4.0	1	243.82	243.82	243.82	265.77	265.77	265.77	357.69	357.69	357.69
2	4.0	5.0	4.8	4	104.68	163.41	237.11	138.15	187.53	253.53	198.62	251.52	315.99
3	5.0	6.0	5.5	11	70.72	150.39	274.92	88.89	196.20	368.17	138.41	288.14	569.65
4	6.0	7.0	6.4	14	80.82	160.05	274.28	99.96	215.80	364.19	153.96	305.64	461.28
5	7.0	8.0	7.3	9	124.45	180.90	280.81	179.84	279.99	470.22	277.74	428.92	749.46
6	8.0	9.0	8.5	4	166.08	183.32	198.63	248.78	269.82	298.03	373.16	399.05	444.78
7	9.0	10.0	9.4	13	132.54	182.69	246.32	178.19	262.87	379.58	262.14	385.92	587.95
8	10.0	11.0	10.6	9	178.34	238.88	297.12	254.17	339.56	416.74	365.51	495.87	615.04
9	11.0	12.0	11.4	13	203.54	230.18	245.30	287.12	326.43	399.64	409.65	474.42	611.82
10	12.0	13.0	12.5	11	168.11	220.46	258.76	228.69	297.39	351.49	322.46	418.27	496.85
11	13.0	14.0	13.5	19	180.77	220.61	269.87	229.31	287.15	369.14	305.43	393.02	521.43
12	14.0	15.0	14.4	23	188.81	215.88	241.35	235.72	277.15	315.01	301.15	373.57	443.82
13	15.0	16.0	15.1	11	208.17	225.65	268.61	257.03	291.16	369.49	330.54	394.72	533.75
14	16.0	17.0	16.5	8	210.47	237.08	276.02	266.63	297.08	335.00	341.19	386.21	426.91
15	17.0	18.0	17.4	8	181.63	237.76	292.07	237.19	307.61	402.94	317.10	410.91	610.83
16	18.0	19.0	18.7	9	219.76	264.93	337.74	275.50	333.98	427.86	358.72	437.94	578.62
17	19.0	20.0	19.6	6	227.11	311.71	355.54	286.04	384.06	428.44	366.32	492.29	540.76
18	20.0	21.0	20.5	5	277.02	347.49	382.69	346.21	463.93	514.11	447.99	641.33	777.17
19	21.0	22.0	0.0	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
20	22.0	23.0	0.0	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
21	23.0	24.0	0.0	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
22	24.0	25.0	0.0	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
23	25.0	26.0	0.0	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

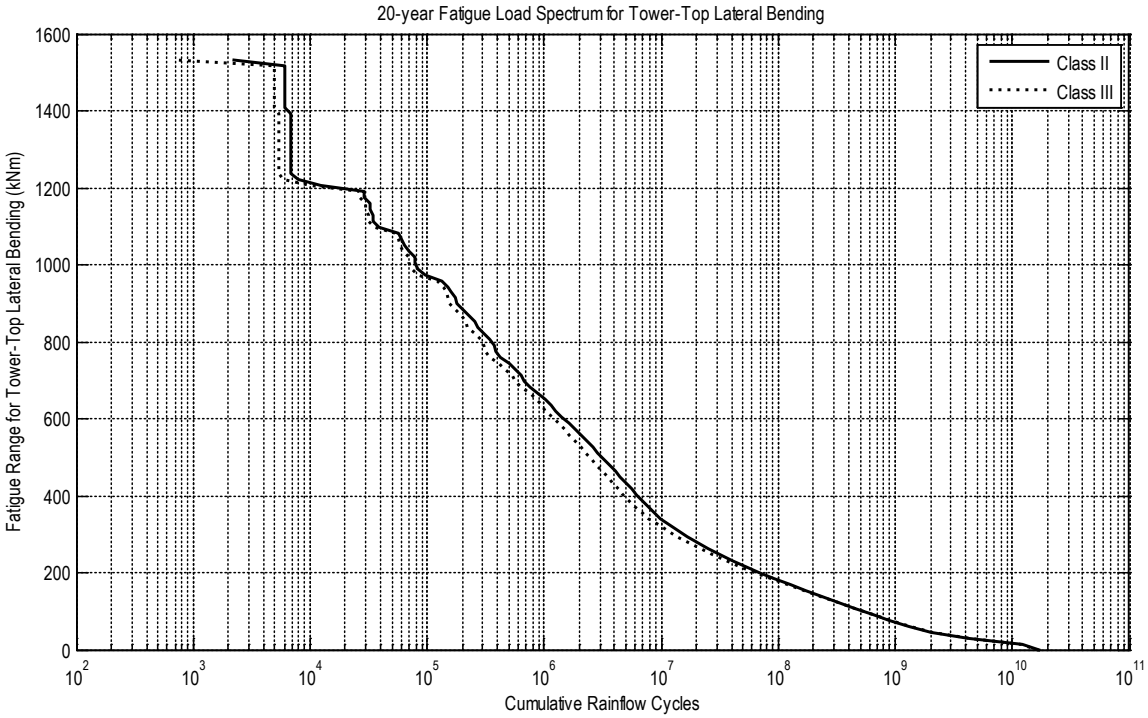


Figure 135. Twenty-year fatigue load spectrum for tower-top lateral bending

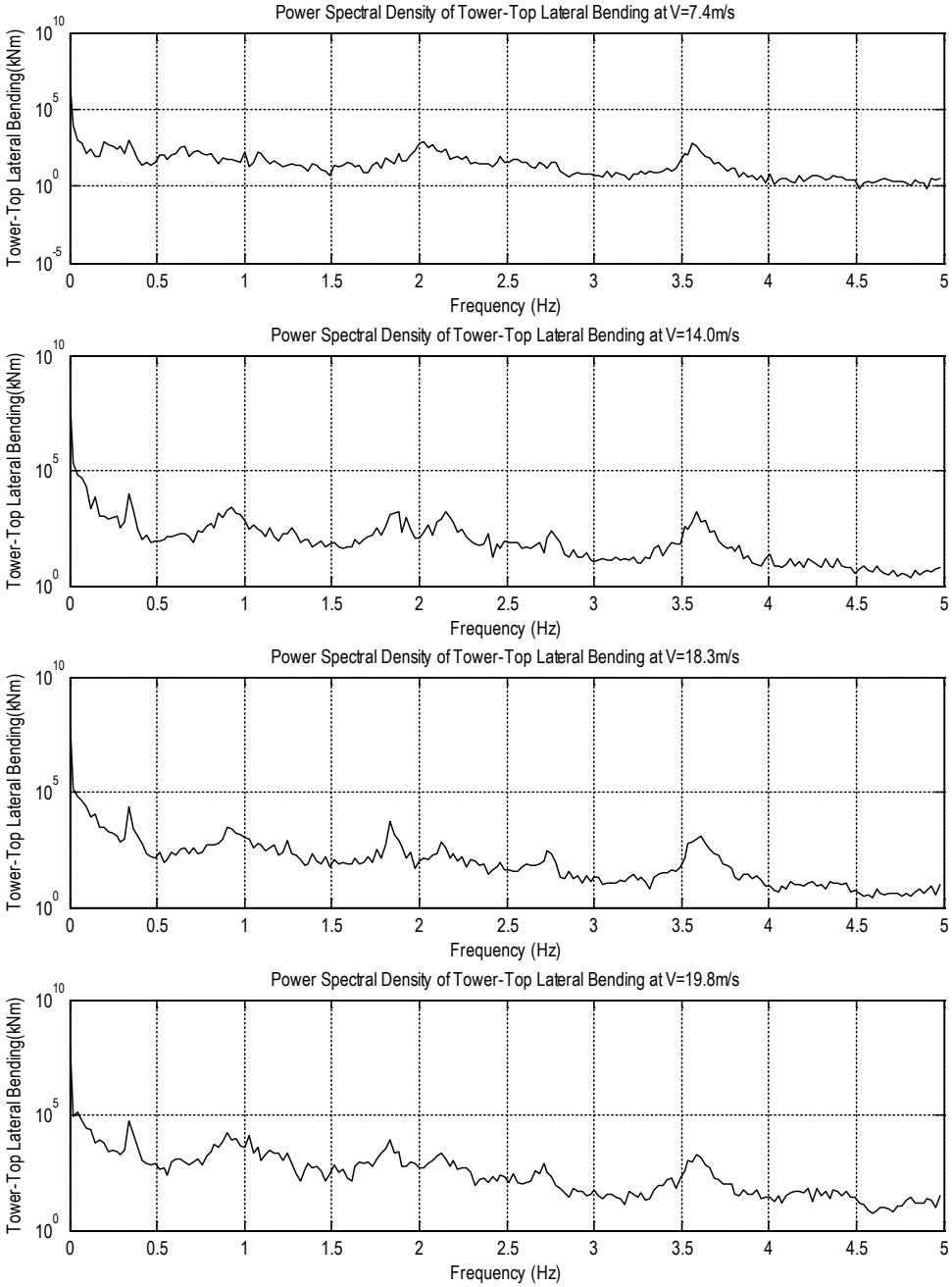


Figure 136. Power spectral density of tower-top lateral bending

Tower-Top Torque

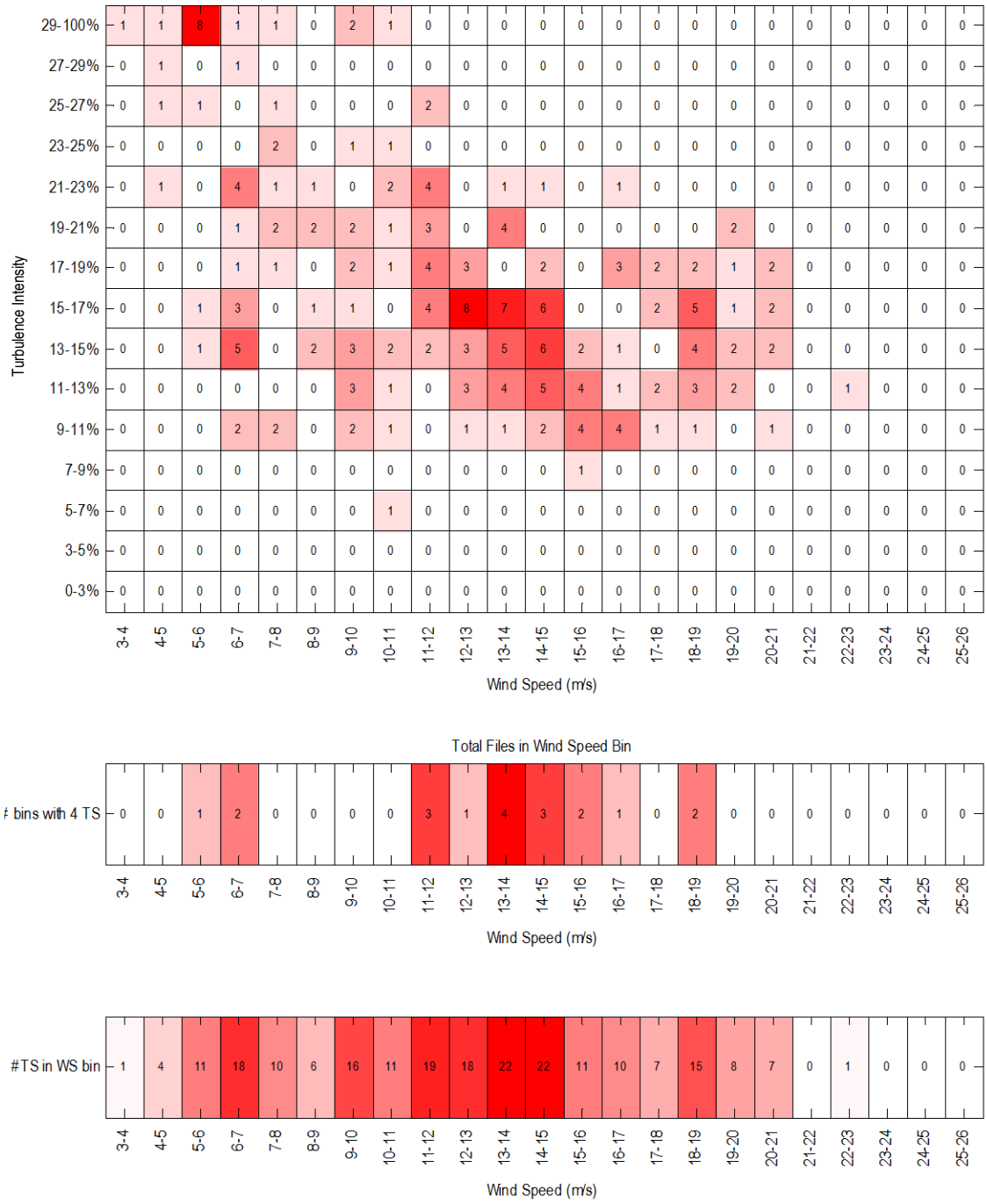


Figure 137. Capture matrix for tower-top torque

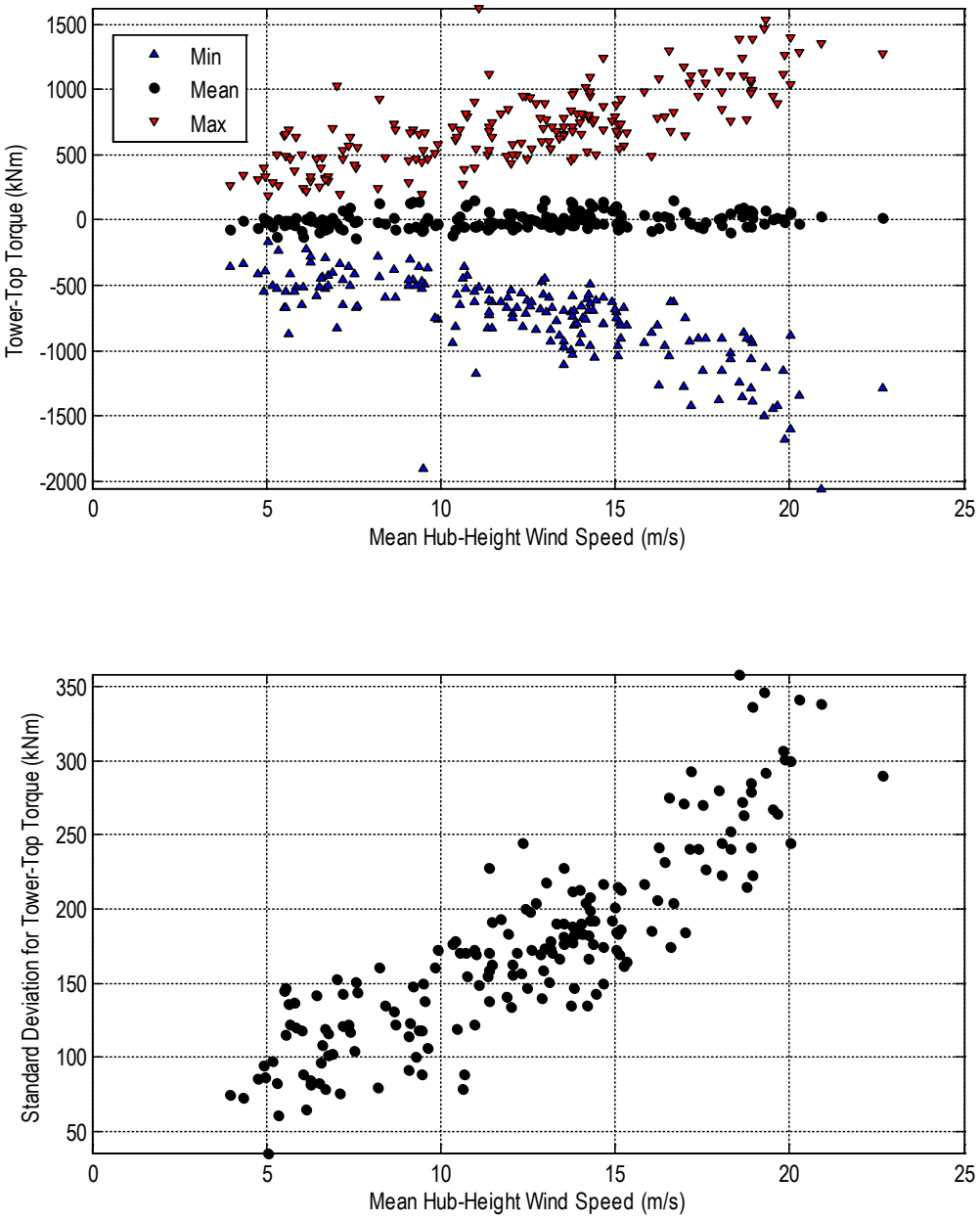


Figure 138. Scatterplot for tower-top torque

Table 67. Binned Data for Tower-Top Torque

Bin #	Bin WS Low	Bin WS High	Mean WS	# Files	Min of Minimums	Mean of Means	Max of Maximums
1	3.0	4.0	4.0	1	-356.57	-71.94	263.82
2	4.0	5.0	4.8	4	-546.97	-19.57	401.35
3	5.0	6.0	5.5	11	-868.08	-25.85	685.55
4	6.0	7.0	6.5	18	-648.75	-36.43	697.05
5	7.0	8.0	7.3	10	-825.02	-17.74	1,029.92
6	8.0	9.0	8.4	6	-587.75	3.39	929.04
7	9.0	10.0	9.5	16	-1,900.59	-11.50	688.31
8	10.0	11.0	10.6	11	-933.12	7.80	904.04
9	11.0	12.0	11.4	19	-1,177.87	-10.43	1,626.87
10	12.0	13.0	12.5	18	-841.47	5.26	945.90
11	13.0	14.0	13.5	22	-1,107.94	1.08	986.10
12	14.0	15.0	14.3	22	-1,045.35	28.97	1,243.75
13	15.0	16.0	15.3	11	-1,037.72	-5.77	981.68
14	16.0	17.0	16.5	10	-1,275.80	11.77	1,291.35
15	17.0	18.0	17.4	7	-1,415.25	-15.42	1,144.16
16	18.0	19.0	18.6	15	-1,388.47	30.15	1,389.20
17	19.0	20.0	19.5	8	-1,675.66	12.00	1,536.01
18	20.0	21.0	20.4	7	-2,054.04	22.87	1,397.90
19	21.0	22.0	0.0	0	0.00	0.00	0.00
20	22.0	23.0	22.7	1	-1,287.86	12.37	1,269.62
21	23.0	24.0	0.0	0	0.00	0.00	0.00
22	24.0	25.0	0.0	0	0.00	0.00	0.00
23	25.0	26.0	0.0	0	0.00	0.00	0.00

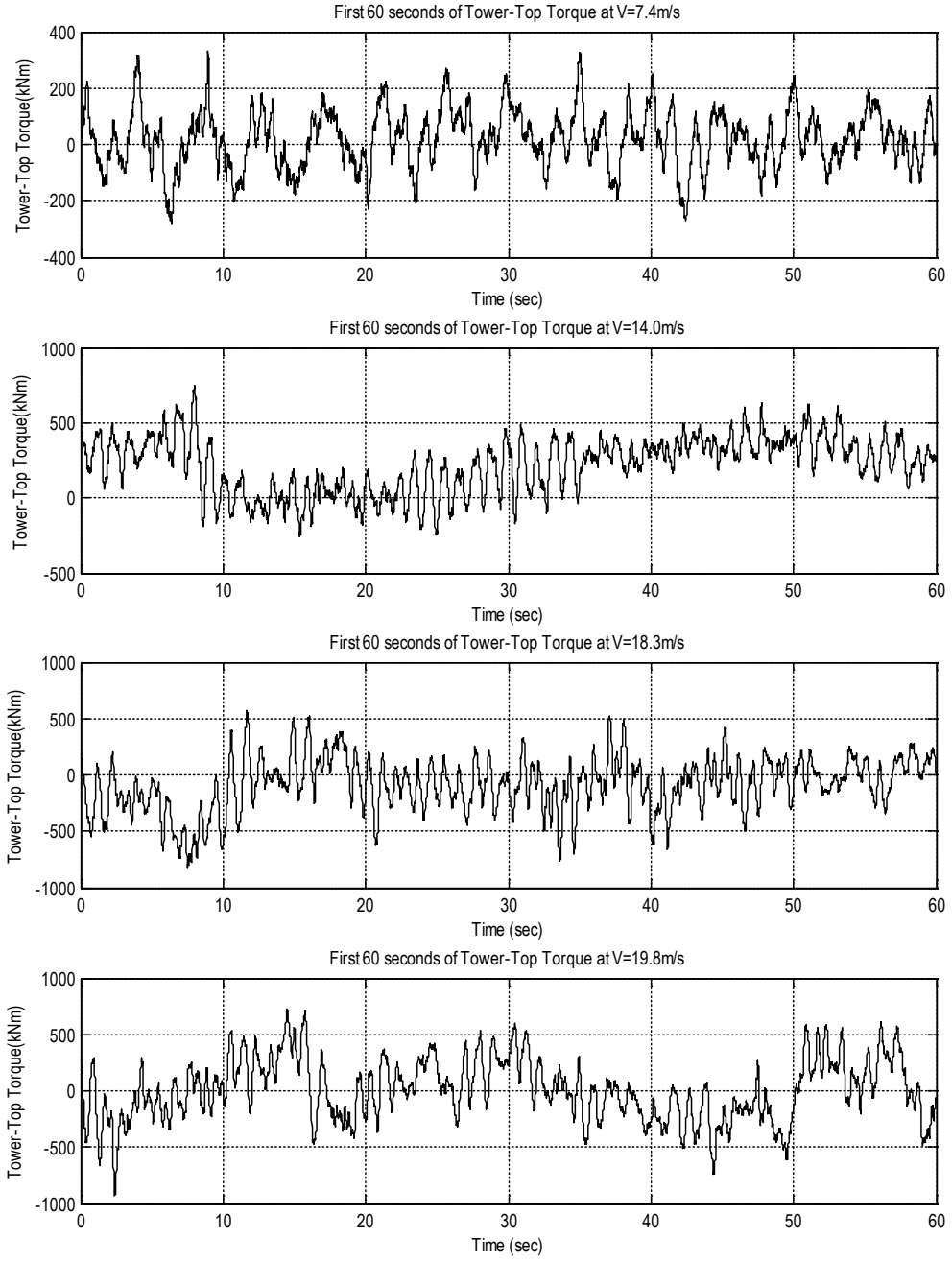


Figure 139. Time series for the first 60 seconds of tower-top torque

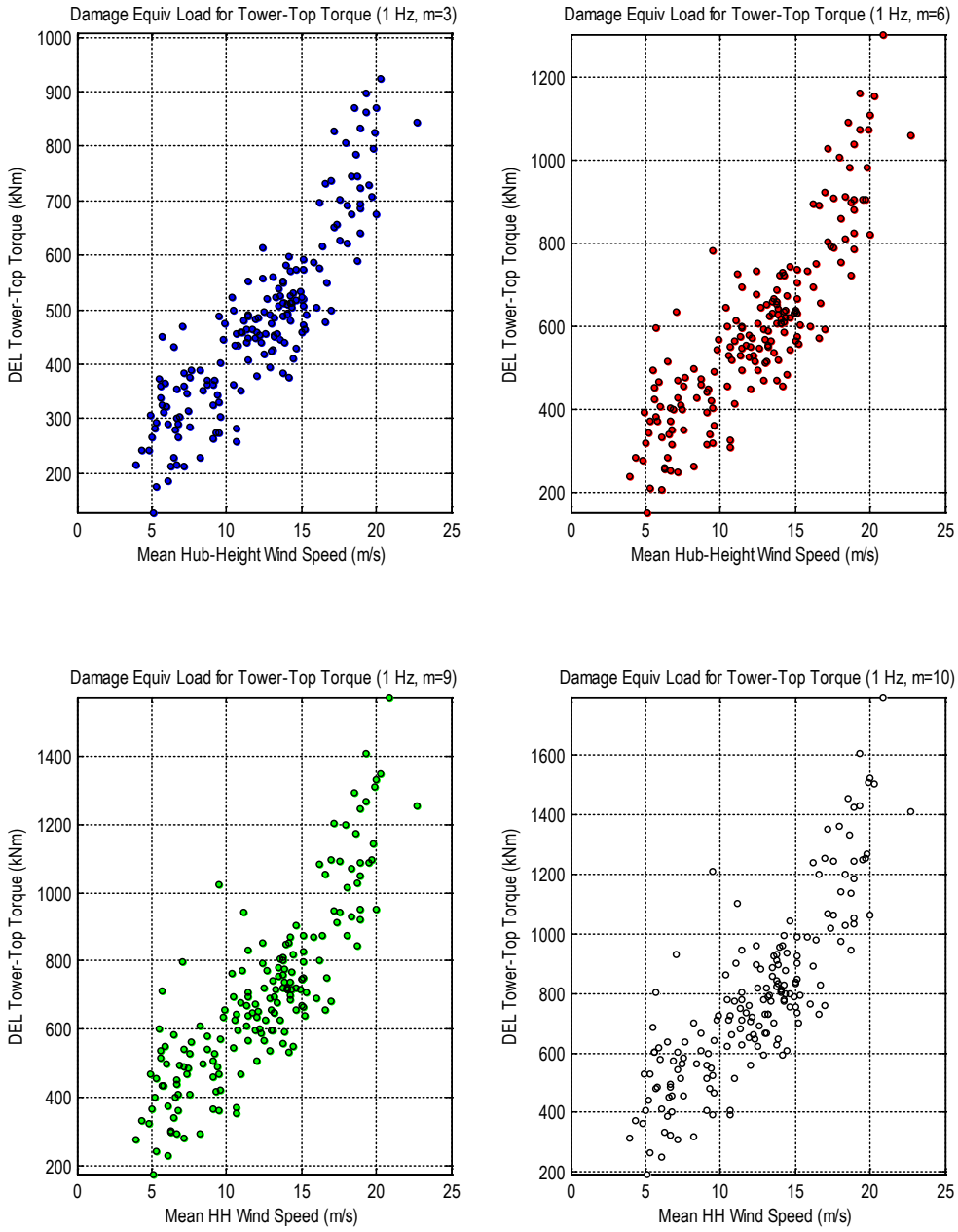


Figure 140. DEL (1 Hz, m=3, 6, 9, 10) for tower-top torque

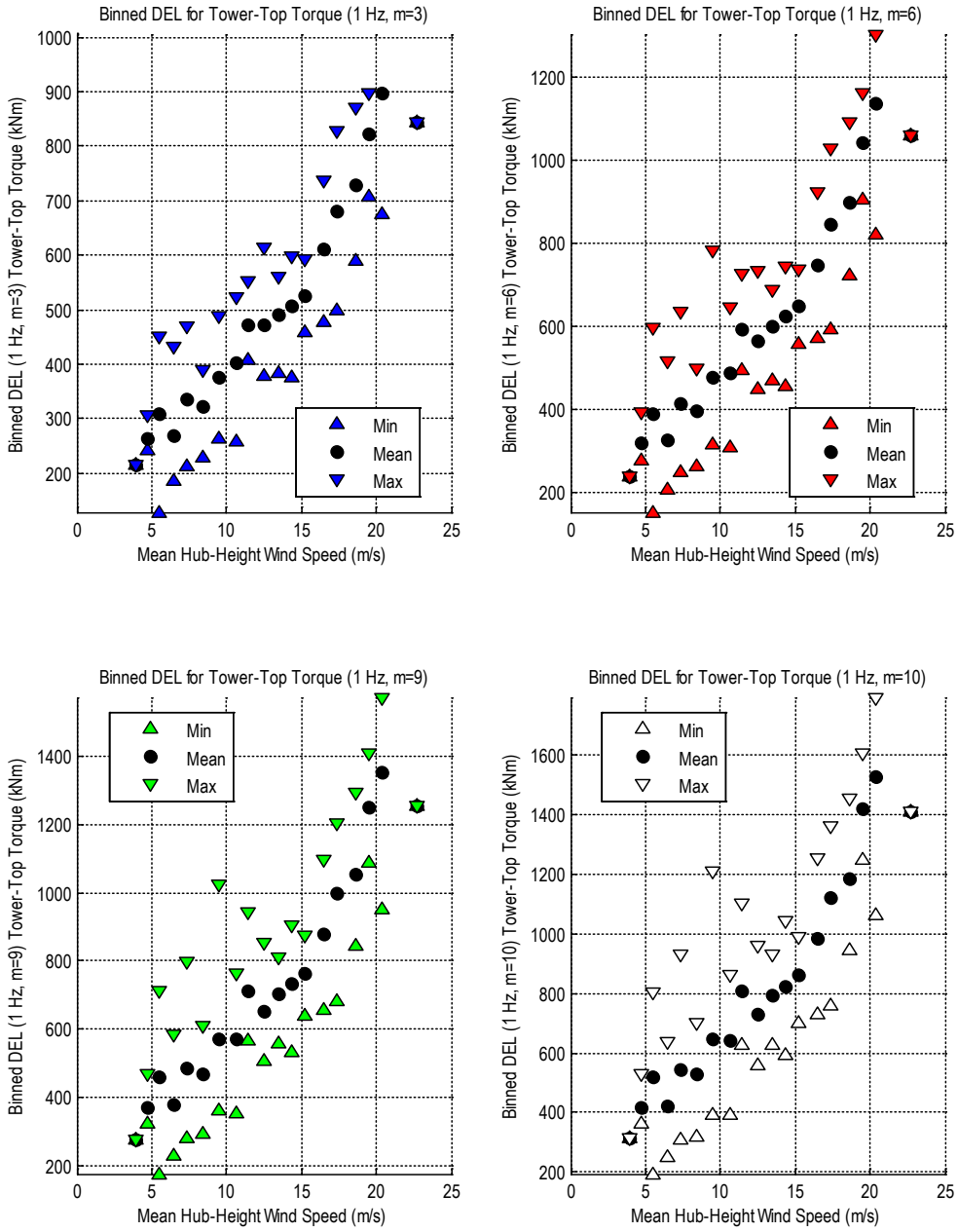


Figure 141. Binned DEL (1 Hz, m=3, 6, 9, 10) for tower-top torque

Table 68. Binned DEL Data for Tower-Top Torque

Bin #	Bin WS Low	Bin WS High	Mean WS	# Files	Min of Del (m=3)	Mean of Del (m=3)	Max of Del (m=3)	Min of Del (m=6)	Mean of Del (m=6)	Max of Del (m=6)	Min of Del (m=9)	Mean of Del (m=9)	Max of Del (m=9)
1	3.0	4.0	4.0	1	215.48	215.48	215.48	240.09	240.09	240.09	312.78	312.78	312.78
2	4.0	5.0	4.8	4	241.55	263.98	305.99	277.47	318.46	393.25	363.17	417.10	530.53
3	5.0	6.0	5.5	11	128.40	309.59	452.04	152.86	388.07	597.33	193.34	518.91	804.50
4	6.0	7.0	6.5	18	186.16	268.71	431.55	208.78	325.38	514.46	247.95	423.23	635.65
5	7.0	8.0	7.3	10	213.77	335.57	469.36	248.87	412.99	636.66	308.32	544.46	929.79
6	8.0	9.0	8.4	6	229.39	322.05	388.53	263.19	397.50	497.63	319.70	529.46	700.16
7	9.0	10.0	9.5	16	264.11	374.72	488.74	316.21	478.48	781.35	393.99	646.40	1,212.25
8	10.0	11.0	10.6	11	259.26	402.48	523.39	309.42	488.89	646.48	389.66	642.02	862.24
9	11.0	12.0	11.4	19	408.58	471.72	552.36	494.03	595.01	727.71	629.06	806.53	1,103.75
10	12.0	13.0	12.5	18	379.34	471.47	612.78	448.36	565.77	735.18	558.10	729.37	959.28
11	13.0	14.0	13.5	22	385.26	490.68	559.92	471.11	599.55	688.47	628.72	795.40	932.65
12	14.0	15.0	14.3	22	375.66	507.74	596.90	455.21	623.52	742.76	595.18	823.92	1,043.12
13	15.0	16.0	15.3	11	457.86	524.74	593.42	557.79	649.54	738.23	701.55	861.21	991.38
14	16.0	17.0	16.5	10	478.89	610.94	737.51	571.32	748.17	922.34	728.05	986.26	1,252.13
15	17.0	18.0	17.4	7	498.36	681.70	828.92	593.99	846.76	1,028.42	760.37	1,123.78	1,361.00
16	18.0	19.0	18.6	15	590.35	728.03	871.14	722.27	897.68	1,093.56	946.89	1,183.42	1,454.30
17	19.0	20.0	19.5	8	707.20	822.14	897.45	906.37	1,043.18	1,162.12	1,247.21	1,420.07	1,609.29
18	20.0	21.0	20.4	7	676.68	897.18	1,006.01	820.02	1,136.56	1,304.21	1,063.22	1,530.26	1,795.85
19	21.0	22.0	0.0	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
20	22.0	23.0	22.7	1	844.87	844.87	844.87	1,060.92	1,060.92	1,060.92	1,413.01	1,413.01	1,413.01
21	23.0	24.0	0.0	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
22	24.0	25.0	0.0	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
23	25.0	26.0	0.0	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

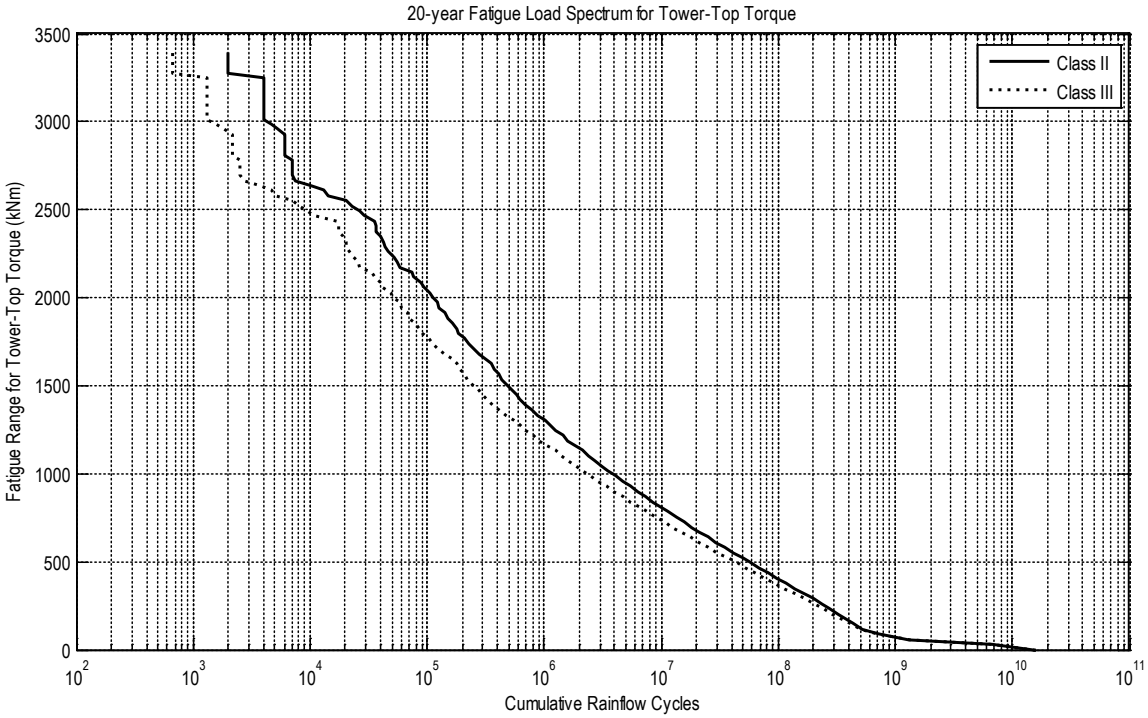


Figure 142. Twenty-year fatigue load spectrum for tower-top torque

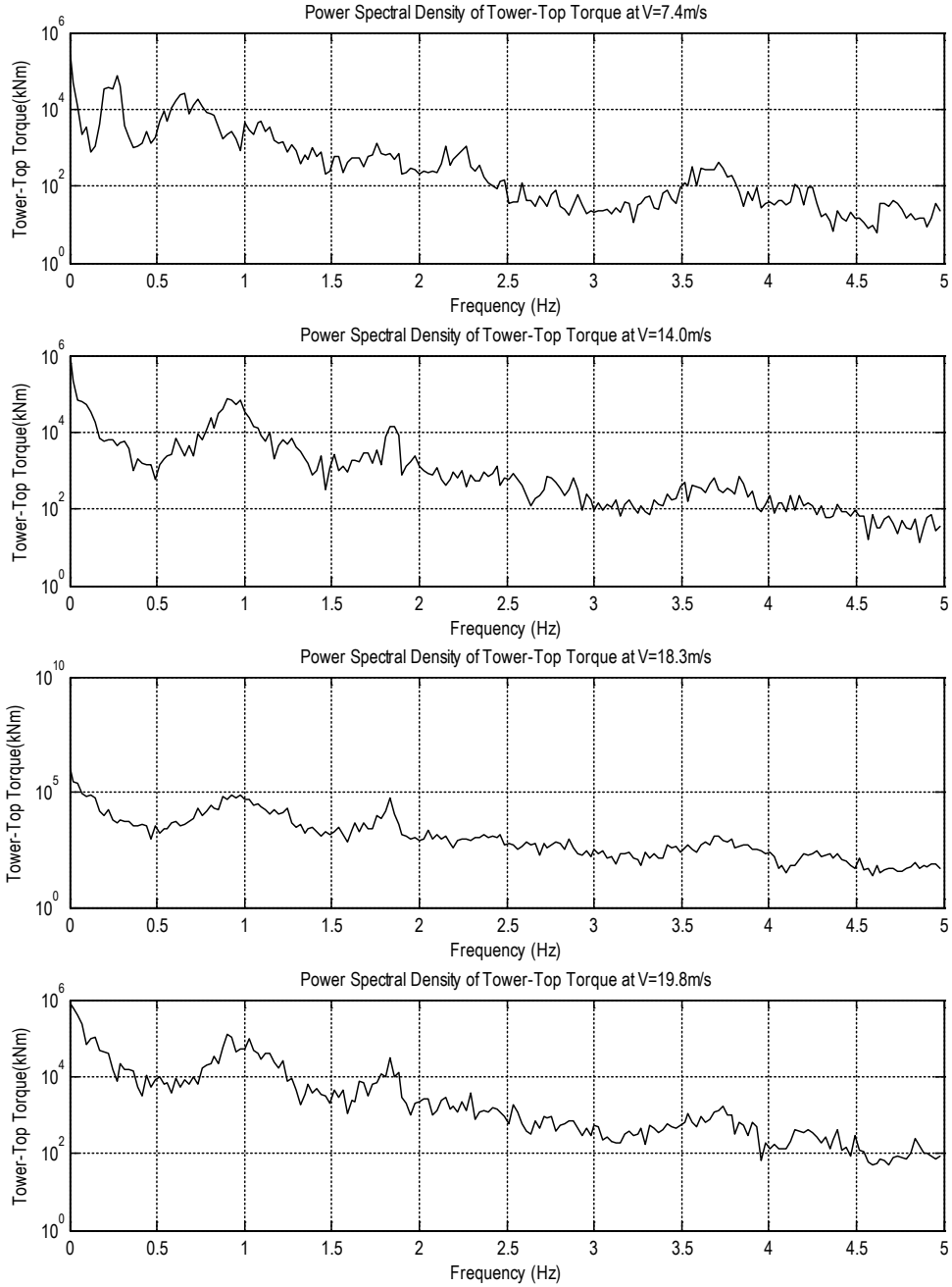


Figure 143. Power spectral density of tower-top torque

Tower-Base Normal Bending

Turbulence Intensity	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-11	11-12	12-13	13-14	14-15	15-16	16-17	17-18	18-19	19-20	20-21	21-22	22-23	23-24	24-25	25-26
29-100%	1	1	8	1	1	1	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
27-29%	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
25-27%	0	1	1	0	1	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
23-25%	0	0	0	0	1	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
21-23%	0	1	0	4	0	1	0	2	5	0	1	1	0	1	0	0	0	0	0	0	0	0	0
19-21%	0	0	0	3	2	2	2	3	3	0	2	0	0	0	0	0	0	0	0	0	0	0	0
17-19%	0	0	0	1	0	0	2	1	6	3	0	4	0	3	2	1	2	2	0	0	0	0	0
15-17%	0	0	1	1	0	1	1	0	2	6	7	6	0	0	2	7	1	0	0	0	0	0	0
13-15%	0	0	1	4	0	2	3	2	2	0	7	7	2	1	2	4	2	2	0	0	0	0	0
11-13%	0	0	0	0	0	0	2	0	0	3	3	4	4	1	2	3	2	0	0	0	0	0	0
9-11%	0	0	0	0	2	0	3	1	0	1	1	0	4	2	1	1	0	1	0	0	0	0	0
7-9%	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
5-7%	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3-5%	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0-3%	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Wind Speed (m/s)

Total Files in Wind Speed Bin

	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-11	11-12	12-13	13-14	14-15	15-16	16-17	17-18	18-19	19-20	20-21	21-22	22-23	23-24	24-25	25-26
# bins with 4 TS	0	0	1	2	0	0	0	0	2	1	2	4	2	0	0	2	0	0	0	0	0	0	0

Wind Speed (m/s)

	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-11	11-12	12-13	13-14	14-15	15-16	16-17	17-18	18-19	19-20	20-21	21-22	22-23	23-24	24-25	25-26
#TS in WS bin	1	4	11	15	7	9	16	11	20	13	21	22	11	8	9	16	7	5	0	0	0	0	0

Wind Speed (m/s)

Figure 144. Capture matrix for tower-base normal bending

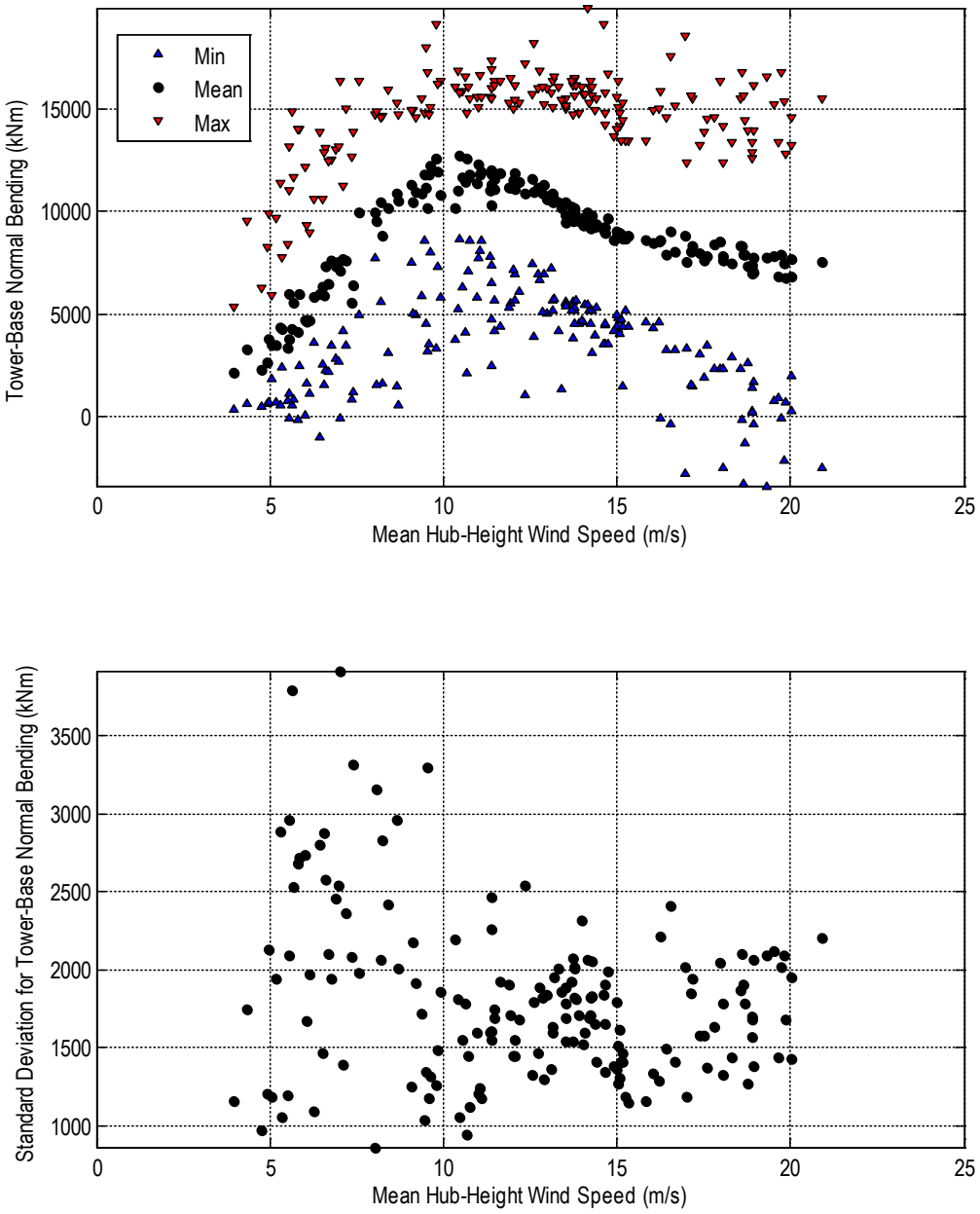


Figure 145. Scatterplot for tower-base normal bending

Table 69. Binned Data for Tower-Base Normal Bending

Bin #	Bin WS Low	Bin WS High	Mean WS	# Files	Min of Minimums	Mean of Means	Max of Maximums
1	3.0	4.0	4.0	1	328.41	2,140.26	5,318.86
2	4.0	5.0	4.8	4	463.88	2,972.27	9,897.02
3	5.0	6.0	5.5	11	-121.15	4,410.42	14,828.62
4	6.0	7.0	6.5	15	-1,019.57	6,254.84	13,838.58
5	7.0	8.0	7.3	7	-99.06	7,400.05	16,327.88
6	8.0	9.0	8.3	9	568.07	10,055.18	15,934.91
7	9.0	10.0	9.5	16	3,221.44	11,368.53	19,109.44
8	10.0	11.0	10.6	11	2,147.80	11,681.87	16,833.23
9	11.0	12.0	11.4	20	2,459.26	11,539.41	17,342.28
10	12.0	13.0	12.5	13	1,035.51	11,181.80	18,195.95
11	13.0	14.0	13.5	21	1,336.56	10,108.96	16,517.02
12	14.0	15.0	14.5	22	3,150.80	9,339.03	19,924.30
13	15.0	16.0	15.3	11	1,508.94	8,770.67	16,317.71
14	16.0	17.0	16.5	8	-2,792.49	8,510.48	18,535.56
15	17.0	18.0	17.5	9	1,508.58	8,042.16	16,339.34
16	18.0	19.0	18.6	16	-3,249.59	7,711.00	16,728.31
17	19.0	20.0	19.6	7	-3,383.85	7,444.25	16,726.79
18	20.0	21.0	20.4	5	-2,483.22	7,425.14	15,454.35
19	21.0	22.0	0.0	0	0.00	0.00	0.00
20	22.0	23.0	0.0	0	0.00	0.00	0.00
21	23.0	24.0	0.0	0	0.00	0.00	0.00
22	24.0	25.0	0.0	0	0.00	0.00	0.00
23	25.0	26.0	0.0	0	0.00	0.00	0.00

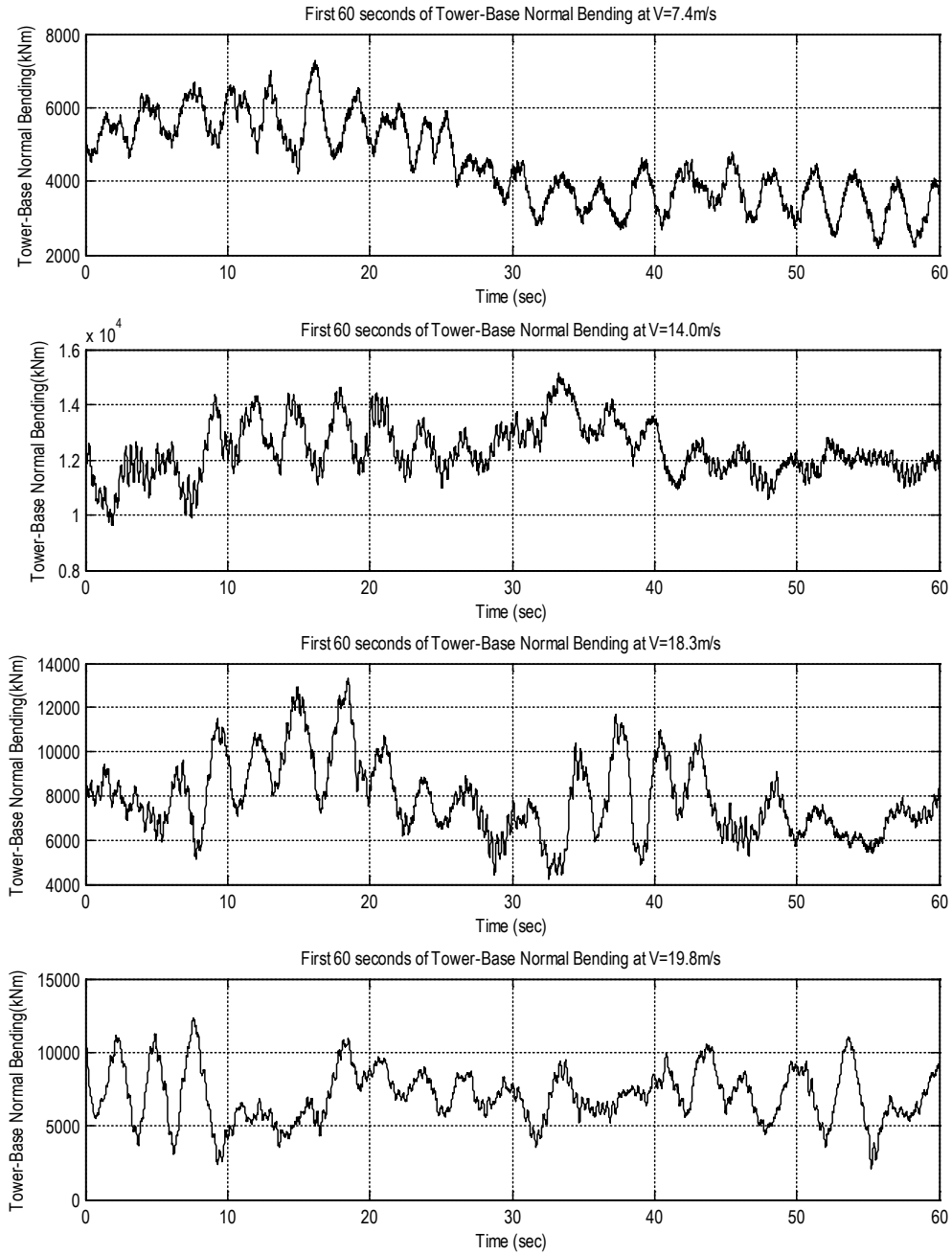


Figure 146. Time series for the first 60 seconds of tower-base normal bending

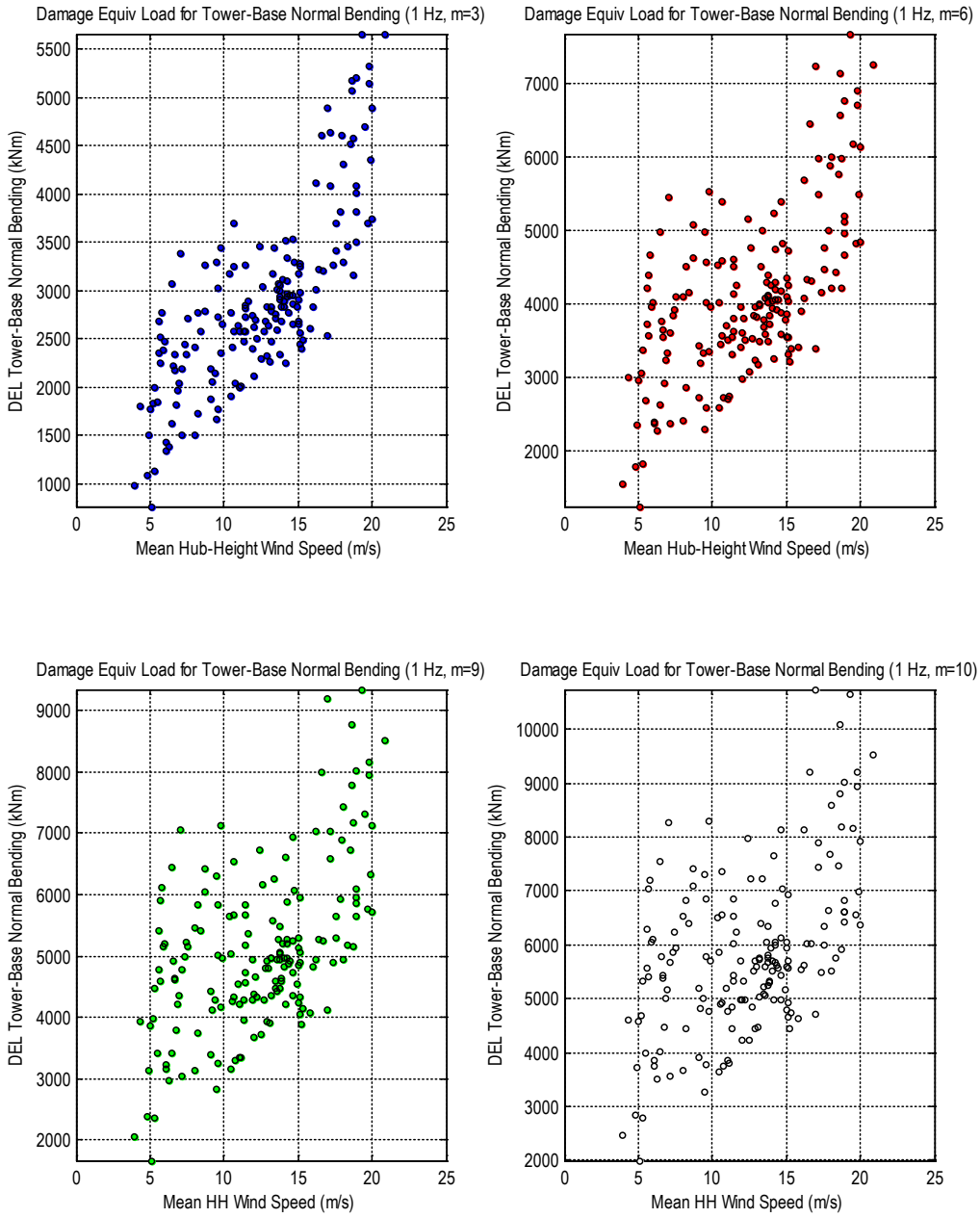


Figure 147. DEL (1 Hz, m=3, 6, 9, 10) for tower-base normal bending

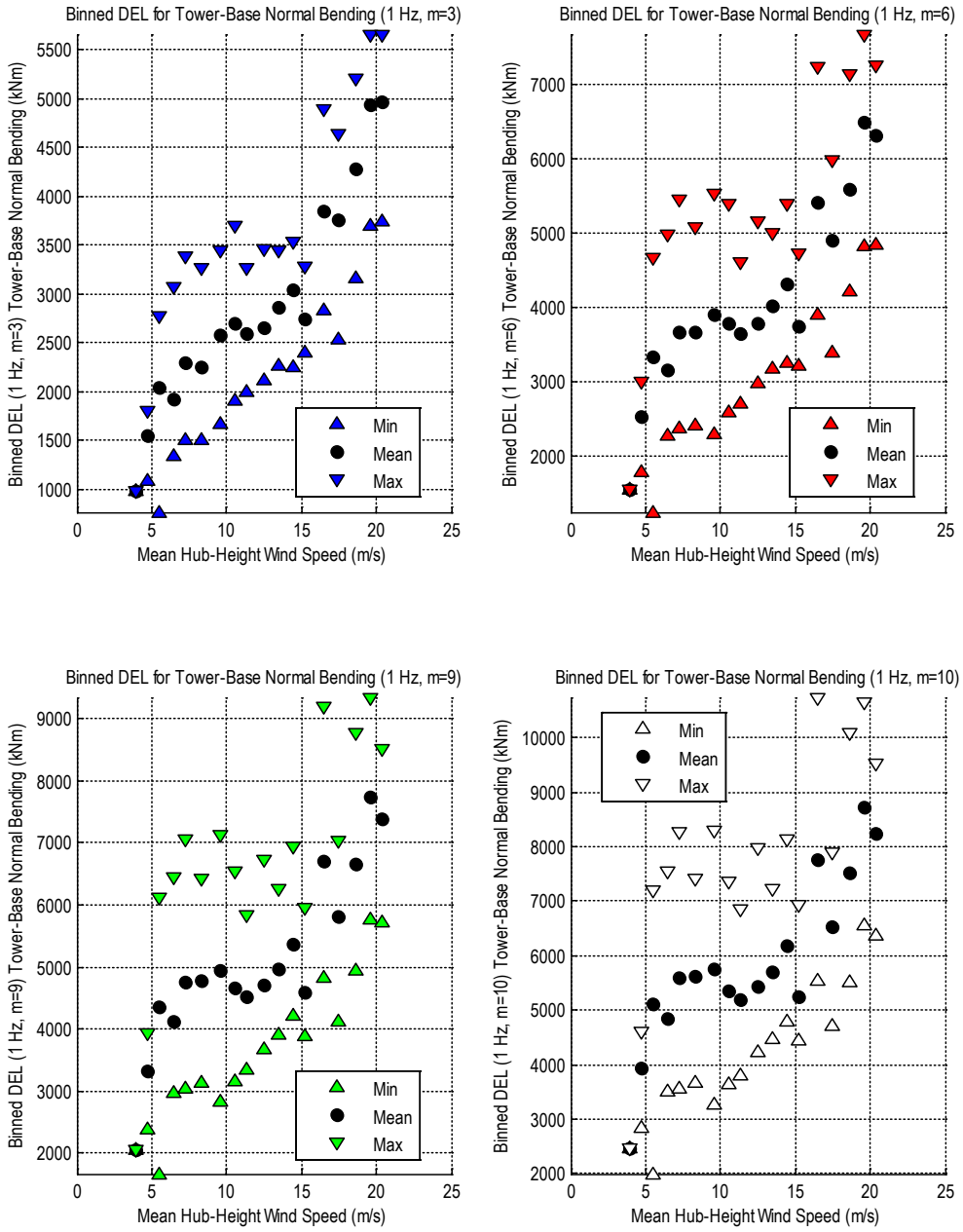


Figure 148. Binned DEL (1 Hz, m=3, 6, 9, 10) for tower-base normal bending

Table 70. Binned DEL Data for Tower-Base Normal Bending

Bin #	Bin WS Low	Bin WS High	Mean WS	# Files	Min of Del (m=3)	Mean of Del (m=3)	Max of Del (m=3)	Min of Del (m=6)	Mean of Del (m=6)	Max of Del (m=6)	Min of Del (m=9)	Mean of Del (m=9)	Max of Del (m=9)
1	3.0	4.0	4.0	1	982.85	982.85	982.85	1,542.15	1,542.15	1,542.15	2,455.94	2,455.94	2,455.94
2	4.0	5.0	4.8	4	1,088.53	1,544.80	1,800.62	1,786.06	2,529.14	3,011.95	2,850.35	3,941.07	4,612.85
3	5.0	6.0	5.5	11	764.83	2,048.36	2,768.33	1,247.09	3,341.53	4,675.41	1,995.41	5,118.62	7,186.18
4	6.0	7.0	6.5	15	1,342.99	1,928.07	3,066.79	2,276.08	3,157.82	4,981.71	3,497.55	4,842.39	7,549.58
5	7.0	8.0	7.3	7	1,497.81	2,295.38	3,385.79	2,373.36	3,670.89	5,451.48	3,565.05	5,585.55	8,266.57
6	8.0	9.0	8.3	9	1,501.41	2,250.36	3,264.76	2,415.90	3,670.51	5,085.38	3,668.31	5,606.82	7,417.26
7	9.0	10.0	9.5	16	1,671.75	2,583.79	3,444.00	2,301.12	3,904.94	5,542.17	3,253.56	5,739.54	8,291.05
8	10.0	11.0	10.6	11	1,907.08	2,691.54	3,697.87	2,581.24	3,794.64	5,388.55	3,645.25	5,352.32	7,355.49
9	11.0	12.0	11.4	20	1,990.93	2,590.24	3,268.41	2,707.10	3,652.01	4,605.94	3,805.36	5,195.03	6,839.90
10	12.0	13.0	12.5	13	2,120.43	2,653.91	3,453.19	2,974.20	3,780.01	5,162.06	4,216.88	5,428.43	7,974.30
11	13.0	14.0	13.5	21	2,263.85	2,867.49	3,441.29	3,170.92	4,031.29	5,005.46	4,474.70	5,712.41	7,224.84
12	14.0	15.0	14.5	22	2,249.19	3,045.19	3,527.61	3,267.02	4,321.51	5,394.26	4,798.16	6,178.61	8,125.16
13	15.0	16.0	15.3	11	2,405.11	2,747.55	3,285.31	3,222.06	3,754.56	4,729.53	4,431.66	5,246.56	6,931.32
14	16.0	17.0	16.5	8	2,832.07	3,847.70	4,892.36	3,903.90	5,408.58	7,236.35	5,546.02	7,752.63	10,740.38
15	17.0	18.0	17.5	9	2,531.58	3,765.16	4,633.93	3,391.04	4,906.75	5,974.93	4,710.37	6,536.39	7,883.62
16	18.0	19.0	18.6	16	3,158.43	4,274.78	5,202.49	4,227.16	5,585.17	7,135.85	5,515.10	7,513.96	10,084.94
17	19.0	20.0	19.6	7	3,704.23	4,935.17	5,651.24	4,828.69	6,495.08	7,680.16	6,552.56	8,734.33	10,649.64
18	20.0	21.0	20.4	5	3,742.33	4,970.87	5,662.76	4,846.39	6,325.36	7,250.68	6,373.76	8,252.54	9,533.79
19	21.0	22.0	0.0	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
20	22.0	23.0	0.0	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
21	23.0	24.0	0.0	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
22	24.0	25.0	0.0	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
23	25.0	26.0	0.0	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

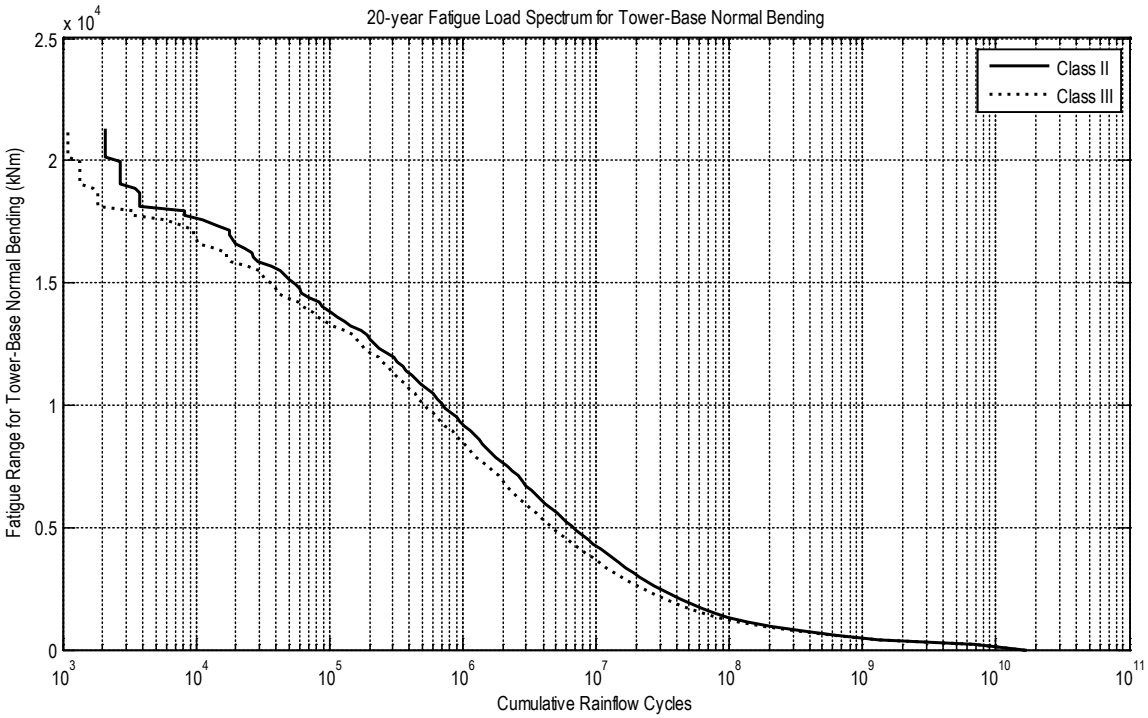


Figure 149. Twenty-year fatigue load spectrum for tower-base normal bending

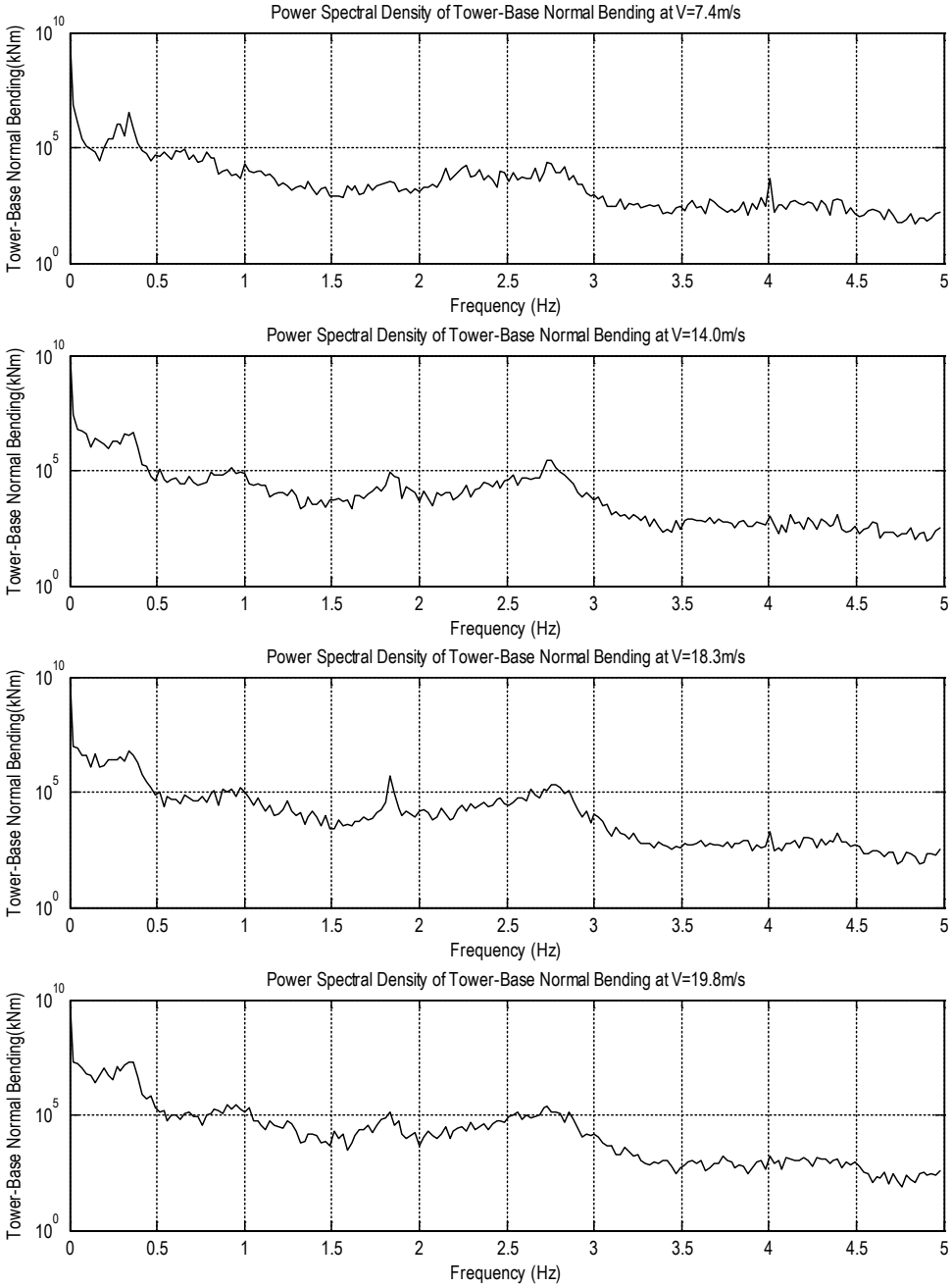


Figure 150. Power spectral density of tower-base normal bending

Tower-Base Lateral Bending

Turbulence Intensity	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-11	11-12	12-13	13-14	14-15	15-16	16-17	17-18	18-19	19-20	20-21	21-22	22-23	23-24	24-25	25-26
29-100%	1	1	8	1	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
27-29%	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
25-27%	0	1	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
23-25%	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
21-23%	0	1	0	4	0	1	0	2	2	0	1	1	0	1	0	0	0	0	0	0	0	0	0
19-21%	0	0	0	1	1	1	2	1	3	0	2	0	0	0	0	0	0	0	0	0	0	0	0
17-19%	0	0	0	1	0	0	0	1	0	3	0	0	0	1	1	1	1	0	0	0	0	0	0
15-17%	0	0	1	1	0	0	1	0	0	3	5	6	0	0	2	2	1	0	0	0	0	0	0
13-15%	0	0	1	0	0	0	1	0	0	0	3	5	1	1	0	2	0	0	0	0	0	0	0
11-13%	0	0	0	0	0	0	0	0	0	2	3	3	2	1	2	3	2	0	0	0	0	0	0
9-11%	0	0	0	0	0	0	0	0	0	1	1	0	4	2	1	1	0	1	0	0	0	0	0
7-9%	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
5-7%	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3-5%	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0-3%	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Wind Speed (m/s)

Total Files in Wind Speed Bin

	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-11	11-12	12-13	13-14	14-15	15-16	16-17	17-18	18-19	19-20	20-21	21-22	22-23	23-24	24-25	25-26
# bins with 4 TS	0	0	1	1	0	0	0	0	0	0	1	2	1	0	0	0	0	0	0	0	0	0	0

Wind Speed (m/s)

	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-11	11-12	12-13	13-14	14-15	15-16	16-17	17-18	18-19	19-20	20-21	21-22	22-23	23-24	24-25	25-26
#TS in WS bin	1	4	11	9	3	2	5	6	5	9	15	15	8	6	6	9	4	1	0	0	0	0	0

Wind Speed (m/s)

Figure 151. Capture matrix for tower-base lateral bending

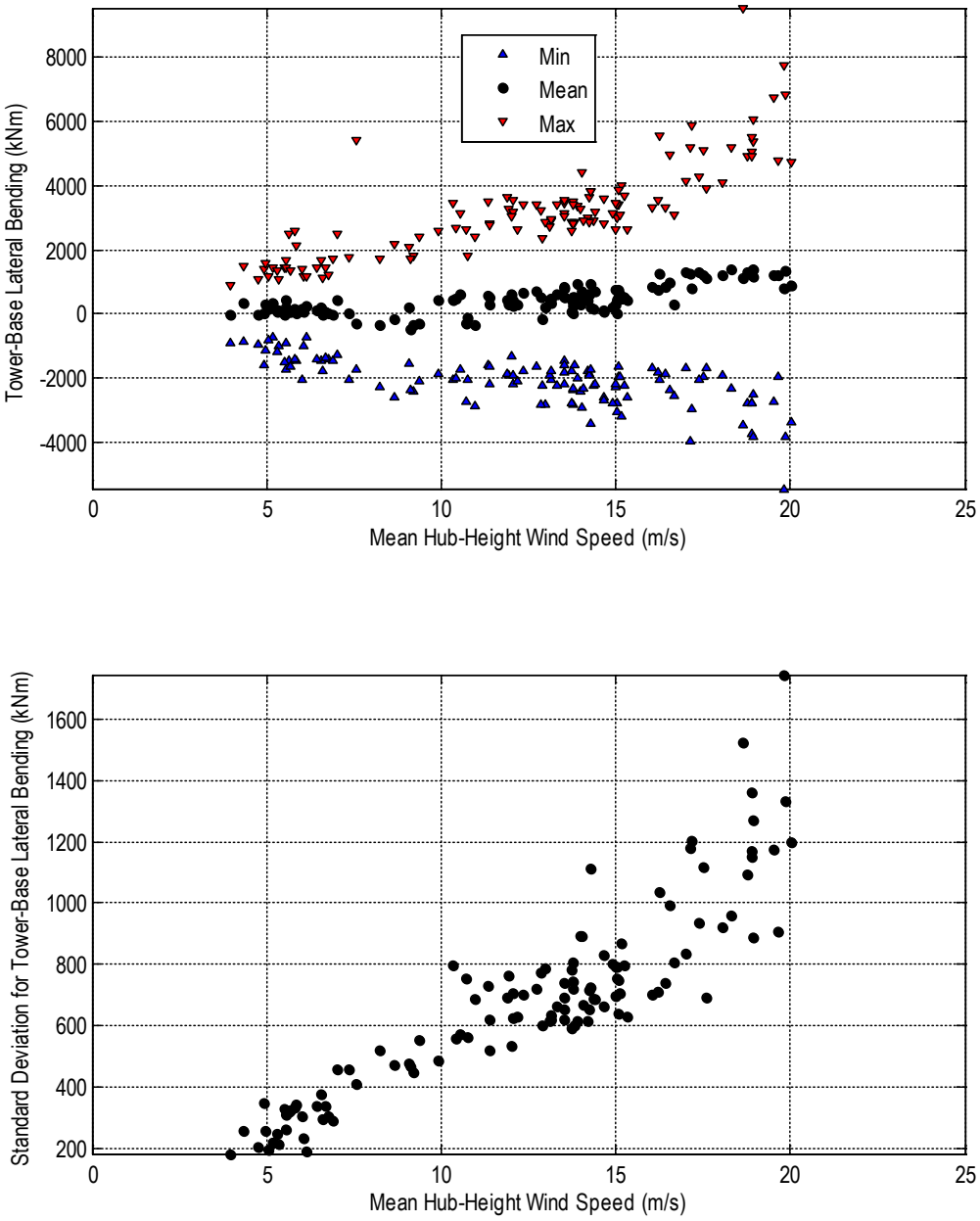


Figure 152. Scatterplot for tower-base lateral bending

Table 71. Binned Data for Tower-Base Lateral Bending

Bin #	Bin WS Low	Bin WS High	Mean WS	# Files	Min of Minimums	Mean of Means	Max of Maximums
1	3.0	4.0	4.0	1	-884.65	-33.92	876.57
2	4.0	5.0	4.8	4	-1,576.01	139.05	1,564.84
3	5.0	6.0	5.5	11	-1,708.72	138.51	2,591.90
4	6.0	7.0	6.5	9	-2,027.95	88.04	1,689.71
5	7.0	8.0	7.3	3	-2,036.28	45.96	5,390.45
6	8.0	9.0	8.5	2	-2,582.85	-242.90	2,150.12
7	9.0	10.0	9.3	5	-2,423.31	-101.59	2,570.20
8	10.0	11.0	10.6	6	-2,857.02	120.19	3,466.78
9	11.0	12.0	11.6	5	-2,189.41	417.63	3,622.78
10	12.0	13.0	12.5	9	-2,830.91	385.97	3,526.11
11	13.0	14.0	13.6	15	-2,830.46	479.45	3,521.28
12	14.0	15.0	14.4	15	-3,419.75	437.19	4,382.73
13	15.0	16.0	15.1	8	-3,187.61	468.08	3,989.09
14	16.0	17.0	16.4	6	-2,562.67	820.09	5,531.17
15	17.0	18.0	17.3	6	-3,944.66	1,156.85	5,852.17
16	18.0	19.0	18.7	9	-3,829.99	1,262.19	9,547.81
17	19.0	20.0	19.7	4	-5,448.96	1,134.72	7,721.29
18	20.0	21.0	20.0	1	-3,383.09	874.39	4,737.94
19	21.0	22.0	0.0	0	0.00	0.00	0.00
20	22.0	23.0	0.0	0	0.00	0.00	0.00
21	23.0	24.0	0.0	0	0.00	0.00	0.00
22	24.0	25.0	0.0	0	0.00	0.00	0.00
23	25.0	26.0	0.0	0	0.00	0.00	0.00

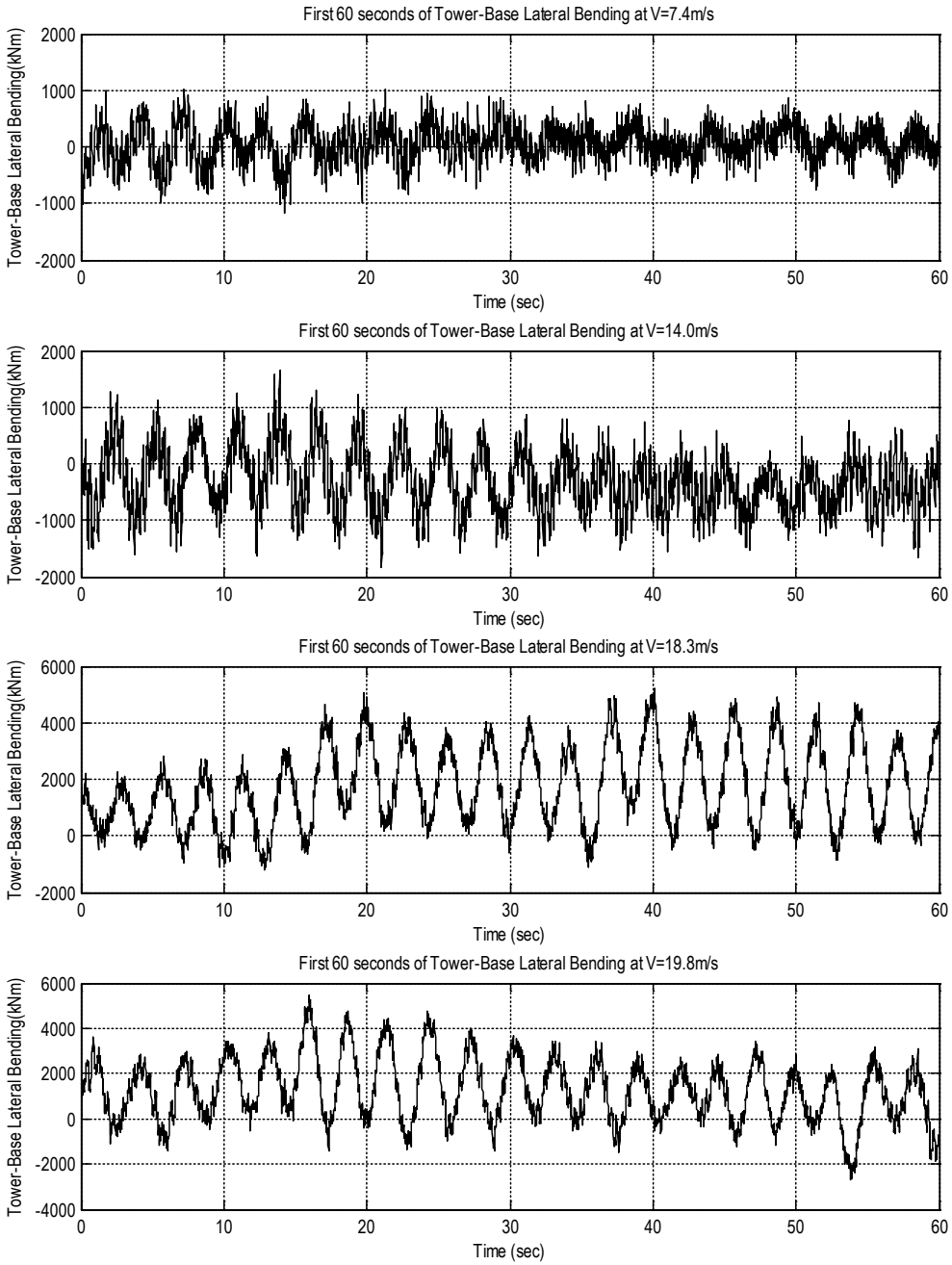


Figure 153. Time series for the first 60 seconds of tower-base lateral bending

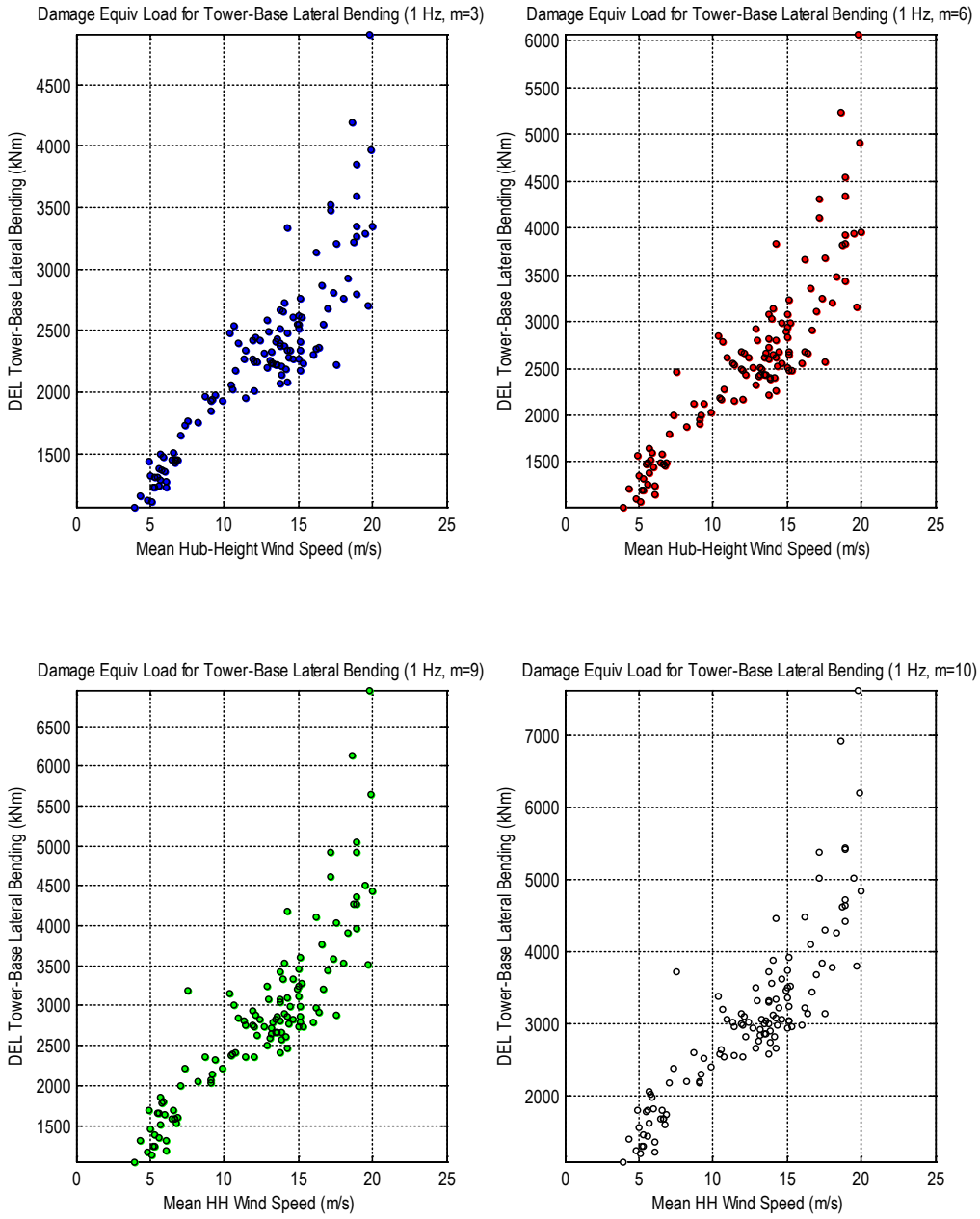


Figure 154. DEL (1 Hz, m=3, 6, 9, 10) for tower-base lateral bending

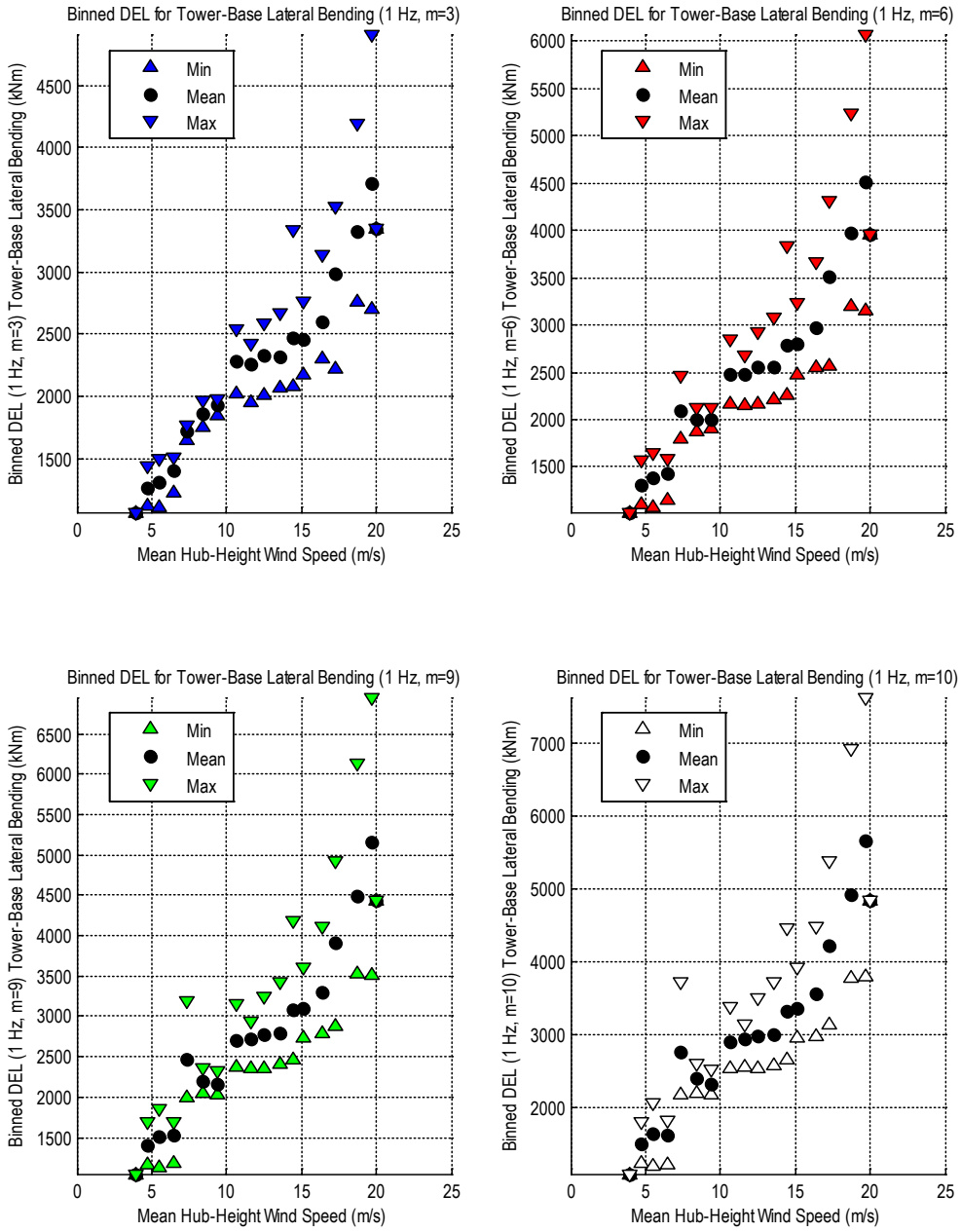


Figure 155. Binned DEL (1 Hz, m=3, 6, 9, 10) for tower-base lateral bending

Table 72. Binned DEL Data for Tower-Base Lateral Bending

Bin #	Bin WS Low	Bin WS High	Mean WS	# Files	Min of Del (m=3)	Mean of Del (m=3)	Max of Del (m=3)	Min of Del (m=6)	Mean of Del (m=6)	Max of Del (m=6)	Min of Del (m=9)	Mean of Del (m=9)	Max of Del (m=9)
1	3.0	4.0	4.0	1	1,071.06	1,071.06	1,071.06	1,021.02	1,021.02	1,021.02	1,093.34	1,093.34	1,093.34
2	4.0	5.0	4.8	4	1,126.44	1,264.46	1,444.77	1,110.95	1,310.92	1,565.29	1,237.89	1,499.89	1,809.92
3	5.0	6.0	5.5	11	1,111.78	1,312.71	1,498.69	1,080.98	1,377.38	1,642.50	1,199.90	1,636.21	2,054.30
4	6.0	7.0	6.5	9	1,224.88	1,400.60	1,504.25	1,157.91	1,424.96	1,576.27	1,214.92	1,622.10	1,816.87
5	7.0	8.0	7.3	3	1,645.58	1,715.32	1,763.25	1,800.75	2,089.95	2,467.09	2,178.05	2,766.38	3,729.85
6	8.0	9.0	8.5	2	1,752.25	1,859.88	1,967.50	1,874.59	1,998.67	2,122.76	2,211.36	2,406.46	2,601.55
7	9.0	10.0	9.3	5	1,850.05	1,926.35	1,980.69	1,907.78	2,006.08	2,128.13	2,183.85	2,318.45	2,512.95
8	10.0	11.0	10.6	6	2,030.29	2,280.19	2,538.41	2,171.25	2,477.95	2,844.28	2,544.54	2,902.79	3,380.02
9	11.0	12.0	11.6	5	1,957.13	2,253.50	2,423.14	2,146.66	2,482.76	2,685.30	2,564.20	2,939.82	3,136.65
10	12.0	13.0	12.5	9	2,010.93	2,331.51	2,582.94	2,164.67	2,547.78	2,931.93	2,542.14	2,988.82	3,507.75
11	13.0	14.0	13.6	15	2,070.98	2,316.19	2,670.99	2,222.66	2,546.86	3,079.45	2,581.59	2,995.44	3,711.96
12	14.0	15.0	14.4	15	2,078.30	2,472.34	3,340.10	2,257.22	2,786.99	3,833.00	2,659.91	3,314.99	4,465.46
13	15.0	16.0	15.1	8	2,173.05	2,460.62	2,768.11	2,474.96	2,801.46	3,238.34	2,952.06	3,355.65	3,924.05
14	16.0	17.0	16.4	6	2,305.42	2,597.33	3,133.57	2,561.18	2,974.87	3,668.13	2,974.17	3,557.88	4,479.79
15	17.0	18.0	17.3	6	2,228.96	2,988.20	3,524.49	2,572.18	3,508.59	4,310.26	3,136.28	4,230.59	5,382.65
16	18.0	19.0	18.7	9	2,758.65	3,327.81	4,191.25	3,200.03	3,978.89	5,230.70	3,777.74	4,912.92	6,919.41
17	19.0	20.0	19.7	4	2,698.23	3,716.08	4,910.21	3,151.91	4,518.86	6,076.24	3,801.75	5,663.47	7,628.19
18	20.0	21.0	20.0	1	3,341.98	3,341.98	3,341.98	3,954.01	3,954.01	3,954.01	4,833.73	4,833.73	4,833.73
19	21.0	22.0	0.0	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
20	22.0	23.0	0.0	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
21	23.0	24.0	0.0	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
22	24.0	25.0	0.0	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
23	25.0	26.0	0.0	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

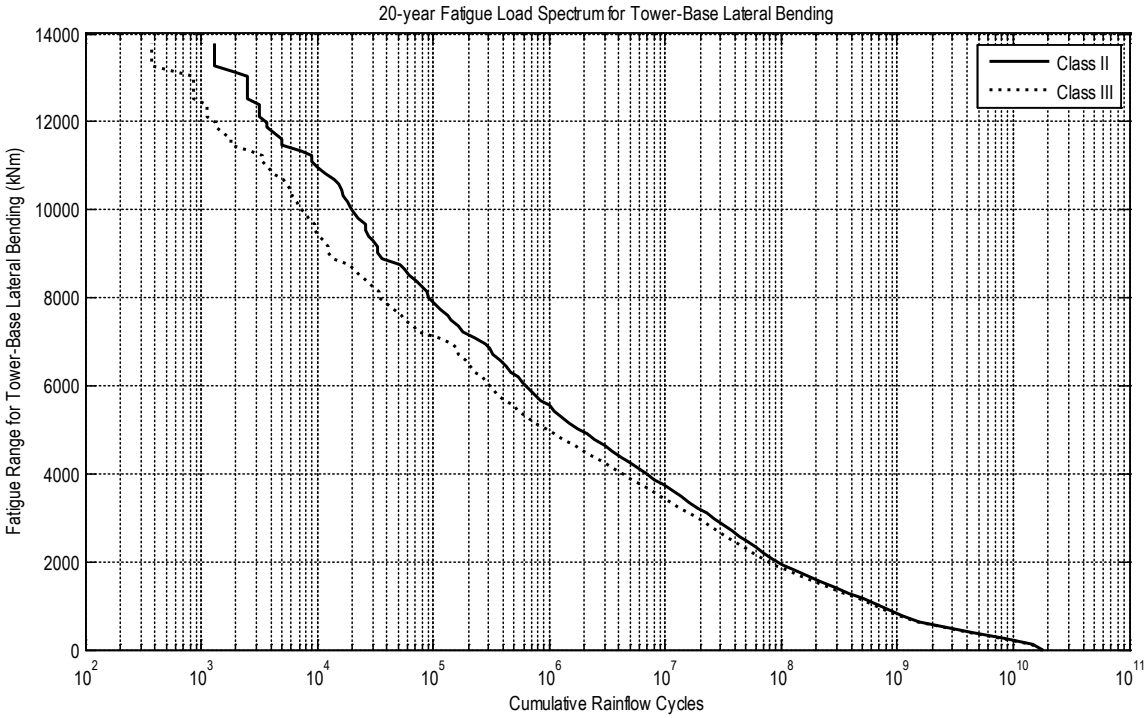


Figure 156. Twenty-year fatigue load spectrum for tower-base lateral bending

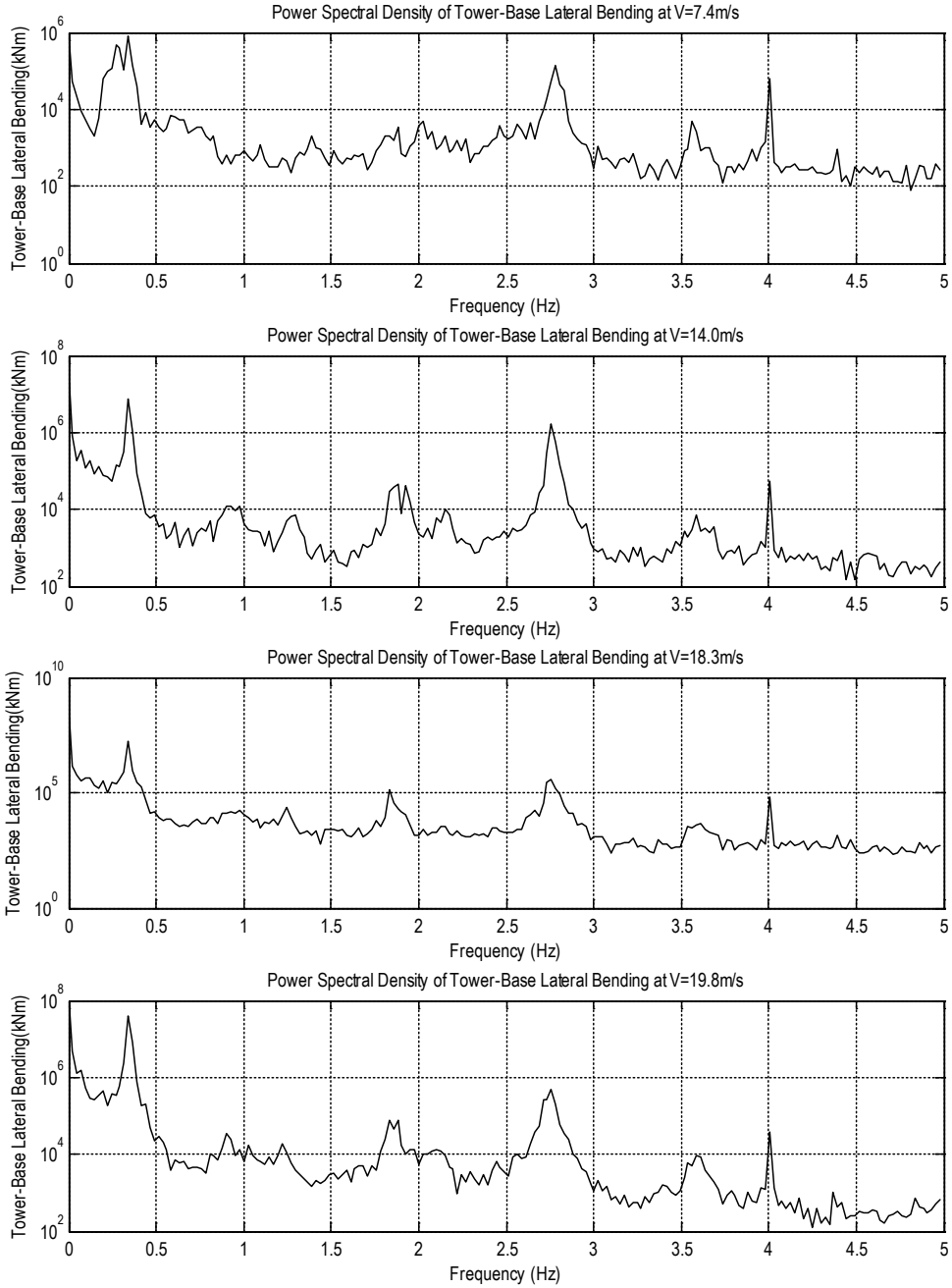


Figure 157. Power spectral density of tower-base lateral bending

Hub-Height Wind Speed

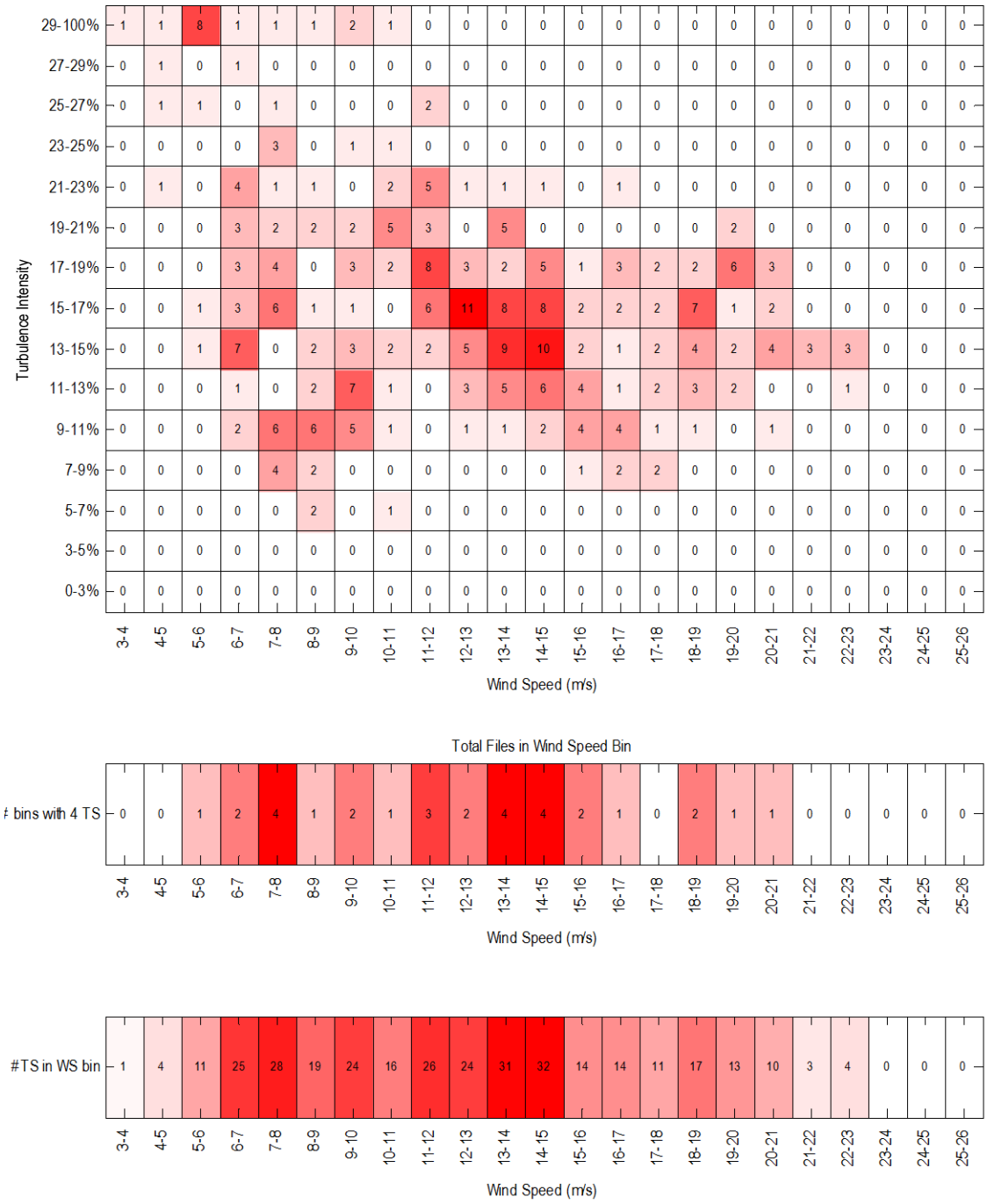


Figure 158. Capture matrix for hub-height wind speed

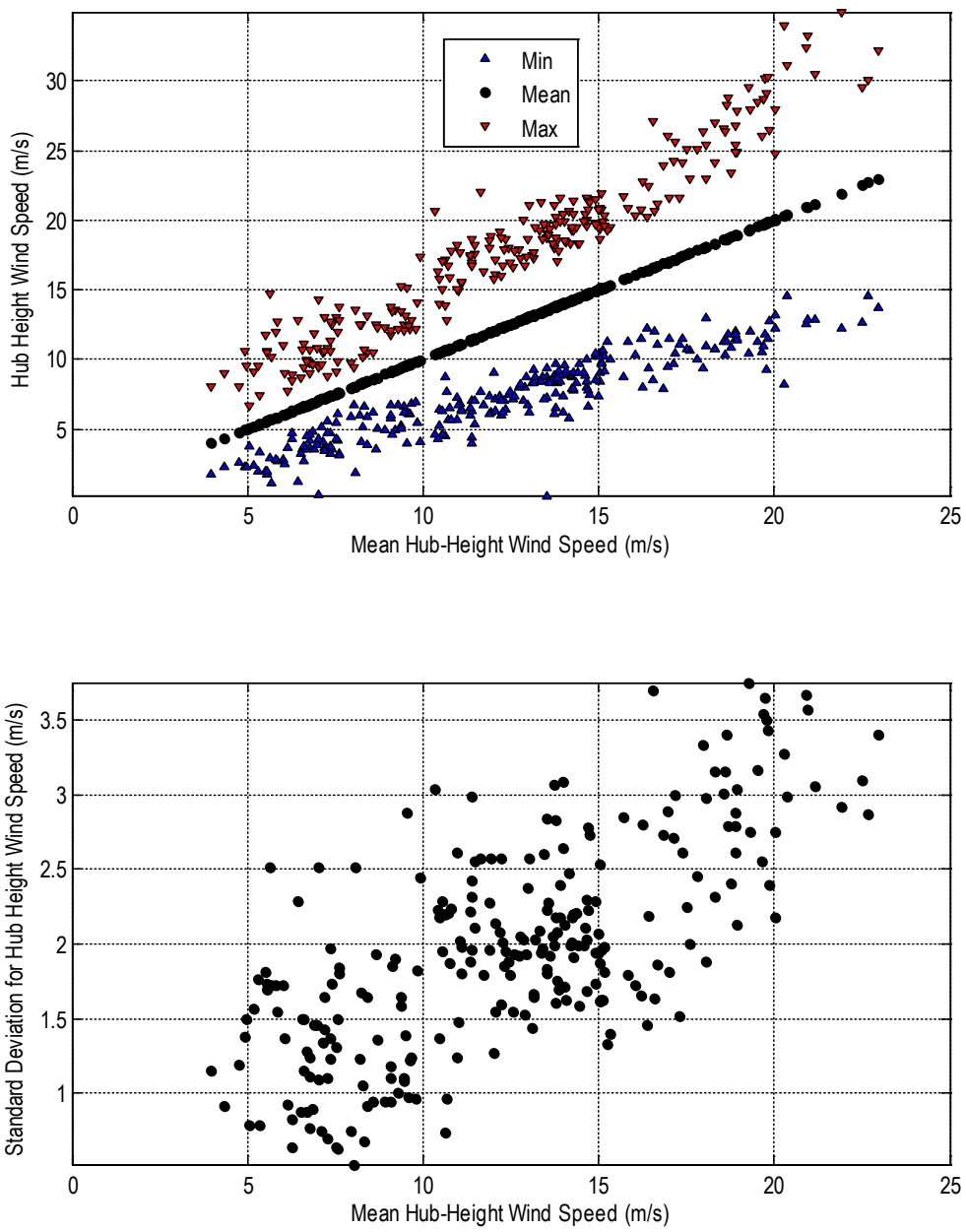


Figure 159. Scatterplot for hub-height wind speed

Table 73. Binned Data for Hub-Height Wind Speed

Bin #	Bin WS Low	Bin WS High	Mean WS	# Files	Min of Minimums	Mean of Means	Max of Maximums
1	3.0	4.0	4.0	1	1.80	3.96	8.02
2	4.0	5.0	4.8	4	2.25	4.76	10.59
3	5.0	6.0	5.5	11	1.15	5.50	14.66
4	6.0	7.0	6.6	25	1.29	6.57	12.83
5	7.0	8.0	7.4	28	0.28	7.37	14.25
6	8.0	9.0	8.4	19	1.89	8.40	13.52
7	9.0	10.0	9.5	24	3.95	9.47	17.32
8	10.0	11.0	10.6	16	4.36	10.62	20.62
9	11.0	12.0	11.4	26	3.95	11.39	21.99
10	12.0	13.0	12.5	24	6.05	12.49	20.02
11	13.0	14.0	13.5	31	0.24	13.53	21.58
12	14.0	15.0	14.5	32	5.83	14.47	21.58
13	15.0	16.0	15.3	14	8.44	15.27	21.90
14	16.0	17.0	16.6	14	7.93	16.55	27.07
15	17.0	18.0	17.5	11	9.35	17.46	26.29
16	18.0	19.0	18.6	17	10.31	18.61	28.72
17	19.0	20.0	19.6	13	9.26	19.59	30.28
18	20.0	21.0	20.4	10	8.25	20.41	33.89
19	21.0	22.0	21.4	3	12.24	21.41	34.95
20	22.0	23.0	22.8	4	12.65	22.77	32.11
21	23.0	24.0	0.0	0	0.00	0.00	0.00
22	24.0	25.0	0.0	0	0.00	0.00	0.00
23	25.0	26.0	0.0	0	0.00	0.00	0.00

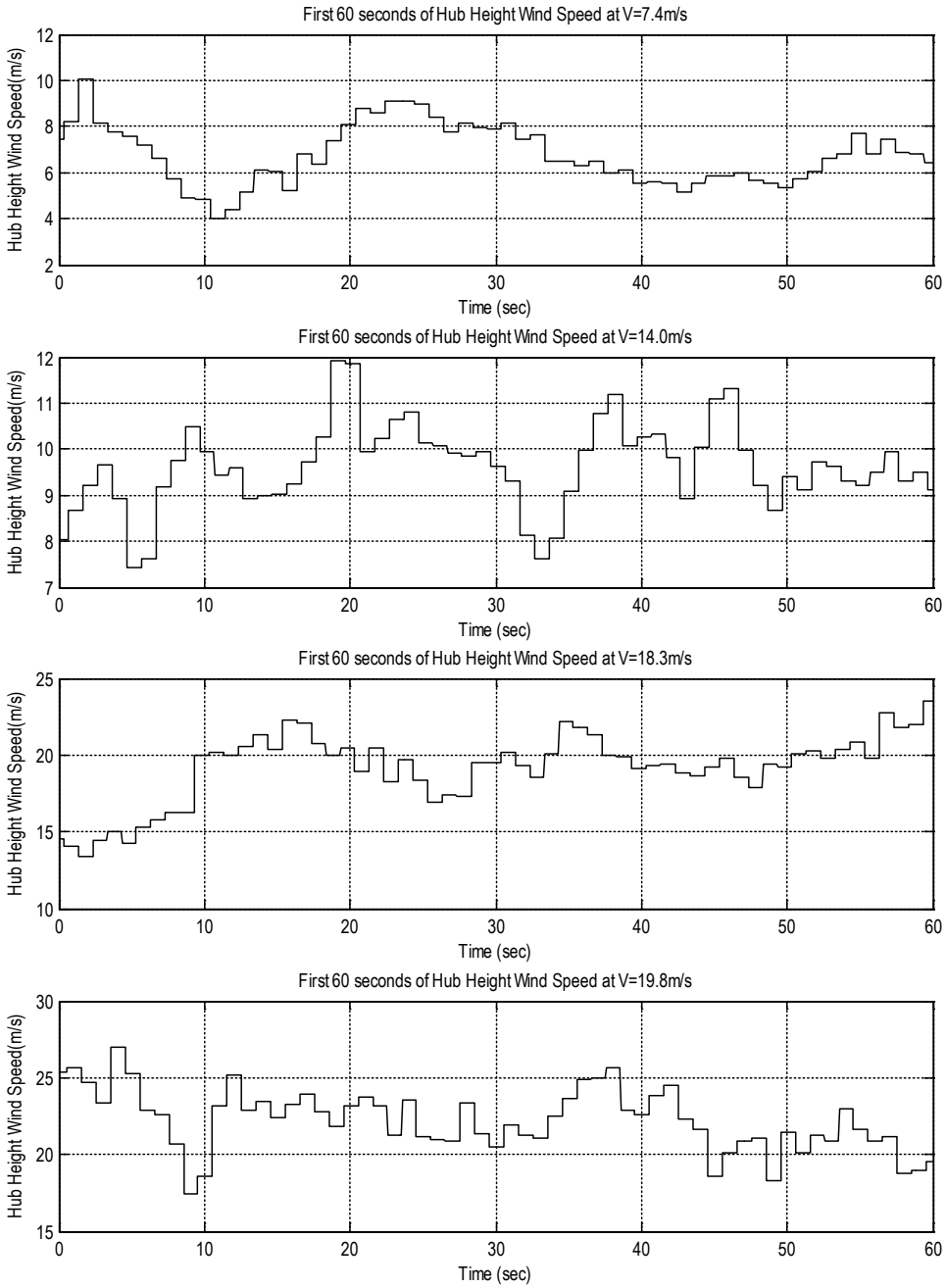


Figure 160. Time series for the first 60 seconds of hub-height wind speed

Wind Speed at 87 m

Turbulence Intensity	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-11	11-12	12-13	13-14	14-15	15-16	16-17	17-18	18-19	19-20	20-21	21-22	22-23	23-24	24-25	25-26
29-100%	0	0	3	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
27-29%	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
25-27%	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
23-25%	0	0	0	0	3	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
21-23%	0	1	0	2	1	0	0	0	2	1	1	1	0	0	0	0	0	0	0	0	0	0	0
19-21%	0	0	0	0	1	1	2	3	3	0	5	0	0	0	0	0	2	0	0	0	0	0	0
17-19%	0	0	0	1	2	0	1	2	2	2	1	0	1	3	2	1	5	3	0	0	0	0	0
15-17%	0	0	0	0	0	1	1	0	2	6	6	8	2	2	2	7	0	2	0	0	0	0	0
13-15%	0	0	1	0	0	0	0	0	0	0	7	8	1	1	2	4	2	4	3	3	0	0	0
11-13%	0	0	0	0	0	0	1	1	0	2	4	3	2	1	2	3	2	0	0	1	0	0	0
9-11%	0	0	0	0	0	0	3	1	0	0	1	0	4	2	1	1	0	1	0	0	0	0	0
7-9%	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
5-7%	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3-5%	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0-3%	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Wind Speed (m/s)

Total Files in Wind Speed Bin

	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-11	11-12	12-13	13-14	14-15	15-16	16-17	17-18	18-19	19-20	20-21	21-22	22-23	23-24	24-25	25-26
# bins with 4 TS	0	0	0	0	0	0	0	0	0	1	4	2	1	0	0	2	1	1	0	0	0	0	0

Wind Speed (m/s)

	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-11	11-12	12-13	13-14	14-15	15-16	16-17	17-18	18-19	19-20	20-21	21-22	22-23	23-24	24-25	25-26
#TS in WS bin	0	2	5	3	8	3	8	9	9	11	25	20	11	9	9	16	11	10	3	4	0	0	0

Wind Speed (m/s)

Figure 161. Capture matrix for wind speed at 87 m

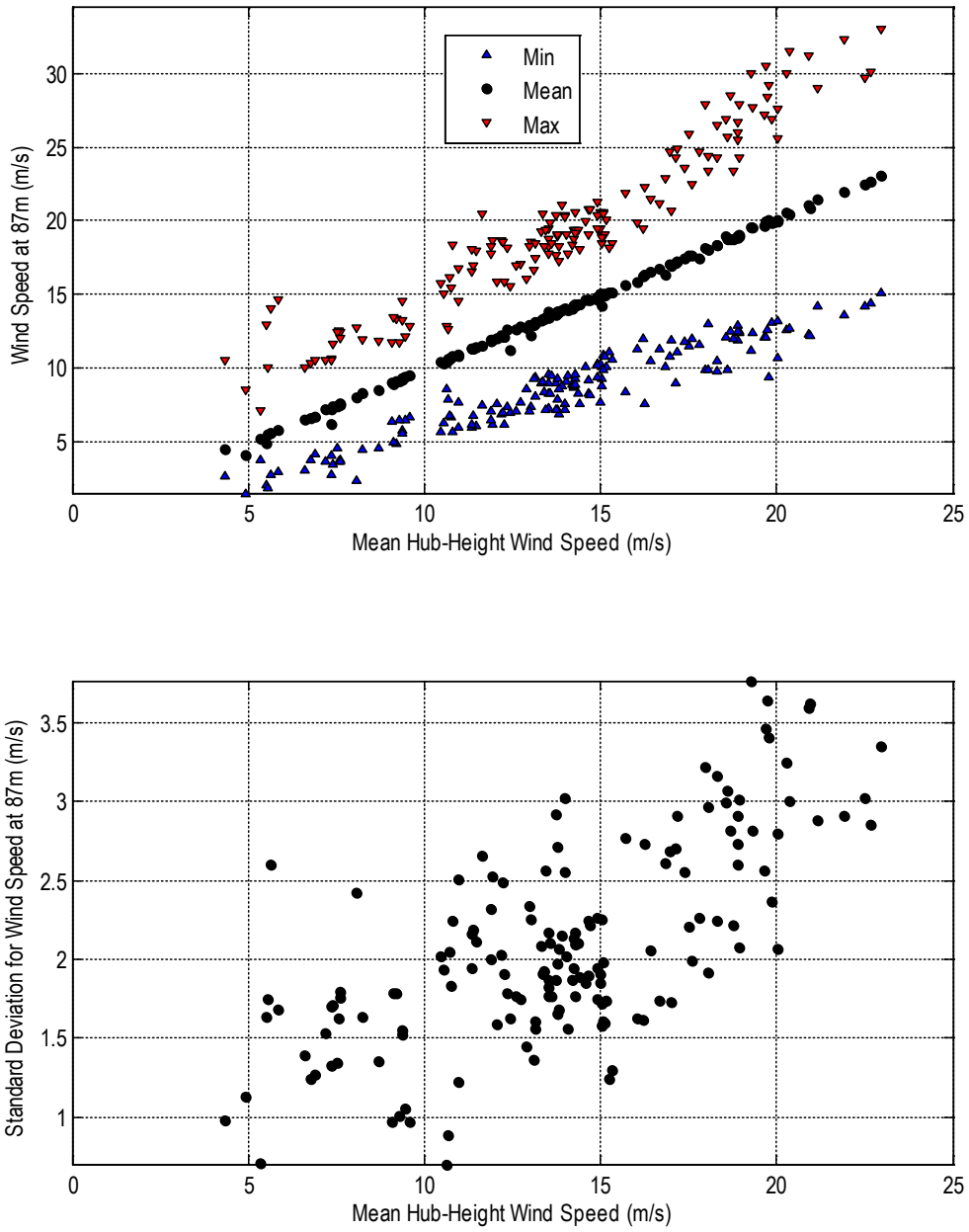


Figure 162. Scatterplot for wind speed at 87 m

Table 74. Binned Data for Wind Speed at 87 m

Bin #	Bin WS Low	Bin WS High	Mean WS	# Files	Min of Minimums	Mean of Means	Max of Maximums
1	3.0	4.0	0.0	0	0.00	0.00	0.00
2	4.0	5.0	4.7	2	1.48	4.23	10.53
3	5.0	6.0	5.6	5	1.79	5.37	14.65
4	6.0	7.0	6.8	3	3.00	6.60	10.48
5	7.0	8.0	7.5	8	2.69	7.22	12.45
6	8.0	9.0	8.3	3	2.33	8.24	12.72
7	9.0	10.0	9.3	8	4.84	9.16	14.51
8	10.0	11.0	10.7	9	5.64	10.61	18.37
9	11.0	12.0	11.6	9	5.96	11.52	20.47
10	12.0	13.0	12.5	11	6.18	12.20	18.59
11	13.0	14.0	13.5	25	6.85	13.40	21.01
12	14.0	15.0	14.5	20	7.53	14.42	21.23
13	15.0	16.0	15.2	11	8.42	14.91	21.81
14	16.0	17.0	16.6	9	7.61	16.48	24.64
15	17.0	18.0	17.5	9	9.00	17.45	27.86
16	18.0	19.0	18.6	16	9.81	18.69	28.49
17	19.0	20.0	19.6	11	9.41	19.78	30.50
18	20.0	21.0	20.4	10	10.71	20.50	34.49
19	21.0	22.0	21.4	3	13.62	21.58	32.30
20	22.0	23.0	22.8	4	14.24	22.81	33.06
21	23.0	24.0	0.0	0	0.00	0.00	0.00
22	24.0	25.0	0.0	0	0.00	0.00	0.00
23	25.0	26.0	0.0	0	0.00	0.00	0.00

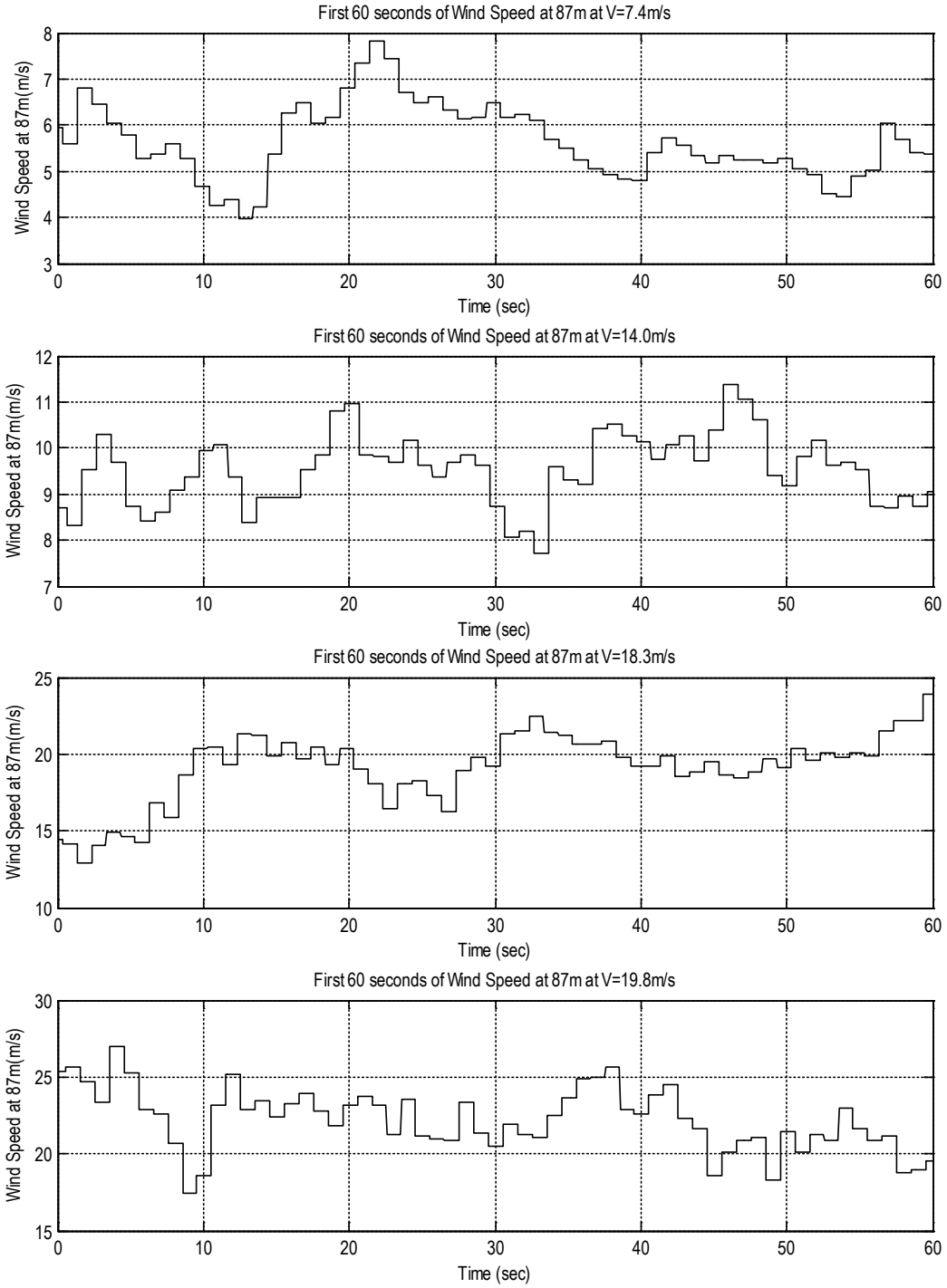


Figure 163. Time series for the first 60 seconds of wind speed at 87 m

Air Pressure

Turbulence Intensity	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-11	11-12	12-13	13-14	14-15	15-16	16-17	17-18	18-19	19-20	20-21	21-22	22-23	23-24	24-25	25-26
29-100%	1	1	8	1	1	1	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
27-29%	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
25-27%	0	1	1	0	1	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
23-25%	0	0	0	0	3	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
21-23%	0	1	0	4	1	1	0	2	5	1	1	1	0	1	0	0	0	0	0	0	0	0	0
19-21%	0	0	0	3	2	2	2	5	3	0	5	0	0	0	0	0	2	0	0	0	0	0	0
17-19%	0	0	0	3	4	0	3	2	8	3	2	5	1	3	2	2	6	3	0	0	0	0	0
15-17%	0	0	1	3	6	1	1	0	6	11	8	8	2	2	2	7	1	2	0	0	0	0	0
13-15%	0	0	1	7	0	2	3	2	2	5	9	10	2	1	2	4	2	4	3	3	0	0	0
11-13%	0	0	0	1	0	2	7	1	0	3	5	6	4	1	2	3	2	0	0	1	0	0	0
9-11%	0	0	0	2	6	6	5	1	0	1	1	2	4	4	1	1	0	1	0	0	0	0	0
7-9%	0	0	0	0	4	2	0	0	0	0	0	0	1	2	2	0	0	0	0	0	0	0	0
5-7%	0	0	0	0	0	2	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3-5%	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0-3%	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Wind Speed (m/s)

Total Files in Wind Speed Bin

	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-11	11-12	12-13	13-14	14-15	15-16	16-17	17-18	18-19	19-20	20-21	21-22	22-23	23-24	24-25	25-26
# bins with 4 TS	0	0	1	2	4	1	2	1	3	2	4	4	2	1	0	2	1	1	0	0	0	0	0

Wind Speed (m/s)

	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-11	11-12	12-13	13-14	14-15	15-16	16-17	17-18	18-19	19-20	20-21	21-22	22-23	23-24	24-25	25-26
#TS in WS bin	1	4	11	25	28	19	24	16	26	24	31	32	14	14	11	17	13	10	3	4	0	0	0

Wind Speed (m/s)

Figure 164. Capture matrix for air pressure

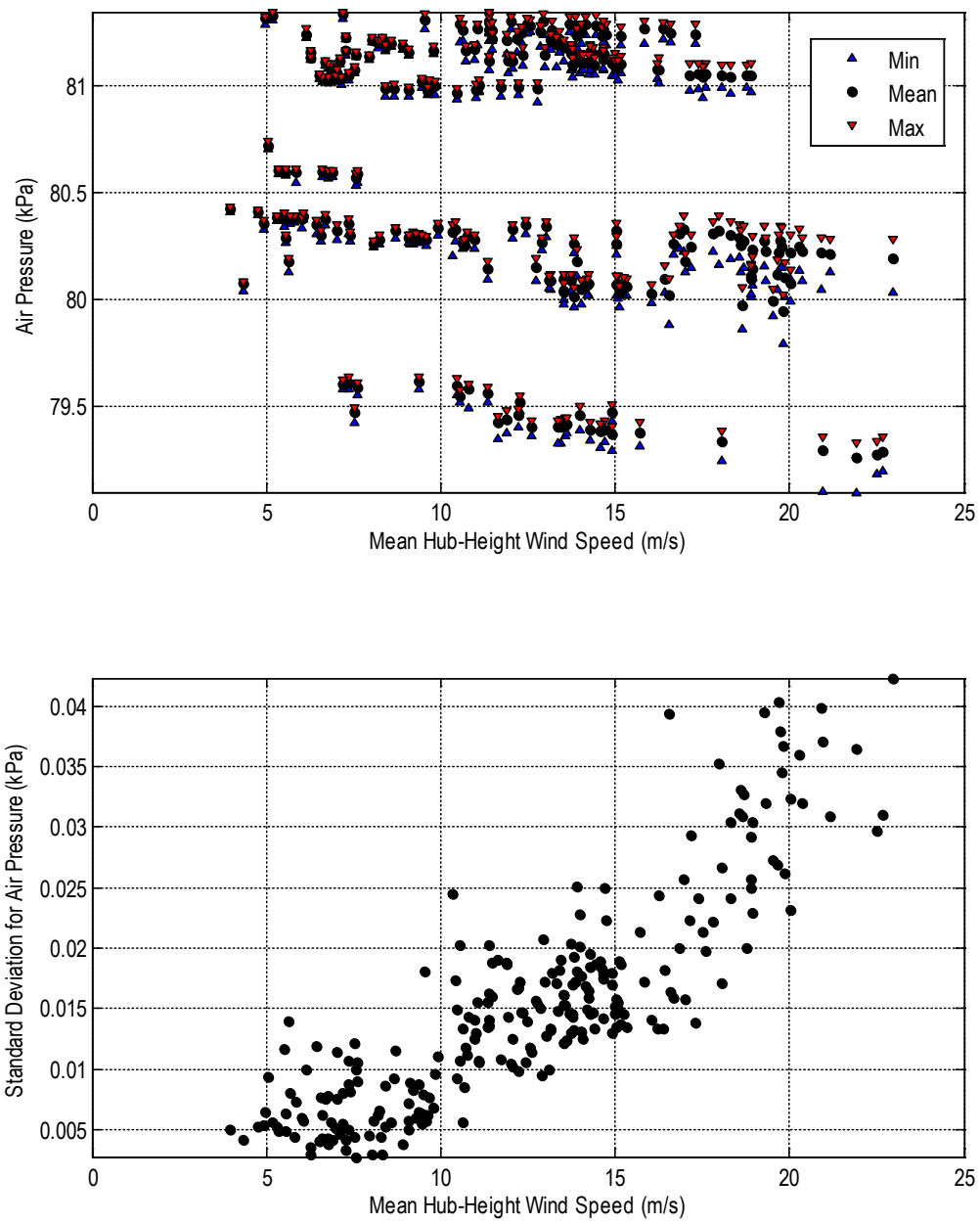


Figure 165. Scatterplot for air pressure

Table 75. Binned Data for Air Pressure

Bin #	Bin WS Low	Bin WS High	Mean WS	# Files	Min of Minimums	Mean of Means	Max of Maximums
1	3.0	4.0	4.0	1	80.41	80.43	80.43
2	4.0	5.0	4.8	4	80.04	80.54	81.32
3	5.0	6.0	5.5	11	80.13	80.53	81.34
4	6.0	7.0	6.6	25	80.27	80.88	81.26
5	7.0	8.0	7.4	28	79.43	80.78	81.34
6	8.0	9.0	8.4	19	80.24	81.03	81.22
7	9.0	10.0	9.5	24	79.59	80.76	81.33
8	10.0	11.0	10.6	16	79.49	80.53	81.31
9	11.0	12.0	11.4	26	79.35	80.92	81.34
10	12.0	13.0	12.5	24	79.37	80.77	81.33
11	13.0	14.0	13.5	31	79.33	80.54	81.32
12	14.0	15.0	14.5	32	79.29	80.80	81.33
13	15.0	16.0	15.3	14	79.32	80.47	81.30
14	16.0	17.0	16.6	14	79.89	80.63	81.29
15	17.0	18.0	17.5	11	80.13	80.73	81.29
16	18.0	19.0	18.6	17	79.25	80.35	81.10
17	19.0	20.0	19.6	13	79.80	80.18	80.34
18	20.0	21.0	20.4	10	79.10	80.12	80.33
19	21.0	22.0	21.4	3	79.10	79.90	80.28
20	22.0	23.0	22.8	4	79.19	79.74	80.28
21	23.0	24.0	0.0	0	0.00	0.00	0.00
22	24.0	25.0	0.0	0	0.00	0.00	0.00
23	25.0	26.0	0.0	0	0.00	0.00	0.00

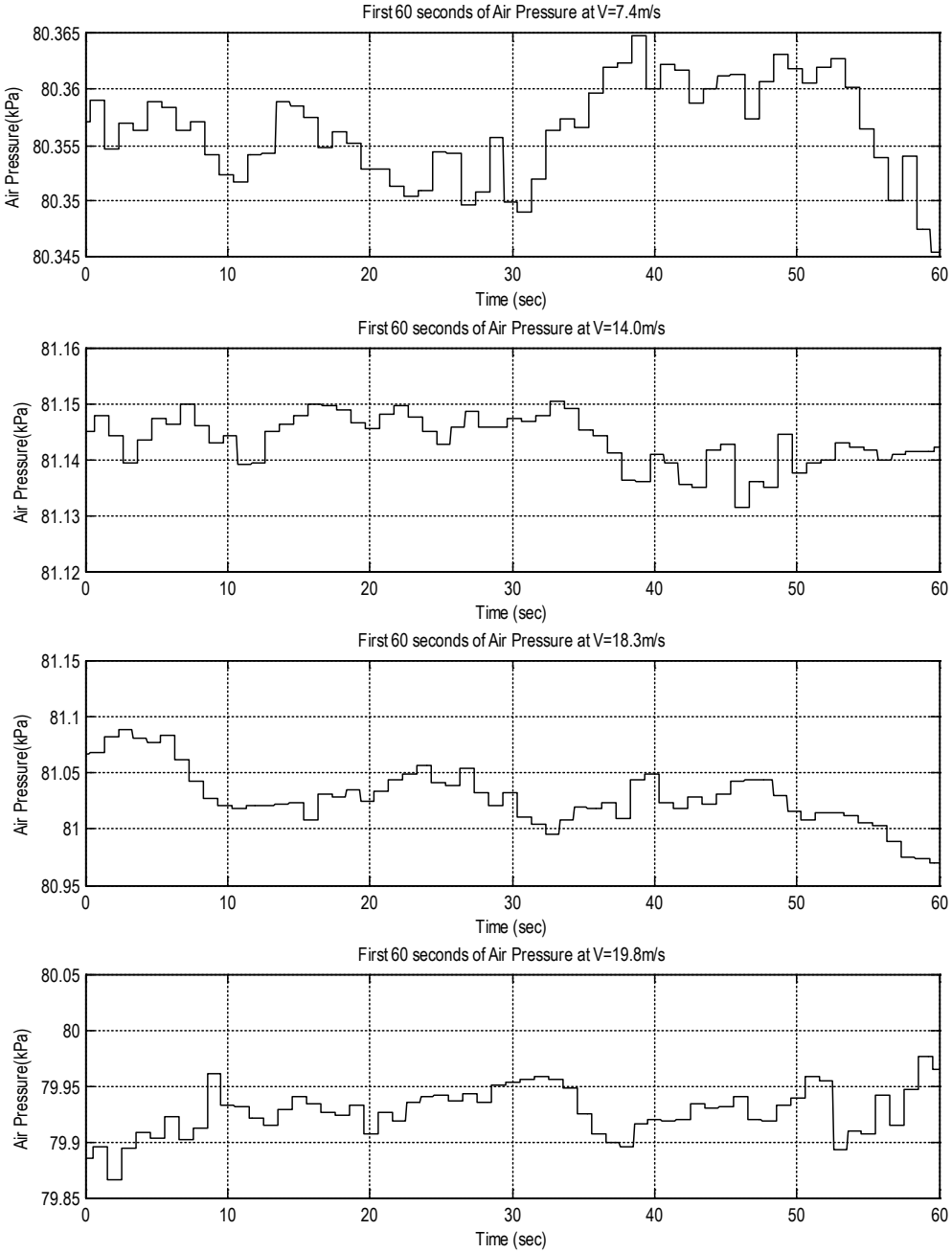


Figure 166. Time series for the first 60 seconds of air pressure

Temperature

Turbulence Intensity	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-11	11-12	12-13	13-14	14-15	15-16	16-17	17-18	18-19	19-20	20-21	21-22	22-23	23-24	24-25	25-26
29-100%	1	1	8	1	1	1	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
27-29%	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
25-27%	0	1	1	0	1	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
23-25%	0	0	0	0	3	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
21-23%	0	1	0	4	1	1	0	2	5	1	1	1	0	1	0	0	0	0	0	0	0	0	0
19-21%	0	0	0	3	2	2	2	5	3	0	5	0	0	0	0	0	2	0	0	0	0	0	0
17-19%	0	0	0	3	4	0	3	2	8	3	2	5	1	3	2	2	6	3	0	0	0	0	0
15-17%	0	0	1	3	6	1	1	0	6	11	8	8	2	2	2	7	1	2	0	0	0	0	0
13-15%	0	0	1	7	0	2	3	2	2	5	9	10	2	1	2	4	2	4	3	3	0	0	0
11-13%	0	0	0	1	0	2	7	1	0	3	5	6	4	1	2	3	2	0	0	1	0	0	0
9-11%	0	0	0	2	6	6	5	1	0	1	1	2	4	4	1	1	0	1	0	0	0	0	0
7-9%	0	0	0	0	4	2	0	0	0	0	0	0	1	2	2	0	0	0	0	0	0	0	0
5-7%	0	0	0	0	0	2	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3-5%	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0-3%	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Wind Speed (m/s)

Total Files in Wind Speed Bin

	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-11	11-12	12-13	13-14	14-15	15-16	16-17	17-18	18-19	19-20	20-21	21-22	22-23	23-24	24-25	25-26
# bins with 4 TS	0	0	1	2	4	1	2	1	3	2	4	4	2	1	0	2	1	1	0	0	0	0	0

Wind Speed (m/s)

	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-11	11-12	12-13	13-14	14-15	15-16	16-17	17-18	18-19	19-20	20-21	21-22	22-23	23-24	24-25	25-26
#TS in WS bin	1	4	11	25	28	19	24	16	26	24	31	32	14	14	11	17	13	10	3	4	0	0	0

Wind Speed (m/s)

Figure 167. Capture matrix for temperature

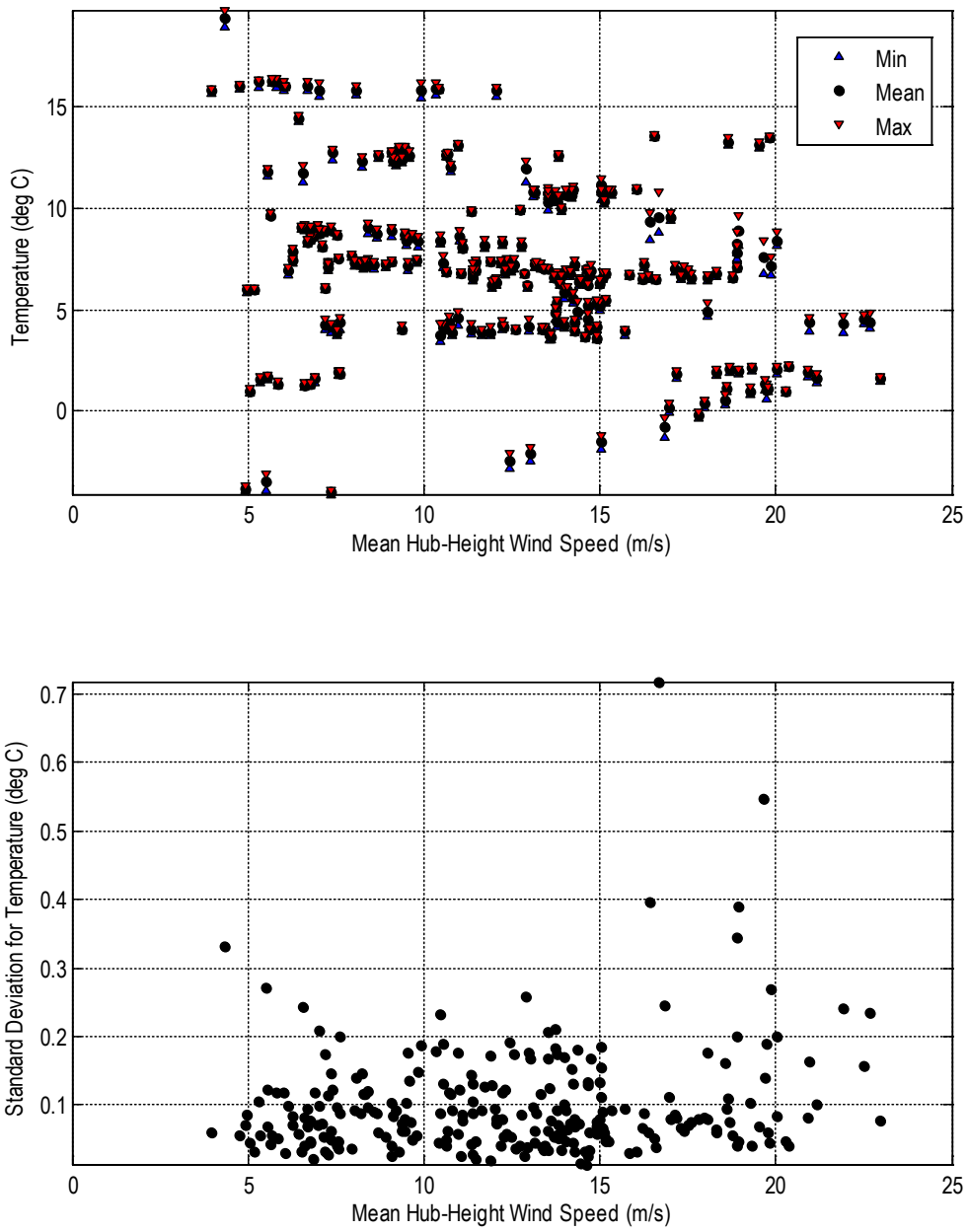


Figure 168. Scatterplot for temperature

Table 76. Binned Data for Temperature

Bin #	Bin WS Low	Bin WS High	Mean WS	# Files	Min of Minimums	Mean of Means	Max of Maximums
1	3.0	4.0	4.0	1	15.70	15.81	15.88
2	4.0	5.0	4.8	4	-3.95	9.39	19.80
3	5.0	6.0	5.5	11	-3.95	7.11	16.41
4	6.0	7.0	6.6	25	1.18	8.89	16.26
5	7.0	8.0	7.4	28	-4.11	7.04	16.22
6	8.0	9.0	8.4	19	6.98	8.42	16.05
7	9.0	10.0	9.5	24	3.92	9.55	16.15
8	10.0	11.0	10.6	16	3.41	8.80	16.17
9	11.0	12.0	11.4	26	3.70	7.09	9.91
10	12.0	13.0	12.5	24	-2.86	6.53	15.98
11	13.0	14.0	13.5	31	-2.46	6.76	12.67
12	14.0	15.0	14.5	32	3.50	6.23	11.08
13	15.0	16.0	15.3	14	-1.89	6.99	11.47
14	16.0	17.0	16.6	14	-1.32	5.86	13.63
15	17.0	18.0	17.5	11	-0.37	4.72	9.77
16	18.0	19.0	18.6	17	0.28	4.79	13.49
17	19.0	20.0	19.6	13	0.61	4.11	13.59
18	20.0	21.0	20.4	10	0.86	2.70	8.84
19	21.0	22.0	21.4	3	1.41	2.53	4.68
20	22.0	23.0	22.8	4	1.43	3.03	4.80
21	23.0	24.0	0.0	0	0.00	0.00	0.00
22	24.0	25.0	0.0	0	0.00	0.00	0.00
23	25.0	26.0	0.0	0	0.00	0.00	0.00

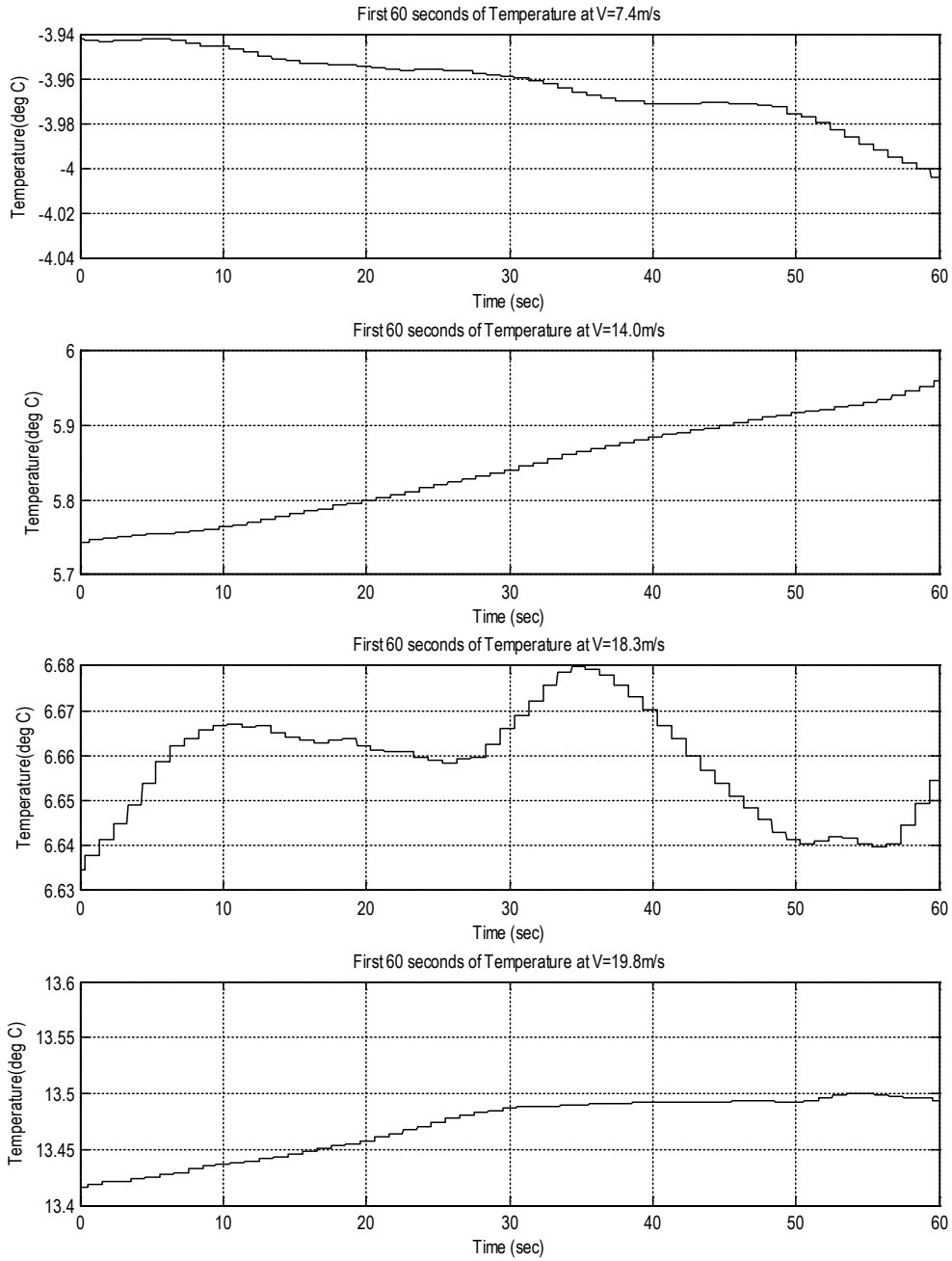


Figure 169. Time series for the first 60 seconds of temperature

Turbine Yaw Error

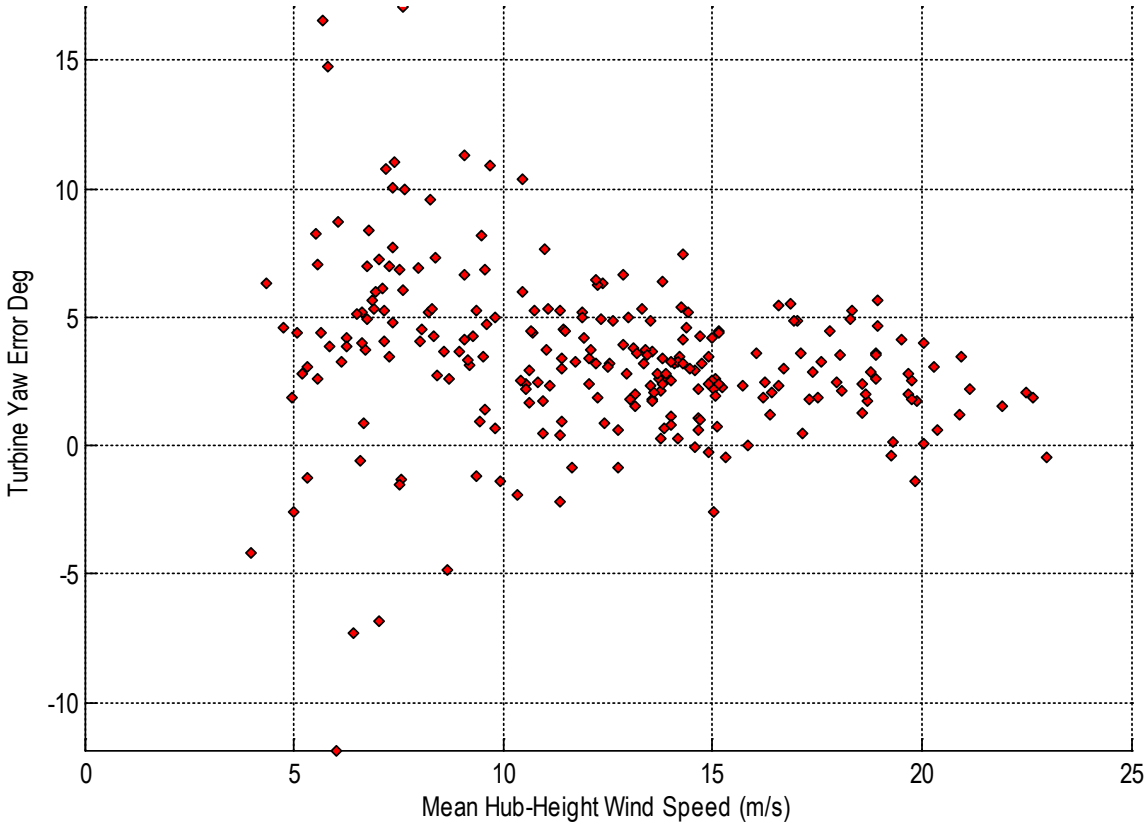


Figure 170. Scatterplot versus time for turbine yaw error

Table 77. Binned Data for Turbine Yaw Error

Bin #	Bin WS Low	Bin WS High	Mean WS	# Files	Min of Minimums	Mean of Means	Max of Maximums
1	3.0	4.0	4.0	1	-4.20	-4.20	-4.20
2	4.0	5.0	4.8	4	-2.57	2.55	6.35
3	5.0	6.0	5.5	11	-1.29	6.05	16.56
4	6.0	7.0	6.6	25	-11.86	3.69	8.70
5	7.0	8.0	7.4	28	-6.81	5.78	17.12
6	8.0	9.0	8.4	19	-4.84	4.29	9.58
7	9.0	10.0	9.5	24	-1.40	4.52	11.33
8	10.0	11.0	10.6	16	-1.91	3.29	10.36
9	11.0	12.0	11.4	26	-2.17	3.39	7.64
10	12.0	13.0	12.5	24	-0.85	3.43	6.62
11	13.0	14.0	13.5	31	0.25	2.87	6.36
12	14.0	15.0	14.5	32	-0.25	2.81	7.45
13	15.0	16.0	15.3	14	-2.58	1.58	4.46
14	16.0	17.0	16.6	14	1.22	3.30	5.52
15	17.0	18.0	17.5	11	0.45	2.91	4.85
16	18.0	19.0	18.6	17	1.24	3.02	5.62
17	19.0	20.0	19.6	13	-1.42	1.41	4.12
18	20.0	21.0	20.4	10	0.08	2.12	4.01
19	21.0	22.0	21.4	3	1.52	1.97	2.20
20	22.0	23.0	22.8	4	-0.44	0.78	2.09
21	23.0	24.0	0.0	0	0.00	0.00	0.00
22	24.0	25.0	0.0	0	0.00	0.00	0.00
23	25.0	26.0	0.0	0	0.00	0.00	0.00

Transient Events

Normal Start at 6.6 m/s

Table 78. Brief Statistical Description for Normal Start at 6.6 m/s

Event Description:	Normal Start at 6.6 m/s			
File Name:	FastWaveforms 2011_03_11 14_07_43 100Hz.tdms			
Date:	11-Mar-2011 14:07:00			
Measured Quantity	mean	sdv	min	max
Wind Speed at 80 m (m/s)	6.6	1.6	4.2	10.1
Wind Direction at 87 m (deg)	301.4	16.2	227.5	339.5
Air Pressure (kPa)	80.3	0.0	80.3	80.3
Temperature (deg C)	15.9	0.1	15.8	16.1
Electric Power (kW)	162.1	103.1	-9.4	312.1
Rotor Speed (rpm)	12.6	1.5	11.0	15.2
Generator Speed (m/s)	991.2	115.3	860.6	1,186.2
Nacelle Yaw Angle (deg)	261.0	0.0	261.0	261.0
Blade 1 Pitch Position (deg)	-1.9	0.0	-1.9	-1.9
Blade 2 Pitch Position (deg)	-1.9	0.0	-1.9	-1.9
Blade 3 Pitch Position (deg)	-2.1	0.0	-2.1	-2.1
Operational Status (-)	20.6	6.6	16.0	30.0
State Fault (-)	2.0	0.0	2.0	2.0
Availability Status (V)	89.9	0.0	89.9	89.9
Tower-Top Normal Acceleration (g)	-0.0	0.0	-0.0	0.0
Tower-Top Lateral Acceleration (g)	0.0	0.0	-0.0	0.0
Blade 1 Flap Bending (kNm)	692.5	279.6	106.5	1,348.2
Blade 1 Leadlag Bending (kNm)	-53.0	458.2	-730.2	723.9
Blade 2 Flap Bending (kNm)	711.7	293.4	51.1	1,358.8
Blade 2 Leadlag Bending (kNm)	59.9	457.4	-626.7	820.5
Blade 3 Flap Bending (kNm)	708.7	280.0	61.6	1,359.0
Blade 3 Leadlag Bending (kNm)	78.9	453.2	-613.9	828.8
Main Shaft Bending 0 (kNm)	8.3	304.2	-493.9	600.2
Main Shaft Bending 90 (kNm)	13.7	301.4	-514.0	565.0
Main Shaft Torque (kNm)	5.7	91.5	-185.0	177.8
Tower-Top Normal Bending (kNm)	-710.8	138.9	-1,369.7	-148.5
Tower-Top Lateral Bending (kNm)	468.3	78.7	204.9	653.5
Tower-Top Torque (kNm)	-31.8	147.6	-385.3	586.9
Tower-Base Normal Bending (kNm)	3,622.6	2,106.5	-99.1	7,801.8
Tower-Base Lateral Bending (kNm)	528.8	313.2	-516.1	1,645.3

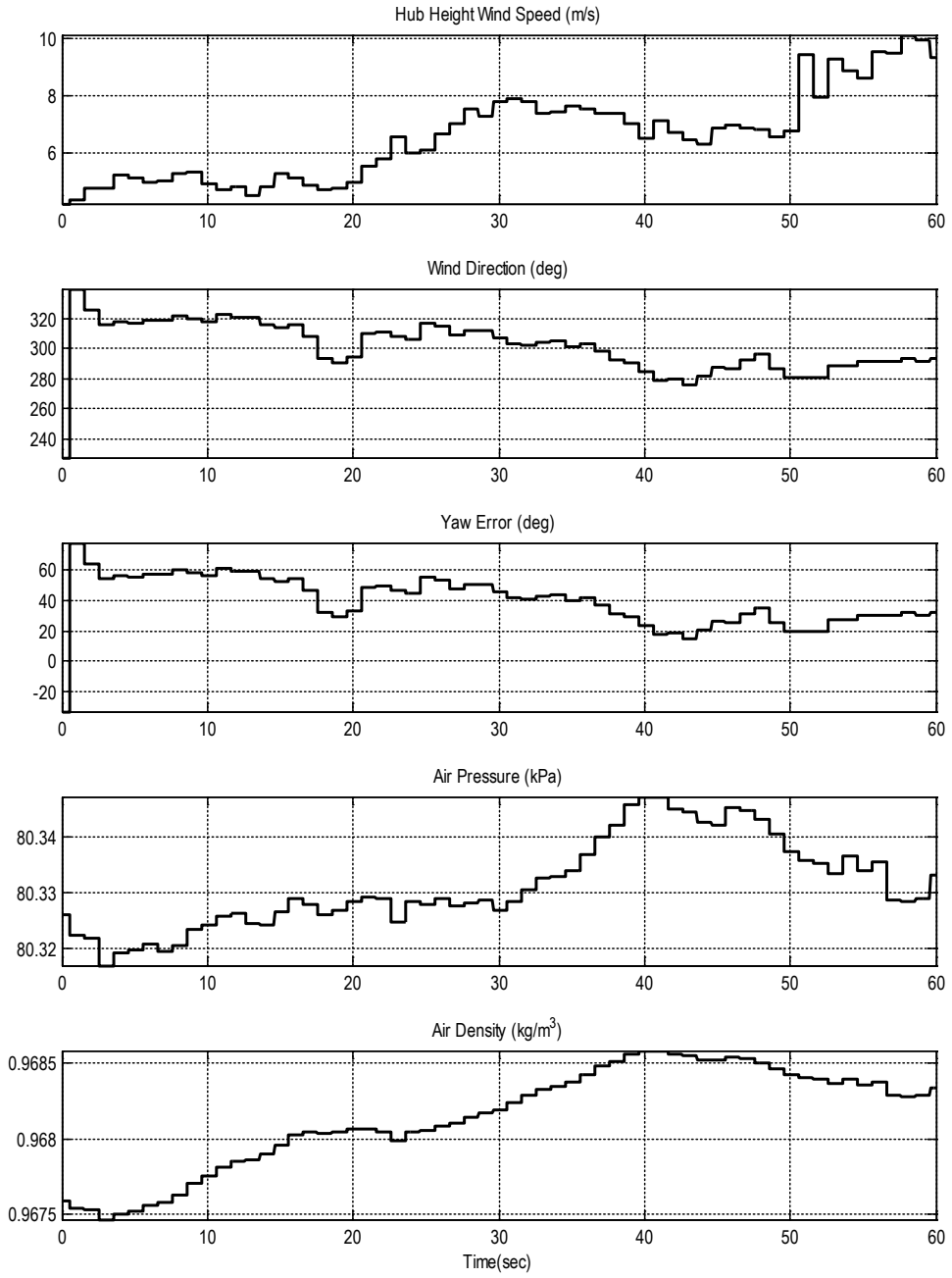


Figure 171. Normal start at 6.6 m/s—met quantities

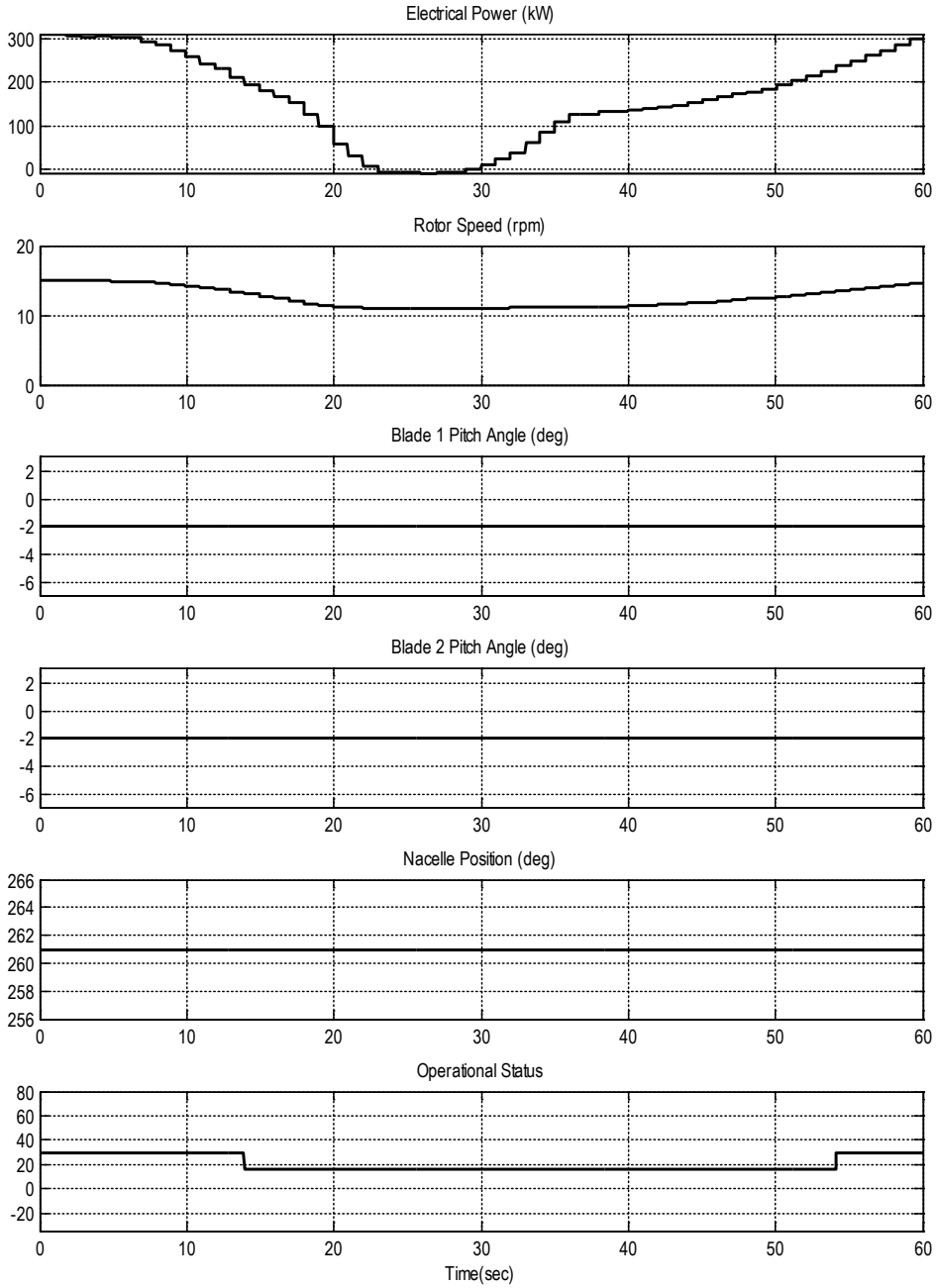


Figure 172. Normal start at 6.6 m/s—wind turbine operational quantities

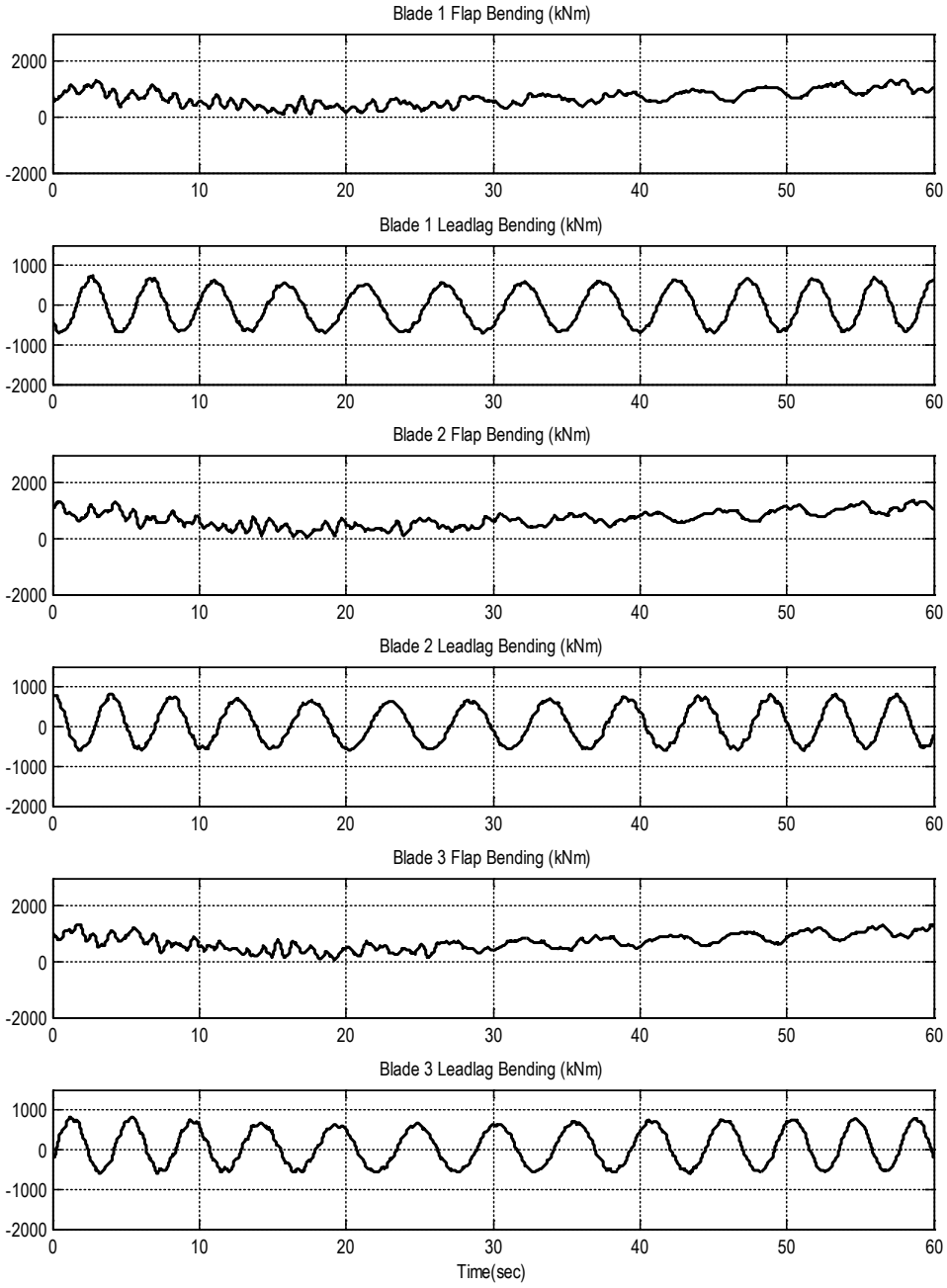


Figure 173. Normal start at 6.6 m/s—blade loads

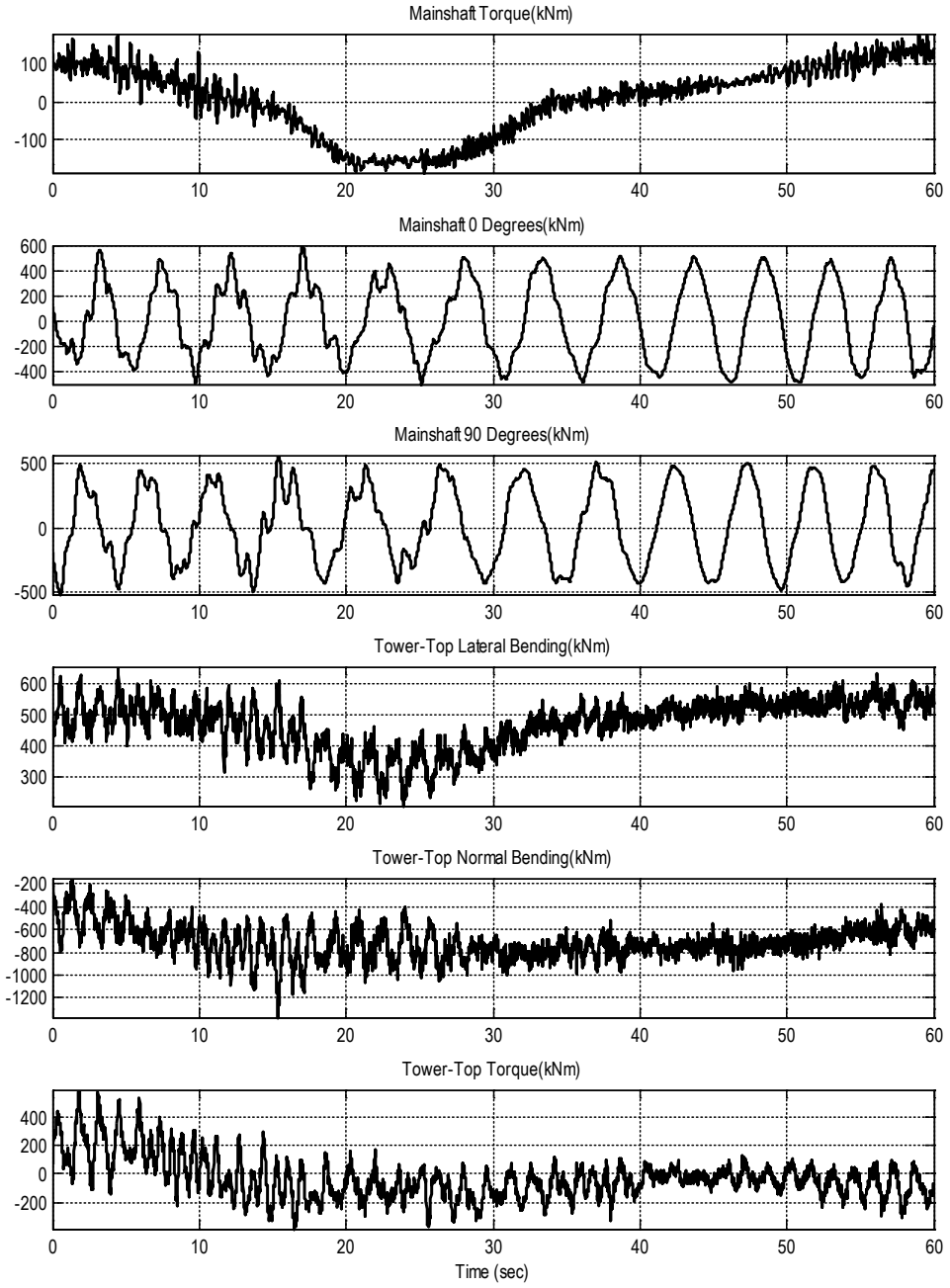


Figure 174. Normal start at 6.6 m/s—shaft and tower-top loads

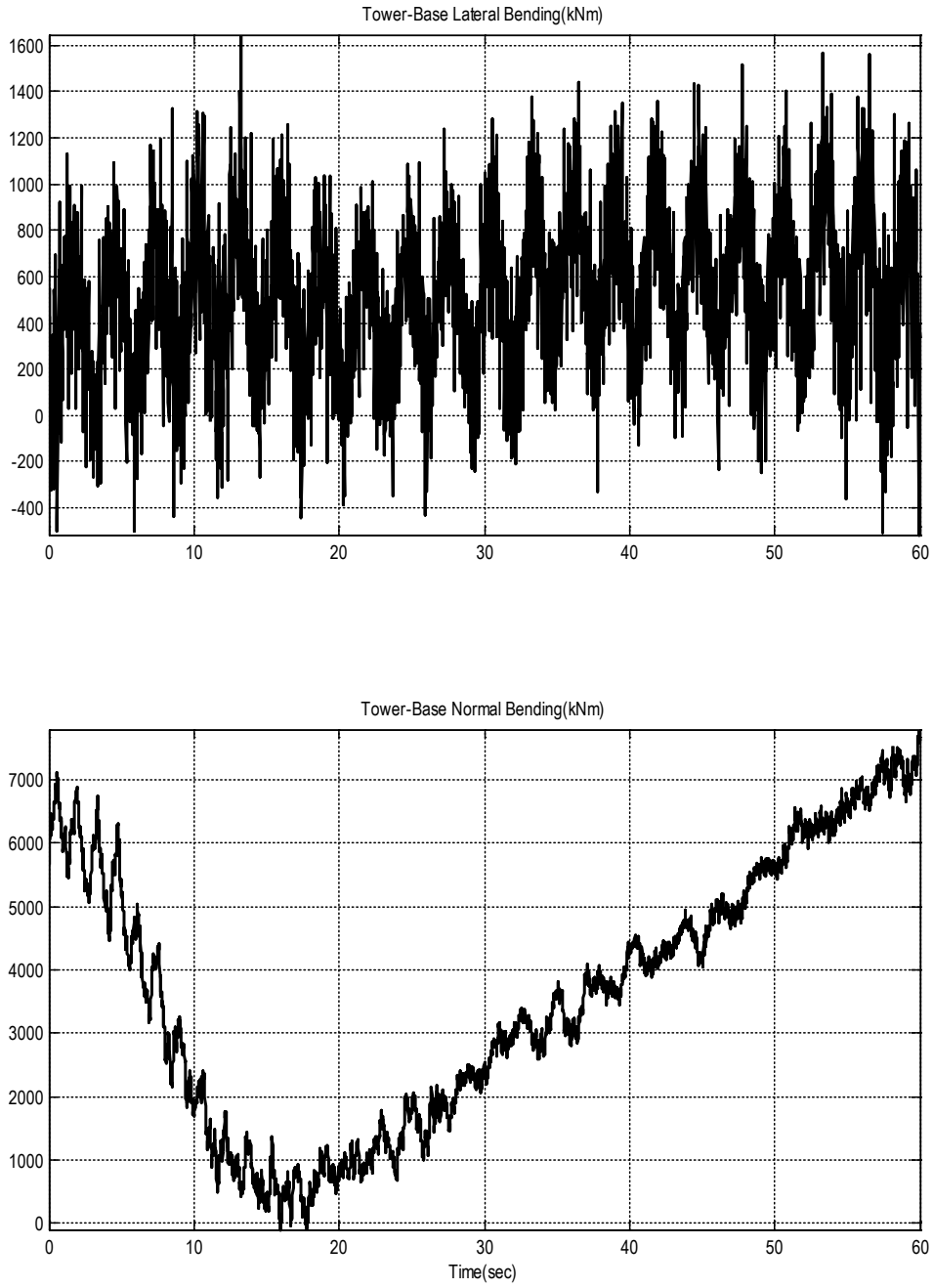


Figure 175. Normal start at 6.6 m/s—tower-base loads

Normal Start at 14.0 m/s

Table 79. Brief Statistical Description for Normal Start at 14.0 m/s

Event Description:	Normal Start at 14.0 m/s			
File Name:	FastWaveforms 2011_03_09 10_16_11 100Hz.tdms			
Date:	09-Mar-2011 10:16:00			
Measured Quantity	mean	sdv	min	max
Wind Speed at 80 m (m/s)	14.0	2.9	8.3	18.2
Wind Direction at 87 m (deg)	280.7	6.9	259.2	294.1
Air Pressure (kPa)	81.1	0.0	81.1	81.2
Temperature (deg C)	4.5	0.1	4.3	4.5
Electric Power (kW)	271.9	353.1	-29.1	976.5
Rotor Speed (rpm)	14.4	2.2	12.3	18.4
Generator Speed (m/s)	1,136.9	174.9	967.6	1,449.8
Nacelle Yaw Angle (deg)	287.2	3.3	278.0	289.0
Blade 1 Pitch Position (deg)	17.8	2.0	14.8	20.9
Blade 2 Pitch Position (deg)	17.8	2.0	14.8	20.9
Blade 3 Pitch Position (deg)	17.8	2.0	14.8	20.8
Operational Status (-)	314.8	287.2	16.0	602.0
State Fault (-)	2.5	0.5	2.0	3.0
Availability Status (V)	90.0	0.0	90.0	90.0
Tower-Top Normal Acceleration (g)	-0.0	0.0	-0.1	0.1
Tower-Top Lateral Acceleration (g)	0.0	0.0	-0.1	0.1
Blade 1 Flap Bending (kNm)	195.7	398.6	-592.8	1,140.7
Blade 1 Leadlag Bending (kNm)	42.7	414.5	-667.4	784.8
Blade 2 Flap Bending (kNm)	176.8	360.0	-489.6	1,055.9
Blade 2 Leadlag Bending (kNm)	82.4	411.8	-563.9	782.1
Blade 3 Flap Bending (kNm)	205.0	376.8	-417.4	1,099.2
Blade 3 Leadlag Bending (kNm)	25.5	399.1	-642.1	710.3
Main Shaft Bending 0 (kNm)	10.7	228.9	-662.9	497.6
Main Shaft Bending 90 (kNm)	16.2	215.5	-567.3	481.4
Main Shaft Torque (kNm)	5.7	272.7	-279.9	548.1
Tower-Top Normal Bending (kNm)	-614.1	238.6	-1,243.1	201.1
Tower-Top Lateral Bending (kNm)	143.5	199.0	-123.1	556.0
Tower-Top Torque (kNm)	174.9	199.1	-380.9	733.7
Tower-Base Normal Bending (kNm)	2,065.4	2,534.5	-1,378.1	7,137.7
Tower-Base Lateral Bending (kNm)	-82.2	562.5	-2,049.6	1,747.8

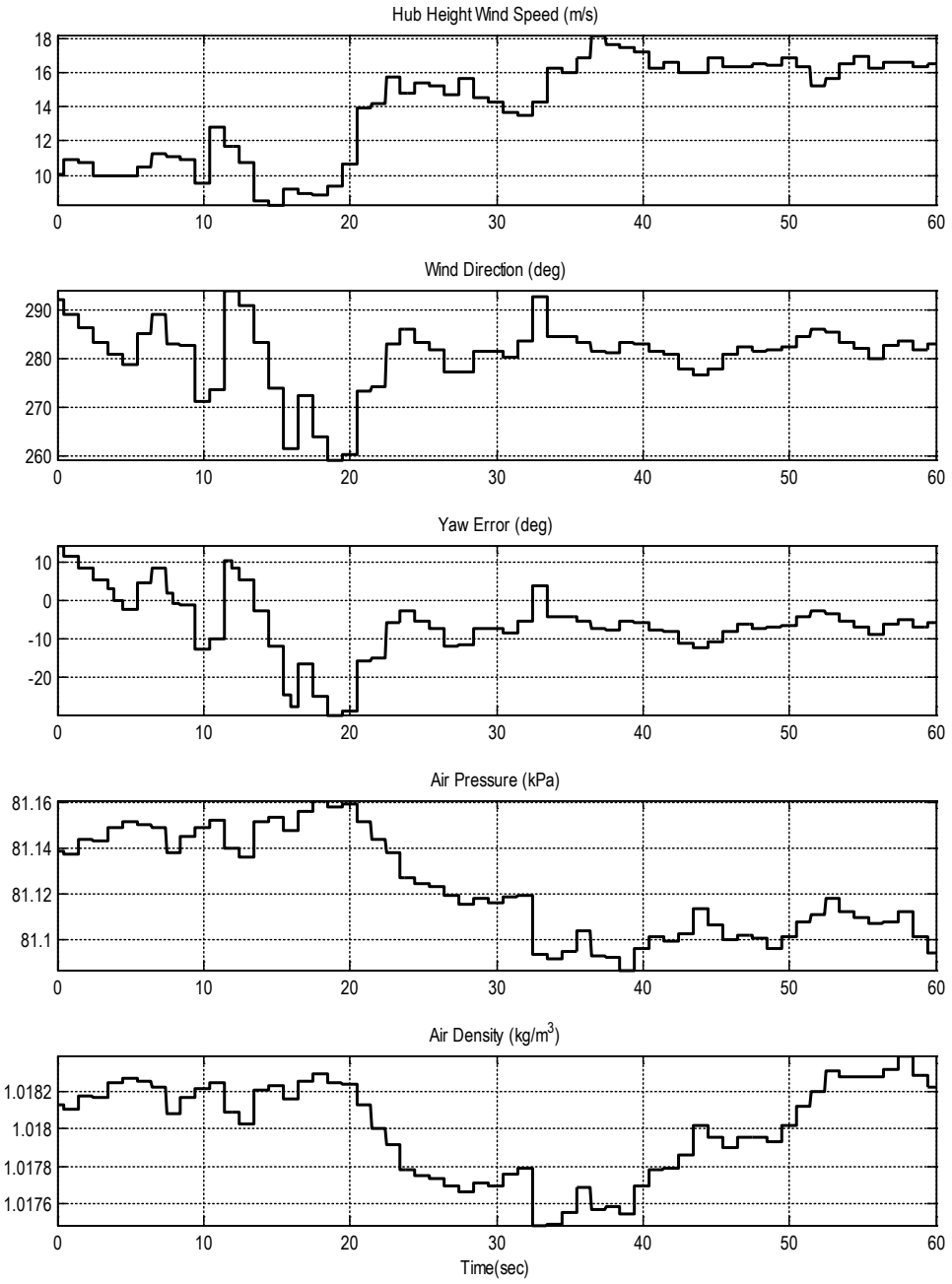


Figure 176. Normal start at 14.0 m/s—met quantities

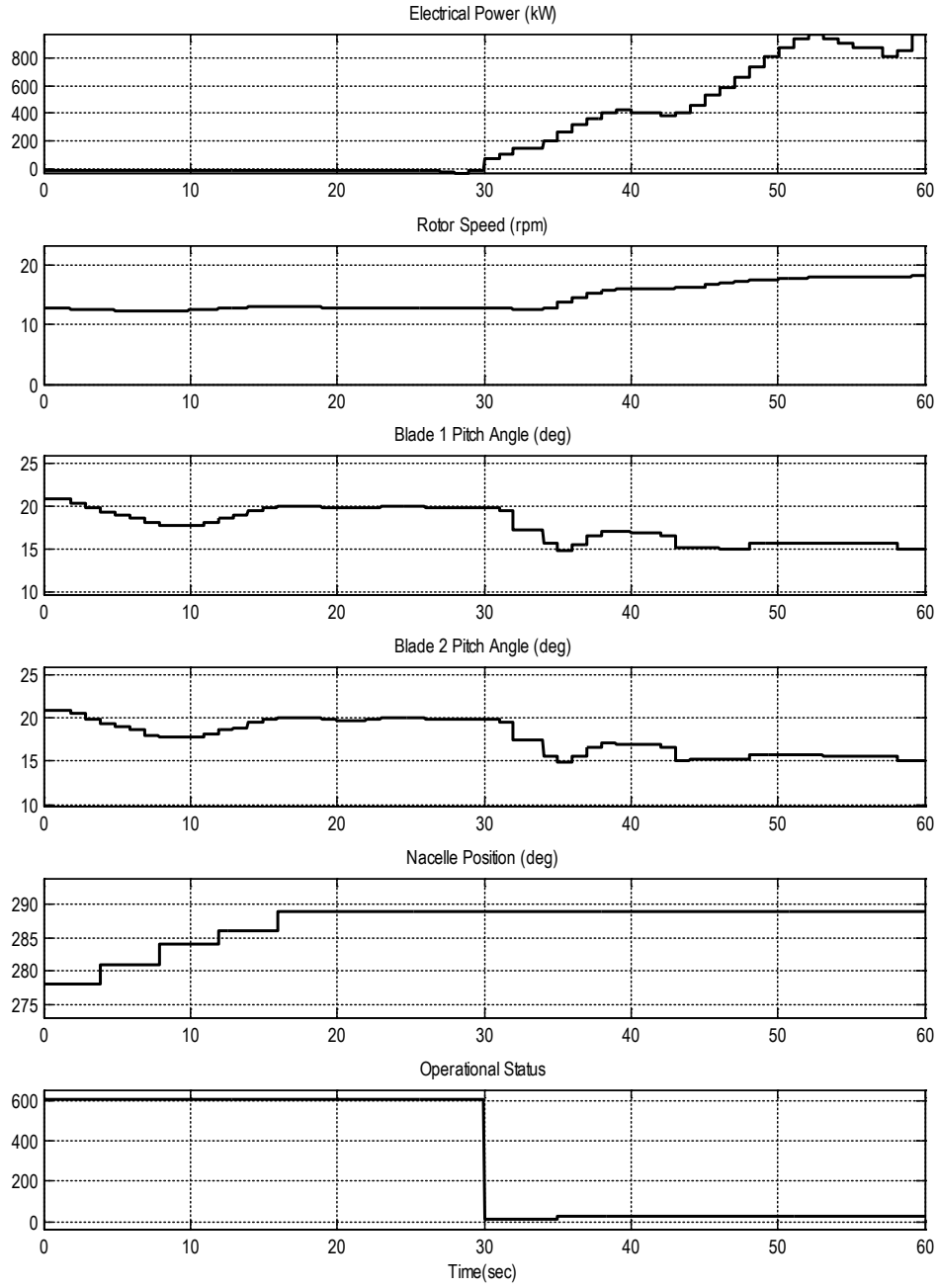


Figure 177. Normal start at 14.0 m/s—wind turbine operational quantities

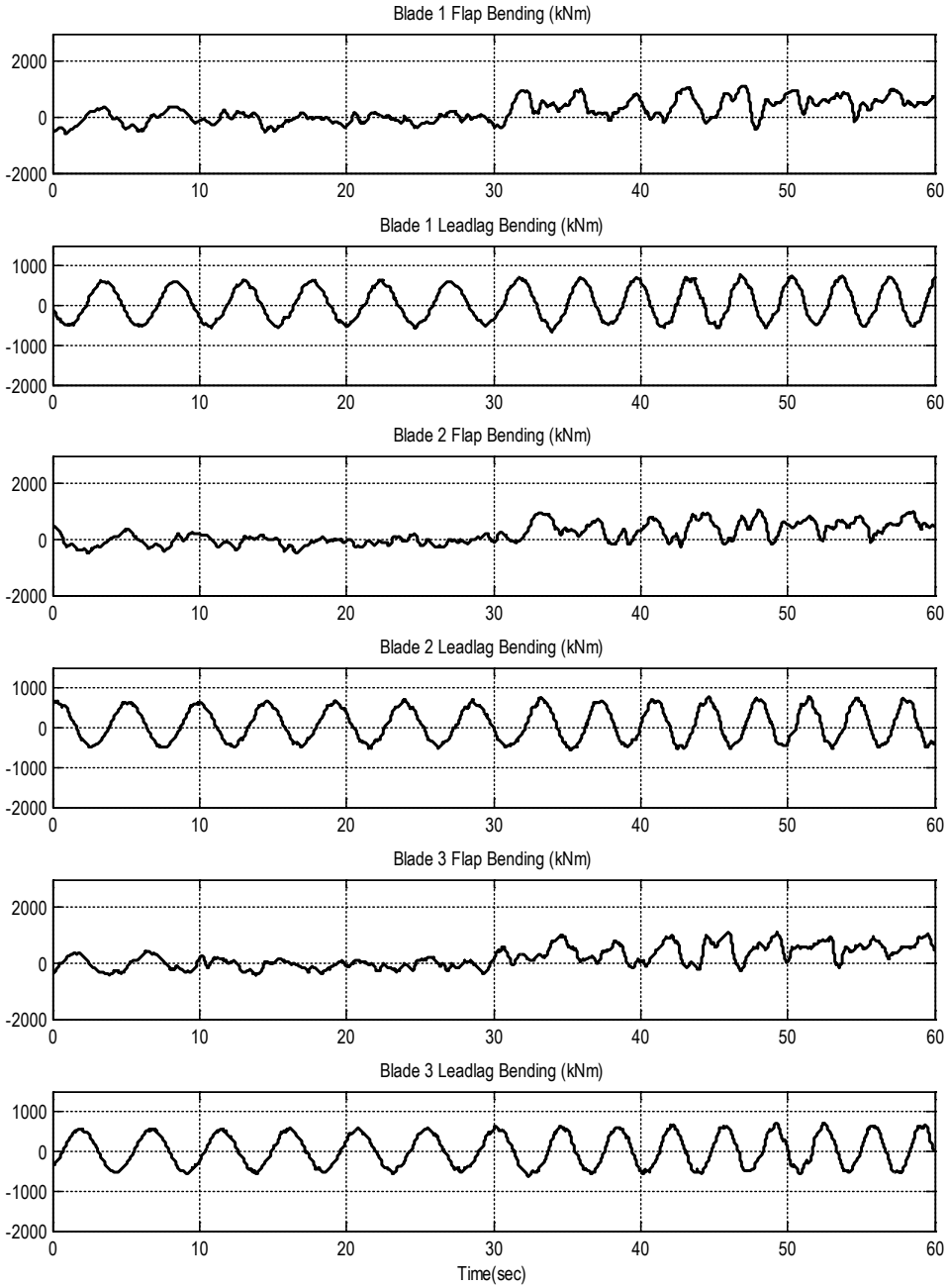


Figure 178. Normal start at 14.0 m/s—blade loads

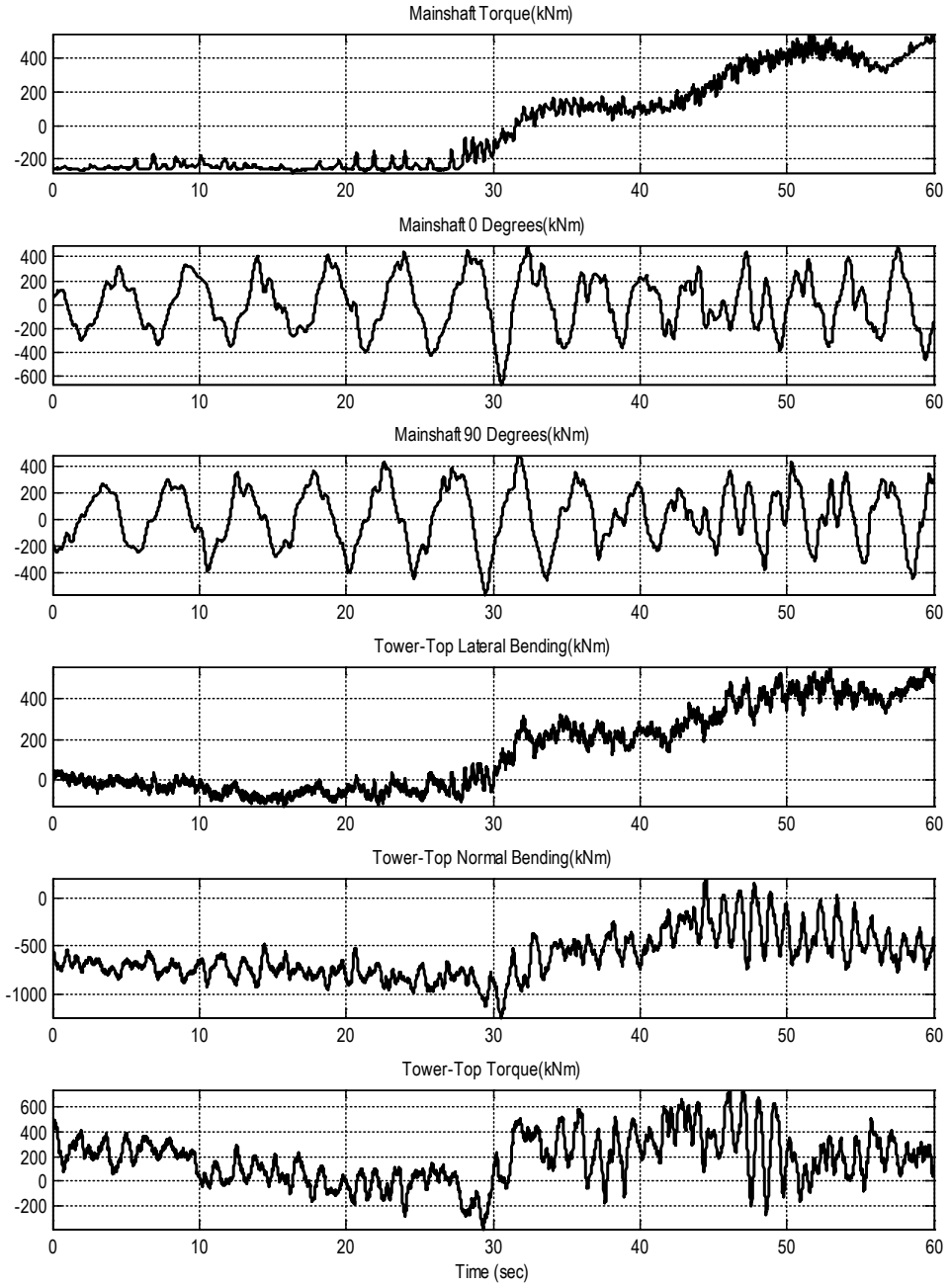


Figure 179. Normal start at 14.0 m/s—shaft and tower-top loads

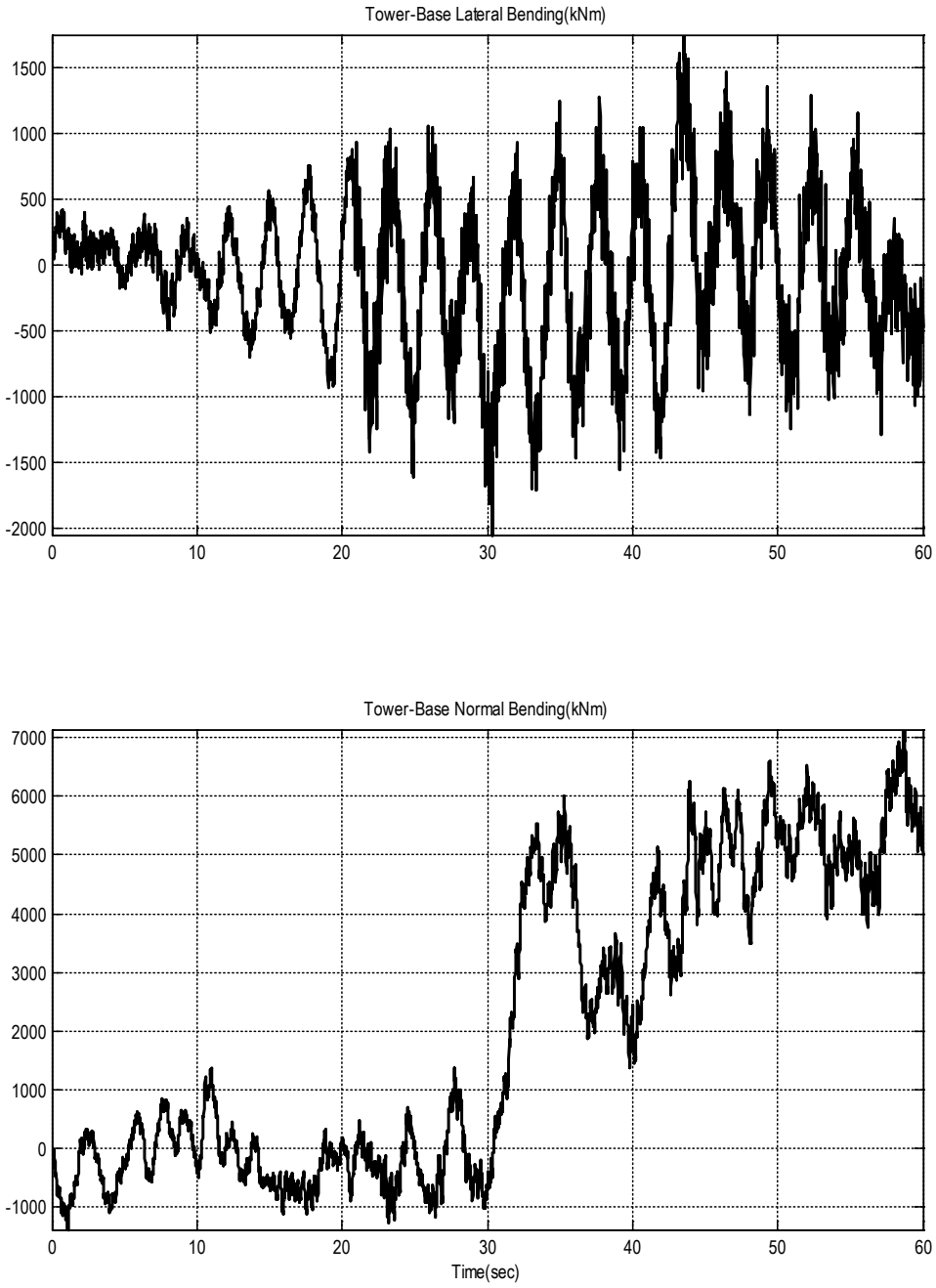


Figure 180. Normal start at 14.0 m/s—tower-base loads

Normal Start at 23.5 m/s

Table 80. Brief Statistical Description for Normal Start at 23.5 m/s

Event Description:	Normal Start at 23.5 m/s			
File Name:	FastWaveforms 2011_03_11 08_07_14 100Hz.tdms			
Date:	11-Mar-2011 08:07:00			
Measured Quantity	mean	sdv	min	max
Wind Speed at 80 m (m/s)	23.5	2.9	17.6	29.5
Wind Direction at 87 m (deg)	272.5	6.4	253.0	282.4
Air Pressure (kPa)	80.0	0.0	79.9	80.0
Temperature (deg C)	13.2	0.0	13.1	13.2
Electric Power (kW)	188.2	241.6	-31.3	711.4
Rotor Speed (rpm)	14.1	1.9	12.2	17.8
Generator Speed (m/s)	1,107.2	151.3	942.9	1,413.1
Nacelle Yaw Angle (deg)	276.4	1.5	275.0	278.0
Blade 1 Pitch Position (deg)	35.3	7.1	22.1	42.4
Blade 2 Pitch Position (deg)	35.3	7.1	22.1	42.5
Blade 3 Pitch Position (deg)	35.3	7.1	22.1	42.4
Operational Status (-)	314.3	287.7	16.0	602.0
State Fault (-)	2.5	0.5	2.0	3.0
Availability Status (V)	89.6	0.0	89.6	89.6
Tower-Top Normal Acceleration (g)	-0.0	0.0	-0.1	0.1
Tower-Top Lateral Acceleration (g)	0.0	0.0	-0.1	0.1
Blade 1 Flap Bending (kNm)	133.0	467.3	-840.6	1,130.3
Blade 1 Leadlag Bending (kNm)	-75.7	369.7	-778.8	603.8
Blade 2 Flap Bending (kNm)	16.2	432.9	-1,069.5	905.8
Blade 2 Leadlag Bending (kNm)	3.0	369.9	-619.8	664.6
Blade 3 Flap Bending (kNm)	94.6	440.2	-820.1	993.7
Blade 3 Leadlag Bending (kNm)	-7.2	372.6	-659.2	619.8
Main Shaft Bending 0 (kNm)	13.8	287.0	-721.7	711.0
Main Shaft Bending 90 (kNm)	26.9	267.9	-794.5	790.7
Main Shaft Torque (kNm)	8.1	211.3	-441.3	497.6
Tower-Top Normal Bending (kNm)	-673.3	275.8	-1,693.3	125.2
Tower-Top Lateral Bending (kNm)	325.8	152.3	-72.2	733.6
Tower-Top Torque (kNm)	34.5	212.7	-646.8	732.5
Tower-Base Normal Bending (kNm)	2,491.0	1,840.6	-2,482.6	6,505.2
Tower-Base Lateral Bending (kNm)	148.2	1,857.3	-5,008.2	4,182.8

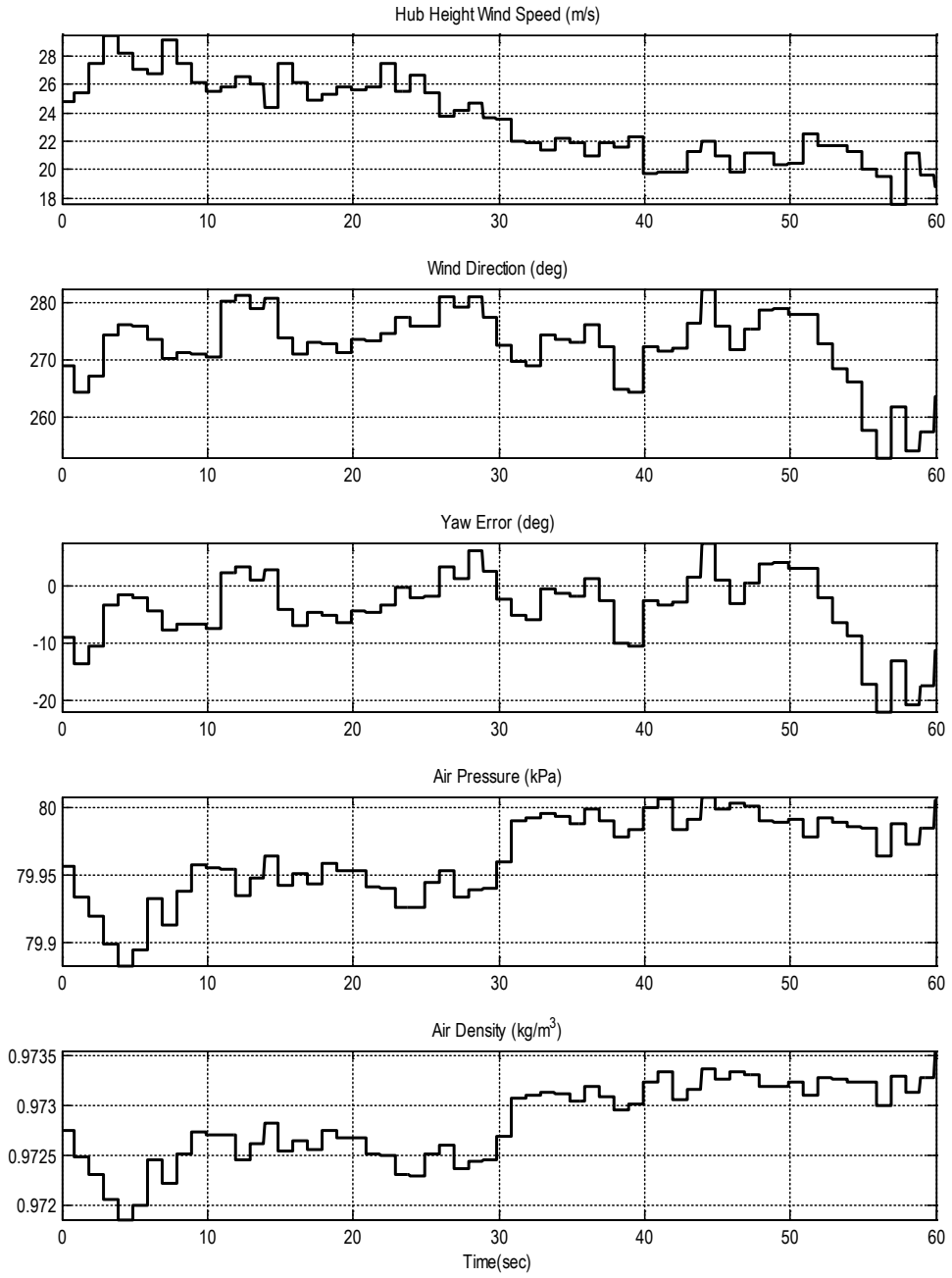


Figure 181. Normal start at 23.5 m/s—met quantities

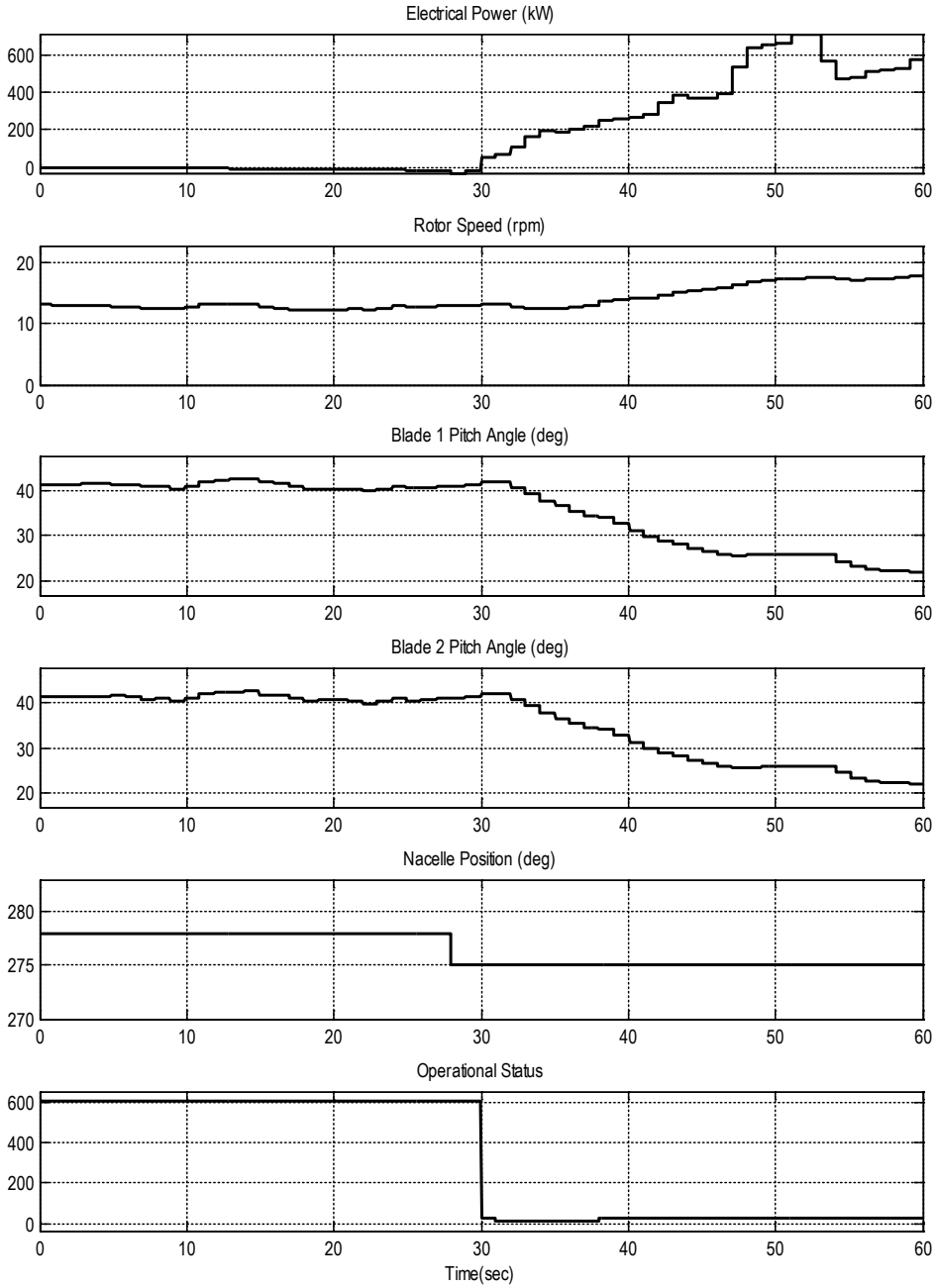


Figure 182. Normal start at 23.5 m/s—wind turbine operational quantities

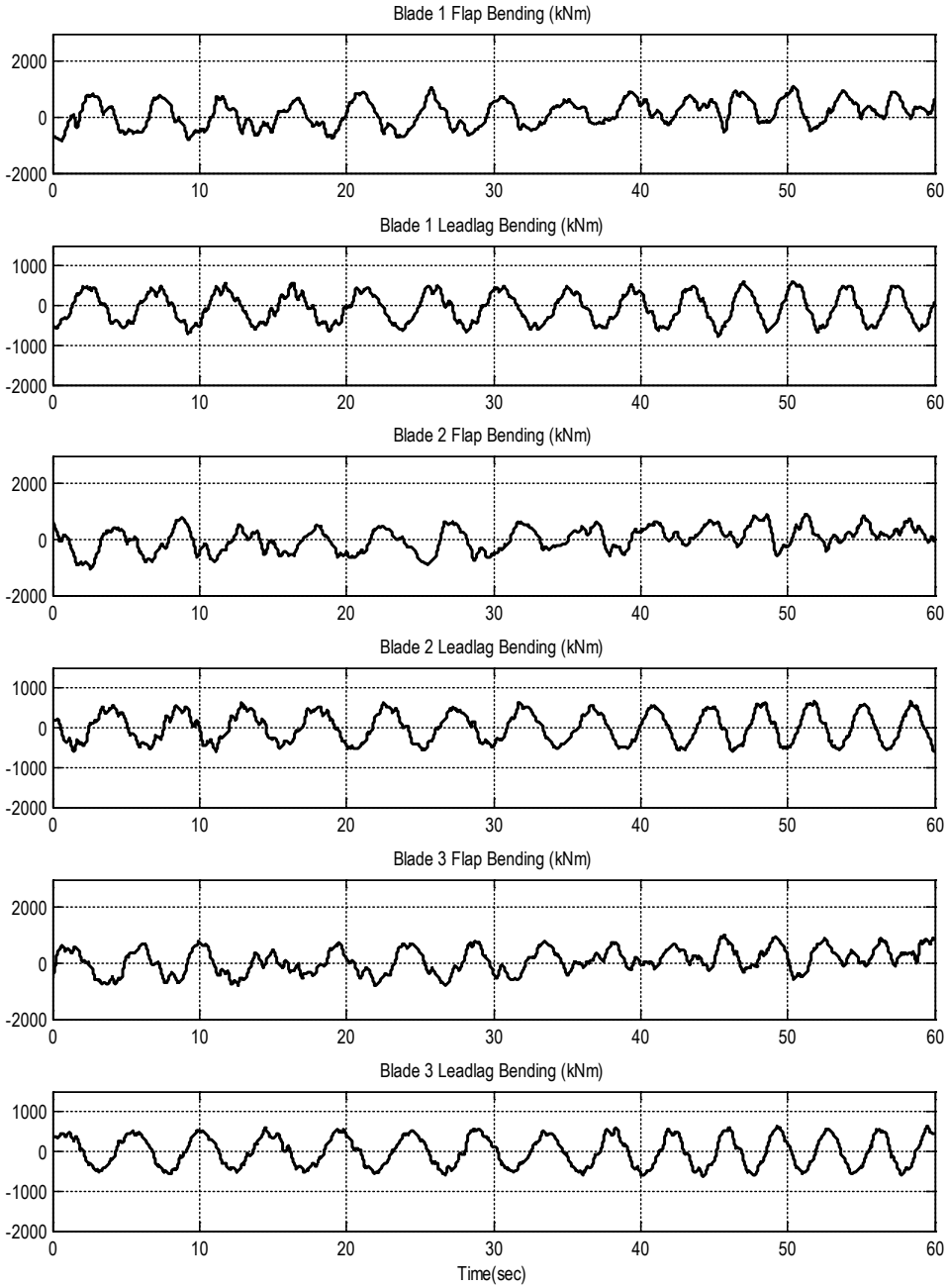


Figure 183. Normal start at 23.5 m/s—blade loads

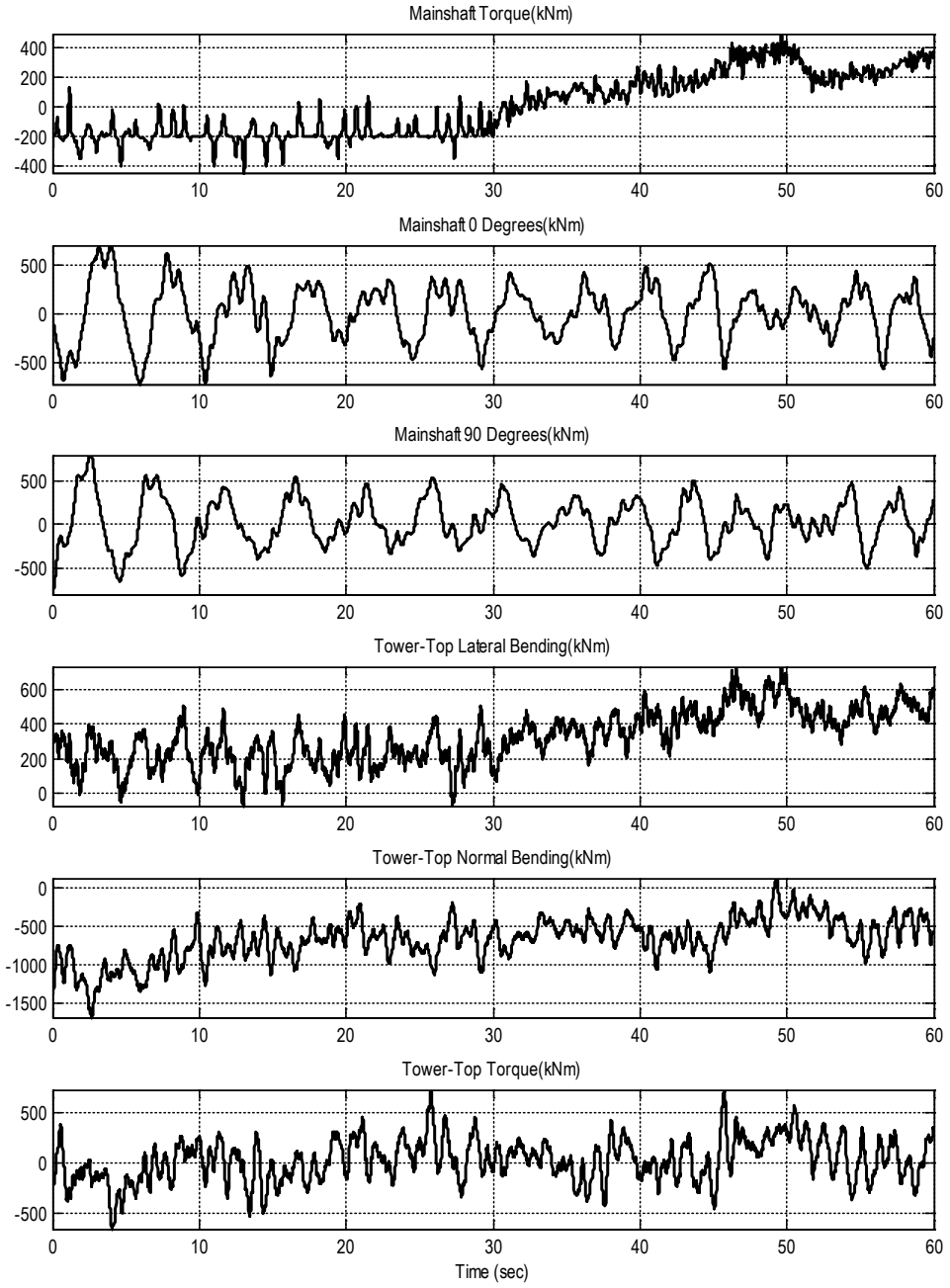


Figure 184. Normal start at 23.5 m/s—shaft and tower-top loads

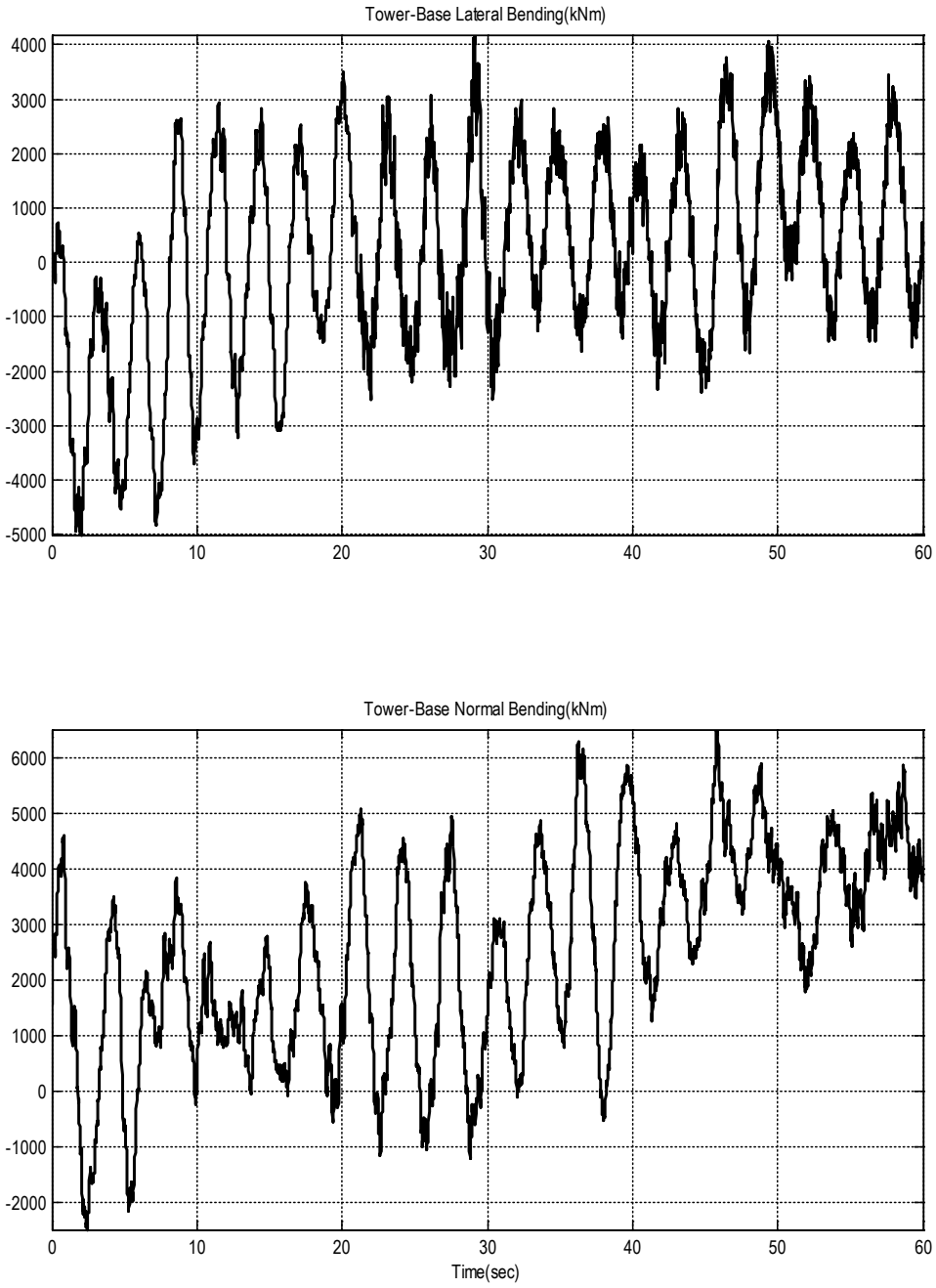


Figure 185. Normal start at 23.5 m/s—tower-base loads

Normal Stop at 7.0 m/s

Table 81. Brief Statistical Description for Normal Stop at 7.0 m/s

Event Description:	Normal Stop at 7.0 m/s			
File Name:	FastWaveforms 2011_03_11 11_07_29 100Hz.tdms			
Date:	11-Mar-2011 11:07:00			
Measured Quantity	mean	sdv	min	max
Wind Speed at 80 m (m/s)	7.0	0.8	5.5	8.8
Wind Direction at 87 m (deg)	340.8	14.3	243.6	353.9
Air Pressure (kPa)	80.3	0.0	80.3	80.3
Temperature (deg C)	14.2	0.0	14.2	14.3
Electric Power (kW)	135.0	163.2	-20.1	521.3
Rotor Speed (rpm)	12.6	1.9	7.4	14.6
Generator Speed (m/s)	979.5	150.6	566.9	1,140.6
Nacelle Yaw Angle (deg)	304.3	12.3	284.0	326.0
Blade 1 Pitch Position (deg)	6.0	10.1	-1.9	28.7
Blade 2 Pitch Position (deg)	6.0	10.1	-1.9	28.7
Blade 3 Pitch Position (deg)	6.0	10.1	-2.0	28.7
Operational Status (-)	364.1	337.0	17.0	701.0
State Fault (-)	1.5	0.5	1.0	2.0
Availability Status (V)	89.8	0.0	89.8	89.8
Tower-Top Normal Acceleration (g)	0.0	0.0	-0.1	0.2
Tower-Top Lateral Acceleration (g)	0.0	0.0	-0.1	0.1
Blade 1 Flap Bending (kNm)	416.2	482.8	-641.4	1,094.8
Blade 1 Leadlag Bending (kNm)	-17.6	438.4	-713.0	737.6
Blade 2 Flap Bending (kNm)	391.9	486.8	-610.0	1,092.0
Blade 2 Leadlag Bending (kNm)	64.2	437.6	-621.7	789.8
Blade 3 Flap Bending (kNm)	382.2	493.5	-645.9	1,073.1
Blade 3 Leadlag Bending (kNm)	28.2	439.3	-630.5	808.5
Main Shaft Bending 0 (kNm)	21.1	260.6	-461.1	507.6
Main Shaft Bending 90 (kNm)	21.1	251.9	-415.1	479.5
Main Shaft Torque (kNm)	-62.1	162.8	-253.0	313.5
Tower-Top Normal Bending (kNm)	-748.3	90.0	-980.0	-527.0
Tower-Top Lateral Bending (kNm)	177.4	76.9	-19.2	374.1
Tower-Top Torque (kNm)	-33.0	98.1	-273.7	269.8
Tower-Base Normal Bending (kNm)	1,724.6	3,222.6	-3,243.7	6,074.7
Tower-Base Lateral Bending (kNm)	505.5	200.4	-206.3	1,433.1

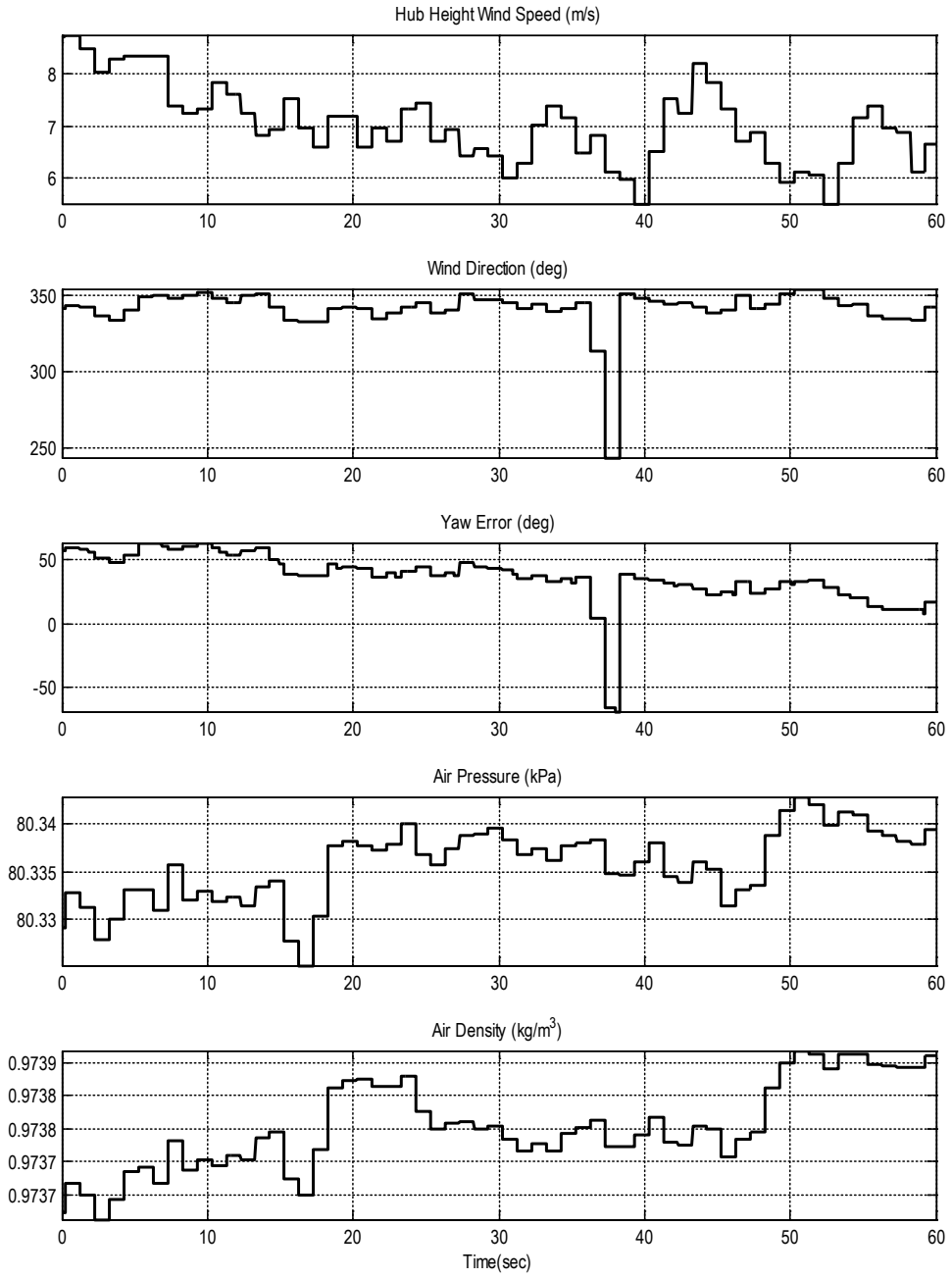


Figure 186. Normal stop at 7.0 m/s—met quantities

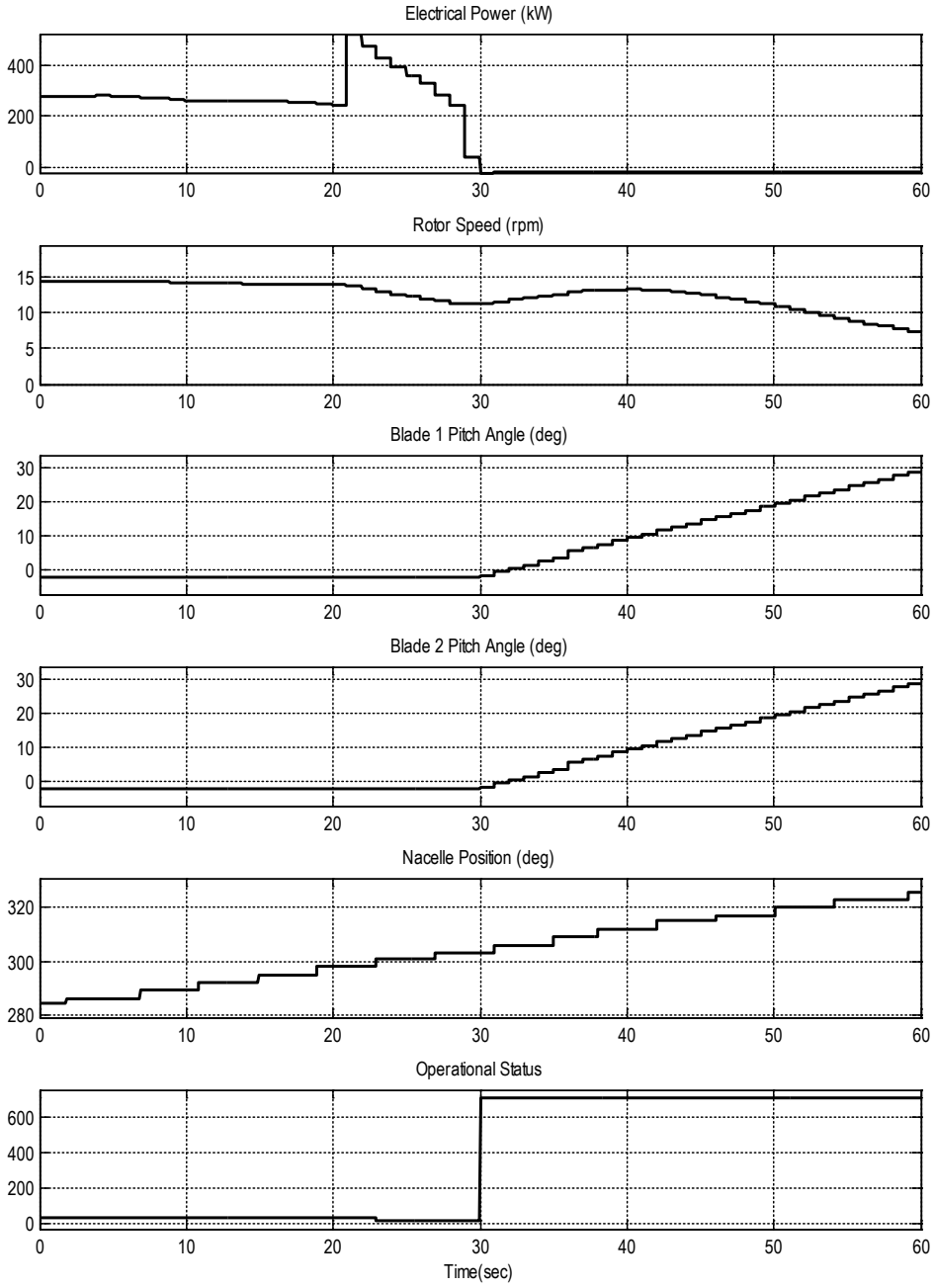


Figure 187. Normal stop at 7.0 m/s—wind turbine operational quantities

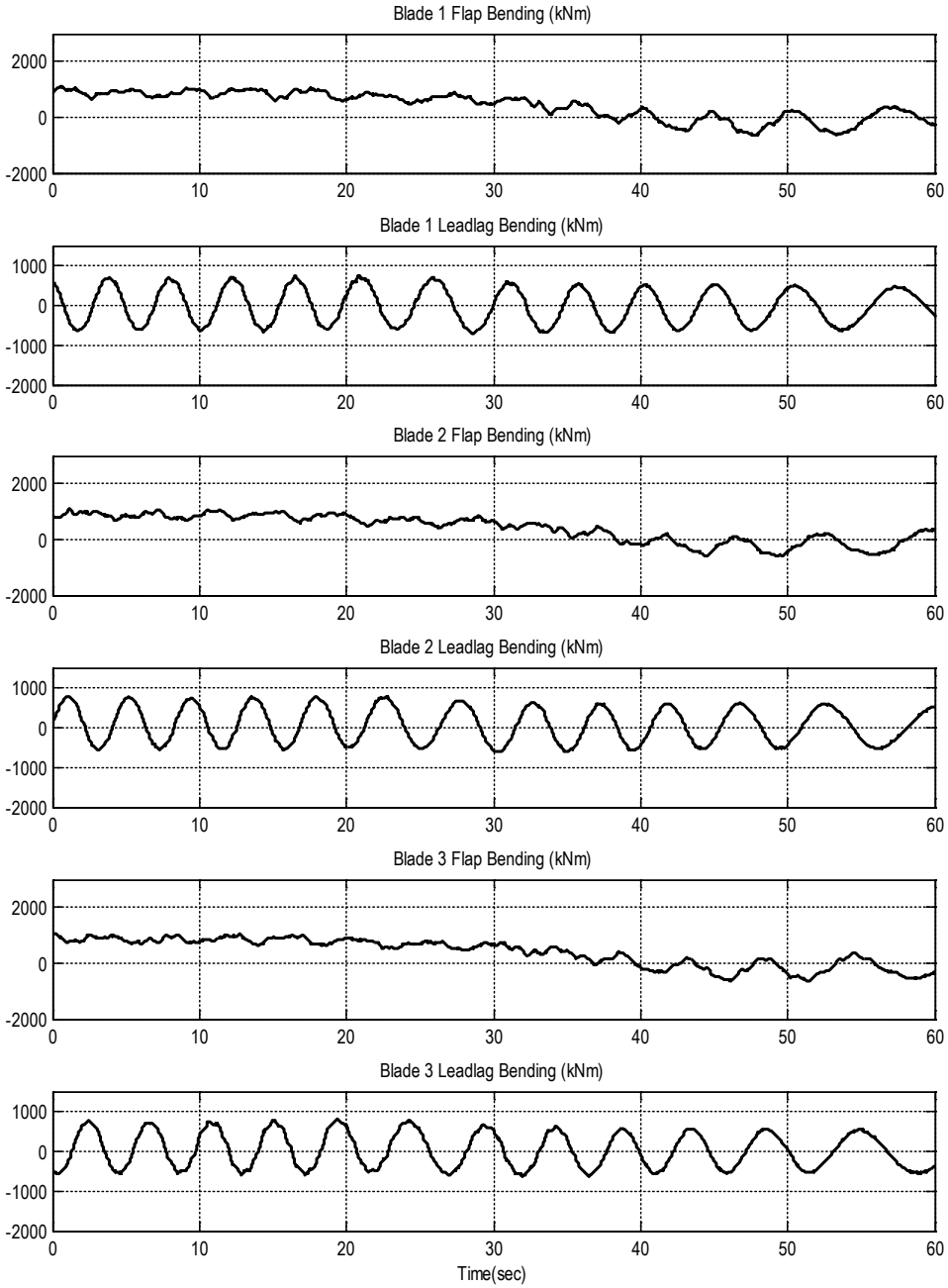


Figure 188. Normal stop at 7.0 m/s—blade loads

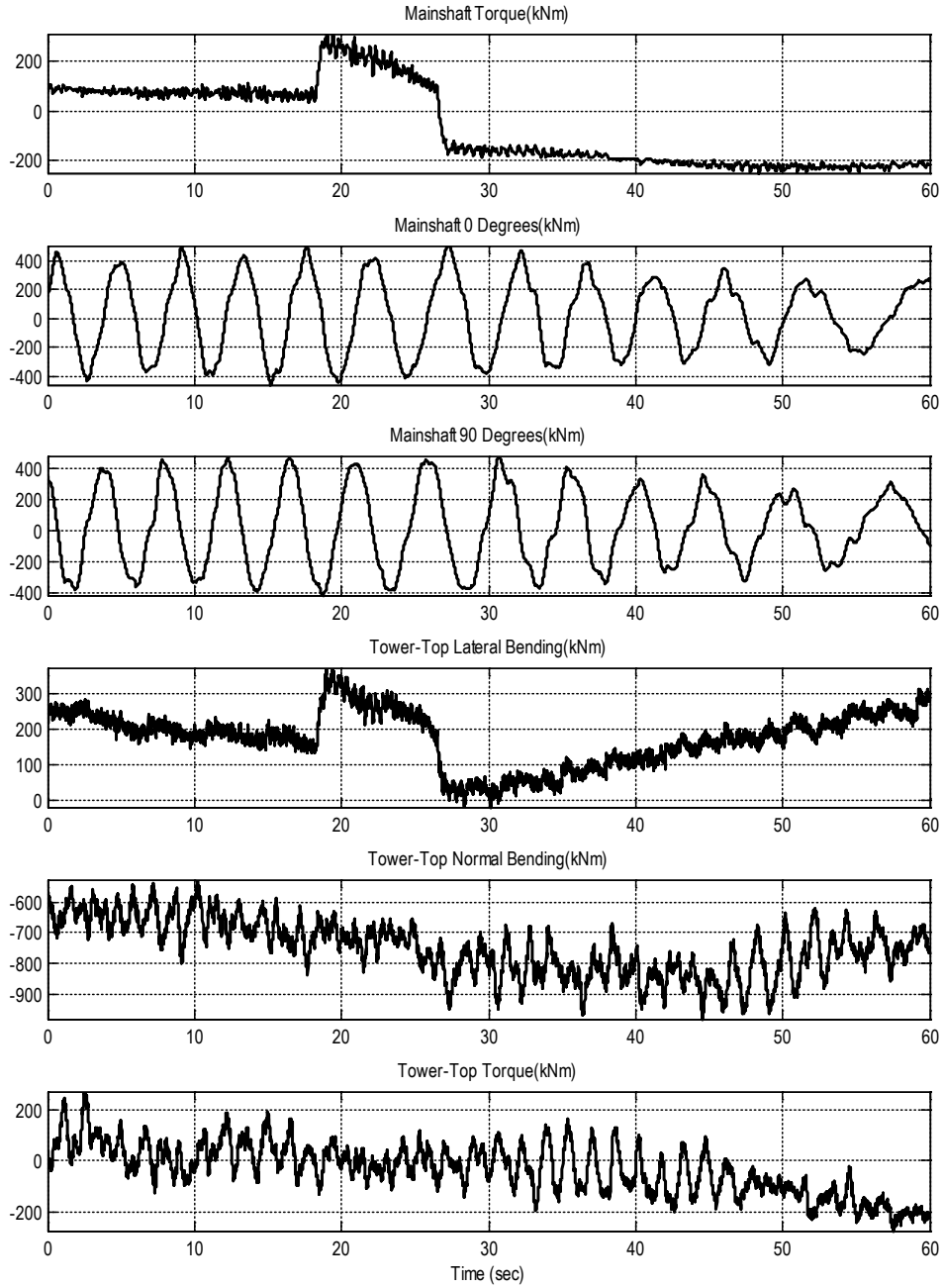


Figure 189. Normal stop at 7.0 m/s—shaft and tower-top loads

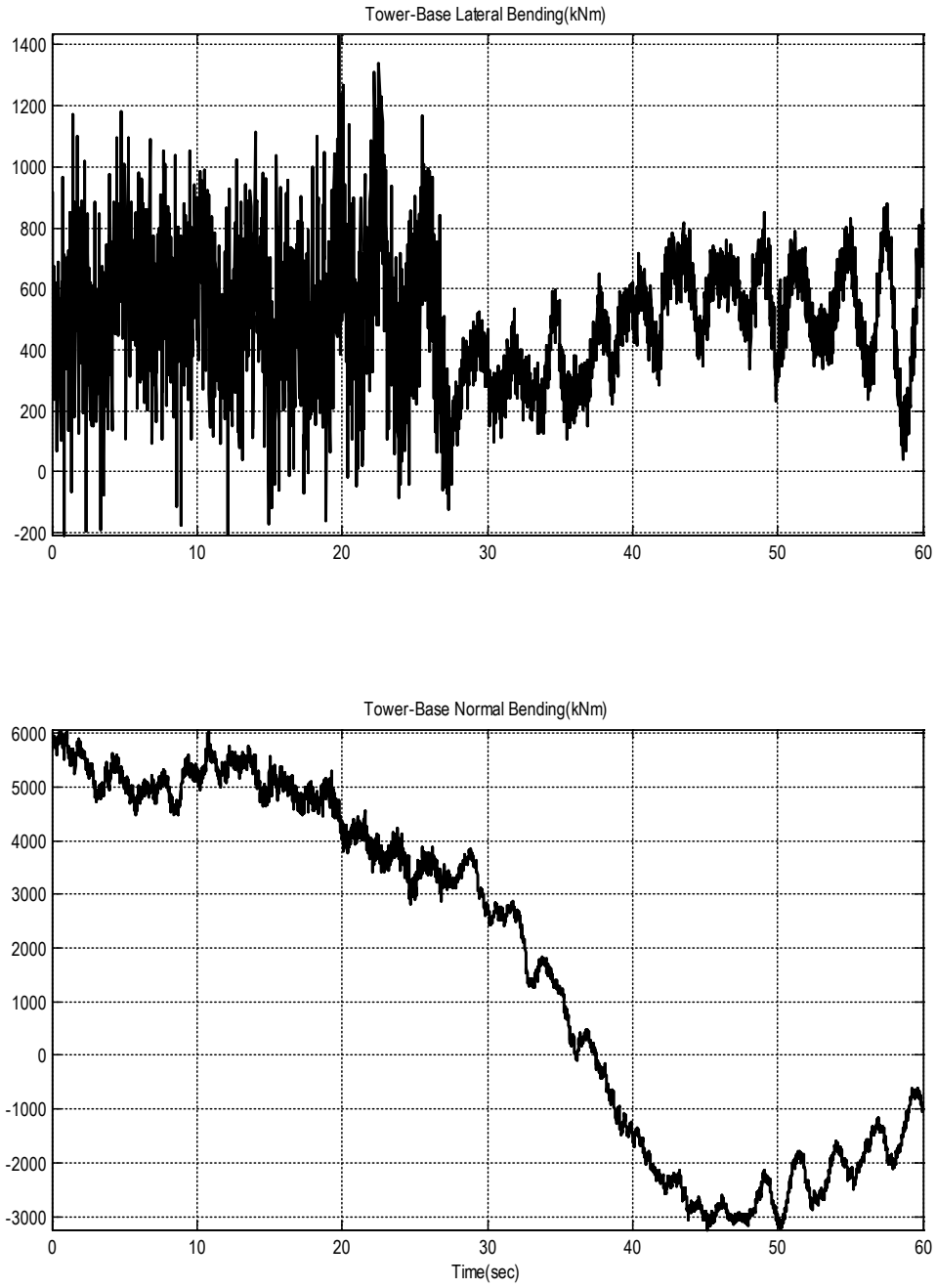


Figure 190. Normal stop at 7.0 m/s—tower-base loads

Normal Stop at 12.2 m/s

Table 82. Brief Statistical Description for Normal Stop at 12.2 m/s

Event Description:	Normal Stop at 12.2 m/s			
File Name:	FastWaveforms 2011_03_03 18_18_12 100Hz.tdms			
Date:	03-Mar-2011 18:18:00			
Measured Quantity	mean	sdv	min	max
Wind Speed at 80 m (m/s)	12.2	1.9	8.7	16.1
Wind Direction at 87 m (deg)	289.1	9.0	265.9	305.9
Air Pressure (kPa)	80.4	0.0	80.3	80.4
Temperature (deg C)	6.5	0.0	6.5	6.6
Electric Power (kW)	241.0	283.8	-26.5	974.6
Rotor Speed (rpm)	10.0	3.9	3.2	17.0
Generator Speed (m/s)	770.6	310.4	235.3	1,320.5
Nacelle Yaw Angle (deg)	298.0	0.0	298.0	298.0
Blade 1 Pitch Position (deg)	24.6	22.6	-2.1	65.4
Blade 2 Pitch Position (deg)	24.6	22.6	-2.1	65.4
Blade 3 Pitch Position (deg)	24.6	22.6	-2.1	65.5
Operational Status (-)	358.8	337.5	17.0	701.0
State Fault (-)	1.5	0.5	1.0	2.0
Availability Status (V)	82.6	0.0	82.6	82.6
Tower-Top Normal Acceleration (g)	-0.0	0.0	-0.0	0.0
Tower-Top Lateral Acceleration (g)	0.0	0.0	-0.0	0.0
Blade 1 Flap Bending (kNm)	293.9	567.5	-671.7	1,468.5
Blade 1 Leadlag Bending (kNm)	-38.6	390.4	-711.3	841.6
Blade 2 Flap Bending (kNm)	317.4	559.0	-713.2	1,399.5
Blade 2 Leadlag Bending (kNm)	52.9	388.3	-573.1	893.1
Blade 3 Flap Bending (kNm)	275.0	573.4	-652.4	1,397.8
Blade 3 Leadlag Bending (kNm)	23.6	389.8	-570.5	921.7
Main Shaft Bending 0 (kNm)	-1,254.3	0.1	-1,254.6	-1,254.0
Main Shaft Bending 90 (kNm)	-1,713.9	0.1	-1,714.1	-1,713.6
Main Shaft Torque (kNm)	-2,627.8	0.1	-2,628.3	-2,627.4
Tower-Top Normal Bending (kNm)	-579.6	288.6	-1,216.9	69.0
Tower-Top Lateral Bending (kNm)	118.2	166.9	-275.6	445.4
Tower-Top Torque (kNm)	27.4	148.6	-425.2	615.0
Tower-Base Normal Bending (kNm)	1,771.0	3,352.6	-2,950.9	8,914.4
Tower-Base Lateral Bending (kNm)	302.0	583.5	-1,476.4	2,398.3

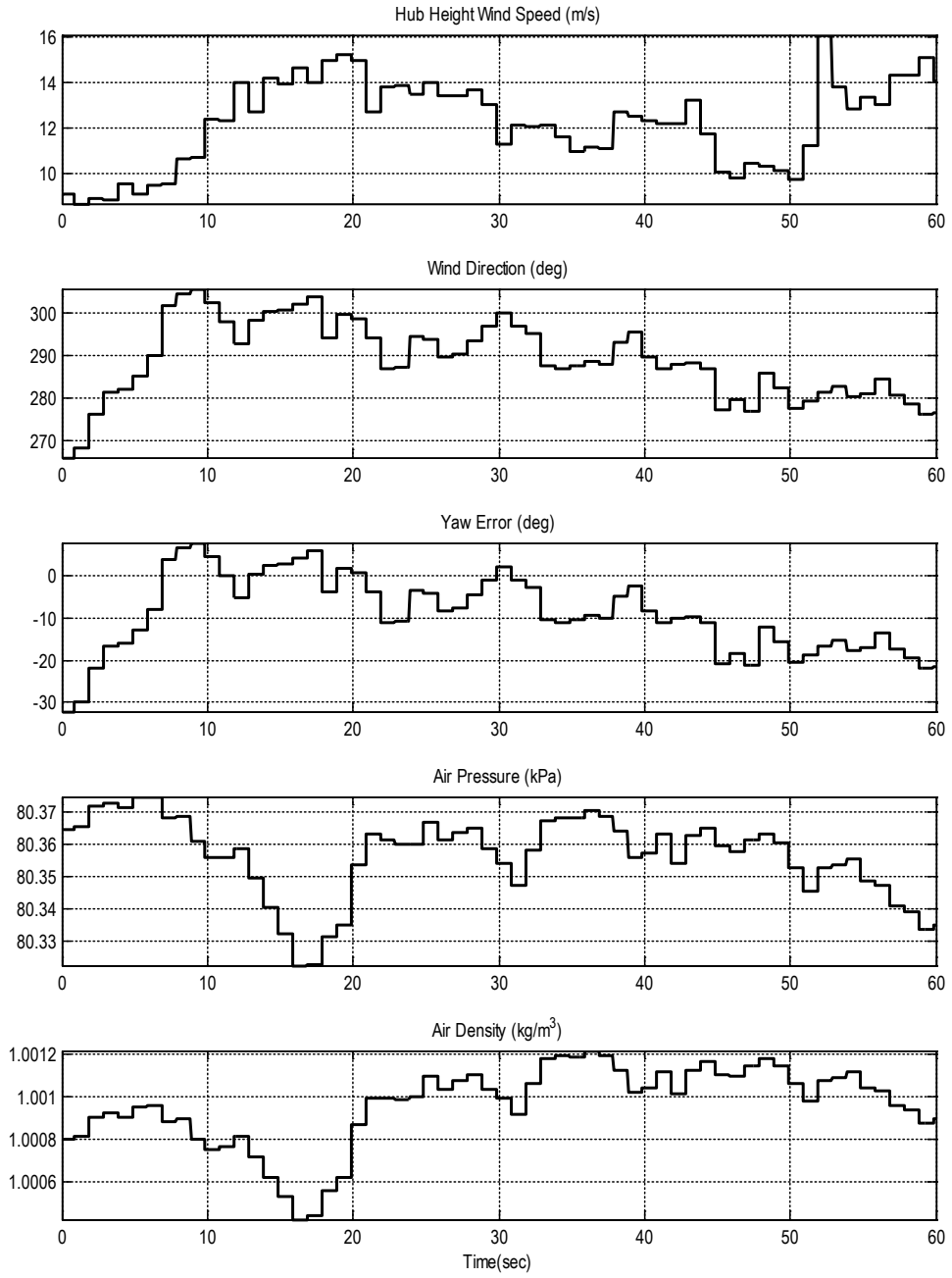


Figure 191. Normal stop at 12.2 m/s—met quantities

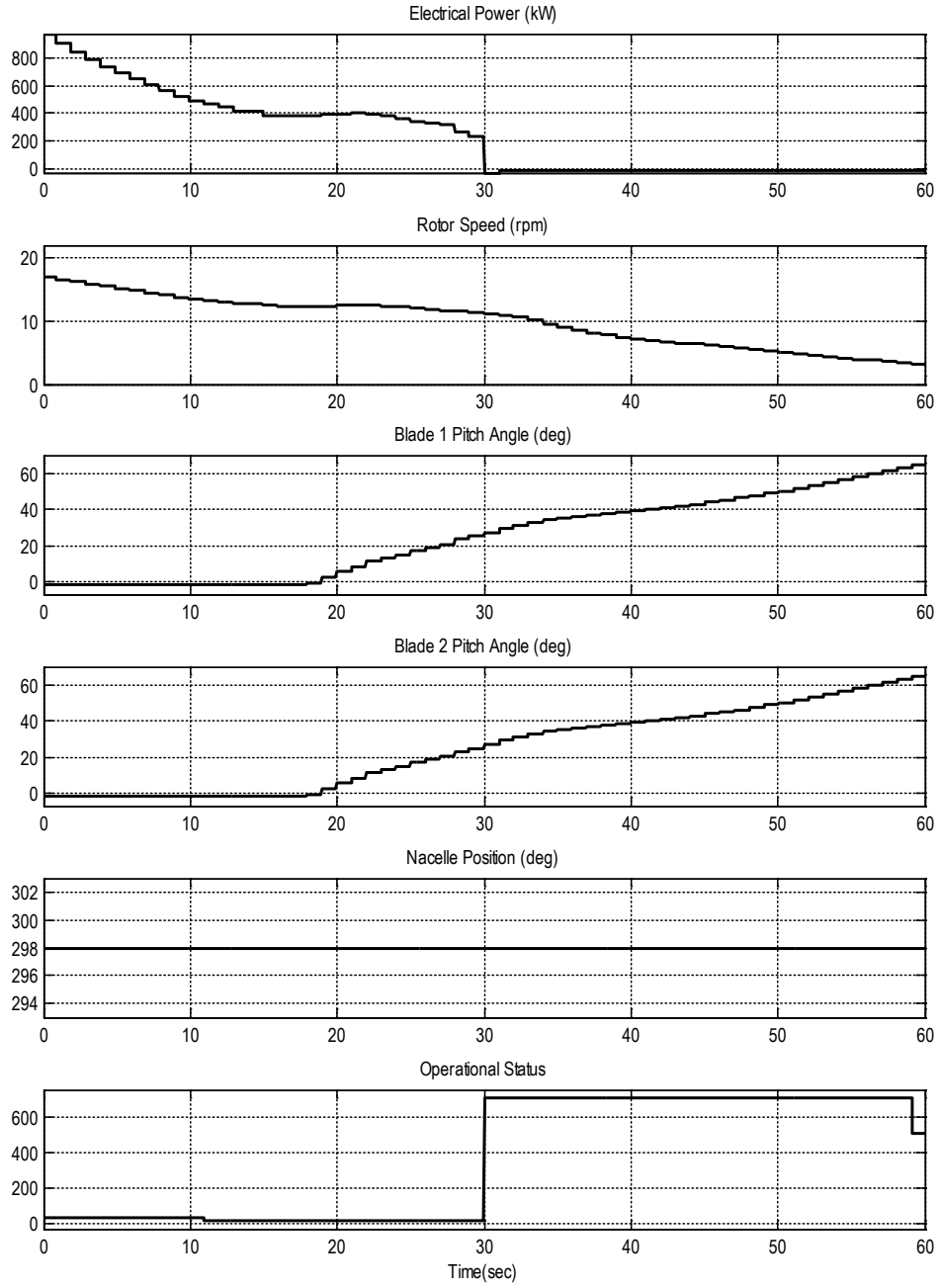


Figure 192. Normal stop at 12.2 m/s—wind turbine operational quantities

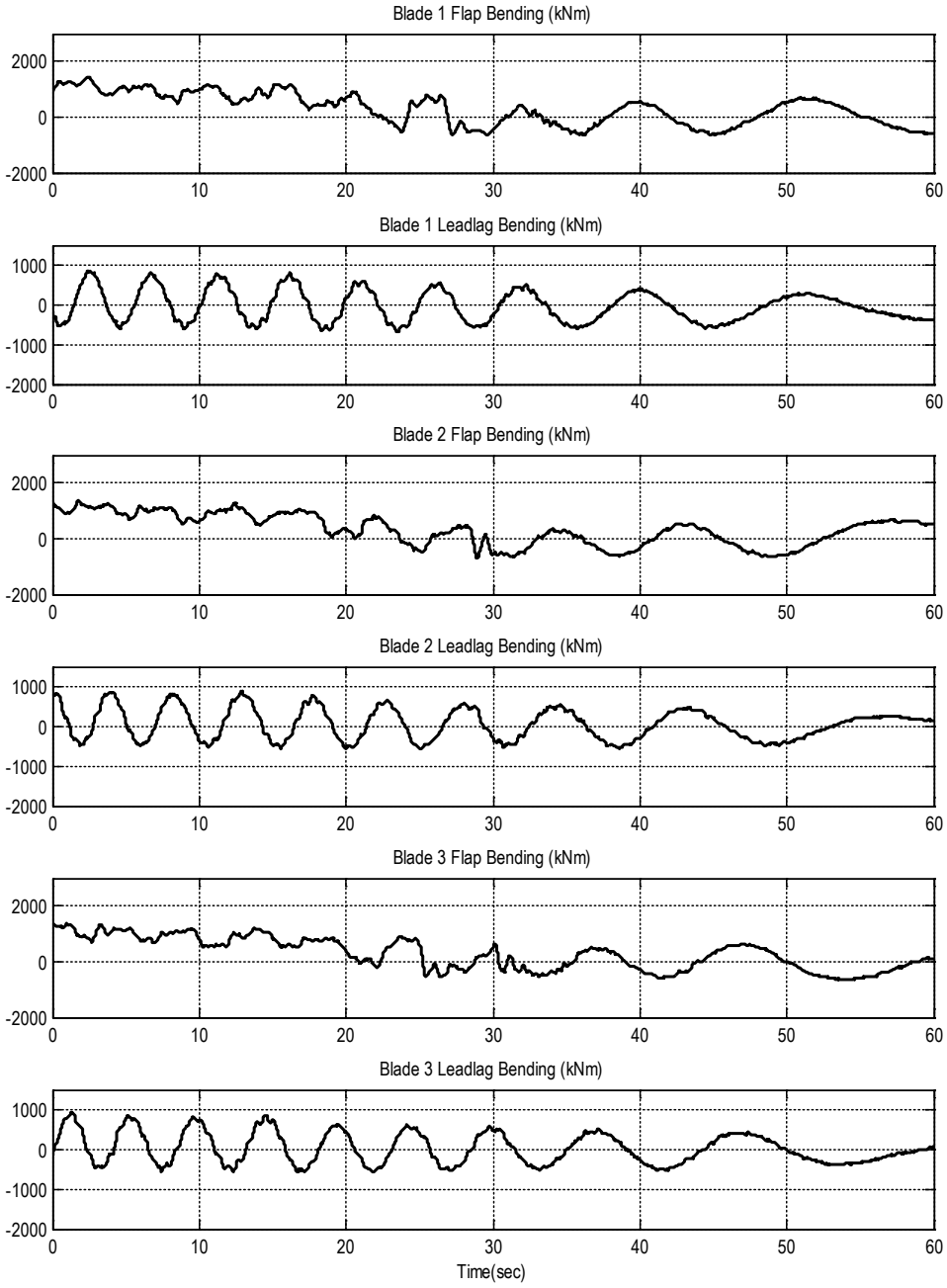


Figure 193. Normal stop at 12.2 m/s—blade loads

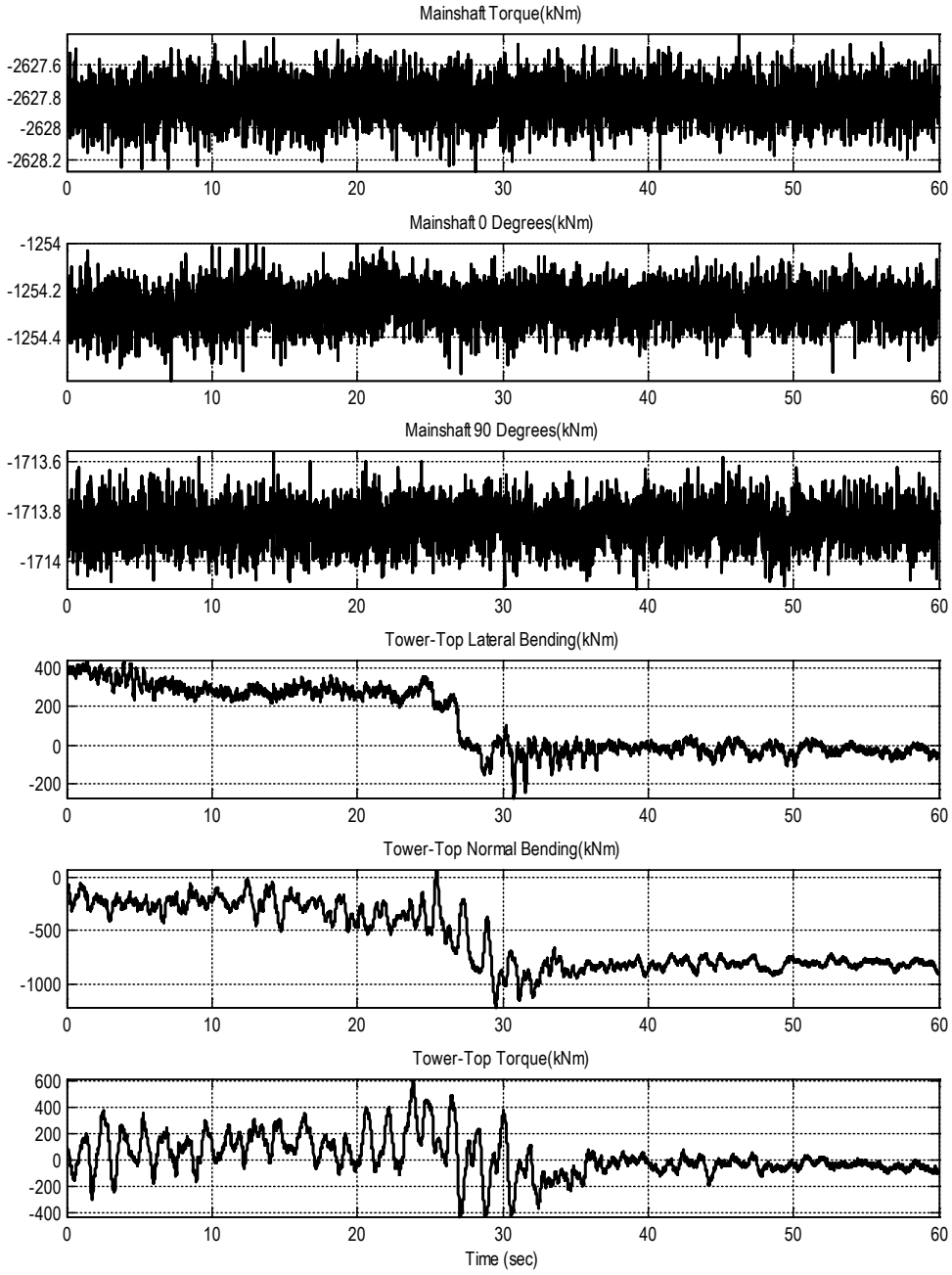


Figure 194. Normal stop at 12.2 m/s—shaft and tower-top loads

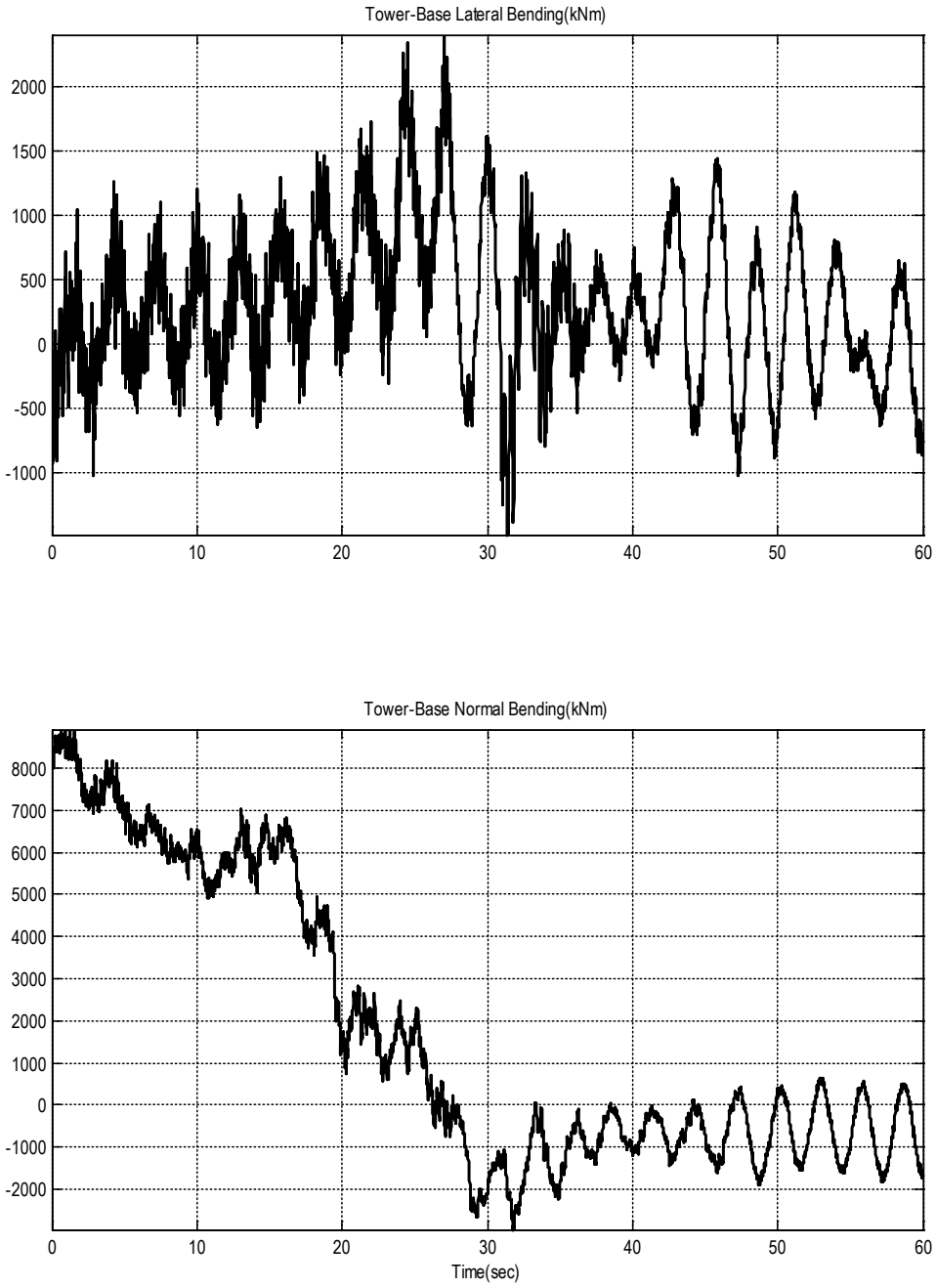


Figure 195. Normal stop at 12.2 m/s—tower-base loads

Normal Stop at 16.1 m/s

Table 83. Brief Statistical Description for Normal Stop at 16.1 m/s

Event Description:	Normal Stop at 16.1 m/s			
File Name:	FastWaveforms 2011_03_09 15_56_38 100Hz.tdms			
Date:	09-Mar-2011 15:56:00			
Measured Quantity	mean	sdv	min	max
Wind Speed at 80 m (m/s)	16.1	1.7	11.6	19.5
Wind Direction at 87 m (deg)	283.3	6.8	267.1	300.0
Air Pressure (kPa)	81.1	0.0	81.1	81.1
Temperature (deg C)	7.3	0.0	7.3	7.3
Electric Power (kW)	367.7	465.2	-26.3	1,583.3
Rotor Speed (rpm)	11.4	4.4	4.6	18.7
Generator Speed (m/s)	883.2	345.3	352.2	1,470.3
Nacelle Yaw Angle (deg)	291.3	6.2	284.0	298.0
Blade 1 Pitch Position (deg)	33.6	13.9	7.4	61.3
Blade 2 Pitch Position (deg)	33.6	13.9	7.3	61.3
Blade 3 Pitch Position (deg)	33.6	13.9	7.4	61.3
Operational Status (-)	363.7	337.4	17.0	701.0
State Fault (-)	1.5	0.5	1.0	2.0
Availability Status (V)	90.3	0.0	90.3	90.3
Tower-Top Normal Acceleration (g)	-0.0	0.0	-0.1	0.1
Tower-Top Lateral Acceleration (g)	0.0	0.0	-0.1	0.1
Blade 1 Flap Bending (kNm)	126.3	480.5	-669.3	1,387.6
Blade 1 Leadlag Bending (kNm)	-17.2	375.7	-747.8	918.7
Blade 2 Flap Bending (kNm)	131.8	468.2	-703.3	1,497.5
Blade 2 Leadlag Bending (kNm)	36.5	370.8	-624.3	864.1
Blade 3 Flap Bending (kNm)	89.9	462.5	-735.8	1,556.9
Blade 3 Leadlag Bending (kNm)	-17.6	360.6	-708.3	772.0
Main Shaft Bending 0 (kNm)	15.2	313.1	-724.0	698.3
Main Shaft Bending 90 (kNm)	11.9	311.3	-698.4	660.1
Main Shaft Torque (kNm)	8.3	331.4	-434.8	726.9
Tower-Top Normal Bending (kNm)	-783.9	249.2	-1,428.7	199.9
Tower-Top Lateral Bending (kNm)	254.9	190.0	-117.9	763.1
Tower-Top Torque (kNm)	-27.7	181.5	-480.8	649.8
Tower-Base Normal Bending (kNm)	609.2	2,209.9	-3,306.0	9,662.6
Tower-Base Lateral Bending (kNm)	148.6	1,609.5	-4,004.1	3,936.9

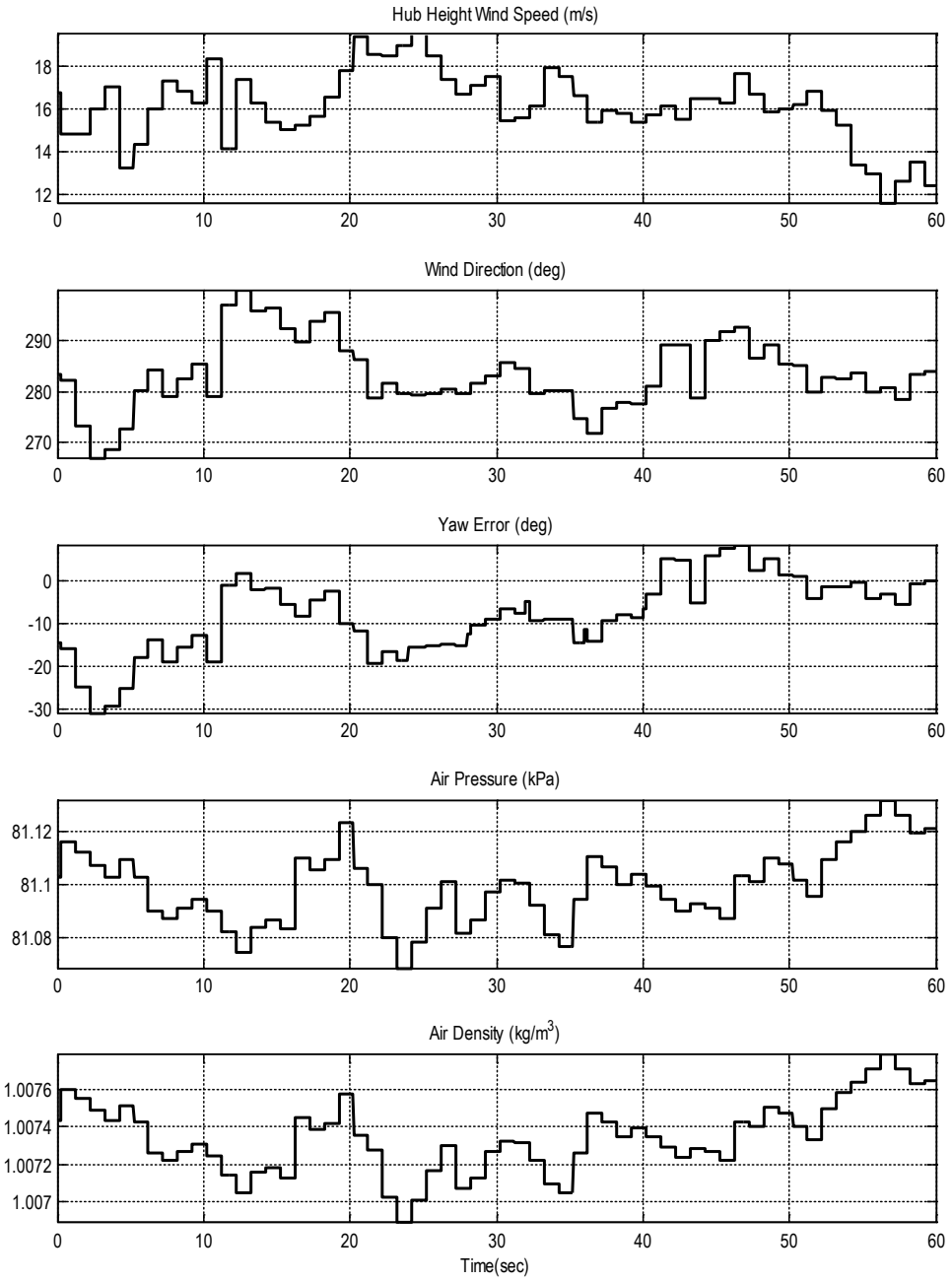


Figure 196. Normal stop at 16.1 m/s—met quantities

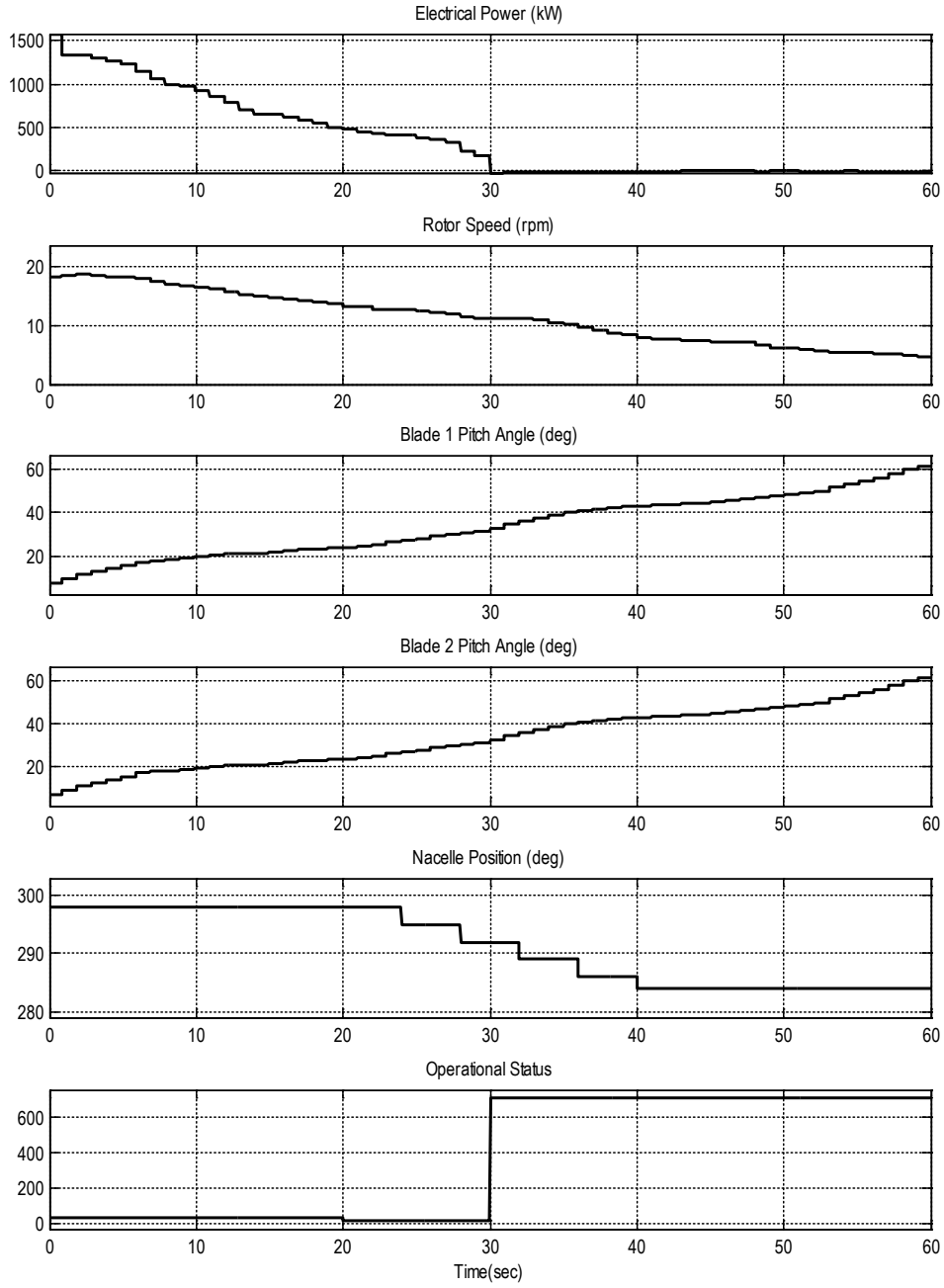


Figure 197. Normal stop at 16.1 m/s—wind turbine operational quantities

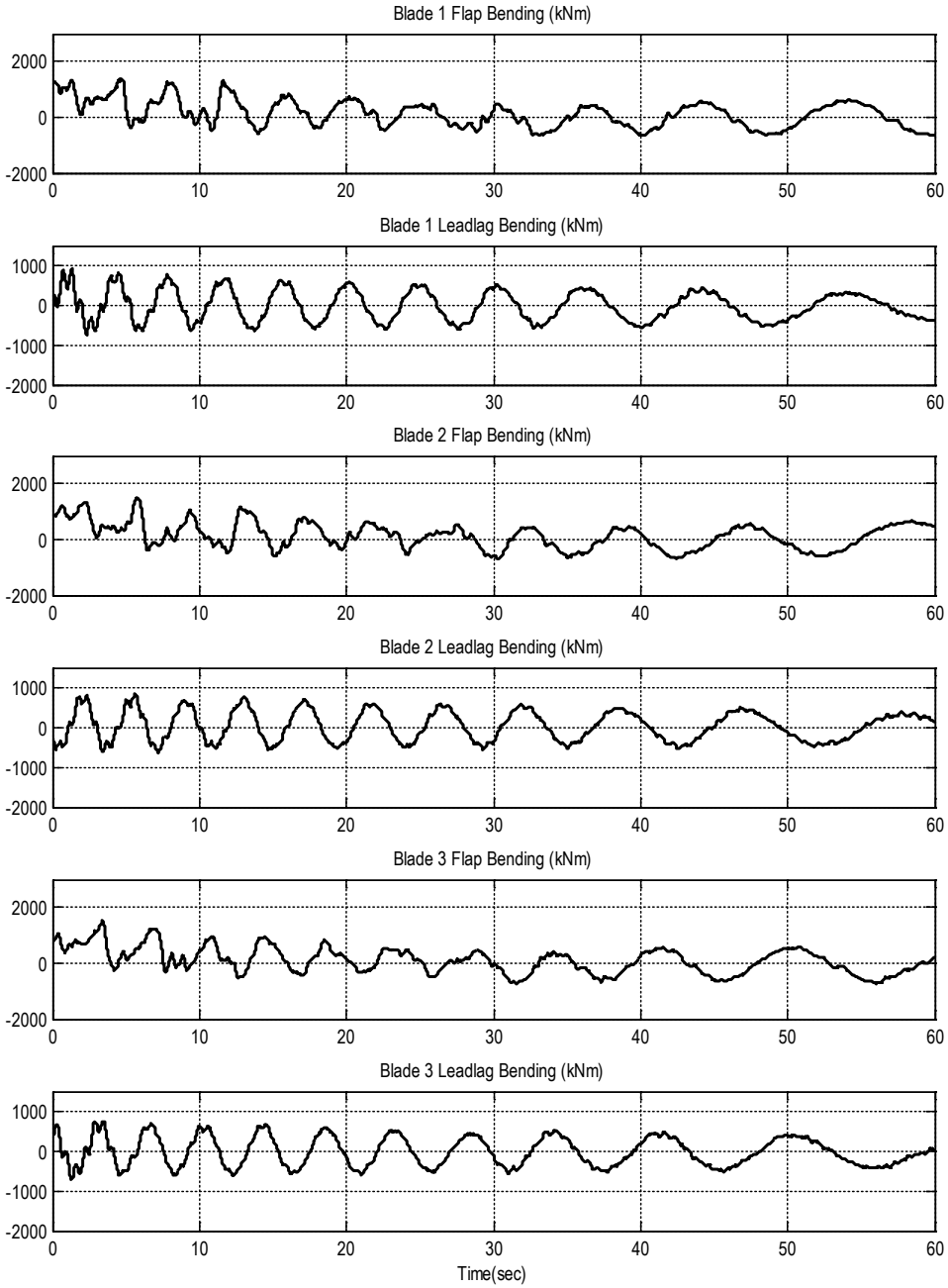


Figure 198. Normal stop at 16.1 m/s—blade loads

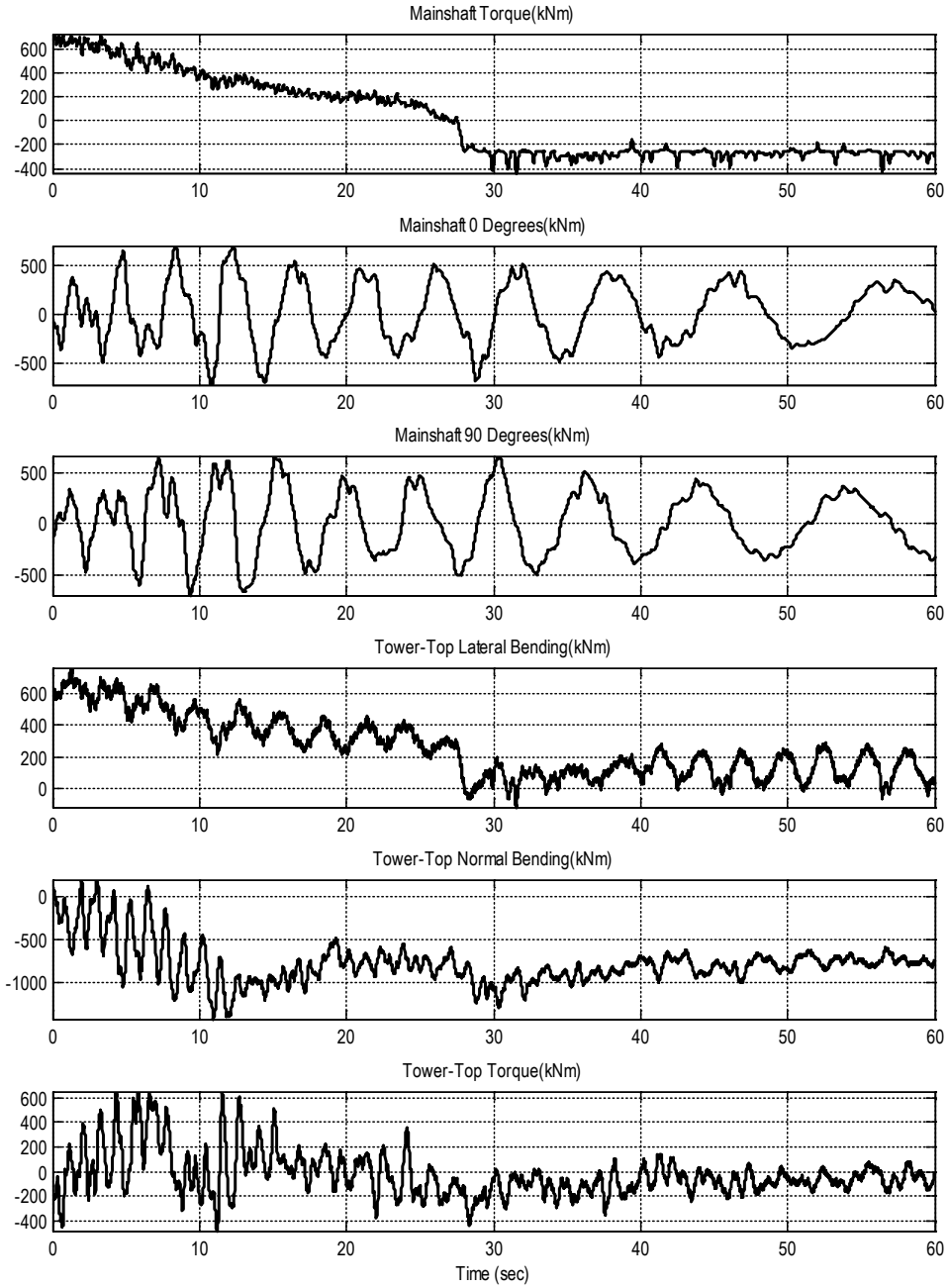


Figure 199. Normal stop at 16.1 m/s—shaft and tower-top loads

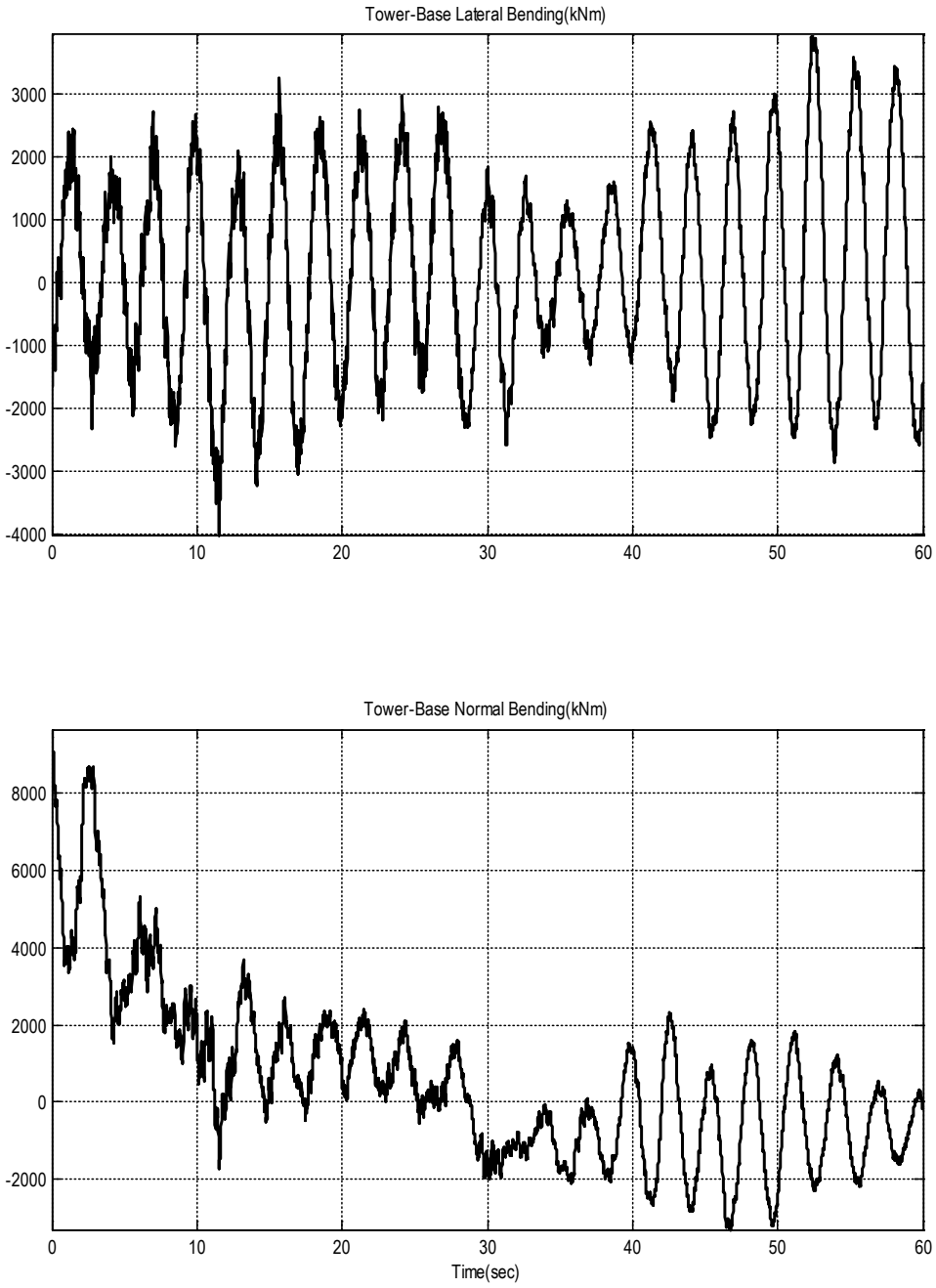


Figure 200. Normal stop at 16.1 m/s—tower-base loads

Parked or Idling (Online)

Parked at 4.2 m/s

Table 84. Brief Statistical Description for Parked at 4.2 m/s

Event Description:	Parked at 4.2 m/s			
File Name:	FastWaveforms 2011_03_08 18_50_35 100Hz.tdms			
Date:	08-Mar-2011 18:50:00			
Measured Quantity	mean	sdv	min	max
Wind Speed at 80 m (m/s)	4.2	2.7	0.3	12.1
Wind Direction at 87 m (deg)	256.3	52.9	7.3	352.2
Air Pressure (kPa)	80.4	0.0	80.4	80.4
Temperature (deg C)	-3.6	0.1	-3.7	-3.4
Electric Power (kW)	-6.1	4.6	-14.7	-2.6
Rotor Speed (rpm)	0.7	1.0	0.0	3.0
Generator Speed (m/s)	74.1	64.5	7.2	238.8
Nacelle Yaw Angle (deg)	219.2	50.4	151.0	270.0
Blade 1 Pitch Position (deg)	57.5	17.2	1.6	68.4
Blade 2 Pitch Position (deg)	57.5	17.2	1.7	68.4
Blade 3 Pitch Position (deg)	57.5	17.2	1.6	68.4
Operational Status (-)	537.4	69.7	501.0	701.0
State Fault (-)	1.2	0.6	1.0	3.0
Availability Status (V)	88.9	0.0	88.9	88.9
Tower-Top Normal Acceleration (g)	0.0	0.0	-0.1	0.1
Tower-Top Lateral Acceleration (g)	0.0	0.0	-0.1	0.1
Blade 1 Flap Bending (kNm)	79.6	454.0	-625.7	743.4
Blade 1 Leadlag Bending (kNm)	20.7	258.3	-521.6	668.3
Blade 2 Flap Bending (kNm)	-5.0	442.7	-736.3	676.7
Blade 2 Leadlag Bending (kNm)	-40.4	256.9	-564.0	620.9
Blade 3 Flap Bending (kNm)	25.9	420.1	-670.3	757.8
Blade 3 Leadlag Bending (kNm)	-68.5	244.2	-618.4	548.2
Main Shaft Bending 0 (kNm)	-35.8	222.1	-387.7	321.1
Main Shaft Bending 90 (kNm)	3.8	232.0	-357.1	345.6
Main Shaft Torque (kNm)	-304.6	4.7	-331.5	-251.3
Tower-Top Normal Bending (kNm)	-822.9	65.1	-987.2	-687.2
Tower-Top Lateral Bending (kNm)	195.1	90.3	-143.0	347.6
Tower-Top Torque (kNm)	-19.0	99.3	-355.8	242.8
Tower-Base Normal Bending (kNm)	-767.7	234.7	-1,321.2	248.9
Tower-Base Lateral Bending (kNm)	114.8	169.3	-620.6	1,073.1

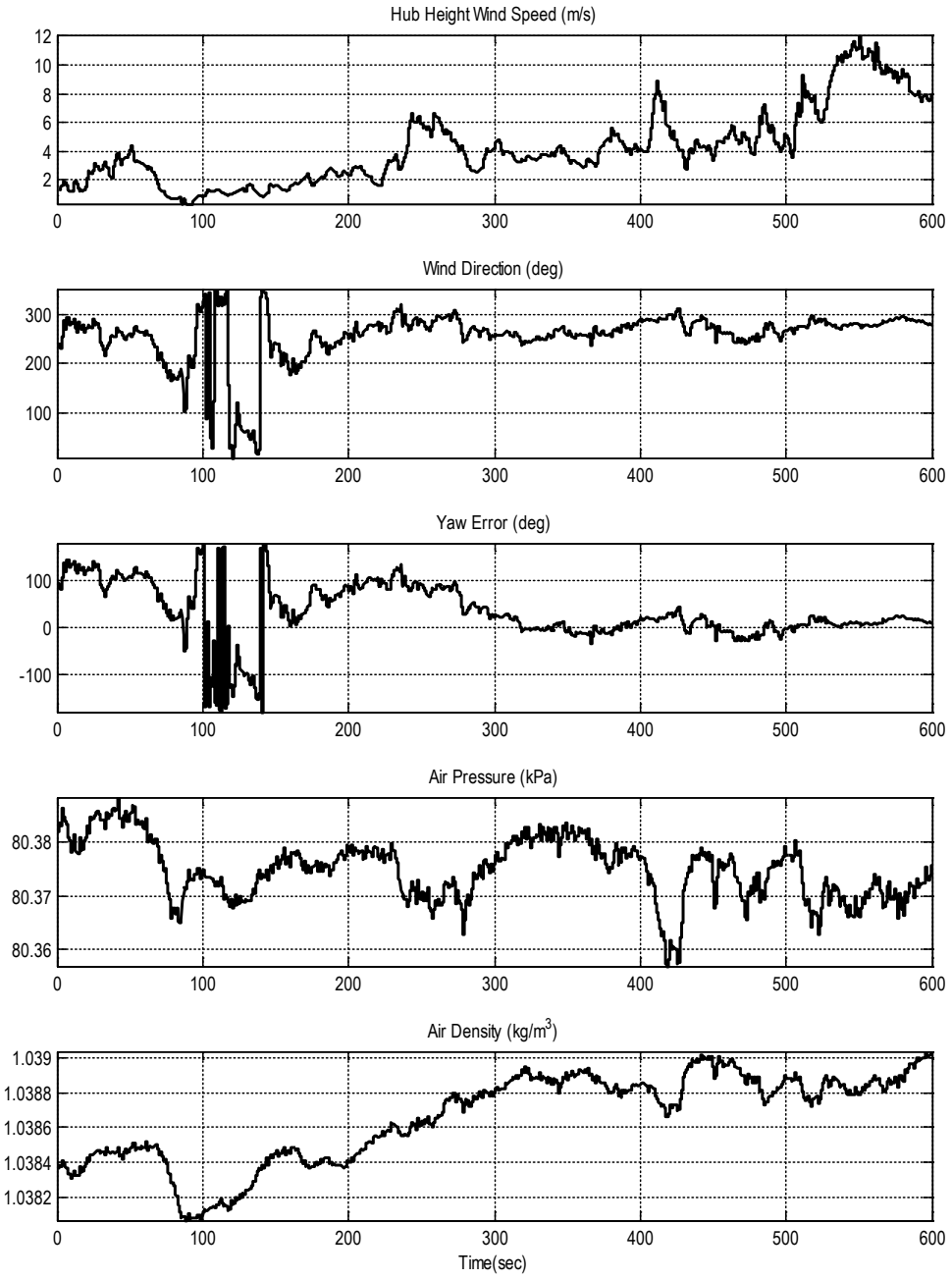


Figure 201. Parked at 4.2 m/s—met quantities

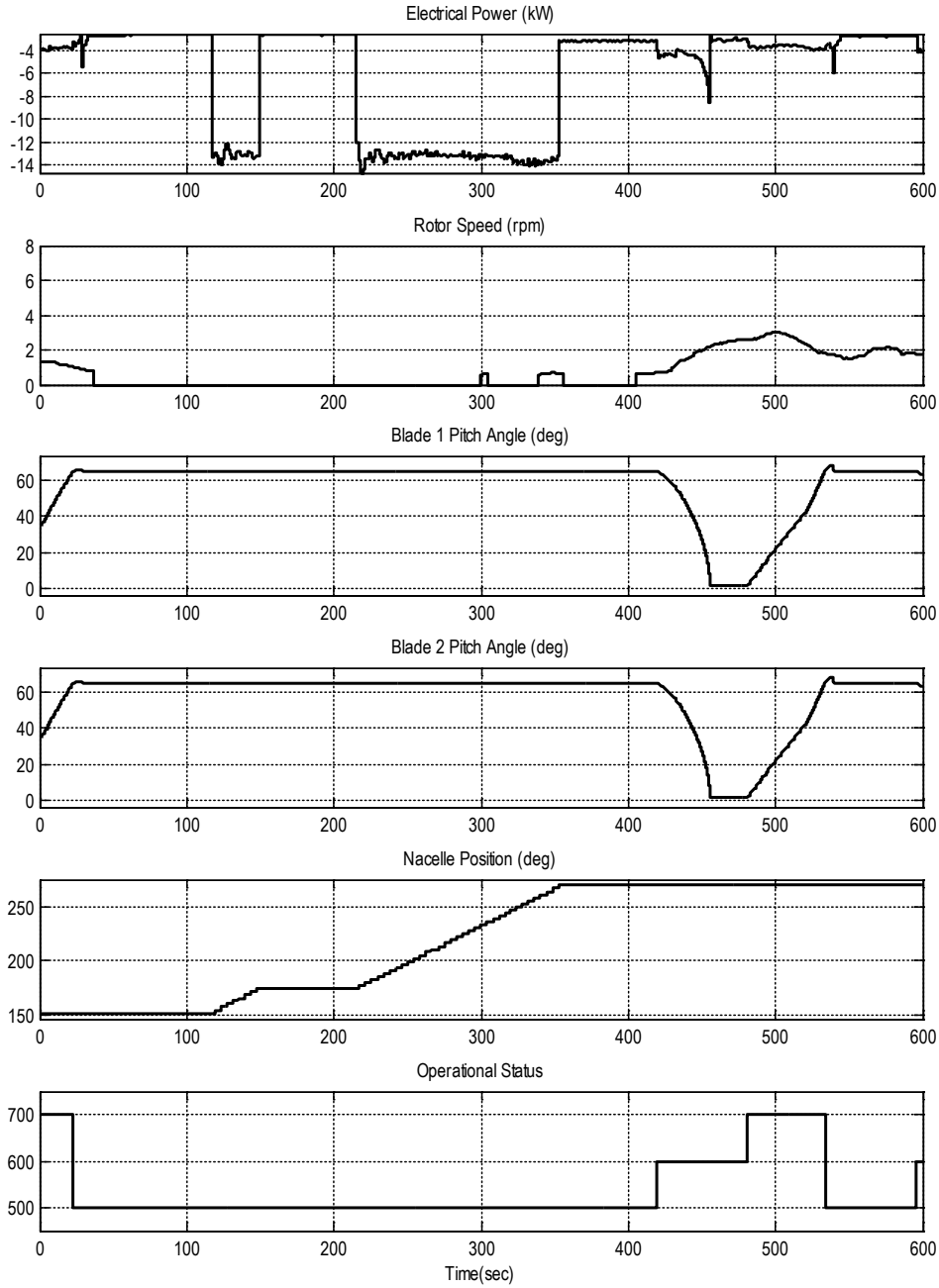


Figure 202. Parked at 4.2 m/s—wind turbine operational quantities

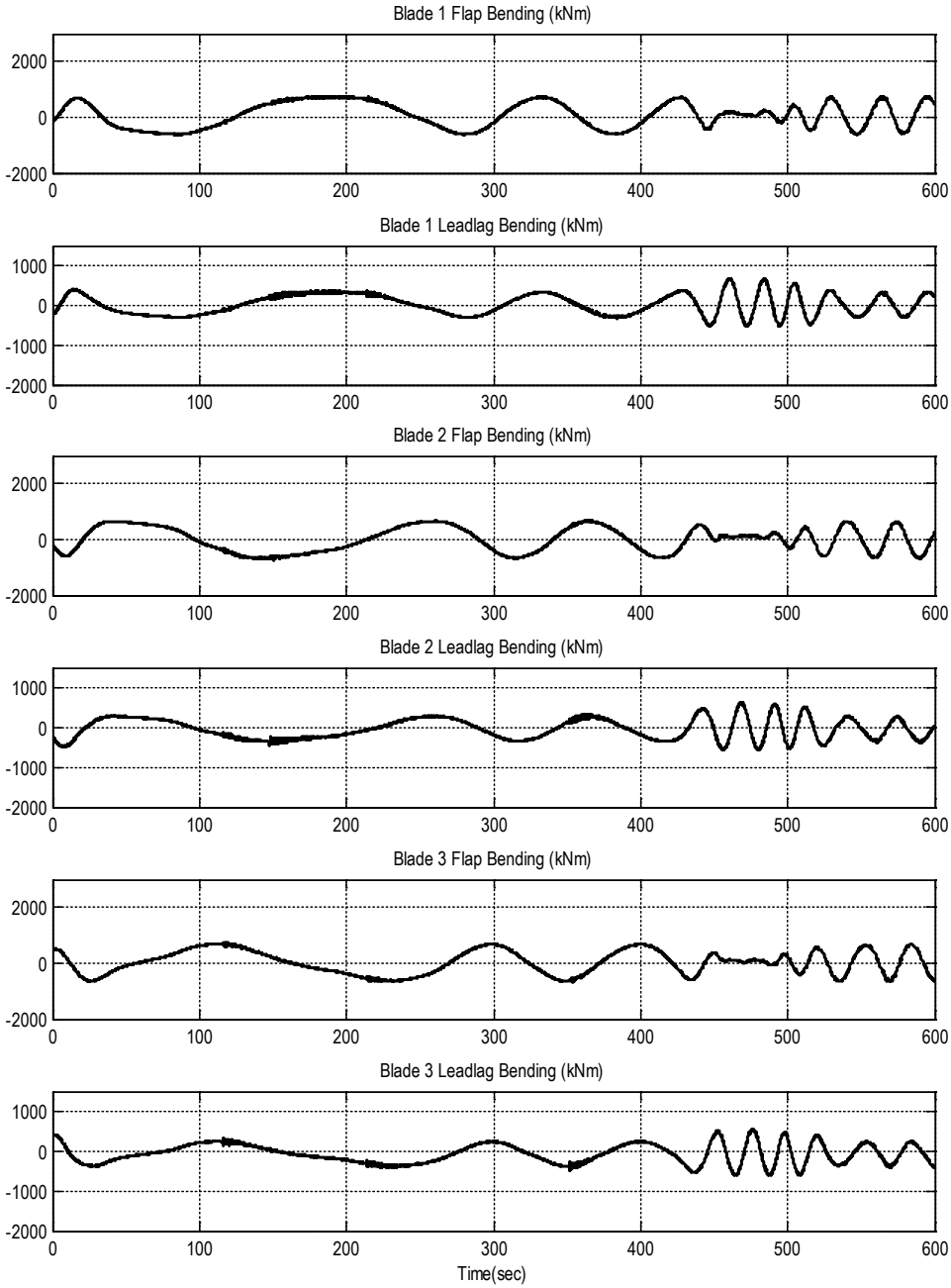


Figure 203. Parked at 4.2 m/s—blade loads

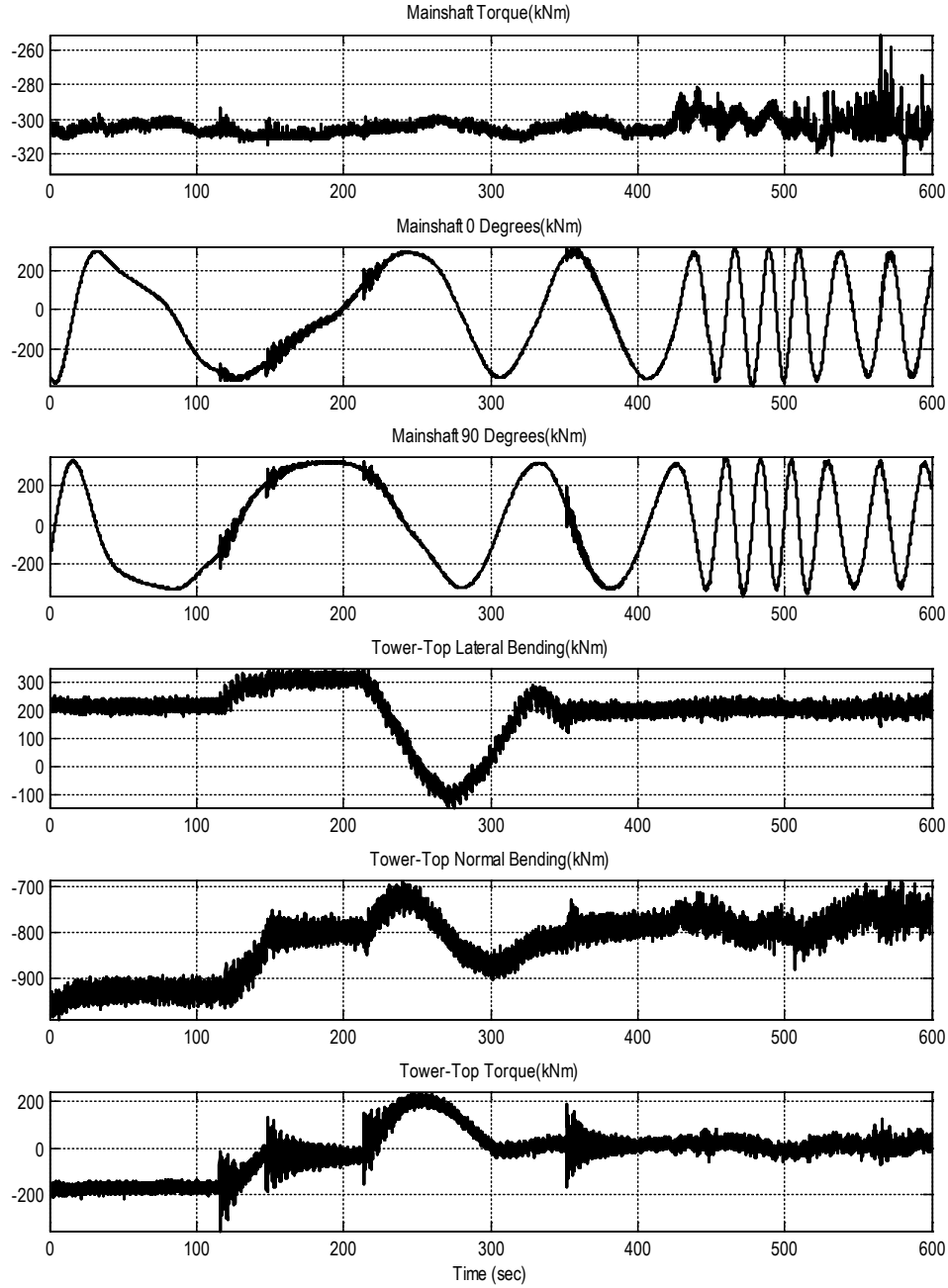


Figure 204. Parked at 4.2 m/s—shaft and tower-top loads

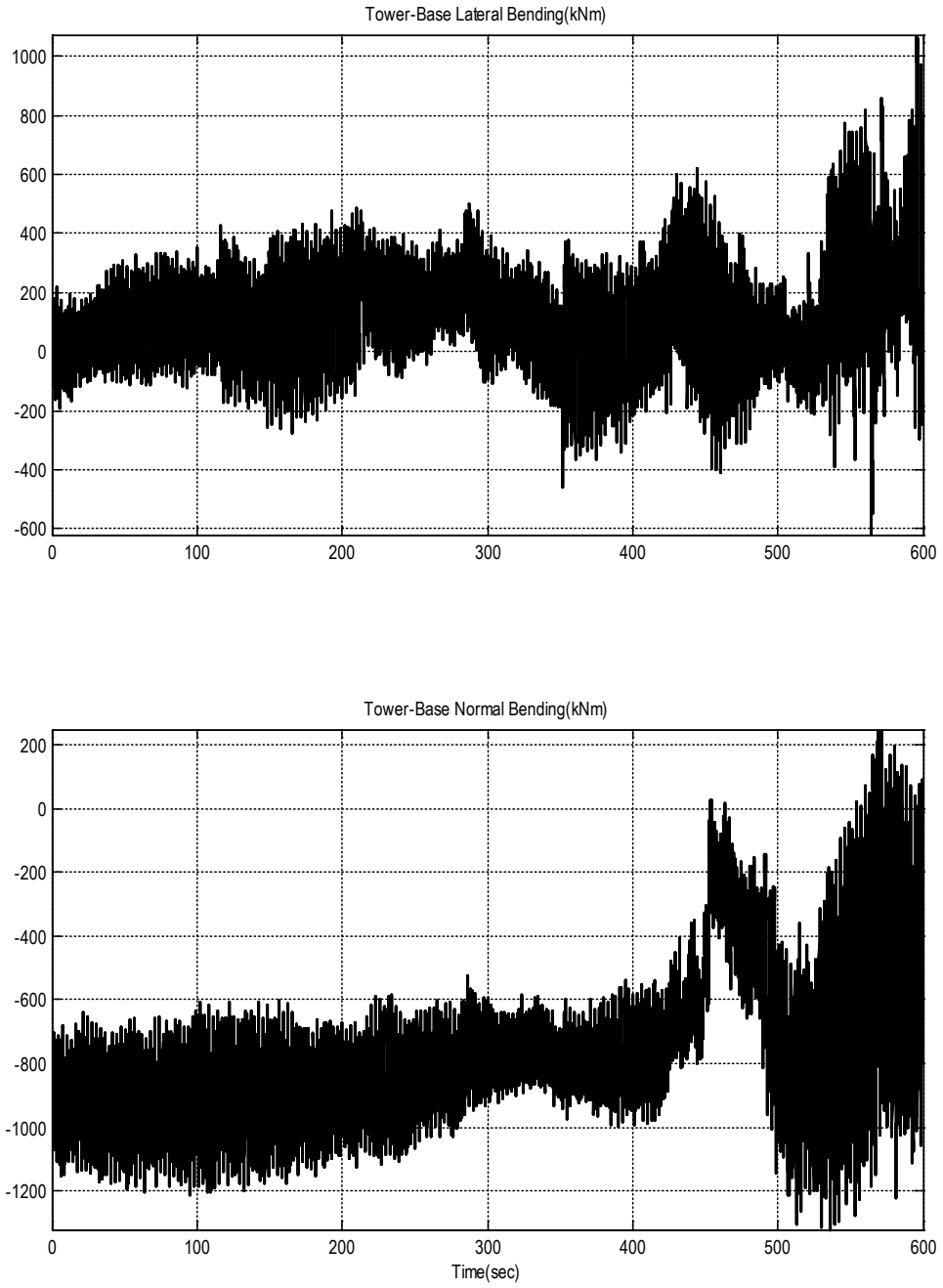


Figure 205. Parked at 4.2 m/s—tower-base loads

Parked at 13.5 m/s

Table 85. Brief Statistical Description for Parked at 13.5 m/s

Event Description:	Parked at 13.5 m/s			
File Name:	FastWaveforms 2011_03_03 16_48_05 100Hz.tdms			
Date:	03-Mar-2011 16:48:00			
Measured Quantity	mean	sdv	min	max
Wind Speed at 80 m (m/s)	13.5	1.5	8.9	18.6
Wind Direction at 87 m (deg)	265.5	5.2	249.0	281.5
Air Pressure (kPa)	80.1	0.0	80.0	80.1
Temperature (deg C)	10.1	0.0	10.1	10.2
Electric Power (kW)	-5.2	1.0	-14.4	-5.0
Rotor Speed (rpm)	0.0	0.0	0.0	0.0
Generator Speed (m/s)	0.0	0.0	0.0	0.0
Nacelle Yaw Angle (deg)	265.8	2.4	261.0	267.0
Blade 1 Pitch Position (deg)	85.0	0.0	85.0	85.0
Blade 2 Pitch Position (deg)	85.0	0.0	85.0	85.0
Blade 3 Pitch Position (deg)	85.0	0.0	85.0	85.0
Operational Status (-)	203.0	0.0	203.0	203.0
State Fault (-)	9.0	0.0	9.0	9.0
Availability Status (V)	81.6	0.0	81.5	81.6
Tower-Top Normal Acceleration (g)	-0.0	0.0	-0.1	0.1
Tower-Top Lateral Acceleration (g)	-0.0	0.0	-0.1	0.1
Blade 1 Flap Bending (kNm)	98.2	63.0	-63.8	257.7
Blade 1 Leadlag Bending (kNm)	-98.8	13.9	-138.6	-39.6
Blade 2 Flap Bending (kNm)	-599.8	35.4	-728.6	-463.9
Blade 2 Leadlag Bending (kNm)	-136.7	15.1	-265.4	-23.6
Blade 3 Flap Bending (kNm)	549.5	47.0	389.7	698.8
Blade 3 Leadlag Bending (kNm)	-24.0	15.0	-144.1	79.6
Main Shaft Bending 0 (kNm)	-1,254.3	0.1	-1,254.6	-1,254.0
Main Shaft Bending 90 (kNm)	-1,713.9	0.1	-1,714.2	-1,713.5
Main Shaft Torque (kNm)	-2,628.0	0.1	-2,628.5	-2,627.5
Tower-Top Normal Bending (kNm)	-754.4	20.3	-837.2	-668.7
Tower-Top Lateral Bending (kNm)	336.2	67.3	100.6	587.7
Tower-Top Torque (kNm)	-16.7	25.9	-192.9	167.2
Tower-Base Normal Bending (kNm)	-593.7	252.2	-1,550.0	236.2
Tower-Base Lateral Bending (kNm)	302.0	664.3	-1,573.1	3,313.6

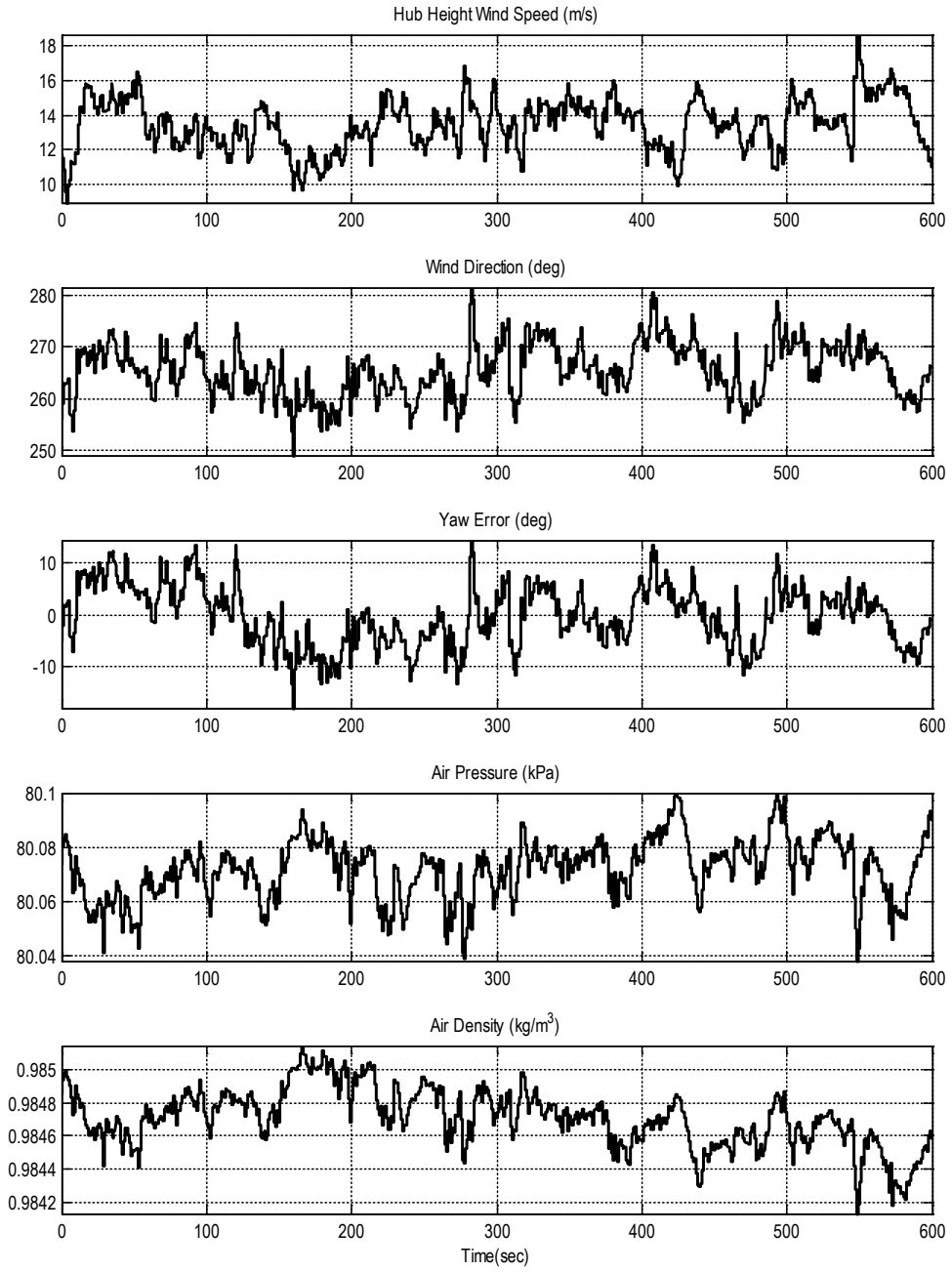


Figure 206. Parked at 13.5 m/s—met quantities

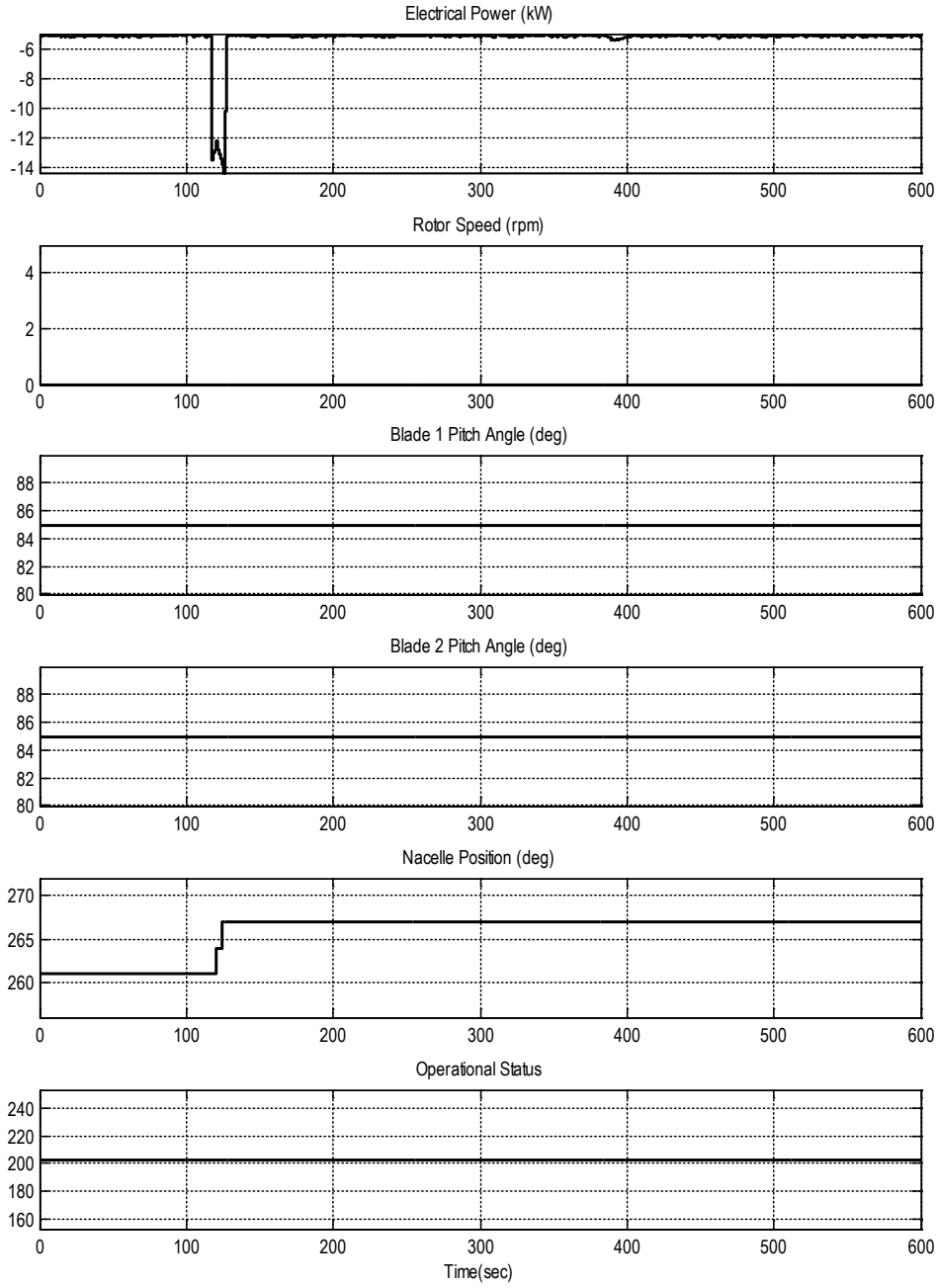


Figure 207. Parked at 13.5 m/s—wind turbine operational quantities

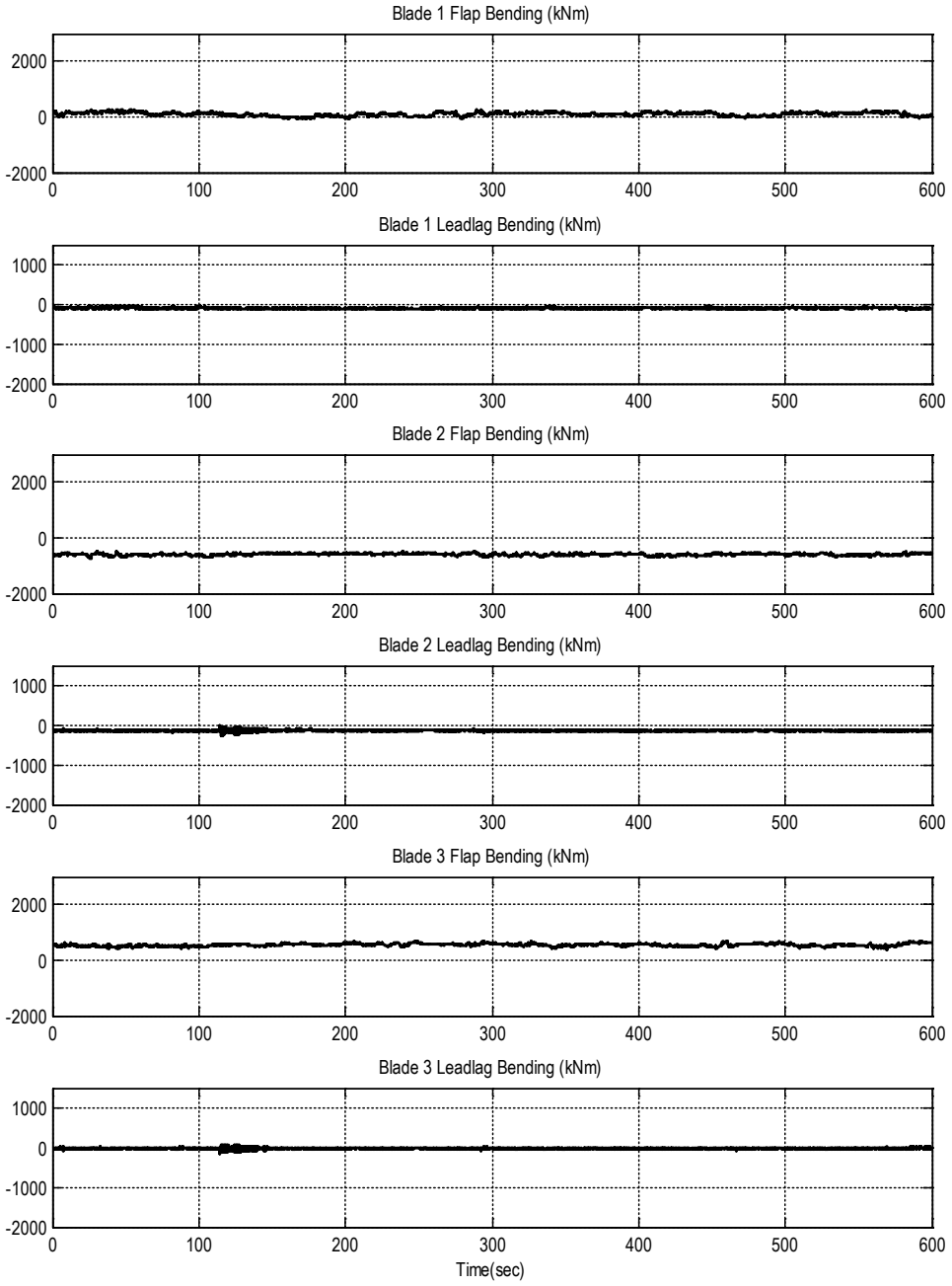


Figure 208. Parked at 13.5 m/s—blade loads

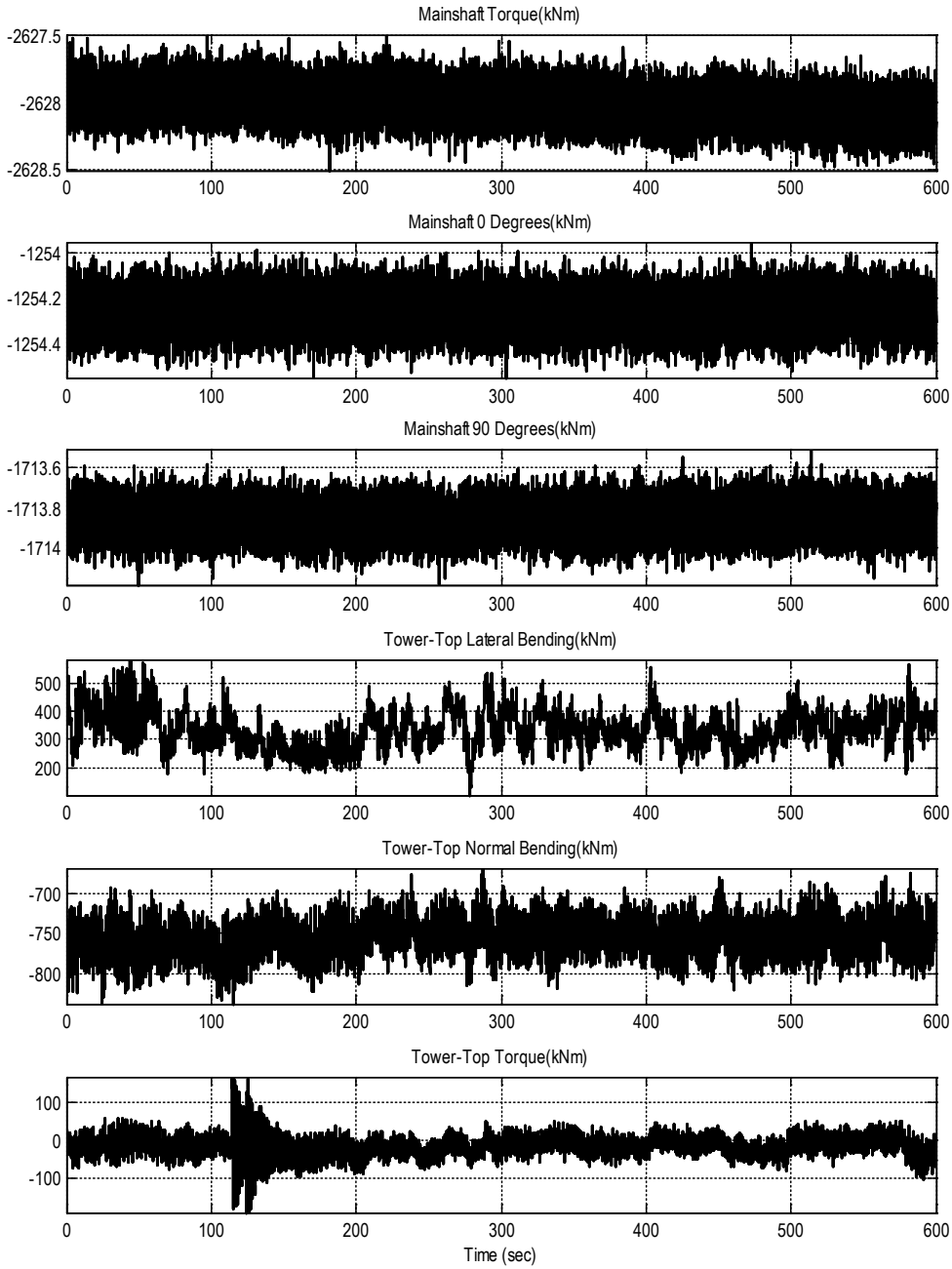


Figure 209. Parked at 13.5 m/s—shaft and tower-top loads

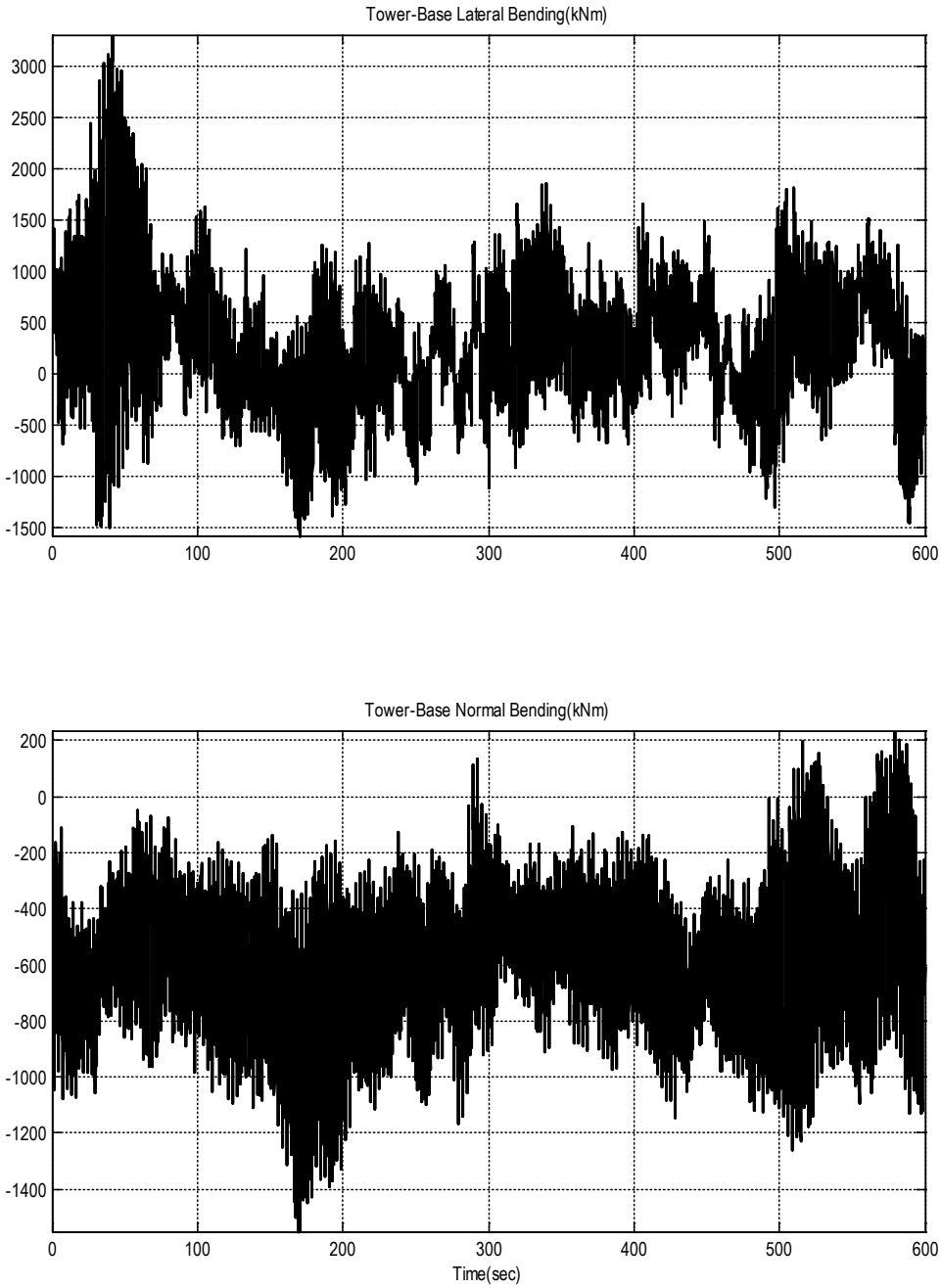


Figure 210. Parked at 13.5 m/s—tower-base loads

Parked at 27.6 m/s

Table 86. Brief Statistical Description for Parked at 27.6 m/s

Event Description:	Parked at 27.6 m/s			
File Name:	FastWaveforms 2011_03_22 18_42_26 100Hz.tdms			
Date:	22-Mar-2011 18:42:00			
Measured Quantity	mean	sdv	min	max
Wind Speed at 80 m (m/s)	27.6	4.9	13.7	41.3
Wind Direction at 87 m (deg)	272.5	8.1	245.4	295.9
Air Pressure (kPa)	79.2	0.1	79.0	79.4
Temperature (deg C)	2.8	0.6	2.0	3.8
Electric Power (kW)	-5.1	0.6	-15.8	-4.9
Rotor Speed (rpm)	1.0	1.0	0.0	8.4
Generator Speed (m/s)	86.0	67.5	0.0	659.3
Nacelle Yaw Angle (deg)	267.0	0.0	267.0	267.0
Blade 1 Pitch Position (deg)	84.7	2.9	54.0	85.6
Blade 2 Pitch Position (deg)	84.6	2.9	54.1	85.6
Blade 3 Pitch Position (deg)	84.7	2.9	54.0	85.7
Operational Status (-)	204.4	33.6	104.0	601.0
State Fault (-)	439.9	492.4	3.0	1,000.0
Availability Status (V)	89.9	0.4	89.6	90.8
Tower-Top Normal Acceleration (g)	0.0	0.0	-0.1	0.1
Tower-Top Lateral Acceleration (g)	0.0	0.0	-0.1	0.1
Blade 1 Flap Bending (kNm)	-38.5	514.6	-1,101.1	1,360.6
Blade 1 Leadlag Bending (kNm)	-16.2	89.1	-305.5	493.6
Blade 2 Flap Bending (kNm)	76.9	519.4	-1,140.7	1,328.6
Blade 2 Leadlag Bending (kNm)	3.0	86.9	-501.6	506.9
Blade 3 Flap Bending (kNm)	21.7	521.5	-1,215.6	1,179.4
Blade 3 Leadlag Bending (kNm)	-21.3	79.1	-470.1	303.3
Main Shaft Bending 0 (kNm)	-30.7	209.3	-437.2	411.3
Main Shaft Bending 90 (kNm)	-17.1	213.7	-442.7	402.2
Main Shaft Torque (kNm)	-254.4	59.3	-723.5	132.7
Tower-Top Normal Bending (kNm)	-726.7	110.4	-1,148.6	-264.8
Tower-Top Lateral Bending (kNm)	296.3	144.6	-377.1	862.7
Tower-Top Torque (kNm)	71.7	106.4	-435.7	456.7
Tower-Base Normal Bending (kNm)	783.6	1,808.5	-4,908.3	5,849.4
Tower-Base Lateral Bending (kNm)	2,207.4	3,306.0	-9,047.7	14,293.1

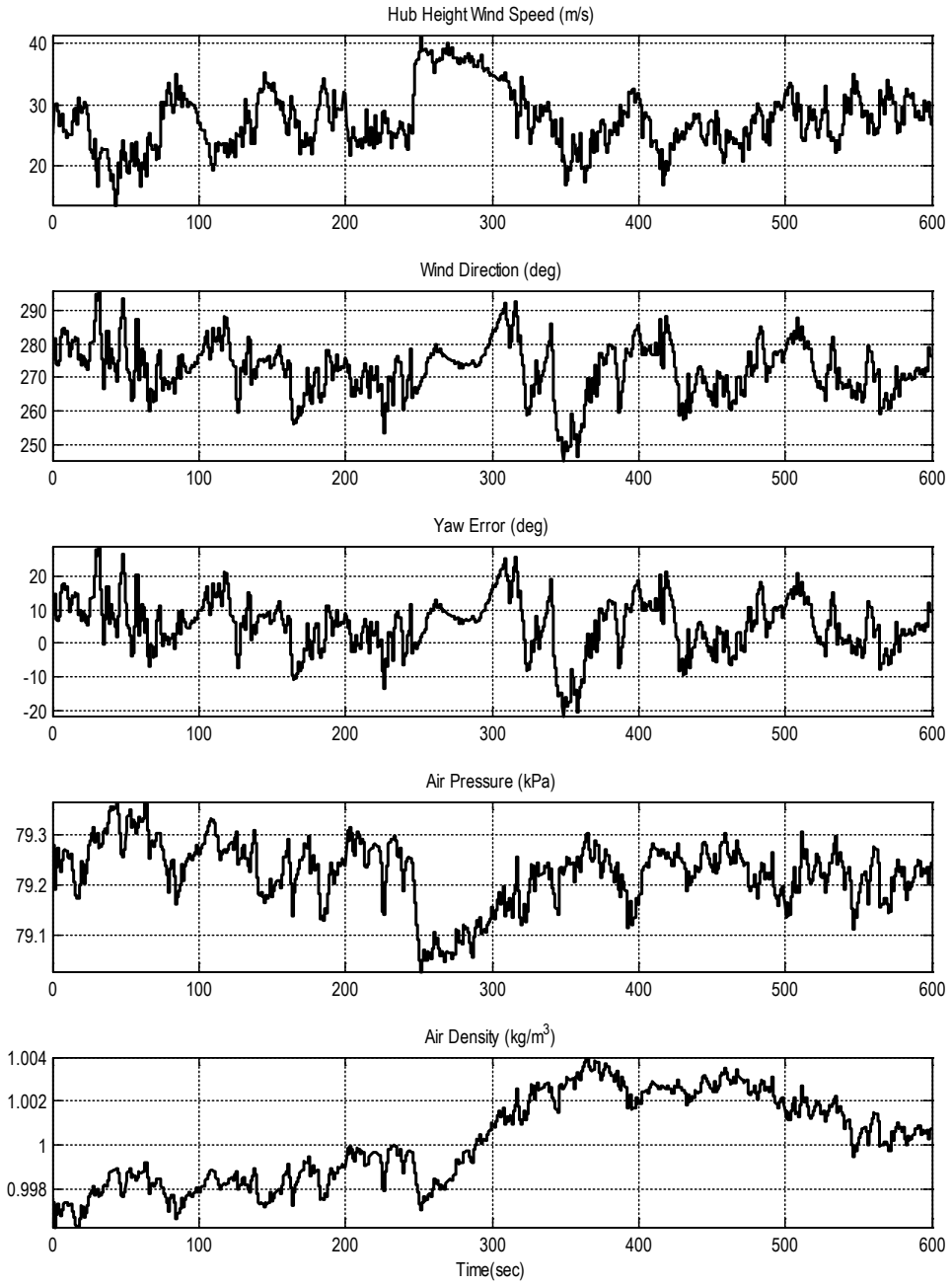


Figure 211. Parked at 27.6 m/s—met quantities

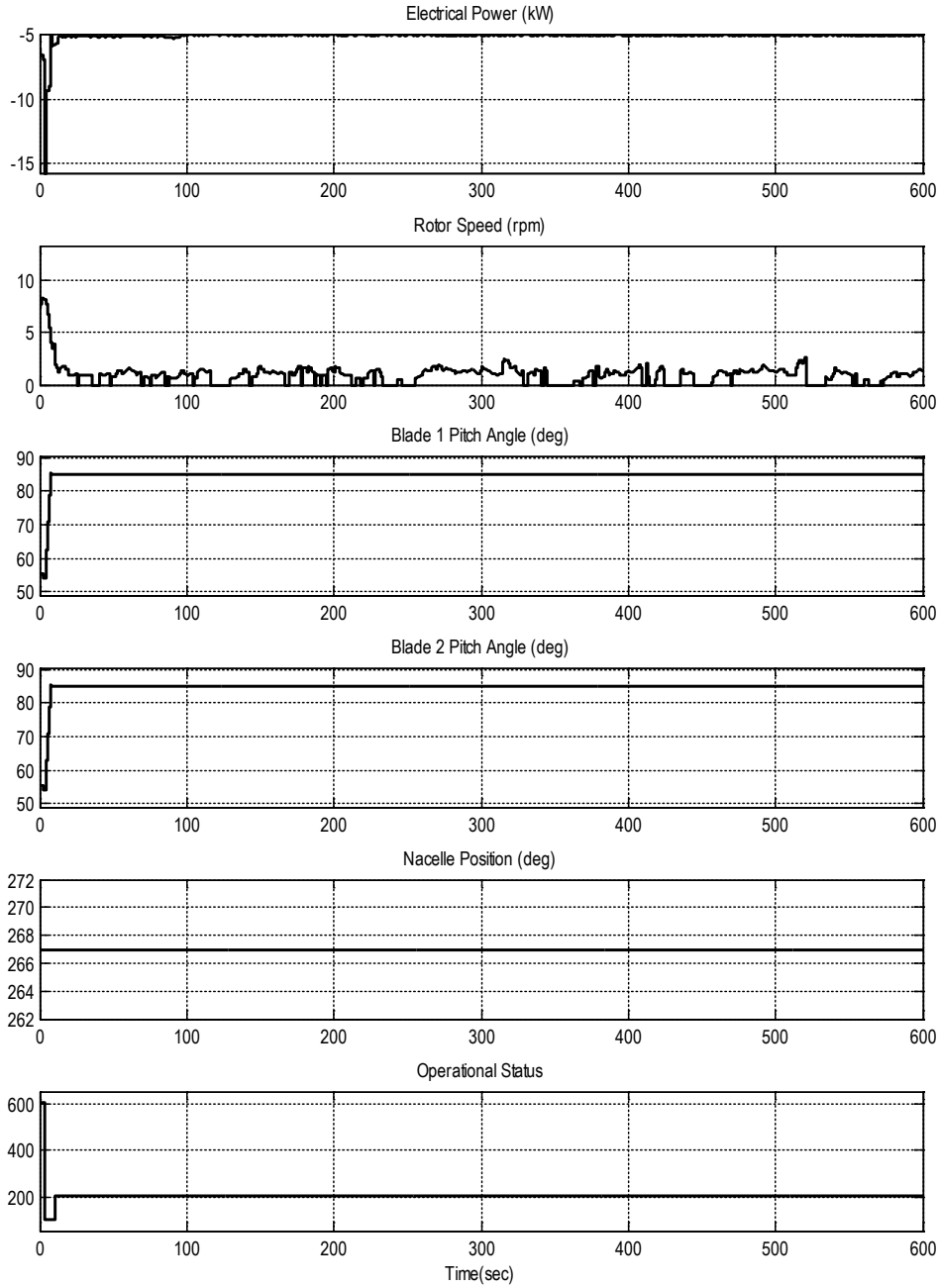


Figure 212. Parked at 27.6 m/s—wind turbine operational quantities

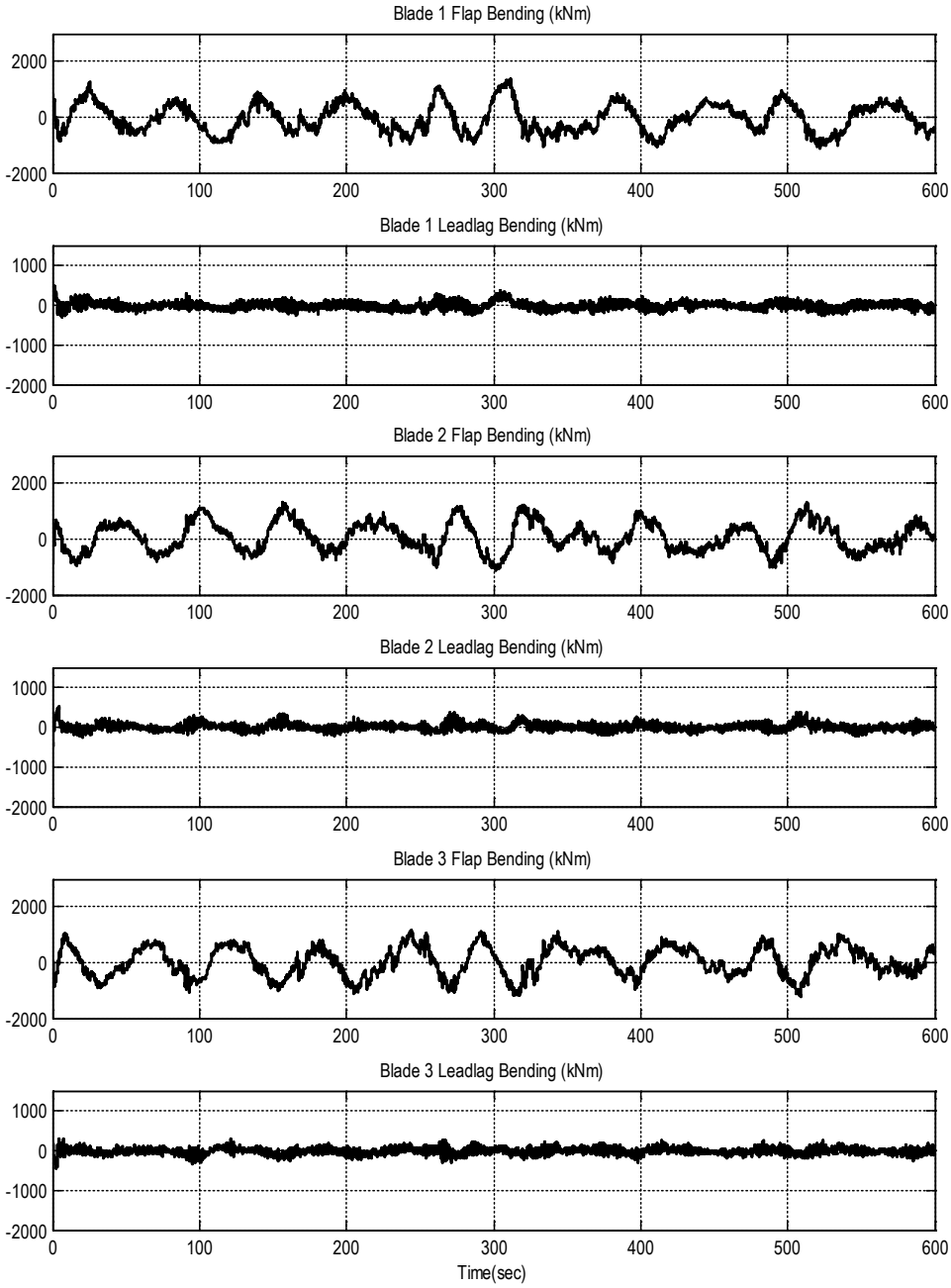


Figure 213. Parked at 27.6 m/s—blade loads

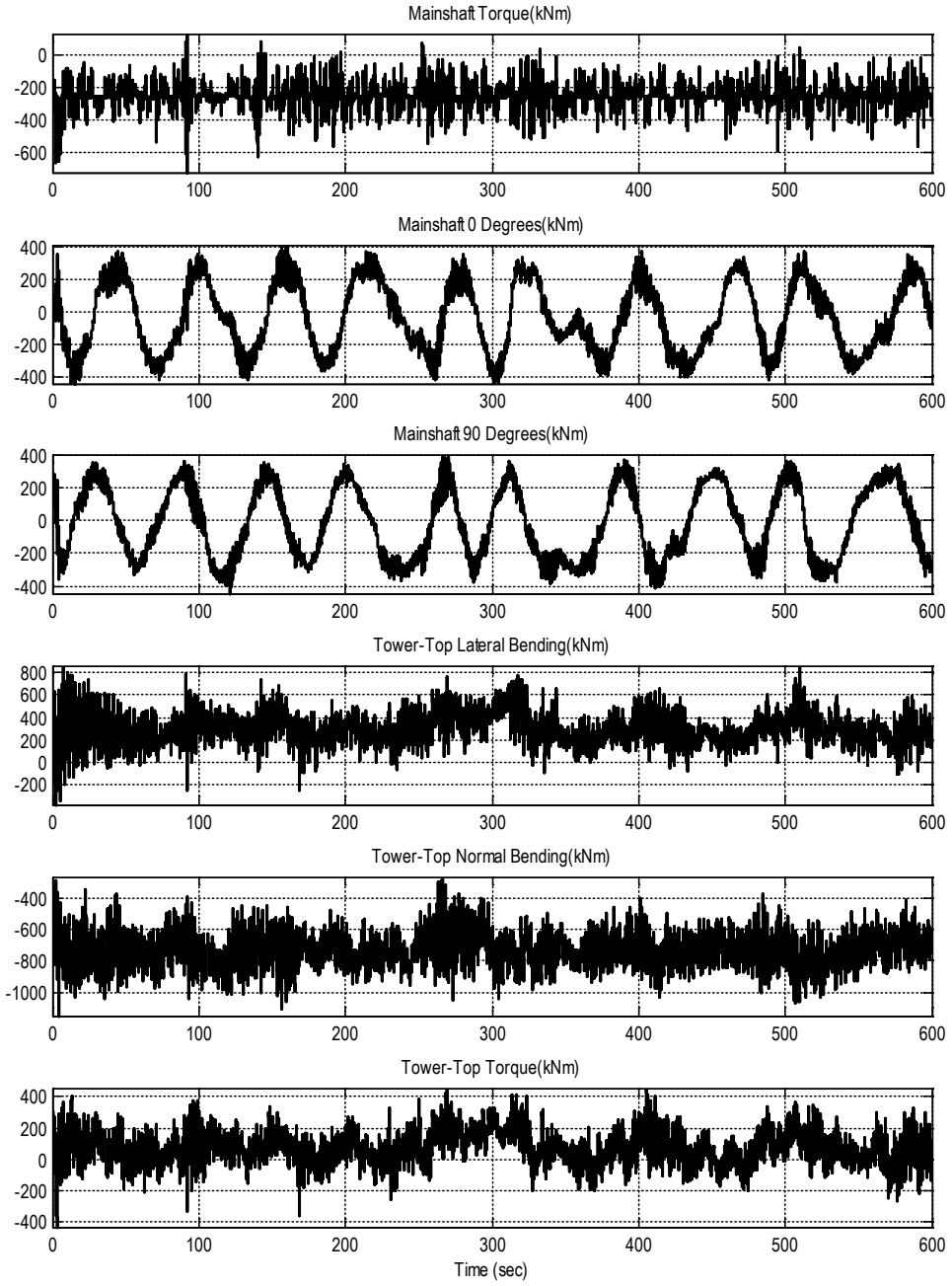


Figure 214. Parked at 27.6 m/s—shaft and tower-top loads

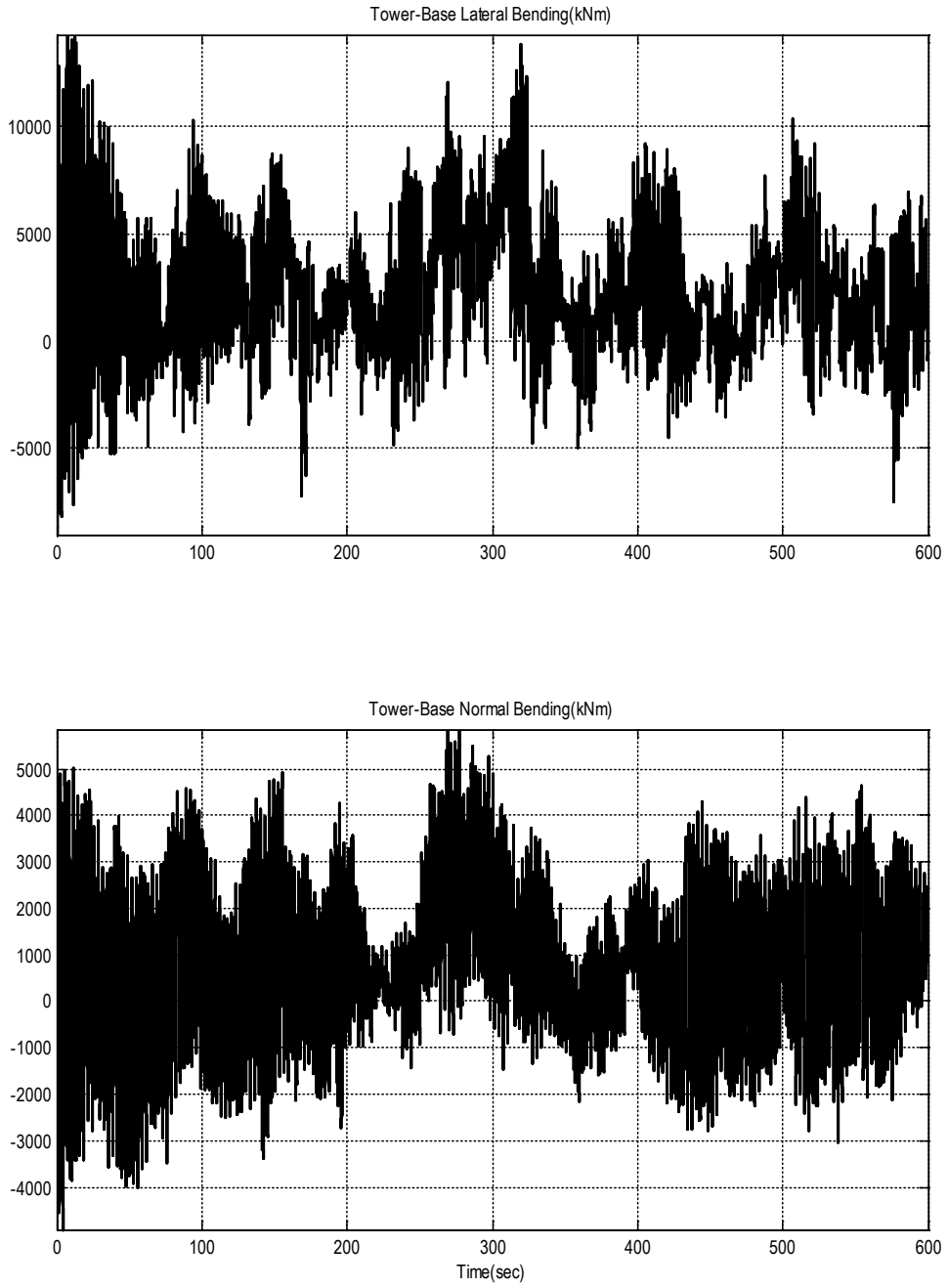


Figure 215. Parked at 27.6 m/s—tower-base loads

Appendix B. Pictures of Test Site

Figure 216. View towards the west. ***Photo by Ismael Mendoza, NREL***

Figure 217. View towards the northwest. ***Photo by Ismael Mendoza, NREL***

Figure 218. View towards the north. ***Photo by Ismael Mendoza, NREL***

Figure 219. View towards the northeast. ***Photo by Ismael Mendoza, NREL***

Figure 220. View towards the east. ***Photo by Ismael Mendoza, NREL***

Figure 221. View towards the southeast. ***Photo by Ismael Mendoza, NREL***

Figure 222. View towards the south. ***Photo by Ismael Mendoza, NREL***

Figure 223. View towards the southwest. ***Photo by Ismael Mendoza, NREL***

Appendix C. Blade Slow Roll Results

This appendix shows the slow rolls used to derive the calibration coefficients for the blade bending moments. The blade signals were calibrated using slow rolls with three different pitch angles: ~0 degrees, ~85 degrees, and ~65 degrees.

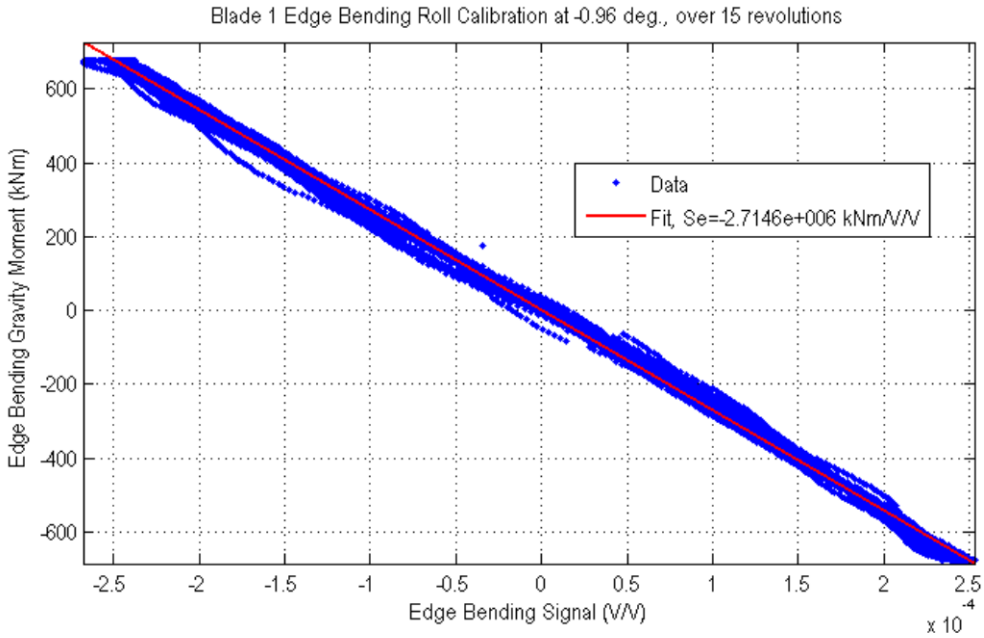


Figure 224. Blade 1 leadlag slow roll calibration

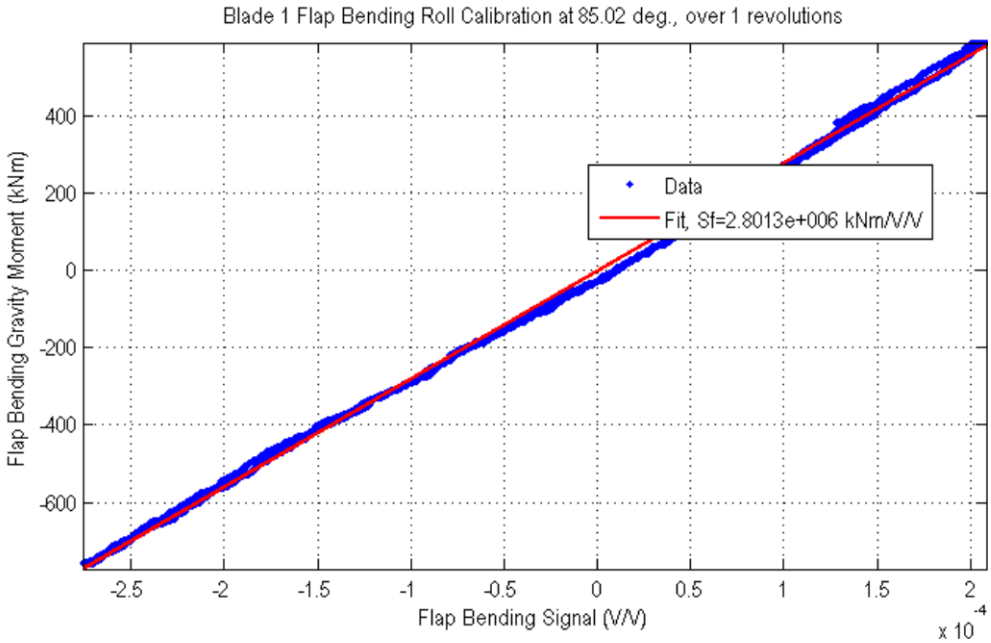


Figure 225. Blade 1 flap slow roll calibration

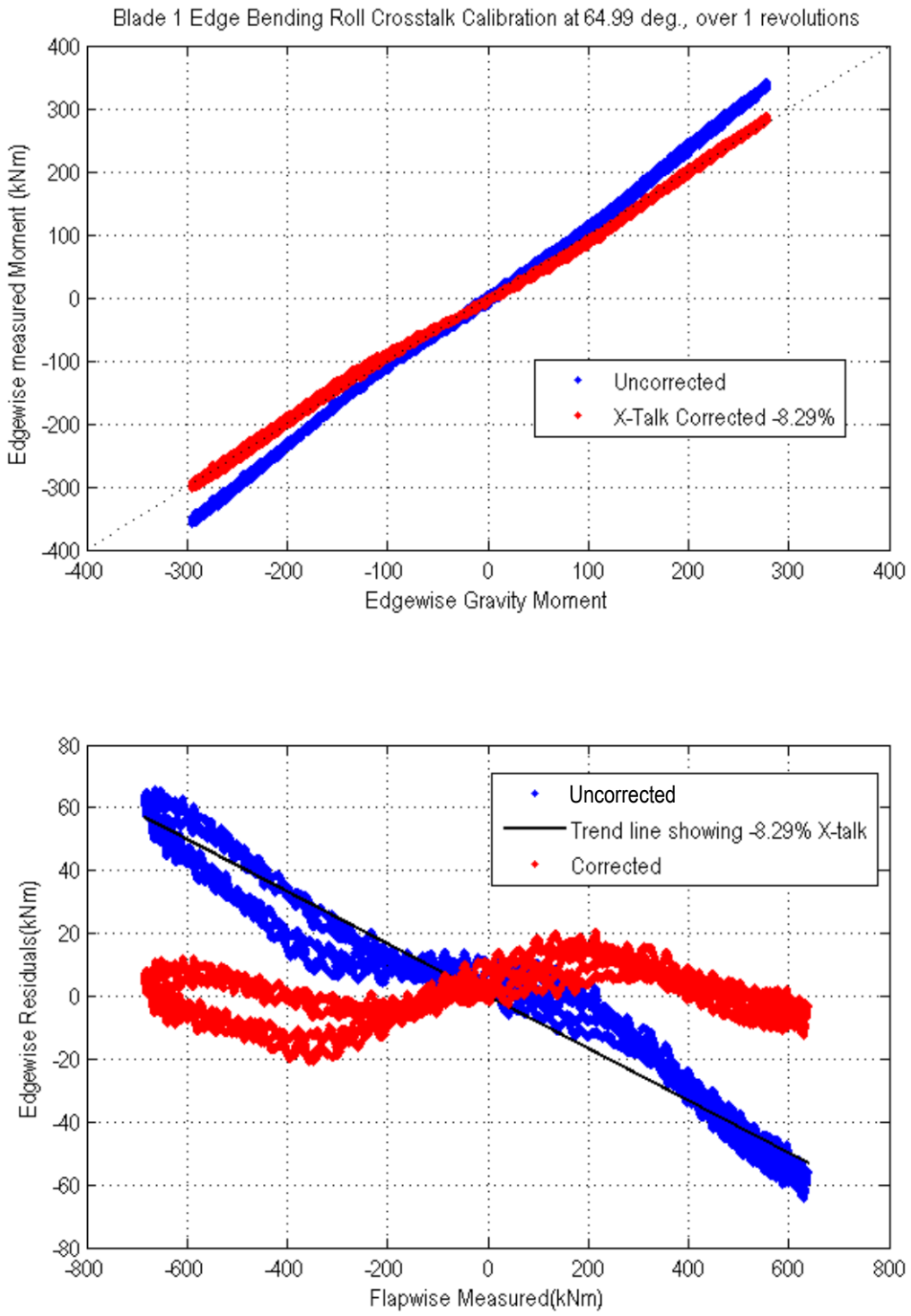
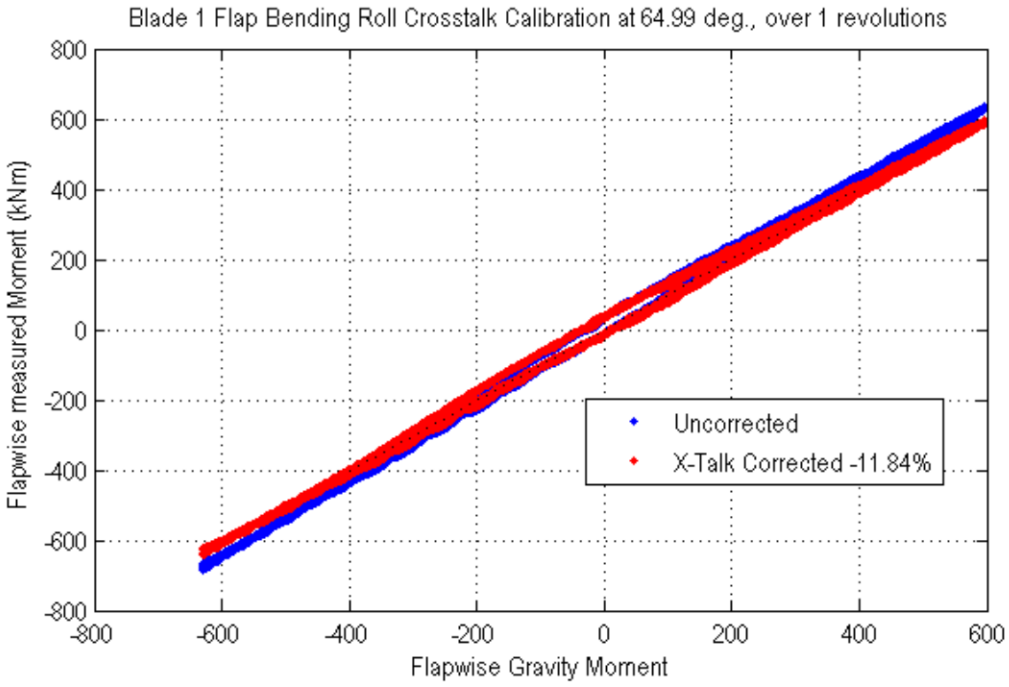


Figure 226. Blade 1 leadlag crosstalk correction



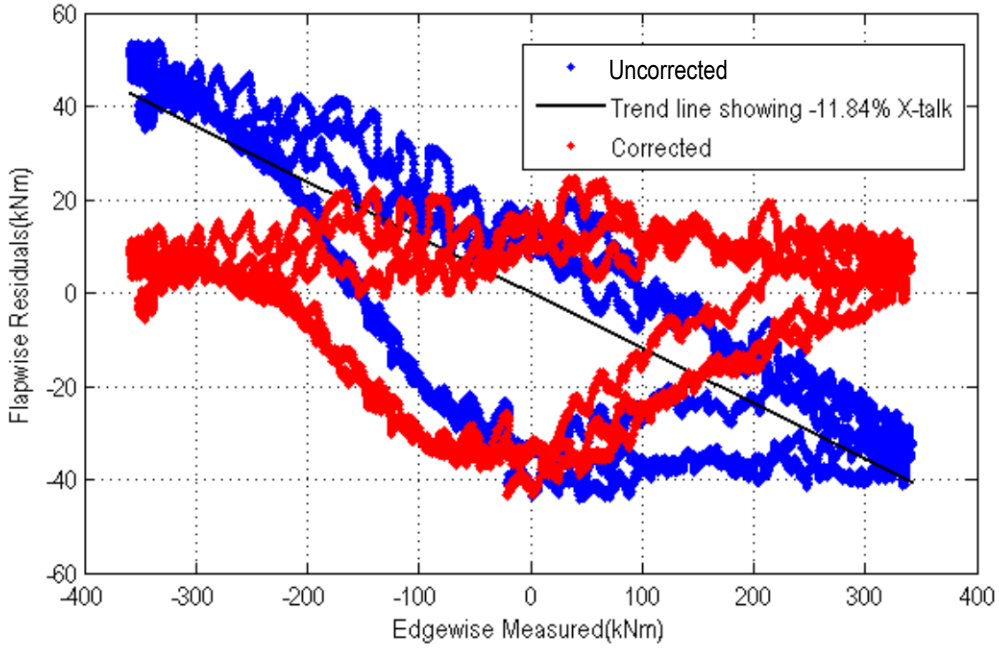


Figure 227. Blade 1 flap crosstalk correction

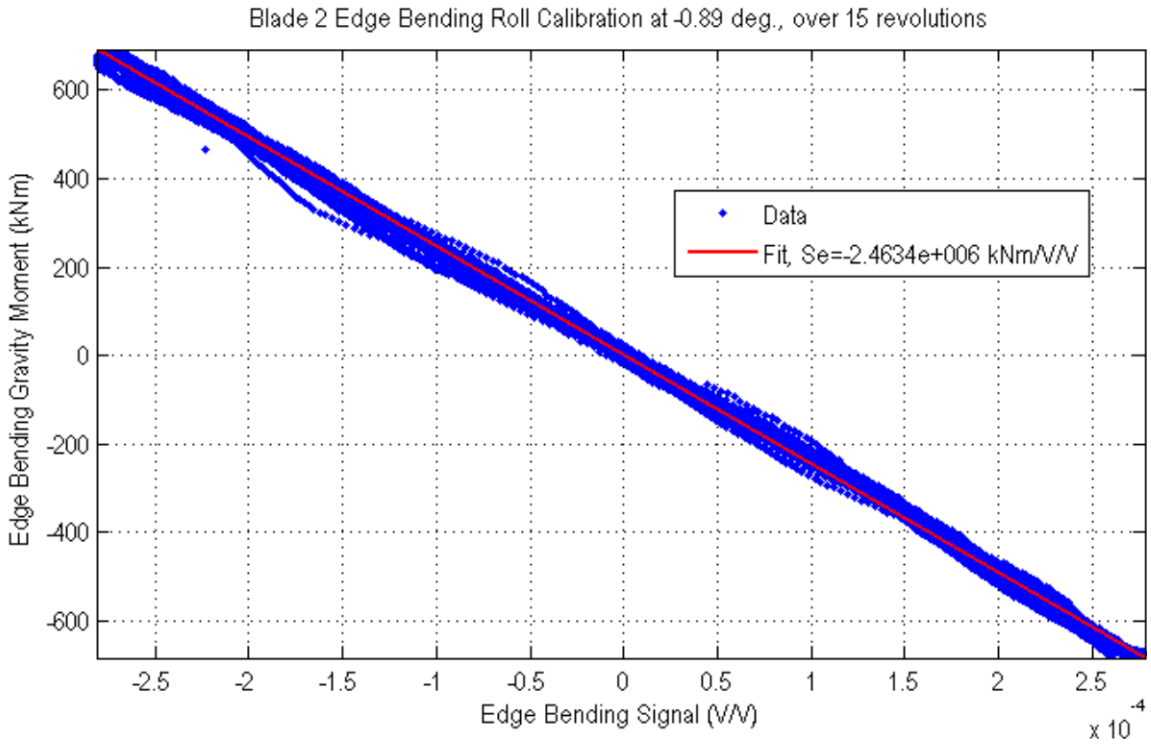


Figure 228. Blade 2 leadlag slow roll calibration

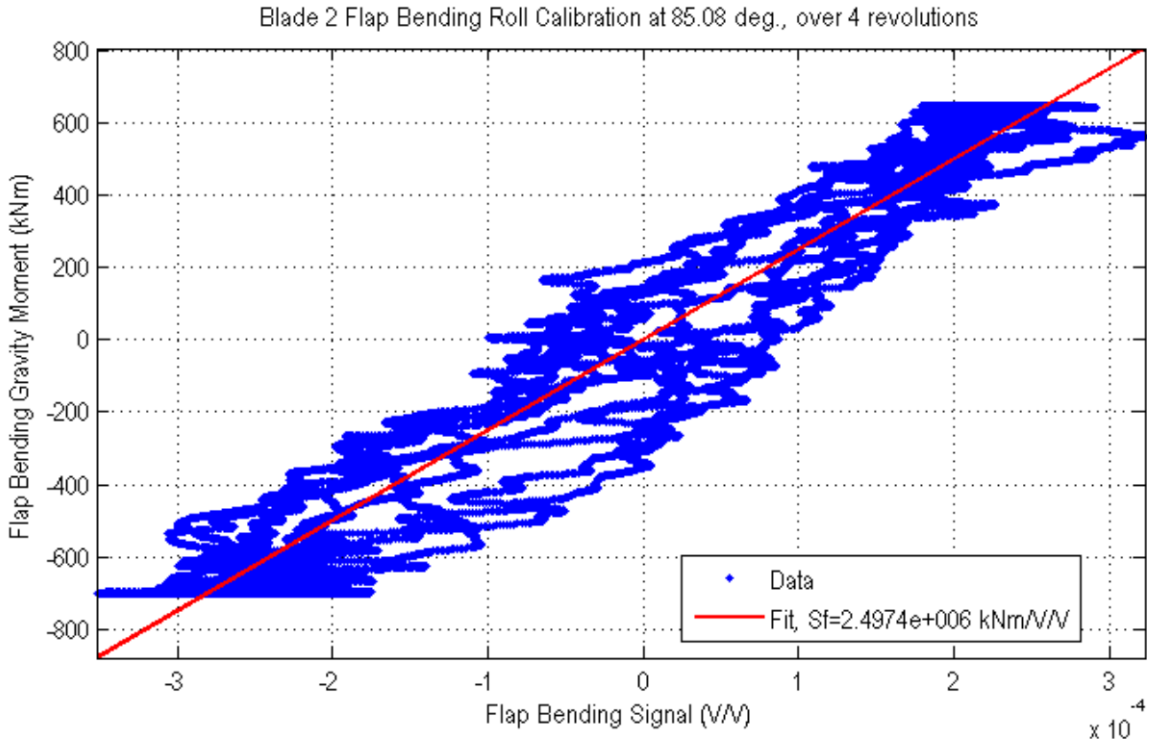


Figure 229. Blade 2 flap slow roll calibration

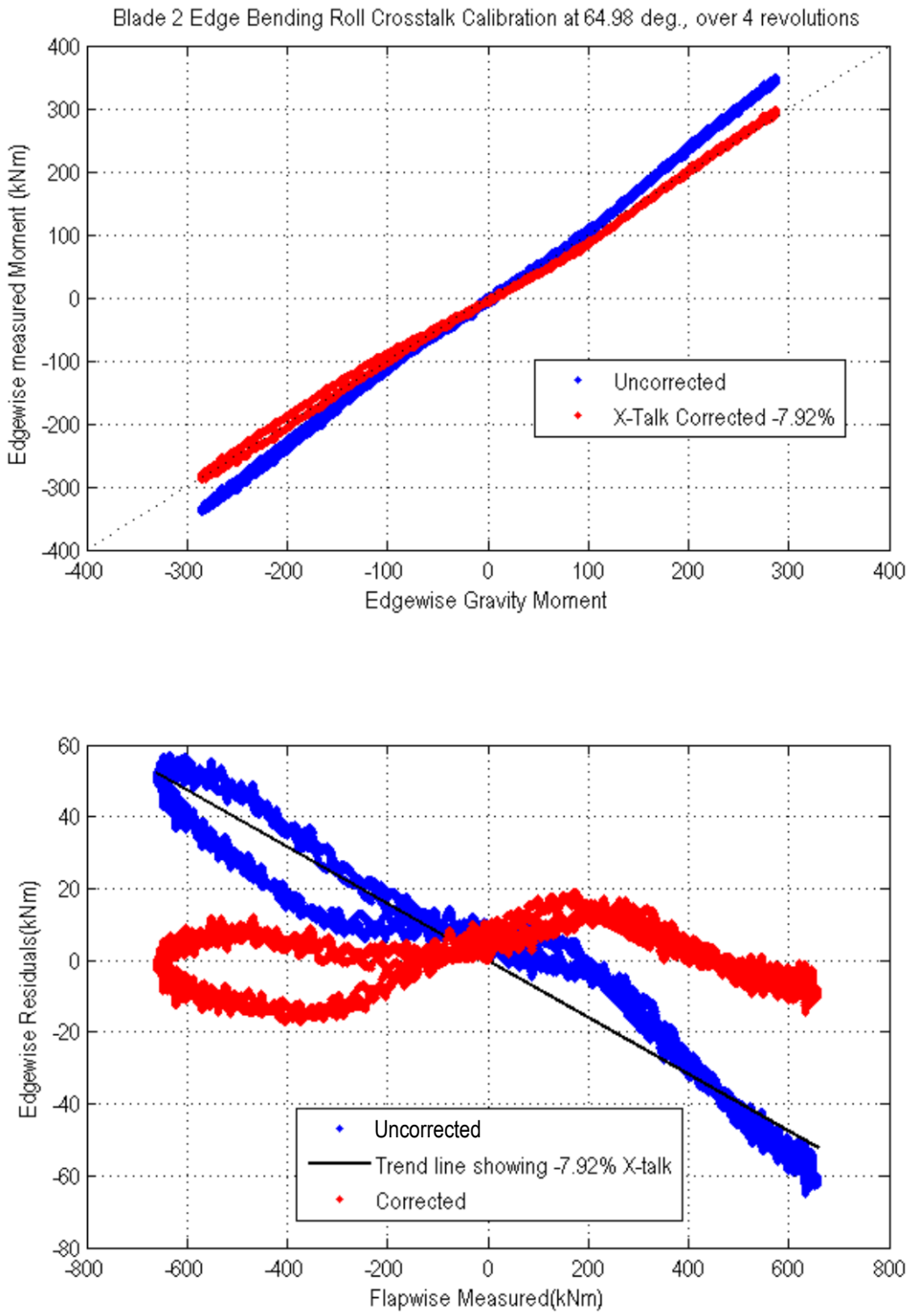


Figure 230. Blade 2 leadlag crosstalk correction

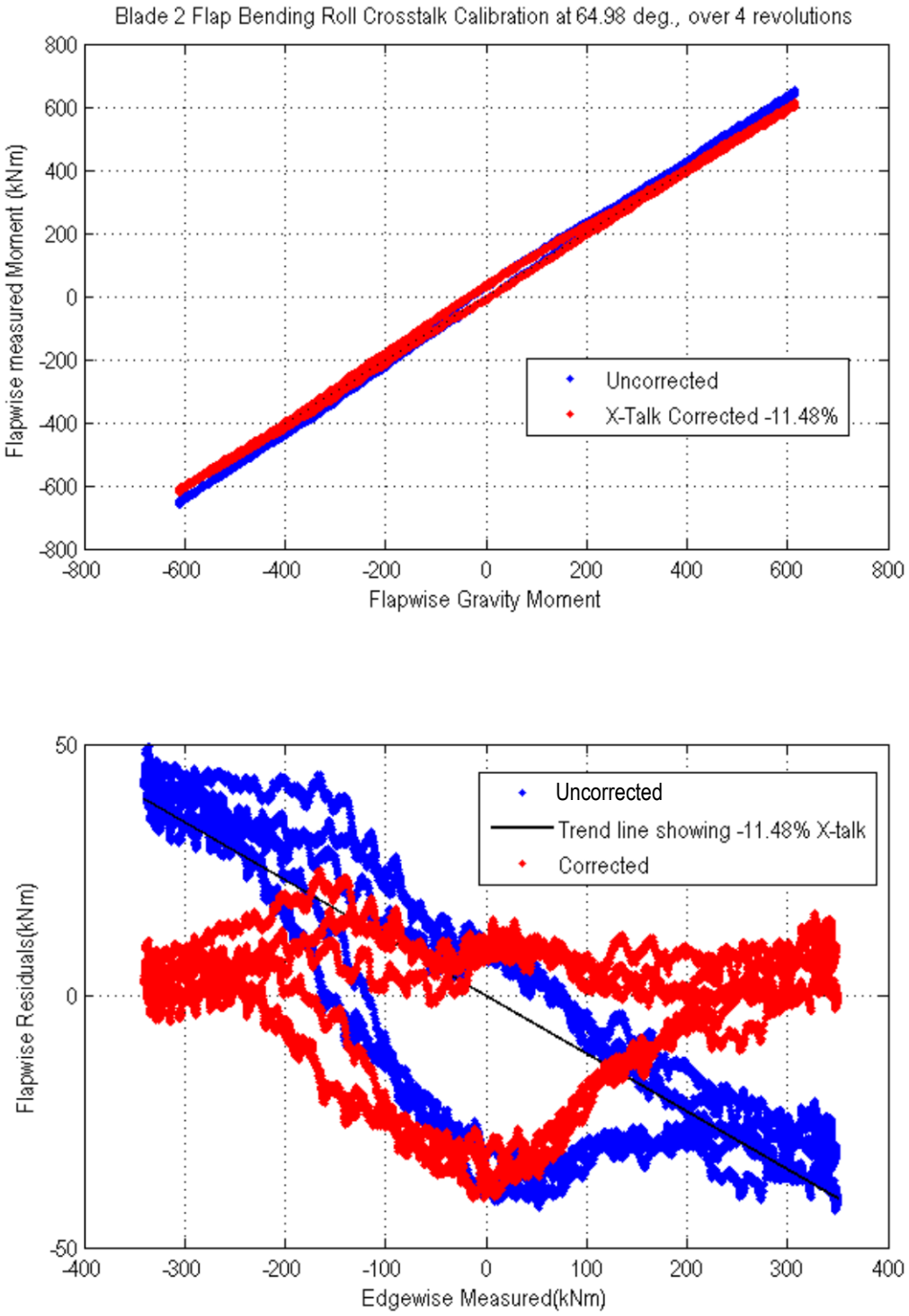


Figure 231. Blade 2 flapwise crosstalk correction

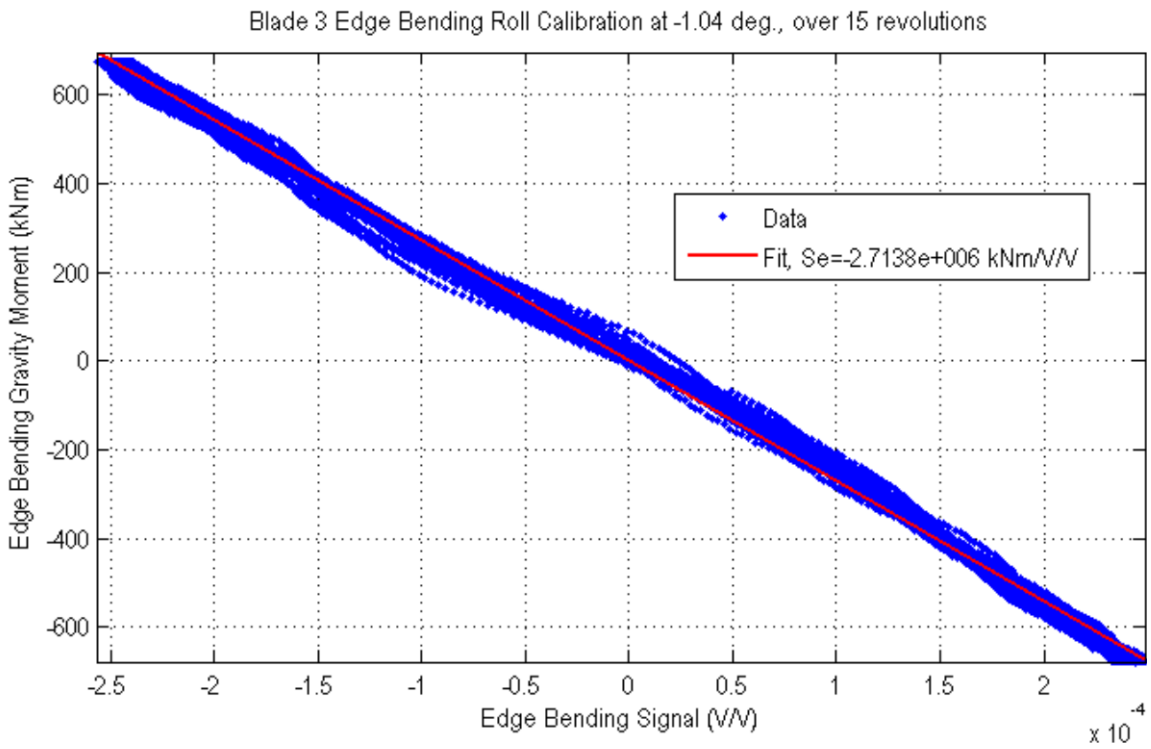


Figure 232. Blade 3 leadlag slow roll calibration

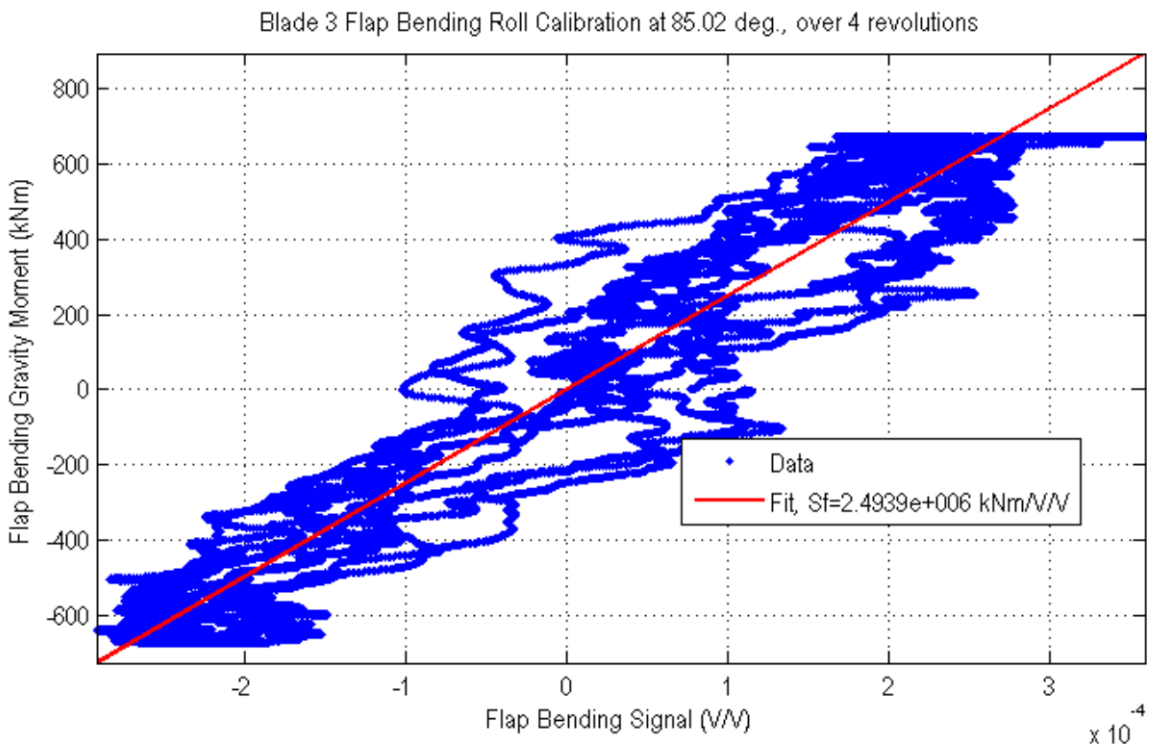


Figure 233. Blade 3 flapwise slow roll calibration

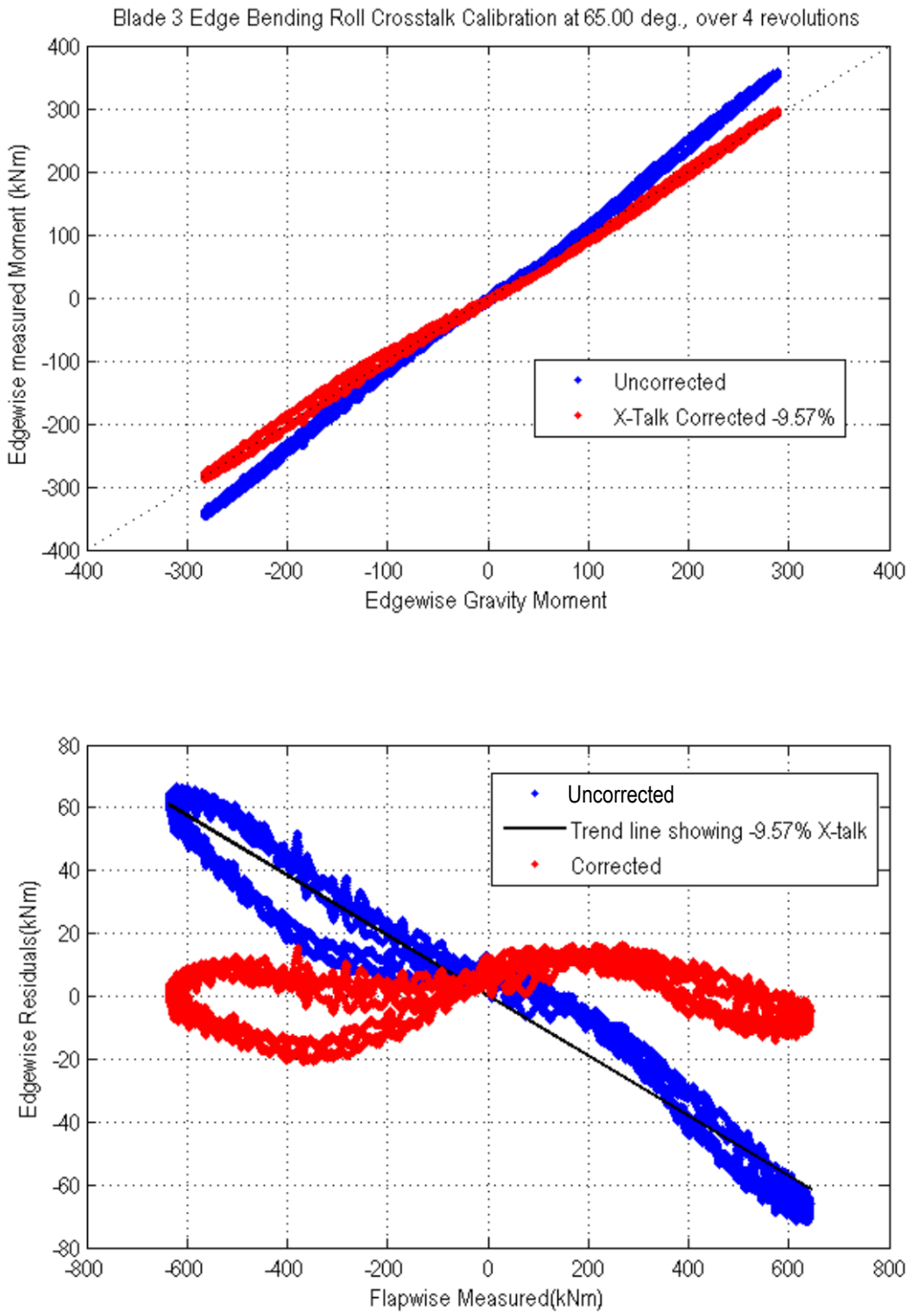


Figure 234. Blade 3 leadlag crosstalk correction

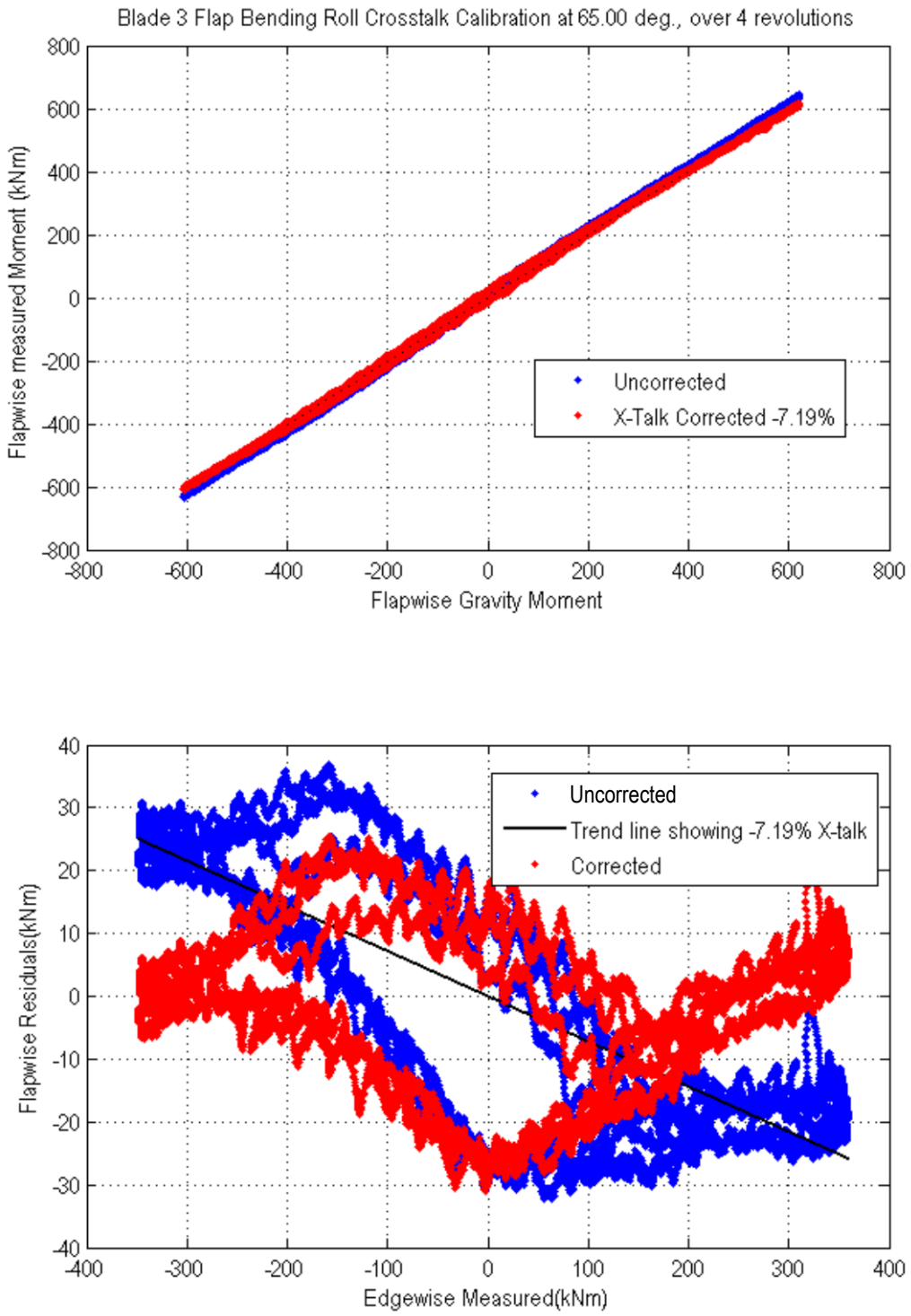


Figure 235. Blade 3 flapwise crosstalk correction

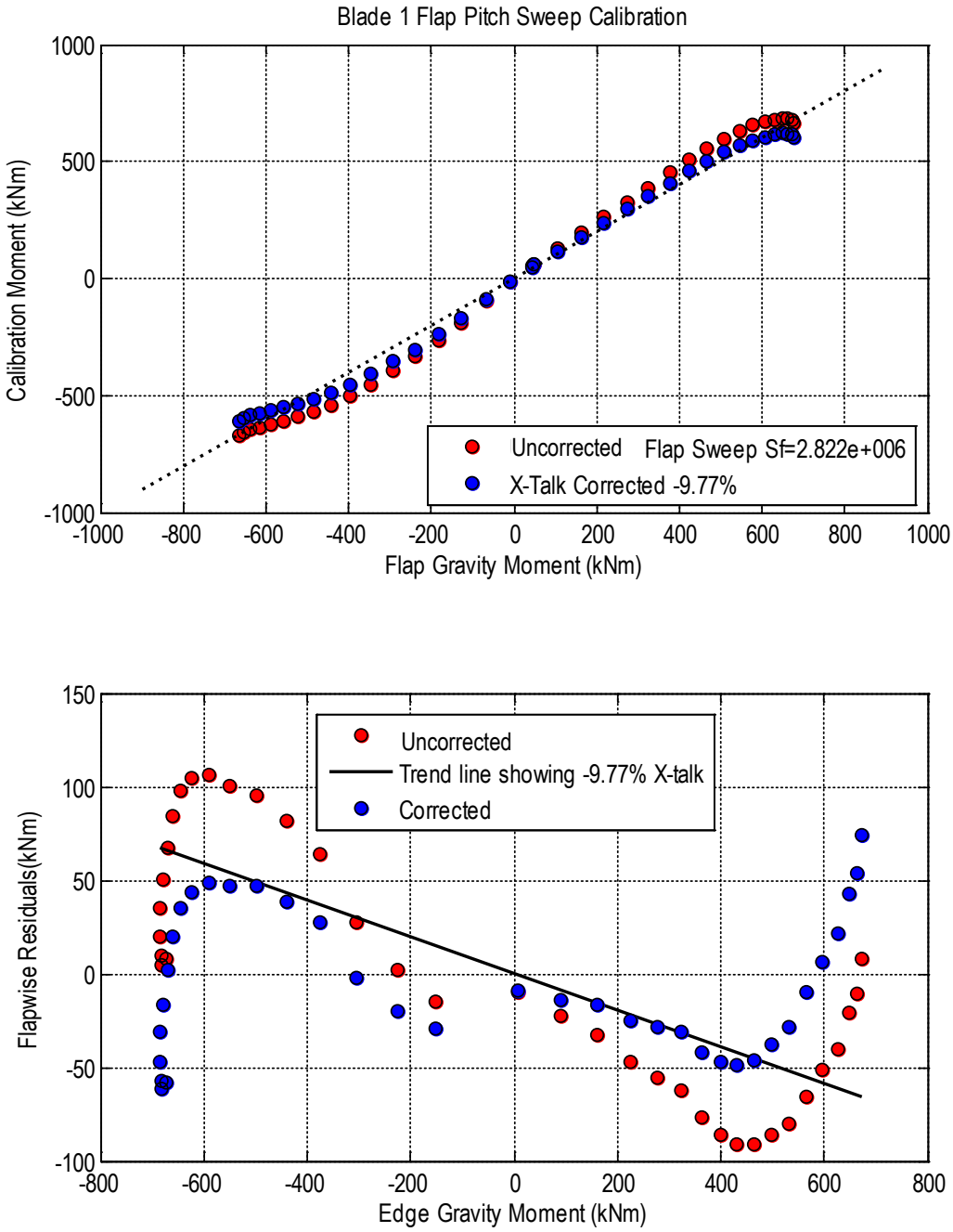
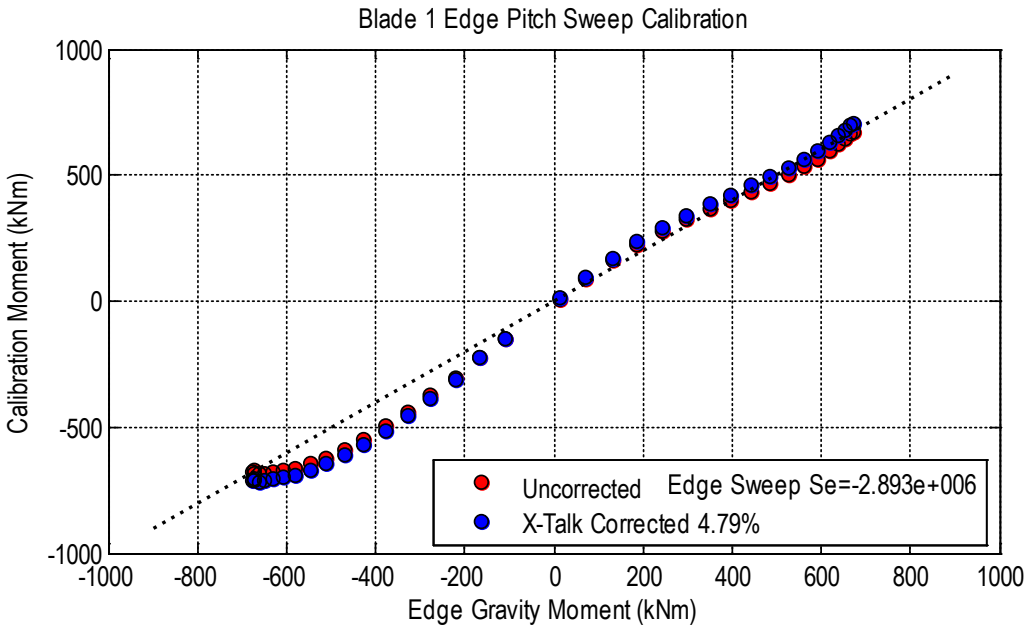


Figure 236. Blade 1 flap pitch sweep calibration results



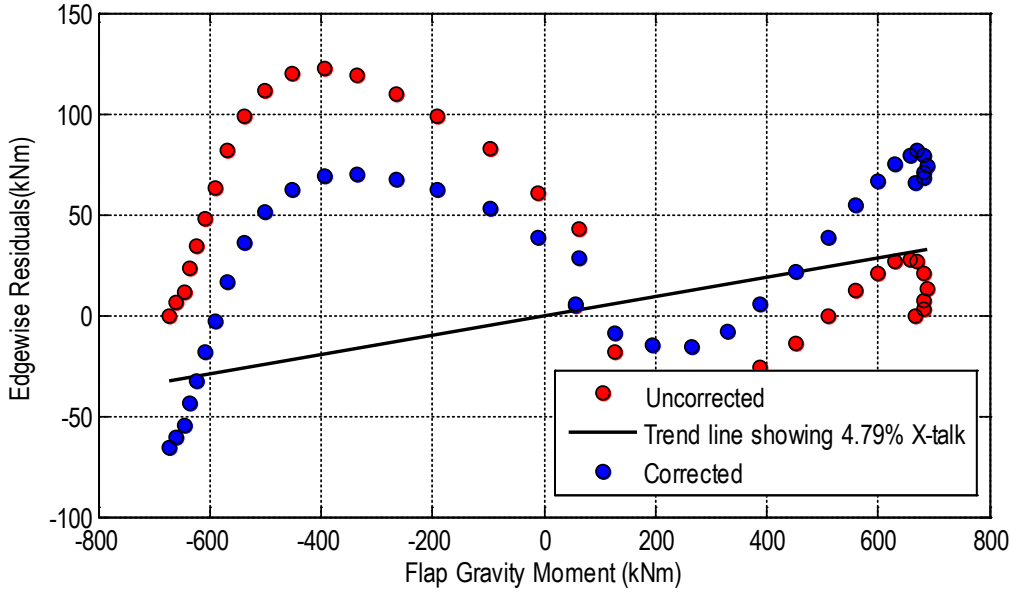
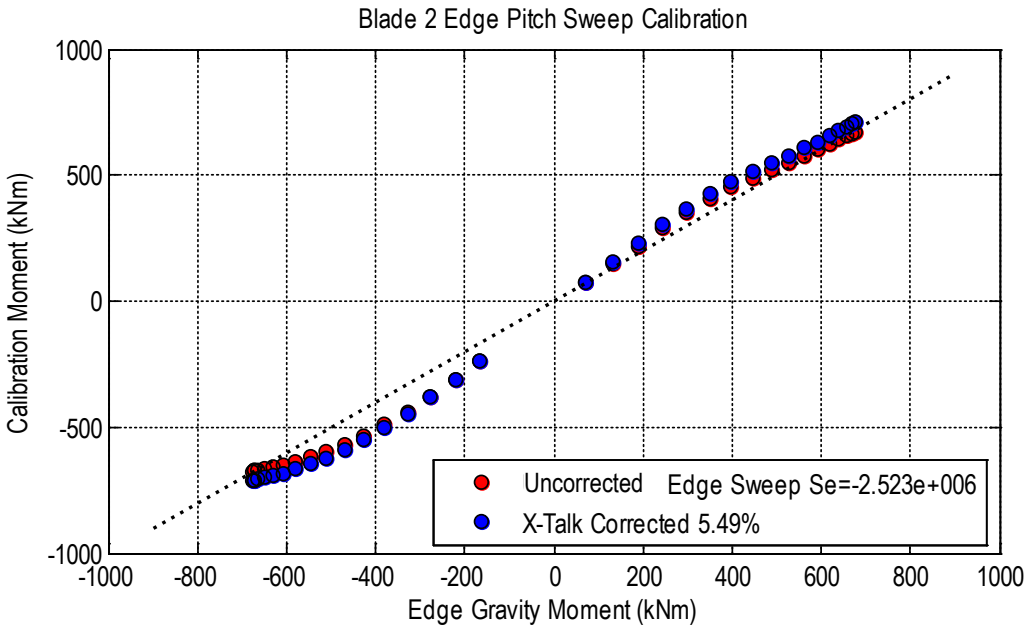


Figure 237. Blade 1 leadlag pitch sweep calibration results



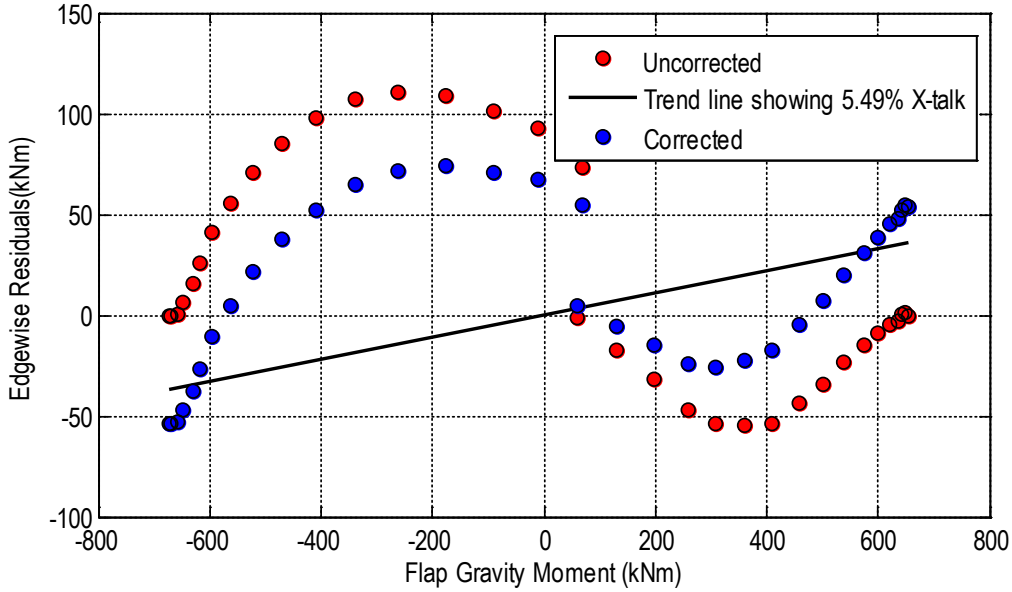
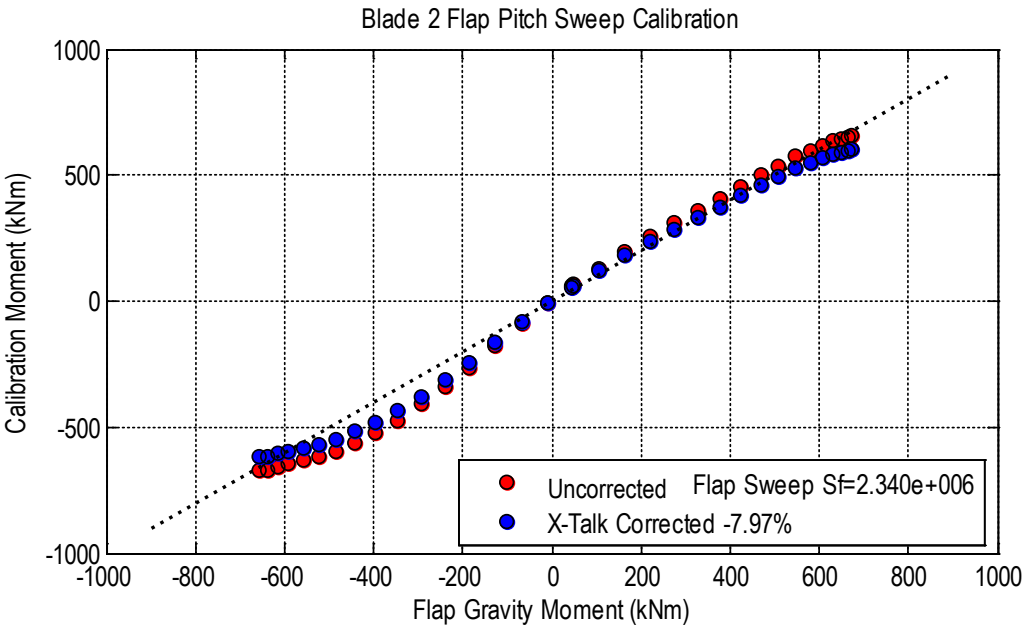


Figure 238. Blade 2 leadlag pitch sweep calibration results



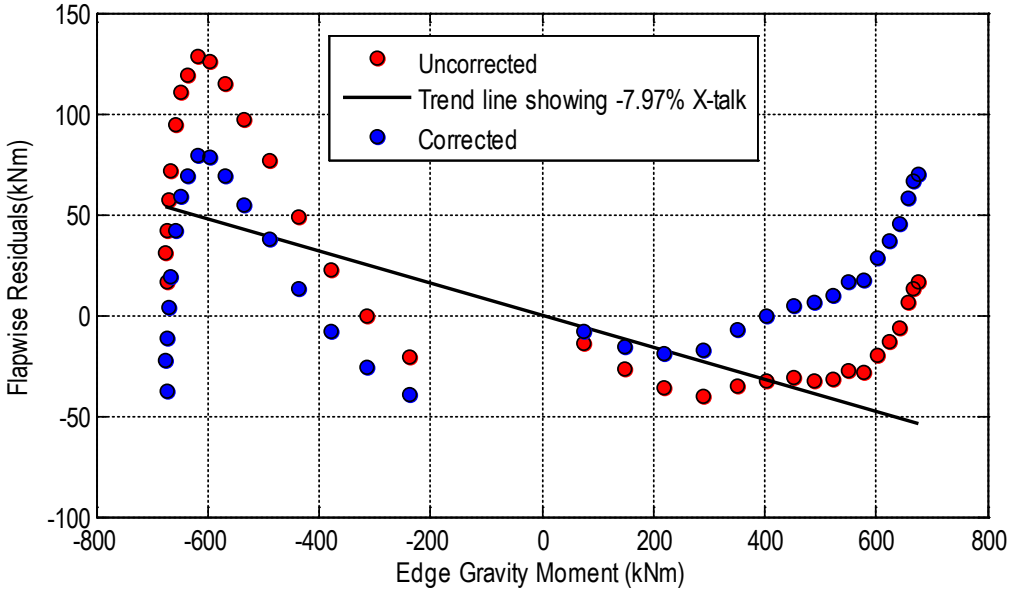
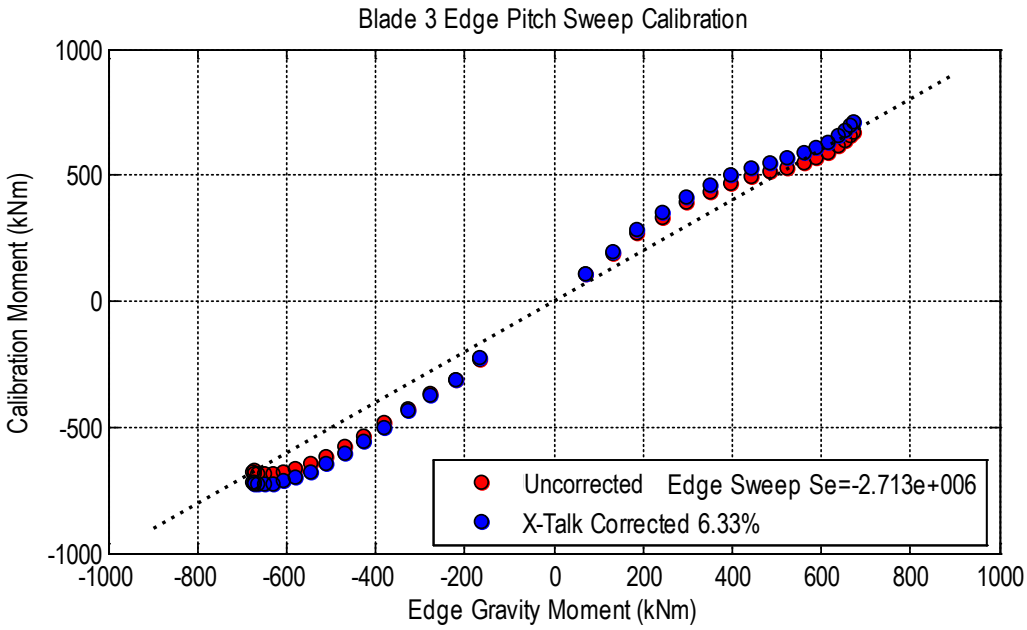


Figure 239. Blade 2 flap pitch sweep calibration results



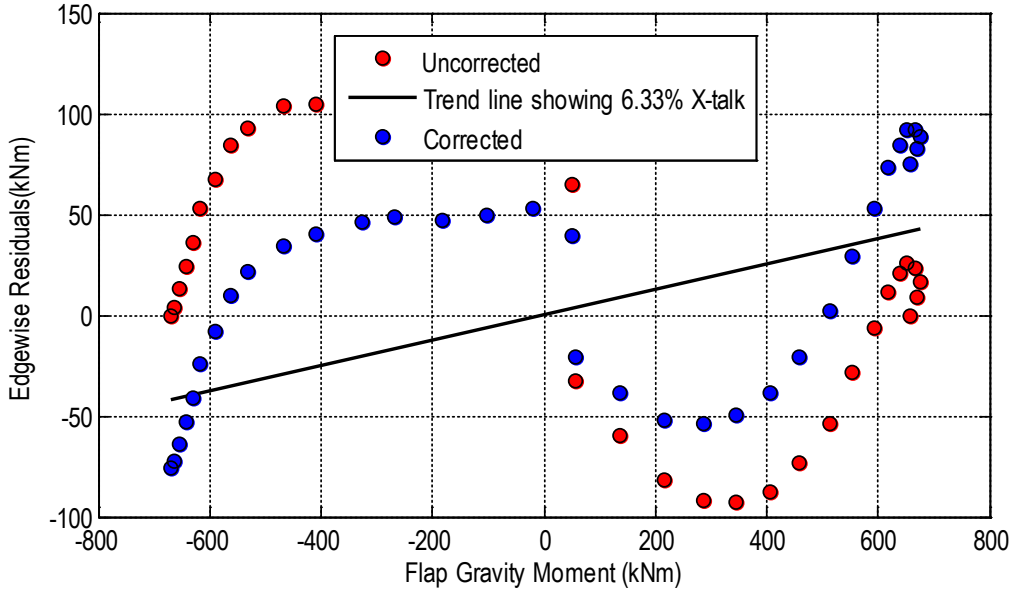
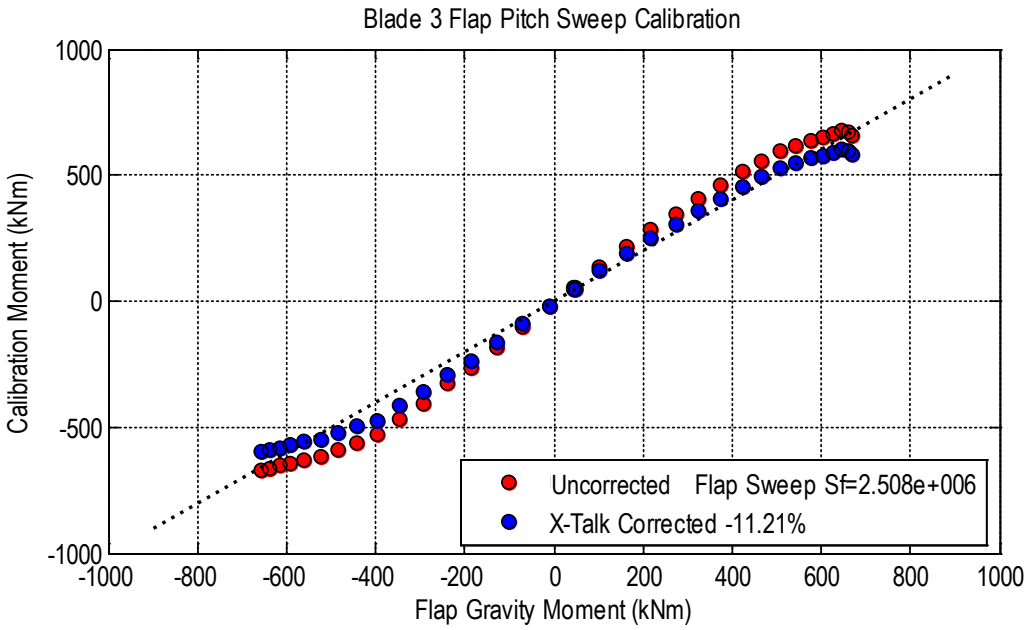


Figure 240. Blade 3 leadlag pitch sweep calibration results



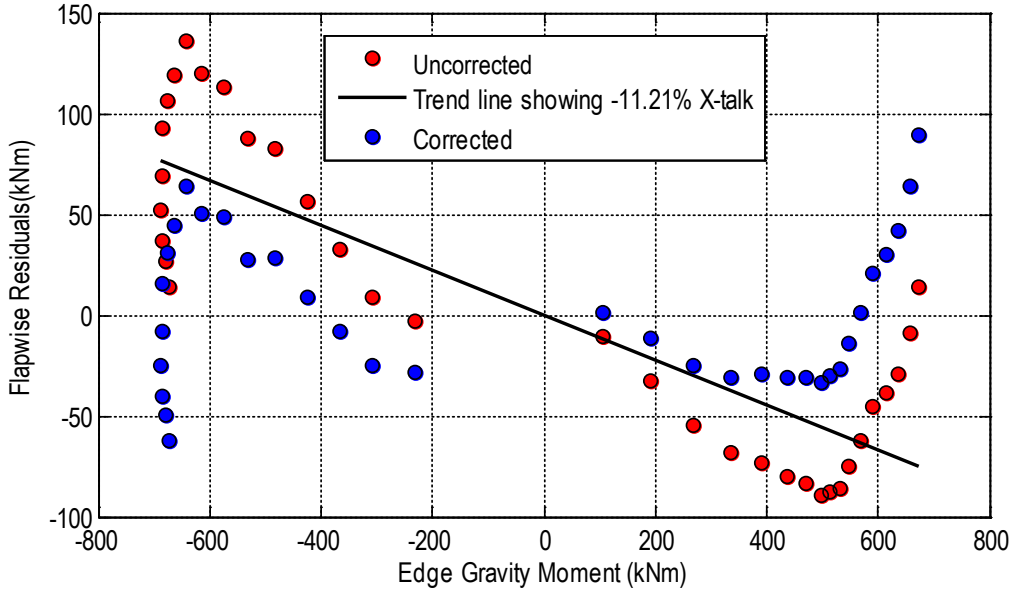


Figure 241. Blade 3 flap pitch sweep calibration results

Appendix D. Main Shaft Slow Roll Results

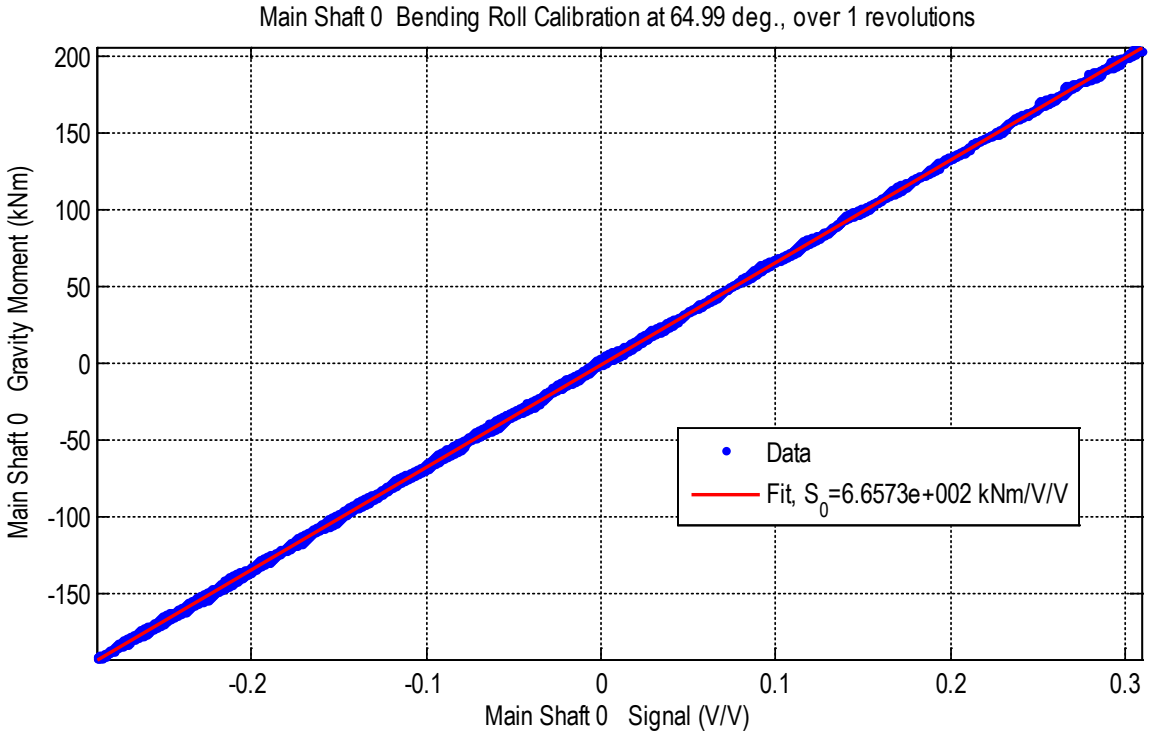


Figure 242. Main shaft bending 0 slow roll calibration

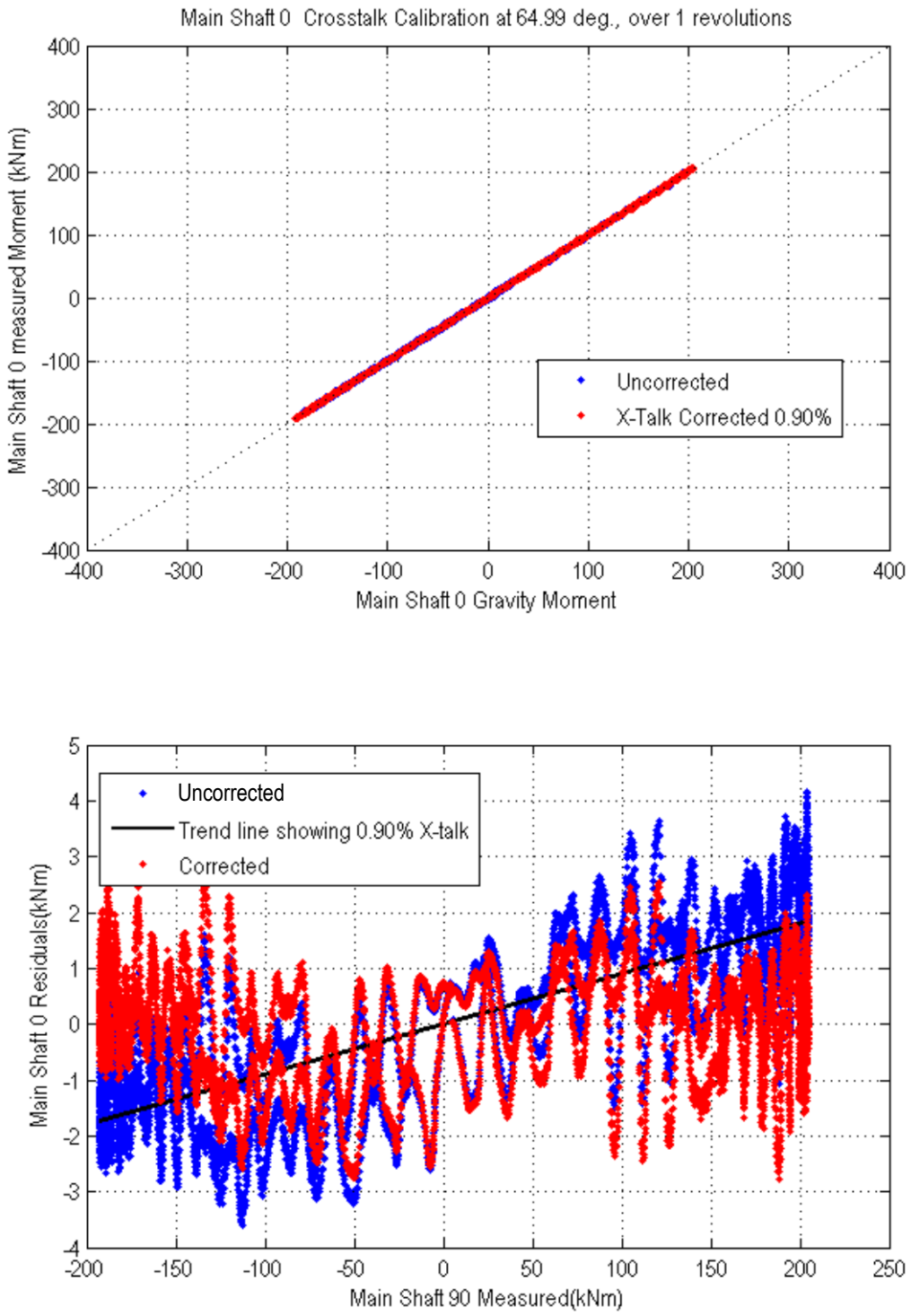


Figure 243. Main shaft bending 0 crosstalk correction

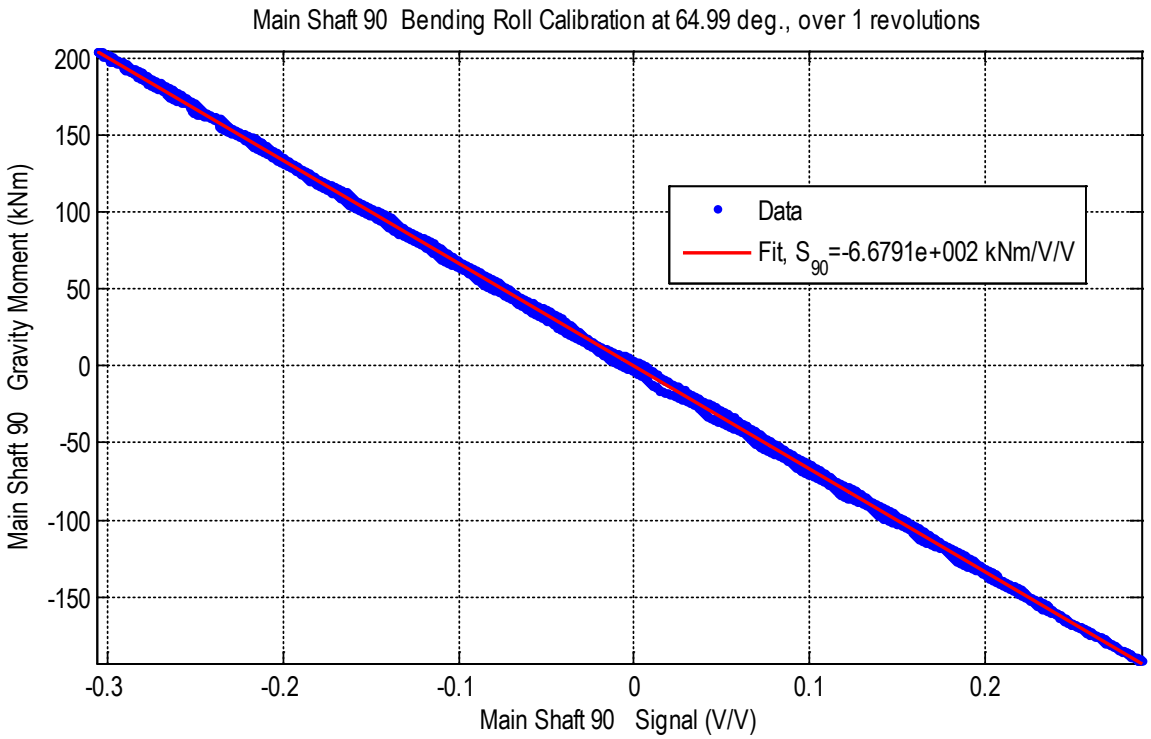


Figure 244. Main shaft bending 90 slow roll calibration

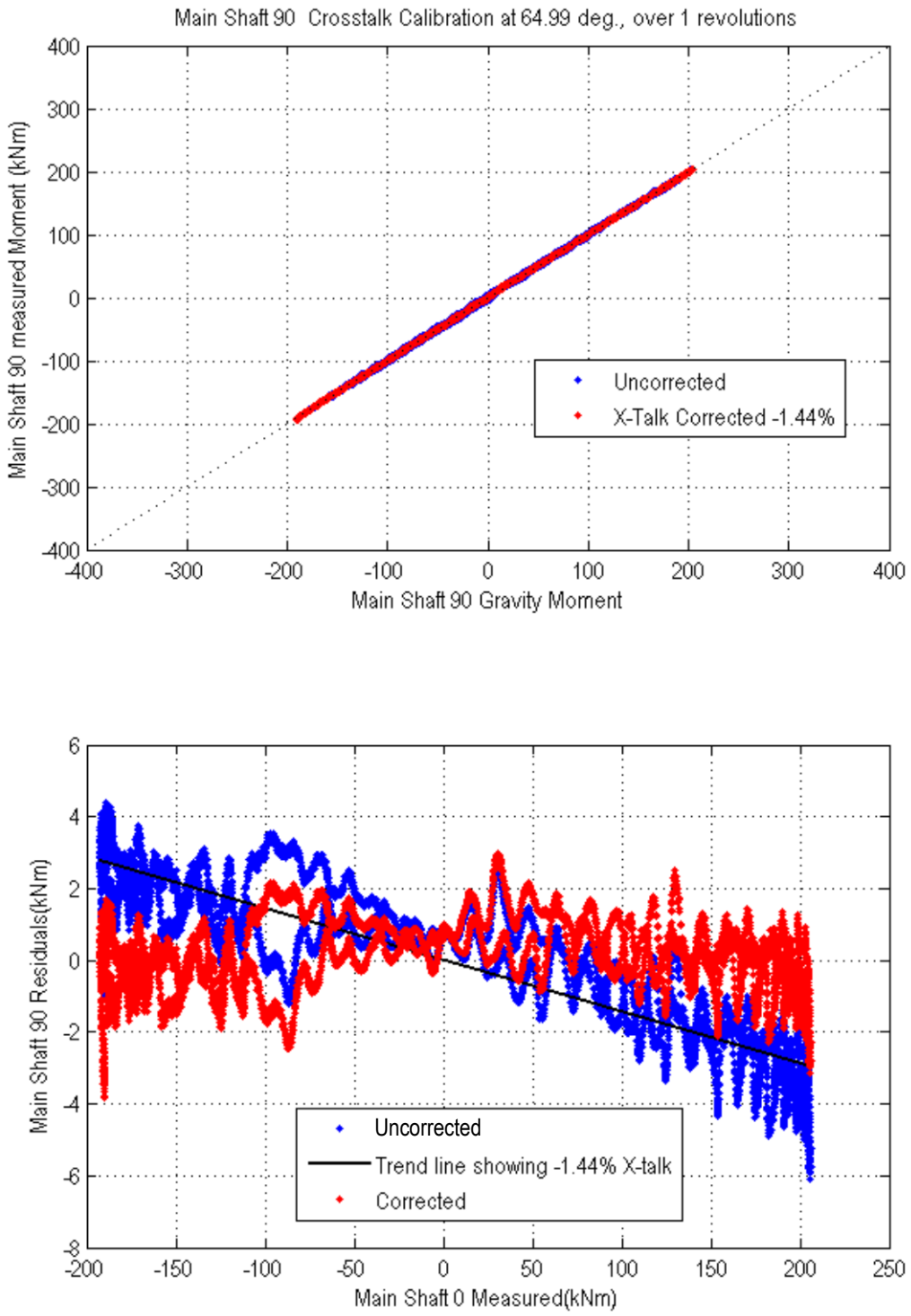


Figure 245. Main shaft bending 90 crosstalk correction

Appendix E. Yaw Sweeps

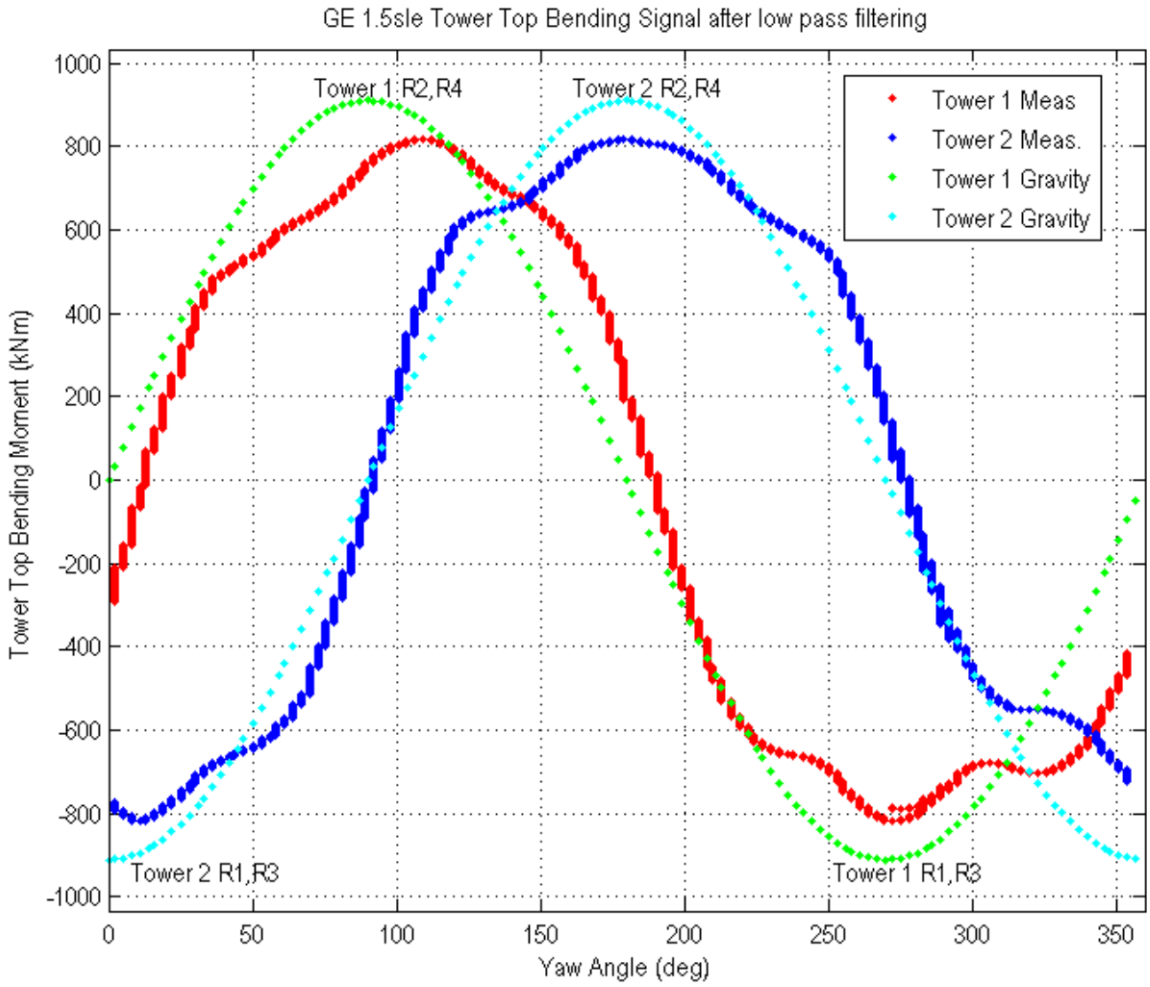


Figure 246. Tower-top nacelle 360 sweep calibration

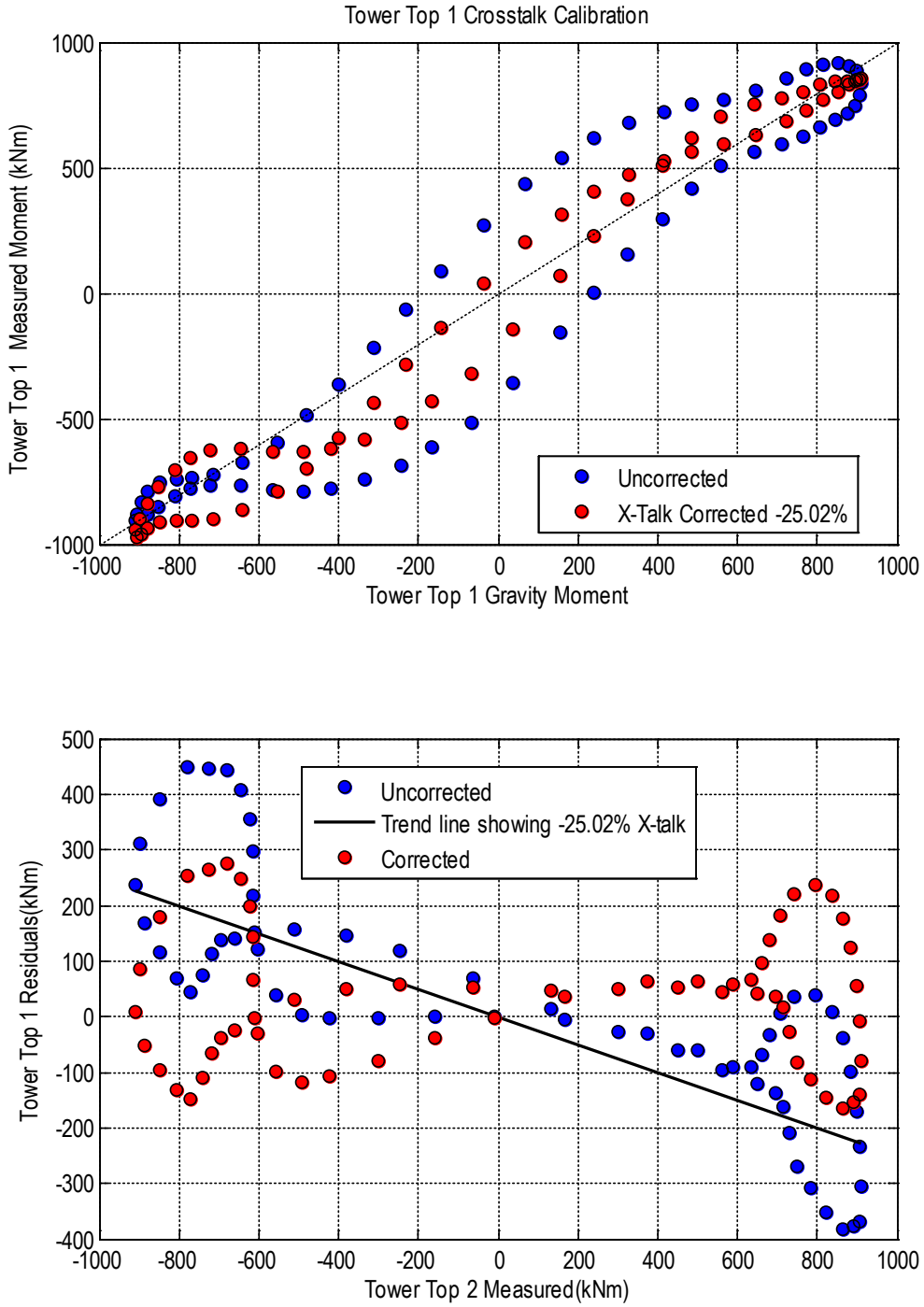


Figure 247. Tower-top 1 crosstalk calibration

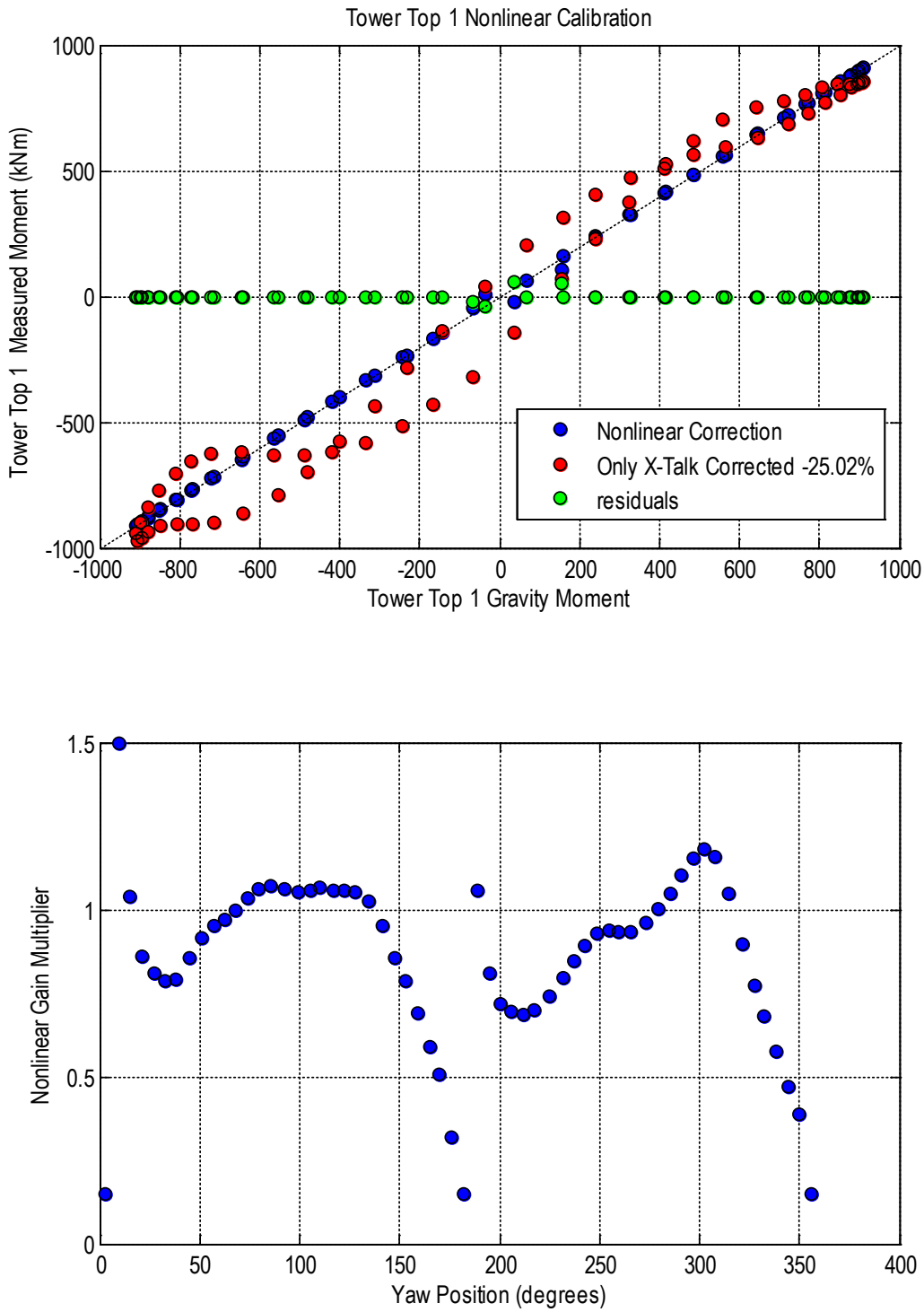
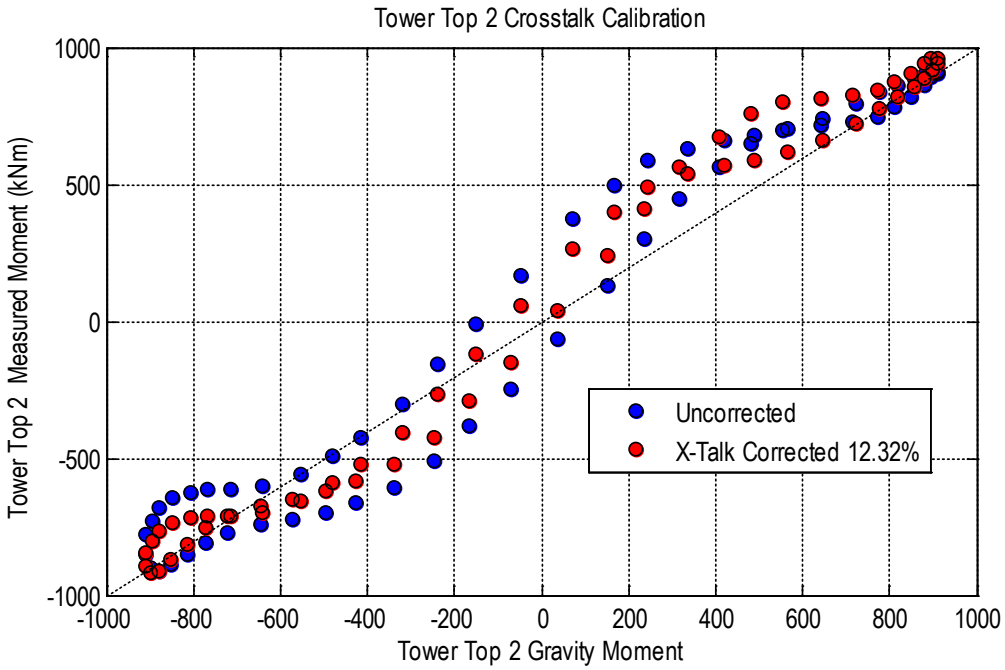


Figure 248. Tower-top 1 nonlinear gain correction



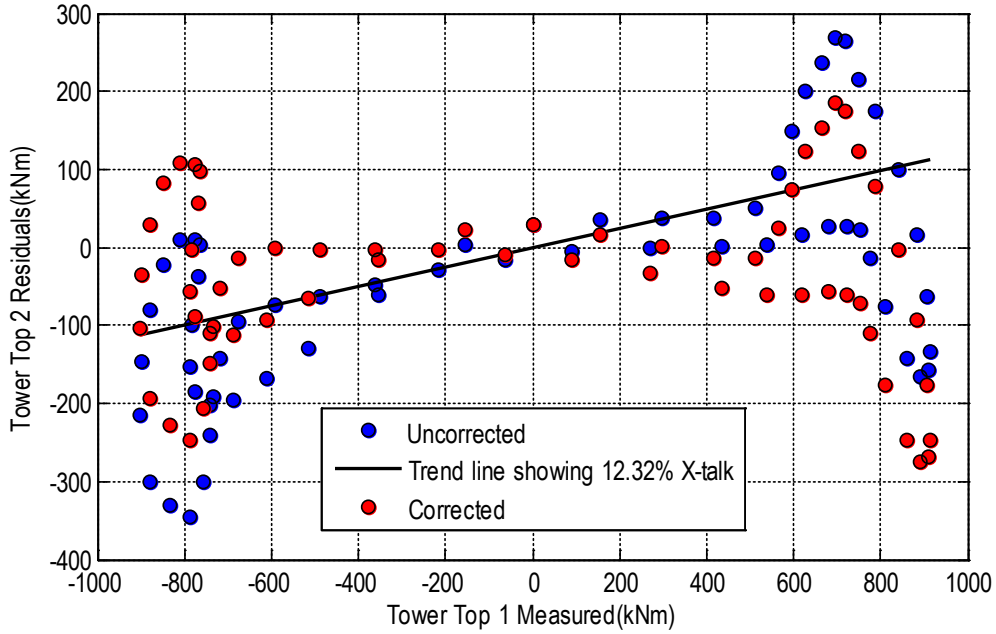
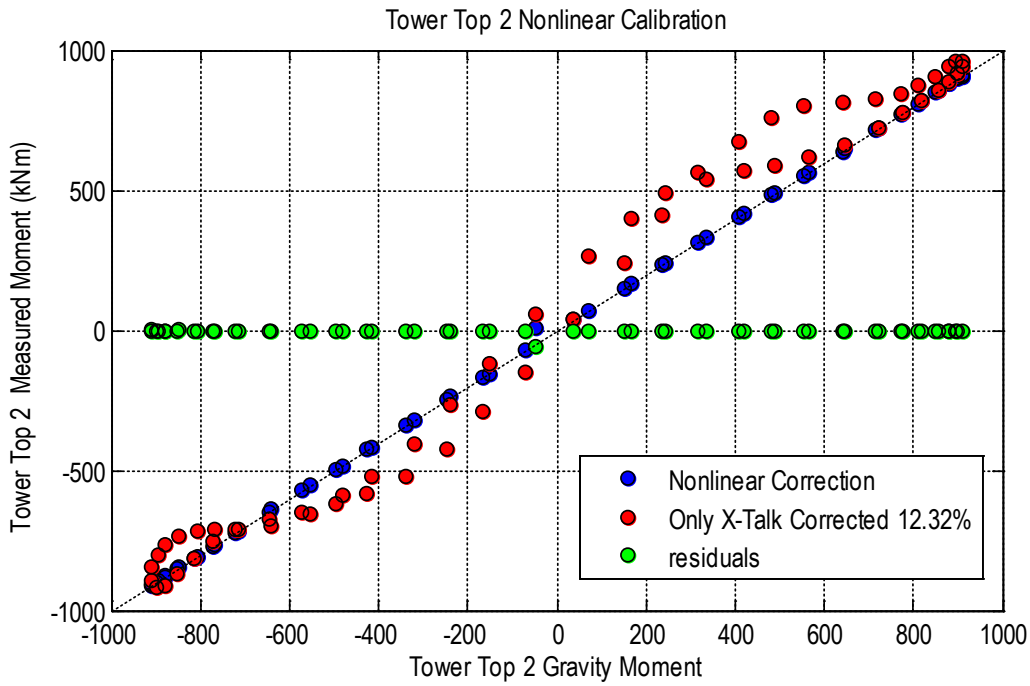


Figure 249. Tower-top 2 crosstalk calibration



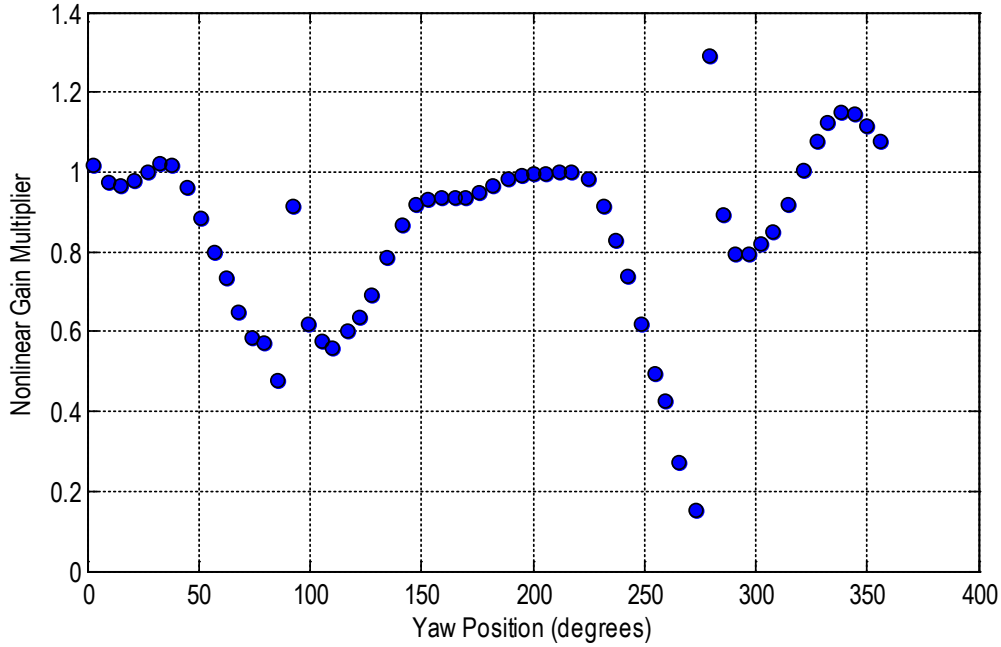


Figure 250. Tower-top 2 nonlinear gain correction

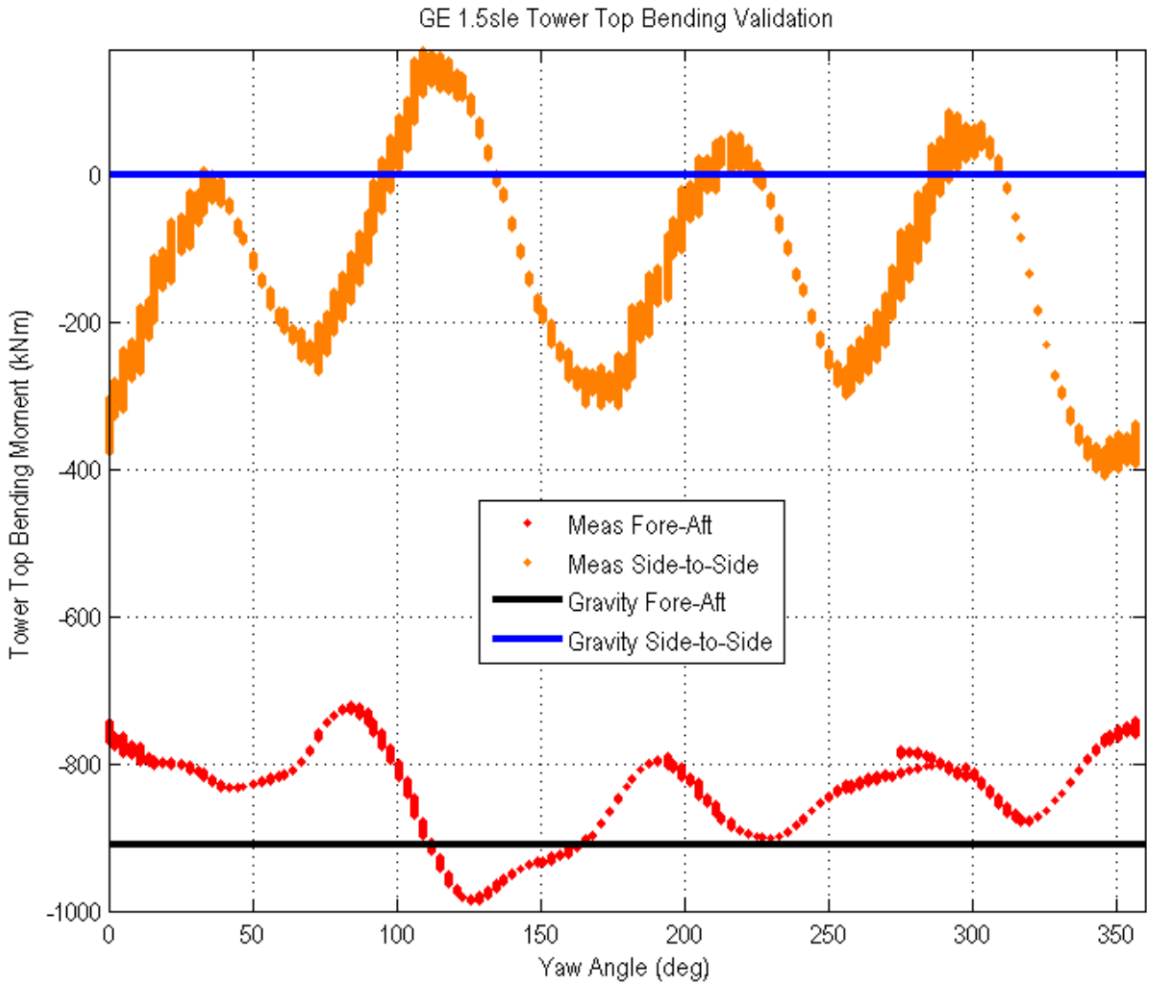


Figure 251. Tower-top nacelle validation original

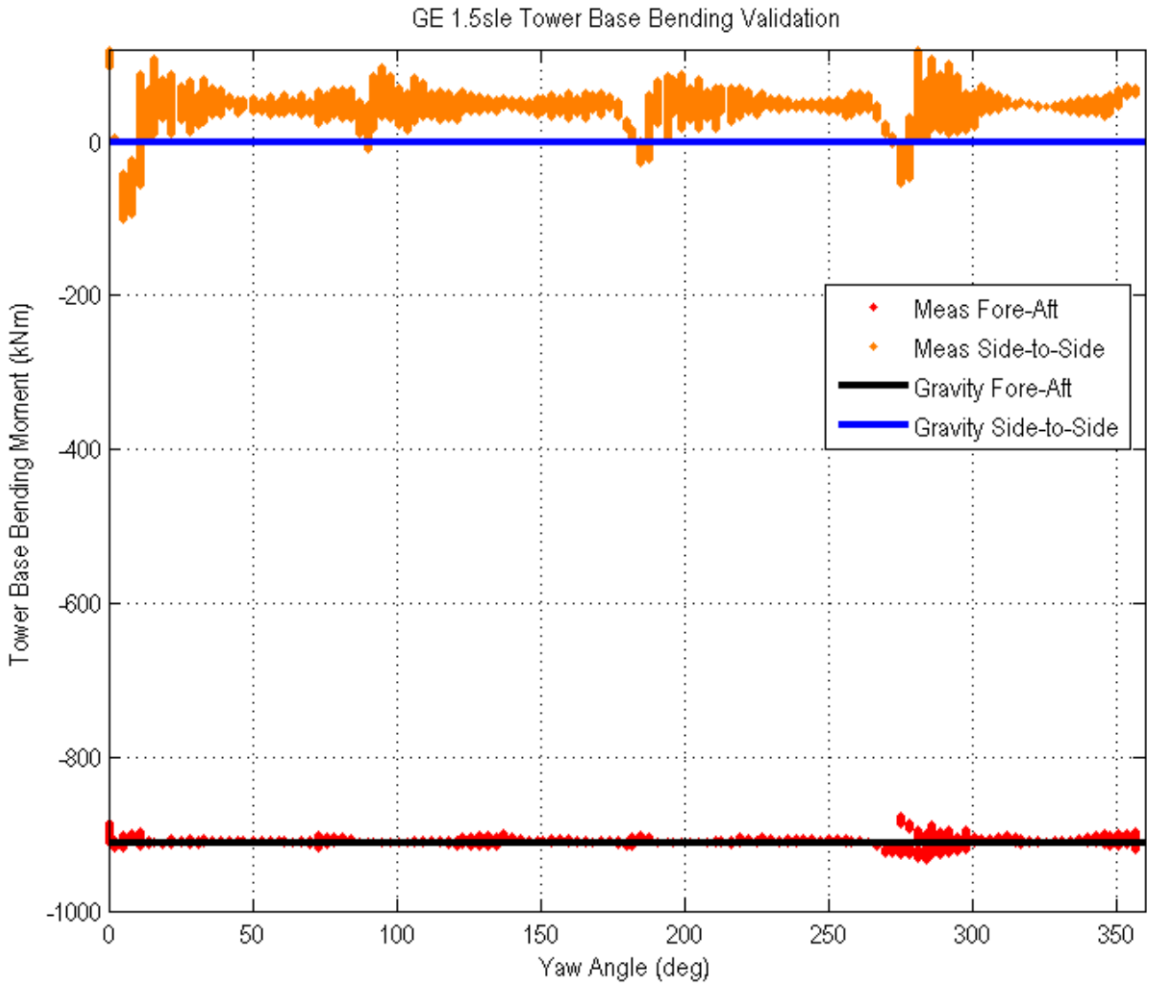


Figure 252. Tower-base nacelle validation nonlinear correction

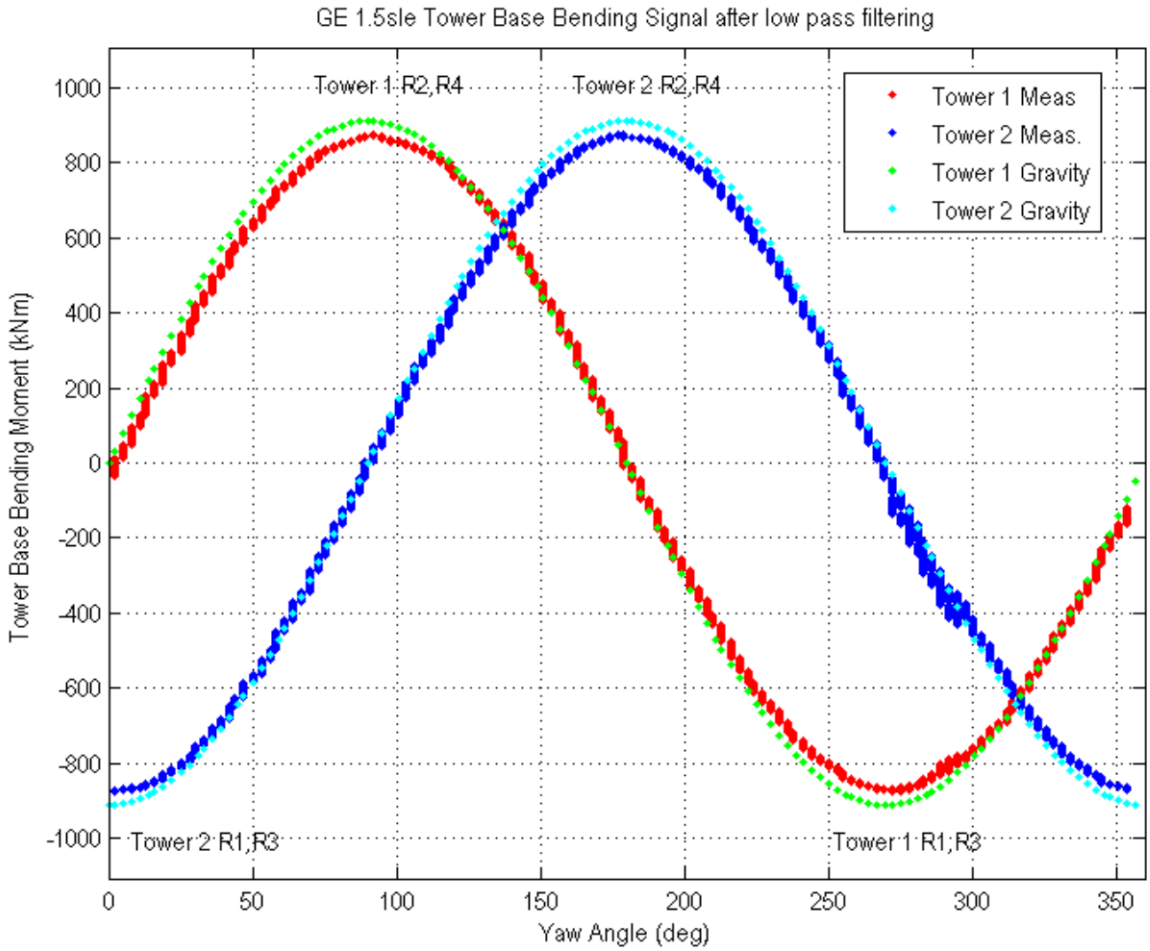


Figure 253. Tower-base nacelle yaw sweep calibration

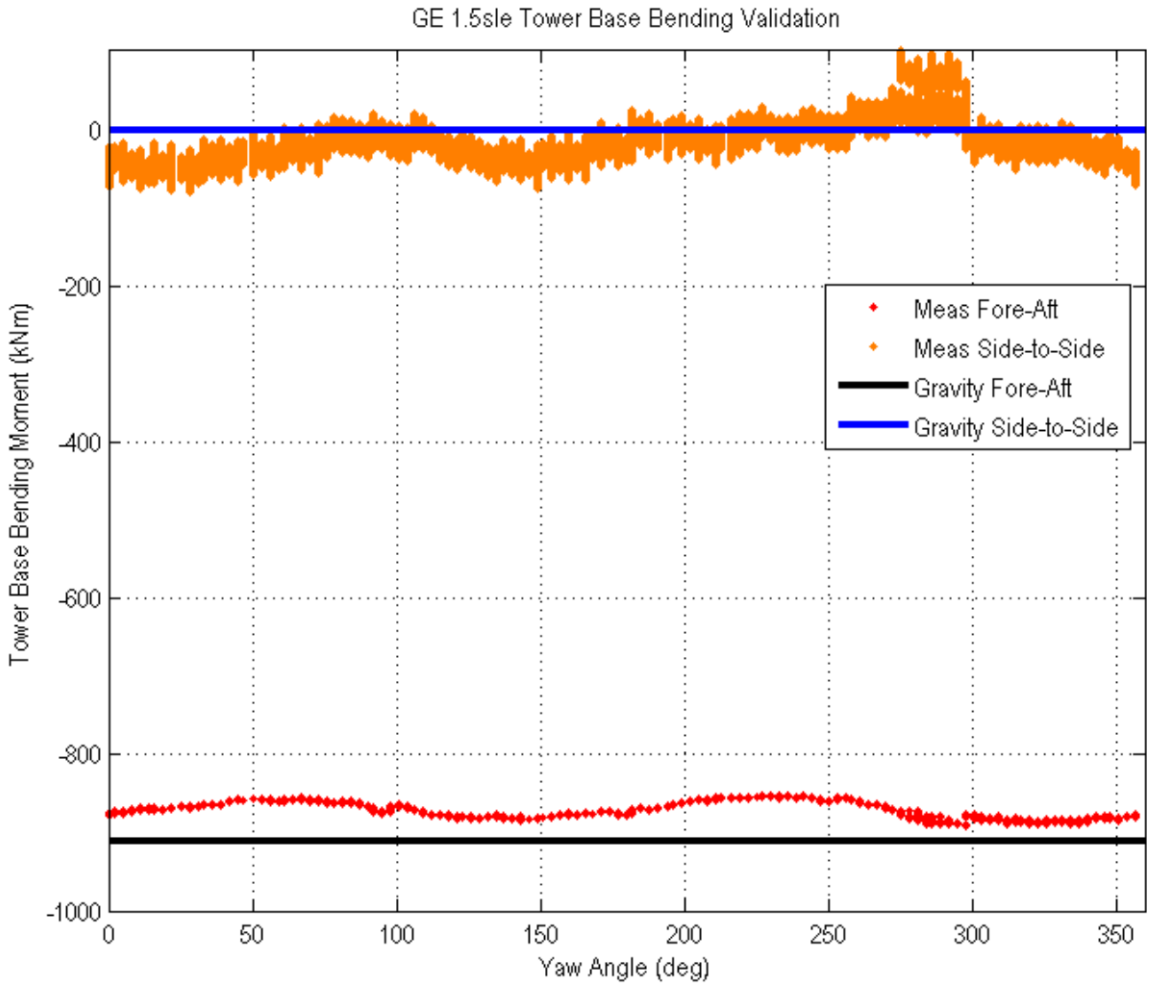


Figure 254. Tower-base nacelle validation

Appendix F. Shunt Calibrations

The shunt calibration is a measure of the system end-to-end gain. It is used on strain gage bridges. A 174.65 kOhm precision resistor was placed parallel to one of the arms of the Wheatstone bridge to simulate a change in gage strain. Using information about the structural composition of the gage location, strain-gage properties, and excitation voltage from the DAQ, an end-to-end analytical calibration of the gain is calculated. Figure 255 through Figure 268 and Table 87 through Table 100 show the results of the shunt calibrations on the blades, main shaft, and tower.

Table 87. Blade 1 Flap Bending Shunt Calibration Results

Client	National Renewable Energy Laboratory		
Turbine	DOE/GE 1.5sle		
Location	National Wind Technology Center, Golden , CO		
Signal	Blade 1 Flap Bending		
Input Data	Value	Units	Approved
(1) Outer Diameter	1950	[mm]	RS
(2) Inner Diameter	1850	[mm]	RS
(3) Modulus of Elasticity	5.00E+04	[N/mm^2]	RS
(4) Poissons Ratio	0.3	[]	RS
(5) Strain Gage Type	II		RS
(6) Strain Gage Resistance	1000	[Ω]	RS
(7) Gage Factor	2.05	[]	RS
(8) Shunt Resistance	174.65	[kΩ]	RS
(9) Excitation	1	[]	RS
(10) Amplifier Gain	1		RS
(11) Calibration Date	2/10/2011		RS
Calculations			
(11) Section Modulus	1.38E+08	[mm^3]	
(12) Voltage Ratio	-1.42E-03	[V/V]	
(12) Simulated Strain	-694.29	microstrain	
(13) Simulatred Stress	-34.71	[N/mm^2]	
(14) Simulated Moment	-4798.38	[kNm]	
Calibrations			
(15) Bridge Voltage	-1.423	[mV]	
(16) Analog Signal Voltage	-0.001	[V]	
(17) Gain	3371342.49	[kNm/V]	
Shunt Calibration Test			
Test Case	Simulated	DAS	Error (%)
(18) e+ s+	0.00142	0.00143	-0.5%
(19) e+ s-	-0.00142	-0.00143	-0.5%
(20) e- s+	0.00142	0.00143	-0.5%
(21) e- s-	-0.00142	-0.00143	-0.5%

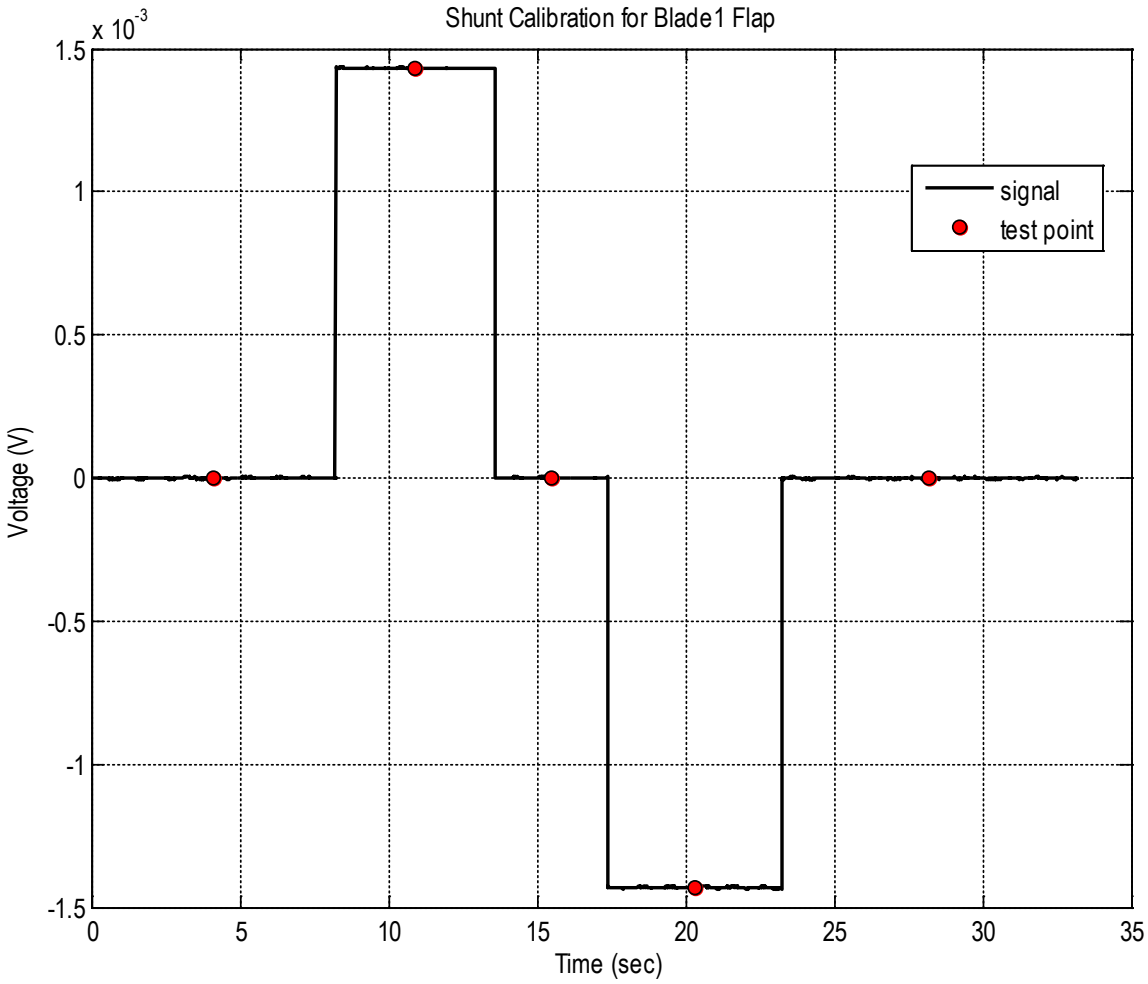


Figure 255. Blade 1 flap bending shunt calibration

Table 88. Blade 1 Leadlag Bending Shunt Calibration Results

Client	National Renewable Energy Laboratory		
Turbine	DOE/GE 1.5sle		
Location	National Wind Technology Center, Golden , CO		
Signal	Blade 1 Edge Bending		

Input Data	Value	Units	Approved
(1) Outer Diameter	1950	[mm]	RS
(2) Inner Diameter	1850	[mm]	RS
(3) Modulus of Elasticity	5.00E+04	[N/mm^2]	RS
(4) Poissons Ratio	0.3	[]	RS
(5) Strain Gage Type	II		RS
(6) Strain Gage Resistance	1000	[Ω]	RS
(7) Gage Factor	2.05	[]	RS
(8) Shunt Resistance	174.65	[kΩ]	RS
(9) Excitation	1	[]	RS
(10) Amplifier Gain	1		RS
(11) Calibration Date	2/10/2011		RS

Calculations			
(11) Section Modulus	1.38E+08	[mm^3]	
(12) Voltage Ratio	-1.42E-03	[V/V]	
(12) Simulated Strain	-694.29	microstrain	
(13) Simulatred Stress	-34.71	[N/mm^2]	
(14) Simulated Moment	-4798.38	[kNm]	

Calibrations			
(15) Bridge Voltage	-1.423	[mV]	
(16) Analog Signal Voltage	-0.001	[V]	
(17) Gain	3371342.49	[kNm/V]	

Shunt Calibration Test

Test Case	Simulated	DAS	Error (%)
(18) e+ s+	0.00142	0.00143	-0.5%
(19) e+ s-	-0.00142	-0.00143	-0.5%
(20) e- s+	0.00142	0.00143	-0.5%
(21) e- s-	-0.00142	-0.00143	-0.5%

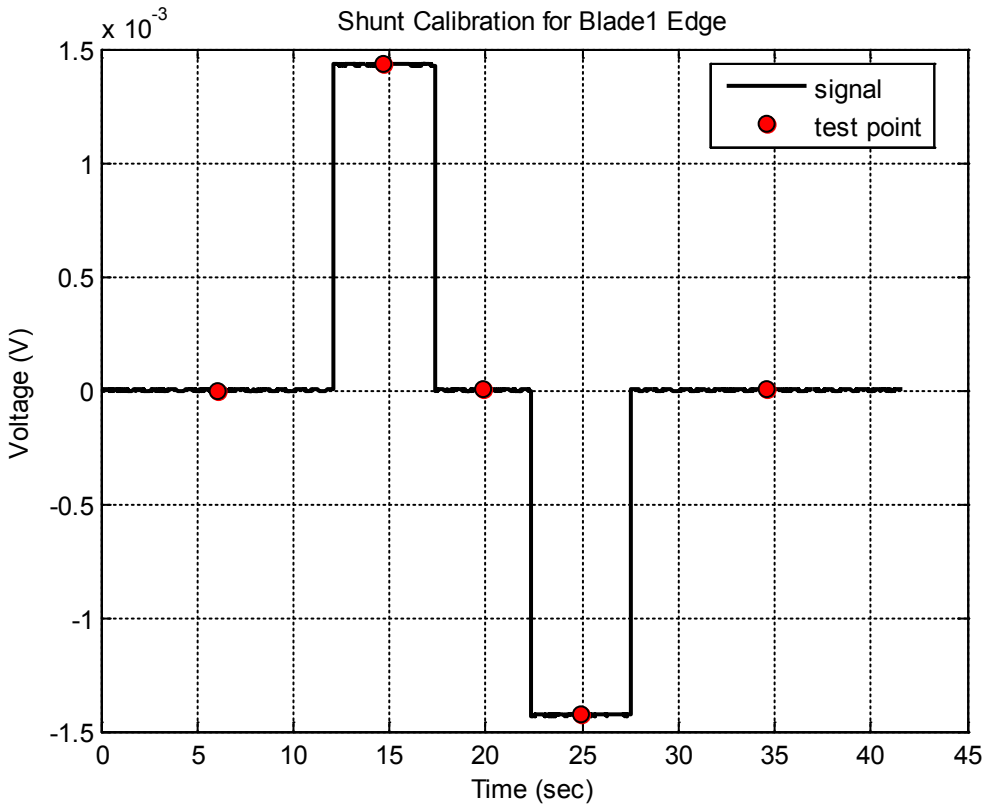


Figure 256. Blade 1 leadlag bending shunt calibration

Table 89. Blade 2 Flap Bending Shunt Calibration Results

Client	National Renewable Energy Laboratory		
Turbine	DOE/GE 1.5sle		
Location	National Wind Technology Center, Golden , CO		
Signal	Blade 2 Flap Bending		

Input Data

	Value	Units	Approved
(1) Outer Diameter	1950	[mm]	RS
(2) Inner Diameter	1850	[mm]	RS
(3) Modulus of Elasticity	5.00E+04	[N/mm^2]	RS
(4) Poissons Ratio	0.3	[]	RS
(5) Strain Gage Type	II		RS
(6) Strain Gage Resistance	1000	[Ω]	RS
(7) Gage Factor	2.05	[]	RS
(8) Shunt Resistance	174.65	[kΩ]	RS
(9) Excitation	1	[]	RS
(10) Amplifier Gain	1		RS
(11) Calibration Date	2/10/2011		RS

Calculations

(11) Section Modulus	1.38E+08	[mm^3]	
(12) Voltage Ratio	-1.42E-03	[V/V]	
(12) Simulated Strain	-694.29	microstrain	
(13) Simulatred Stress	-34.71	[N/mm^2]	
(14) Simulated Moment	-4798.38	[kNm]	

Calibrations

(15) Bridge Voltage	-1.423	[mV]	
(16) Analog Signal Voltage	-0.001	[V]	
(17) Gain	3371342.49	[kNm/V]	

Shunt Calibration Test

Test Case	Simulated	DAS	Error (%)
(18) e+ s+	0.00142	0.00143	-0.5%
(19) e+ s-	-0.00142	-0.00143	-0.5%
(20) e- s+	0.00142	0.00143	-0.5%
(21) e- s-	-0.00142	-0.00143	-0.5%

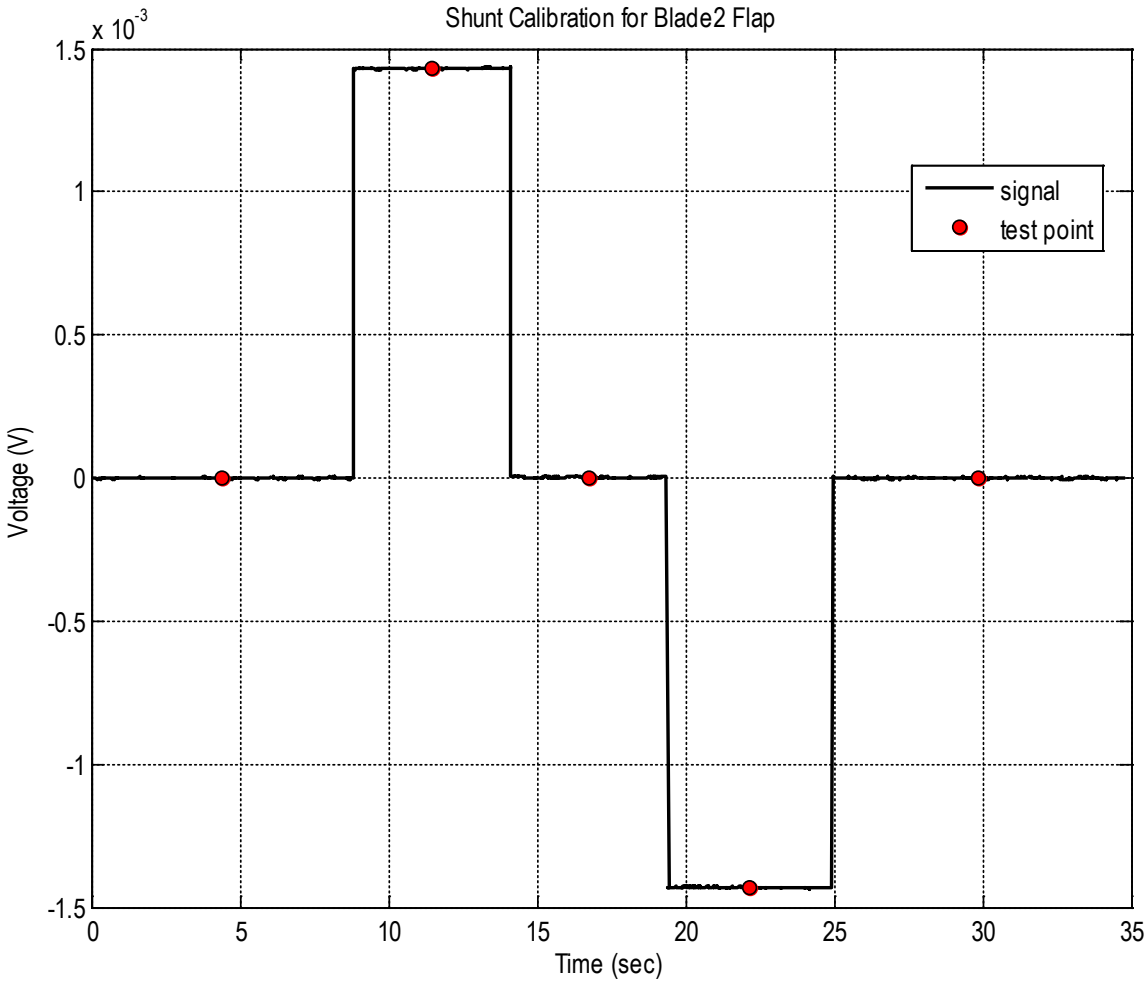


Figure 257. Blade 2 flap bending shunt calibration

Table 90. Blade 2 Leadlag Bending Shunt Calibration Results

Client	National Renewable Energy Laboratory		
Turbine	DOE/GE 1.5sle		
Location	National Wind Technology Center, Golden , CO		
Signal	Blade 2 Edge Bending		

Input Data	Value	Units	Approved
(1) Outer Diameter	1950	[mm]	RS
(2) Inner Diameter	1850	[mm]	RS
(3) Modulus of Elasticity	5.00E+04	[N/mm^2]	RS
(4) Poissons Ratio	0.3	[]	RS
(5) Strain Gage Type	II		RS
(6) Strain Gage Resistance	1000	[Ω]	RS
(7) Gage Factor	2.05	[]	RS
(8) Shunt Resistance	174.65	[kΩ]	RS
(9) Excitation	1	[]	RS
(10) Amplifier Gain	1		RS
(11) Calibration Date	2/10/2011		RS

Calculations			
(11) Section Modulus	1.38E+08	[mm^3]	
(12) Voltage Ratio	-1.42E-03	[V/V]	
(12) Simulated Strain	-694.29	microstrain	
(13) Simulatred Stress	-34.71	[N/mm^2]	
(14) Simulated Moment	-4798.38	[kNm]	

Calibrations			
(15) Bridge Voltage	-1.423	[mV]	
(16) Analog Signal Voltage	-0.001	[V]	
(17) Gain	3371342.49	[kNm/V]	

Shunt Calibration Test

Test Case	Simulated	DAS	Error (%)
(18) e+ s+	0.00142	0.00143	-0.4%
(19) e+ s-	-0.00142	-0.00143	-0.4%
(20) e- s+	0.00142	0.00143	-0.4%
(21) e- s-	-0.00142	-0.00143	-0.4%

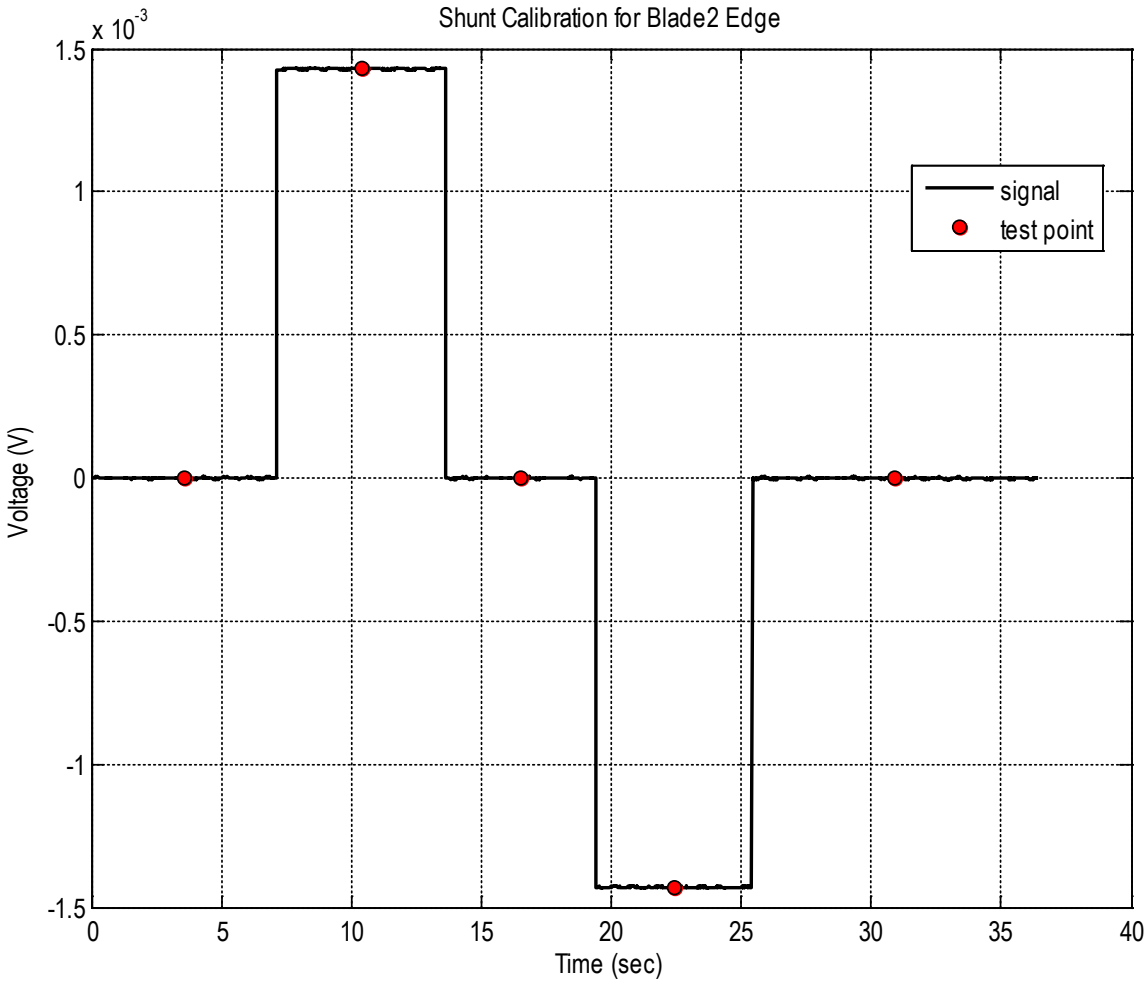


Figure 258. Blade 2 leadlag bending shunt calibration

Table 91. Blade 3 Flap Bending Shunt Calibration Results

Client	National Renewable Energy Laboratory		
Turbine	DOE/GE 1.5sle		
Location	National Wind Technology Center, Golden , CO		
Signal	Blade 3 Flap Bending		

Input Data	Value	Units	Approved
(1) Outer Diameter	1950	[mm]	RS
(2) Inner Diameter	1850	[mm]	RS
(3) Modulus of Elasticity	5.00E+04	[N/mm^2]	RS
(4) Poissons Ratio	0.3	[]	RS
(5) Strain Gage Type	II		RS
(6) Strain Gage Resistance	1000	[Ω]	RS
(7) Gage Factor	2.05	[]	RS
(8) Shunt Resistance	174.65	[kΩ]	RS
(9) Excitation	1	[]	RS
(10) Amplifier Gain	1		RS
(11) Calibration Date	2/10/2011		RS

Calculations			
(11) Section Modulus	1.38E+08	[mm^3]	
(12) Voltage Ratio	-1.42E-03	[V/V]	
(12) Simulated Strain	-694.29	microstrain	
(13) Simulatred Stress	-34.71	[N/mm^2]	
(14) Simulated Moment	-4798.38	[kNm]	

Calibrations			
(15) Bridge Voltage	-1.423	[mV]	
(16) Analog Signal Voltage	-0.001	[V]	
(17) Gain	3371342.49	[kNm/V]	

Shunt Calibration Test

Test Case	Simulated	DAS	Error (%)
(18) e+ s+	0.00142	0.00143	-0.3%
(19) e+ s-	-0.00142	-0.00143	-0.6%
(20) e- s+	0.00142	0.00143	-0.3%
(21) e- s-	-0.00142	-0.00143	-0.6%

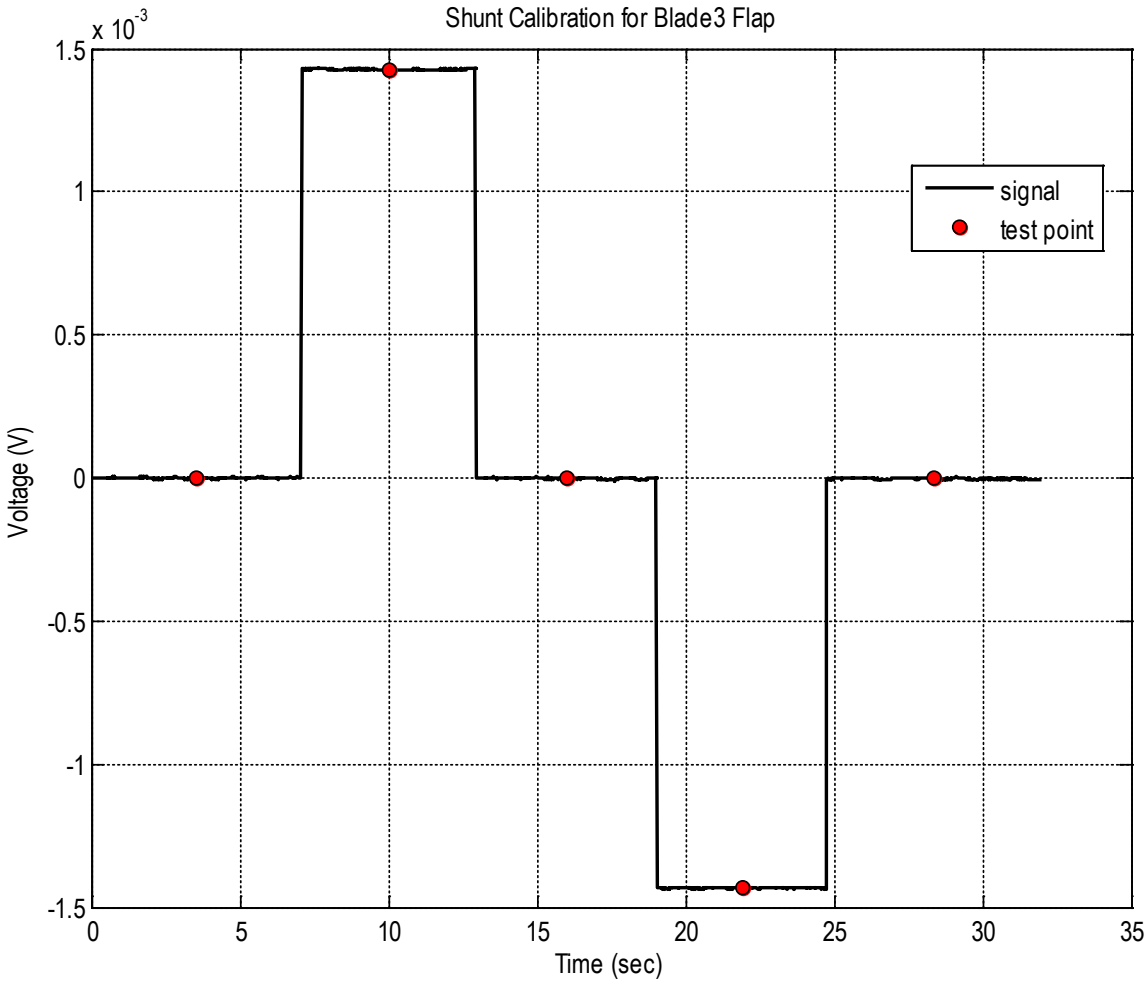


Figure 259. Blade 3 flap bending shunt calibration

Table 92. Blade 3 Leadlag Bending Shunt Calibration Results

Client	National Renewable Energy Laboratory		
Turbine	DOE/GE 1.5sle		
Location	National Wind Technology Center, Golden , CO		
Signal	Blade 3 Edge Bending		

Input Data	Value	Units	Approved
(1) Outer Diameter	1950	[mm]	RS
(2) Inner Diameter	1850	[mm]	RS
(3) Modulus of Elasticity	5.00E+04	[N/mm^2]	RS
(4) Poissons Ratio	0.3	[]	RS
(5) Strain Gage Type	II		RS
(6) Strain Gage Resistance	1000	[Ω]	RS
(7) Gage Factor	2.05	[]	RS
(8) Shunt Resistance	174.65	[kΩ]	RS
(9) Excitation	1	[]	RS
(10) Amplifier Gain	1		RS
(11) Calibration Date	2/10/2011		RS

Calculations			
(11) Section Modulus	1.38E+08	[mm^3]	
(12) Voltage Ratio	-1.42E-03	[V/V]	
(12) Simulated Strain	-694.29	microstrain	
(13) Simulatred Stress	-34.71	[N/mm^2]	
(14) Simulated Moment	-4798.38	[kNm]	

Calibrations			
(15) Bridge Voltage	-1.423	[mV]	
(16) Analog Signal Voltage	-0.001	[V]	
(17) Gain	3371342.49	[kNm/V]	

Shunt Calibration Test

Test Case	Simulated	DAS	Error (%)
(18) e+ s+	0.00142	0.00143	-0.3%
(19) e+ s-	-0.00142	-0.00143	-0.4%
(20) e- s+	0.00142	0.00143	-0.3%
(21) e- s-	-0.00142	-0.00143	-0.4%

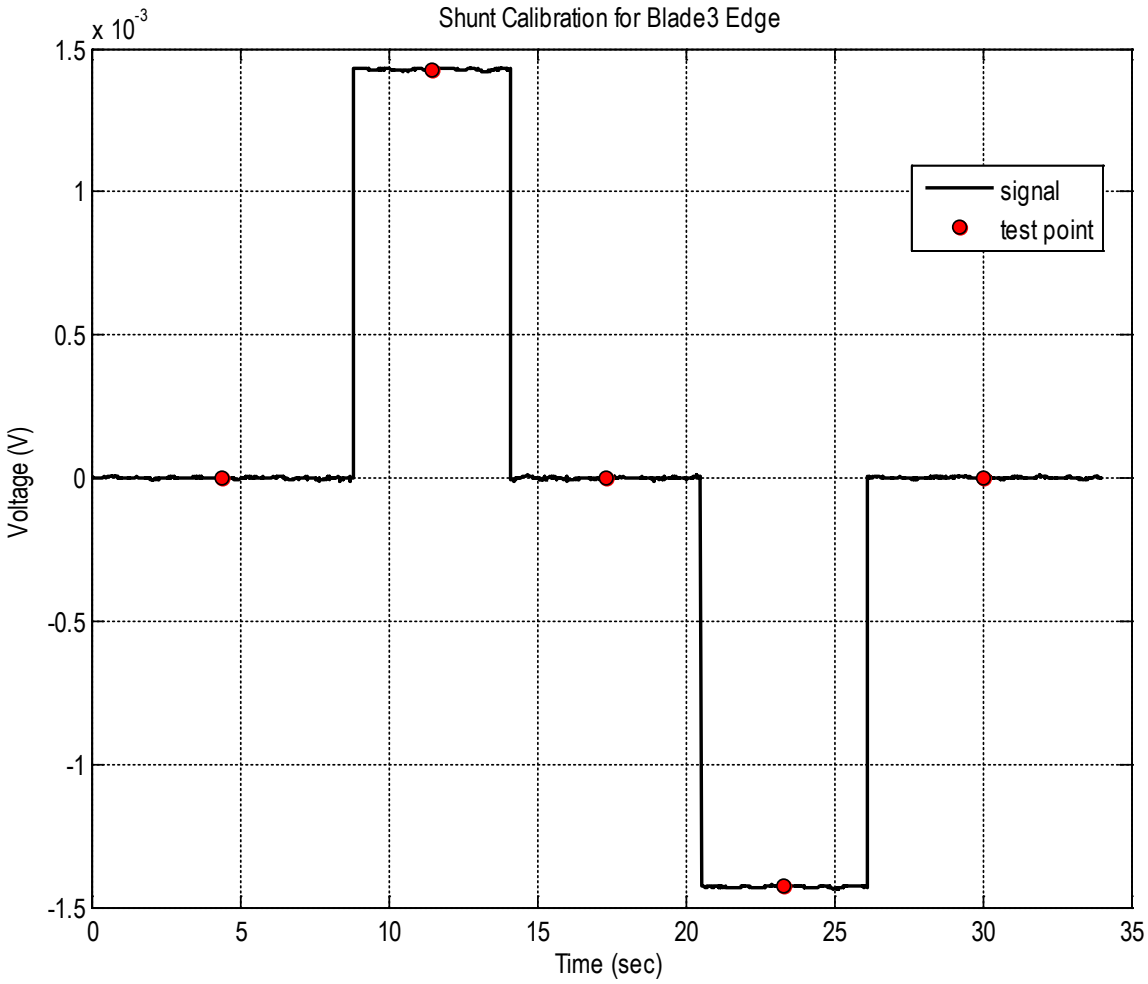


Figure 260. Blade 3 leadlag bending shunt calibration

Table 93. Main Shaft Bending 0 Shunt Calibration Results

Client	National Renewable Energy Laboratory		
Turbine	DOE/GE 1.5sle		
Location	National Wind Technology Center, Golden , CO		
Signal	Main Shaft Downwind 0 Bending		

Input Data	Value	Units	Approved
(1) Outer Diameter	581	[mm]	RS
(2) Inner Diameter	40	[mm]	RS
(3) Modulus of Elasticity	2.10E+05	[N/mm^2]	RS
(4) Poissons Ratio	0.3	[]	RS
(5) Strain Gage Type	II		RS
(6) Strain Gage Resistance	350	[Ω]	RS
(7) Gage Factor	2.02	[]	RS
(8) Shunt Resistance	174.65	[kΩ]	RS
(9) Amplifier Gain	999	[]	RS
(10) Excitation	3	[]	RS
(11) Calibration Date	2/10/2011		RS

Calculations			
(12) Section Modulus	1.93E+07	[mm^3]	
(13) Voltage Ratio	-5.00E-04	[V/V]	
(14) Simulated Strain	-247.52	microstrain	
(15) Simulatred Stress	-51.98	[N/mm^2]	
(16) Simulated Moment	-1000.82	[kNm]	

Calibrations			
(17) Bridge Voltage	-1.500	[mV]	
(18) Analog Signal Voltage	-1.499	[V]	
(19) Gain	667.88	[kNm/V]	

Shunt Calibration Test

Test Case	Simulated	DAS	Error (%)
(18) e+ s+	-1.499	-1.497	0.1%
(19) e+ s-	1.499	1.482	1.1%
(20) e- s+	-1.499	-1.479	1.3%
(21) e- s-	1.499	1.482	1.1%

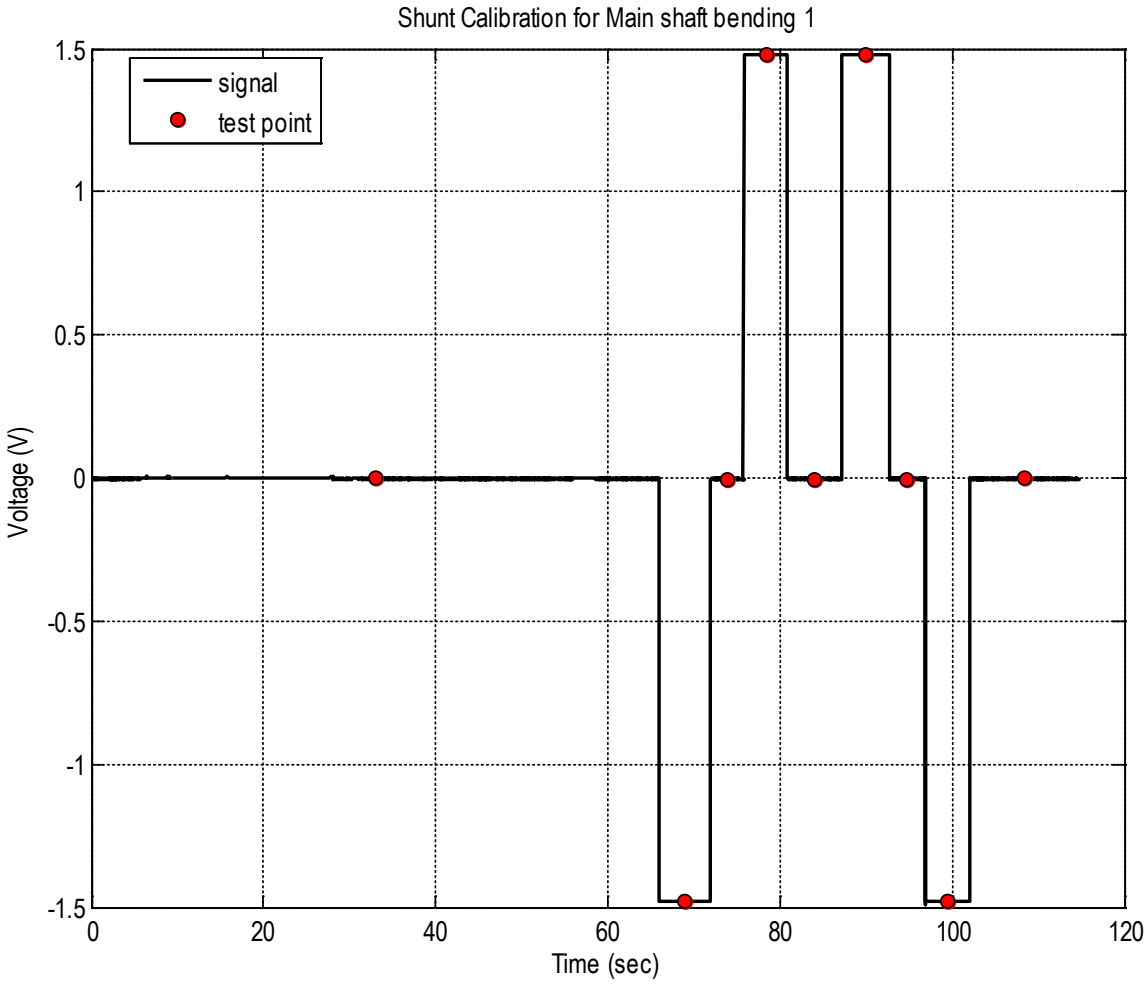


Figure 261. Main shaft bending 0 shunt calibration

Table 94. Main Shaft Bending 90 Shunt Calibration Results

Client	National Renewable Energy Laboratory		
Turbine	DOE/GE 1.5sle		
Location	National Wind Technology Center, Golden , CO		
Signal	Main Shaft Downwind 90 Bending		

Input Data	Value	Units	Approved
(1) Outer Diameter	581	[mm]	RS
(2) Inner Diameter	40	[mm]	RS
(3) Modulus of Elasticity	2.10E+05	[N/mm^2]	RS
(4) Poissons Ratio	0.3	[]	RS
(5) Strain Gage Type	II		RS
(6) Strain Gage Resistance	350	[Ω]	RS
(7) Gage Factor	2.02	[]	RS
(8) Shunt Resistance	174.65	[kΩ]	RS
(9) Amplifier Gain	999	[]	RS
(10) Excitation	3	[]	RS
(11) Calibration Date	2/10/2011		RS

Calculations			
(12) Section Modulus	1.93E+07	[mm^3]	
(13) Voltage Ratio	-5.00E-04	[V/V]	
(14) Simulated Strain	-247.52	microstrain	
(15) Simulatred Stress	-51.98	[N/mm^2]	
(16) Simulated Moment	-1000.82	[kNm]	

Calibrations			
(17) Bridge Voltage	-1.500	[mV]	
(18) Analog Signal Voltage	-1.499	[V]	
(19) Gain	667.88	[kNm/V]	

Shunt Calibration Test

Test Case	Simulated	DAS	Error (%)
(18) e+ s+	-1.499	-1.498	0.0%
(19) e+ s-	1.499	1.482	1.1%
(20) e- s+	-1.499	-1.489	0.6%
(21) e- s-	1.499	1.482	1.1%

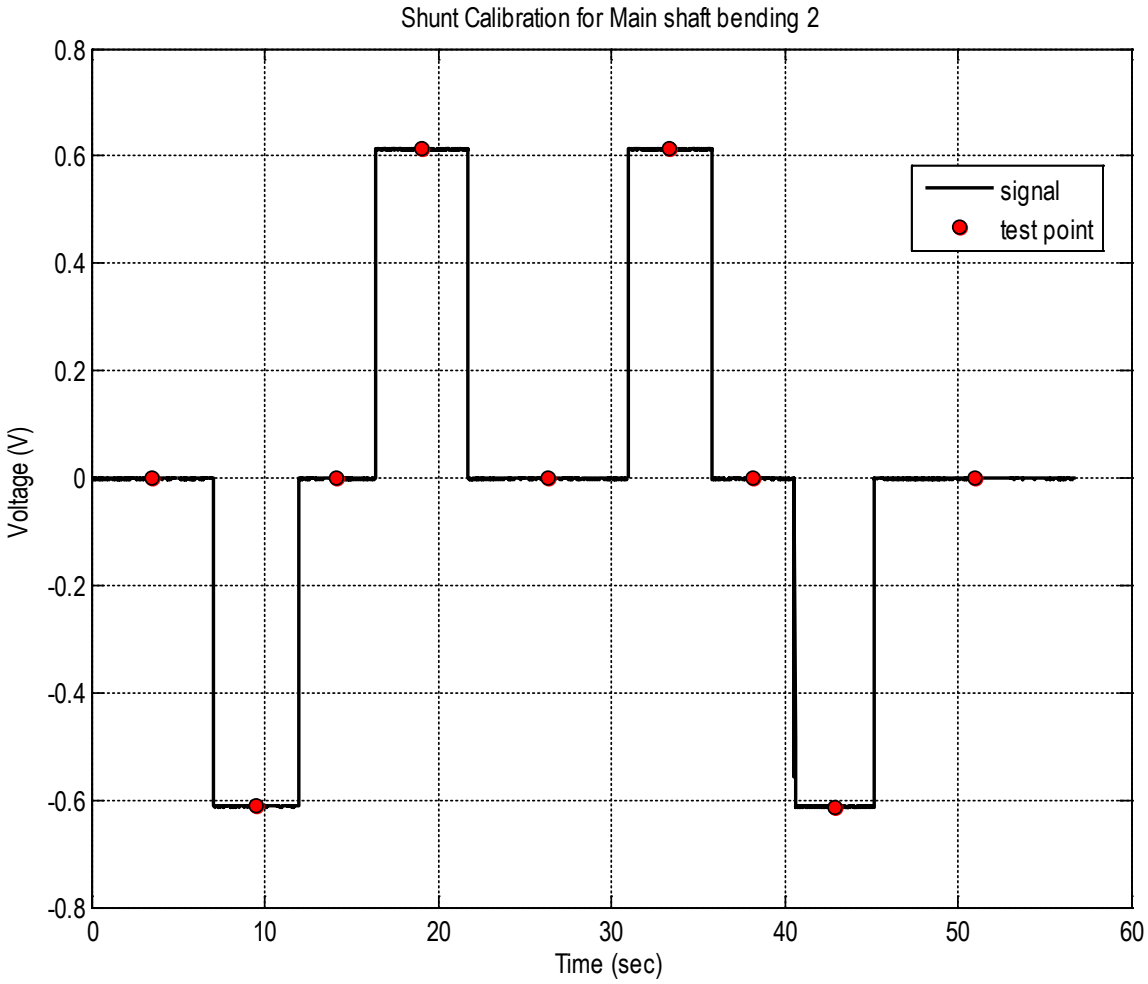


Figure 262. Main shaft bending 90 shunt calibration

Table 95. Main Shaft Torque Shunt Calibration Results

Client	National Renewable Energy Laboratory		
Turbine	DOE/GE 1.5sle		
Location	National Wind Technology Center, Golden , CO		
Signal	Main Shaft Downwind Torsion		

Input Data

	Value	Units	Approved
(1) Outer Diameter	581	[mm]	RS
(2) Inner Diameter	40	[mm]	RS
(3) Modulus of Elasticity	2.10E+05	[N/mm^2]	RS
(4) Pissons Ratio	0.3	[]	RS
(5) Strain Gage Type	S		RS
(6) Strain Gage Resistance	350	[Ω]	RS
(7) Gage Factor	2.03	[]	RS
(8) Shunt Resistance	174.65	[kΩ]	RS
(9) Excitation	3	[]	RS
(9) Amplifier Gain	999	[]	RS
(10) Calibration Date	2/10/2011		RS

Calculations

Polar Moment	3.85E+07	[mm^3]	
Voltage Ratio	-0.0005	[V/V]	
Simulated Strain	-246.3054187	[micro-strain]	
Shear Modulus	80769	[N/mm^2]	
Torque	-1532	[kNm]	

Calibrations

(15) Bridge Voltage	-1.50	[mV]	
(16) Analog Signal Voltage	-1.50	[V]	
(17) Gain	1022.45	[kNm/V]	

Shunt Calibration Test

Test Case	Simulated	DAS	Error (%)
(18) e+ s+	-1.499	-1.480	1.2%
(19) e+ s-	1.499	1.490	0.6%
(20) e- s+	-1.499	-1.480	1.2%
(21) e- s-	1.499	1.480	1.3%

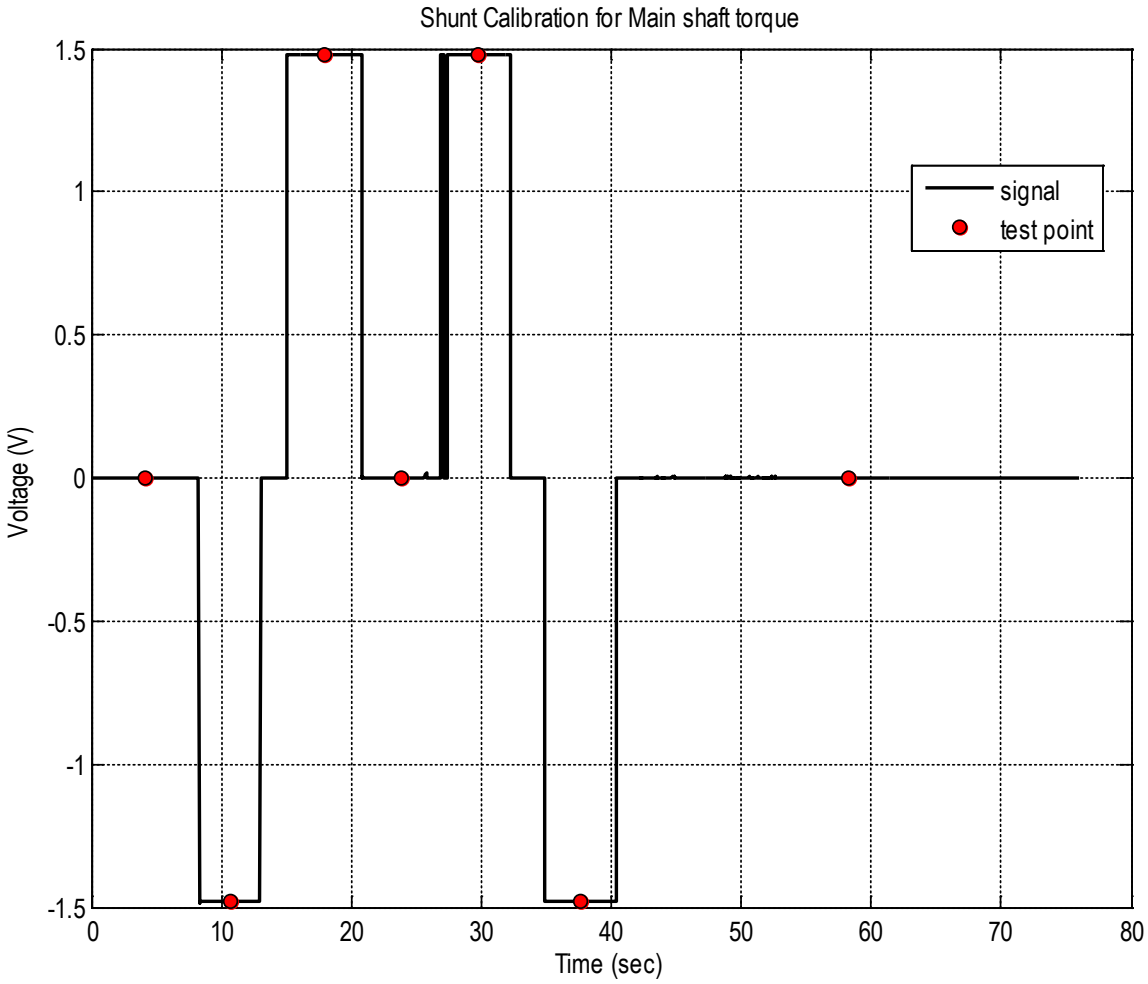


Figure 263. Main shaft torque shunt calibration

Table 96. Tower-Top 1 Bending Shunt Calibration Results

Client	National Renewable Energy Laboratory		
Turbine	DOE/GE 1.5sle		
Location	National Wind Technology Center, Golden , CO		
Signal	TowerTop Bending 1		

Input Data

	Value	Units	Approved
(1) Outer Diameter	2564	[mm]	RS
(2) Inner Diameter	2540	[mm]	RS
(3) Modulus of Elasticity	2.10E+05	[N/mm^2]	RS
(4) Poissons Ratio	0.3	[]	RS
(5) Strain Gage Type	T		RS
(6) Strain Gage Resistance	350	[Ω]	RS
(7) Gage Factor	2.02	[]	RS
(8) Excitation Voltage	5	[V]	RS
(8) Shunt Resistance	174.65	[kΩ]	RS
(9) Calibration Date	2/10/2011		RS

1

Calculations

(11) Section Modulus	6.11E+07	[mm^3]	
(12) Voltage Ratio	-5.00E-04	[V/V]	
(12) Simulated Strain	-380.81	microstrain	
(13) Simulatred Stress	-79.97	[N/mm^2]	
(14) Simulated Moment	-4886	[kNm]	

Calibrations

(15) Bridge Voltage	2.98E-05	[mV]	
(16) Analog Signal Voltage	0.00	[V]	
(17) Gain	9.77E+06	[kNm/V/V]	

Shunt Calibration Test

Test Case	Simulated	DAS	Error (%)
(18) e+ s+	5.0000E-04	5.0331E-04	-0.7%
(19) e+ s-	-5.0000E-04	-5.0237E-04	-0.5%
(20) e- s+	5.0000E-04	5.0288E-04	-0.6%
(21) e- s-	-5.0000E-04	-5.0317E-04	-0.6%

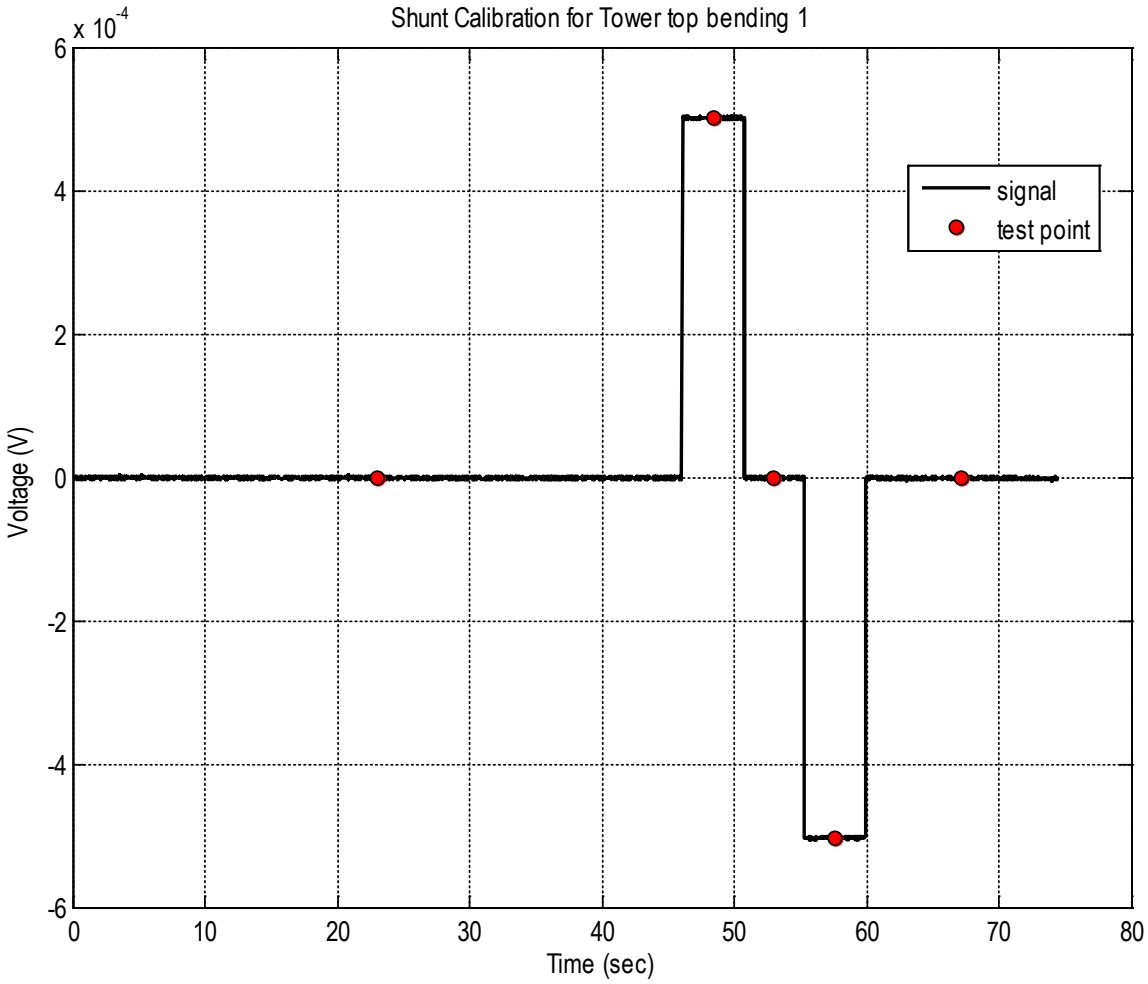


Figure 264. Tower-top 1 bending shunt calibration

Table 97. Tower-Top 2 Bending Shunt Calibration Results

Client	National Renewable Energy Laboratory		
Turbine	DOE/GE 1.5sle		
Location	National Wind Technology Center, Golden , CO		
Signal	TowerTop Bending 2		

Input Data

	Value	Units	Approved
(1) Outer Diameter	2564	[mm]	RS
(2) Inner Diameter	2540	[mm]	RS
(3) Modulus of Elasticity	2.10E+05	[N/mm^2]	RS
(4) Poissons Ratio	0.3	[]	RS
(5) Strain Gage Type	T		RS
(6) Strain Gage Resistance	350	[Ω]	RS
(7) Gage Factor	2.02	[]	RS
(8) Excitation Voltage	5	[V]	RS
(8) Shunt Resistance	174.65	[kΩ]	RS
(9) Calibration Date	2/10/2011		RS
		1	

Calculations

(11) Section Modulus	6.11E+07	[mm^3]	
(12) Voltage Ratio	-5.00E-04	[V/V]	
(12) Simulated Strain	-380.81	microstrain	
(13) Simulatred Stress	-79.97	[N/mm^2]	
(14) Simulated Moment	-4886	[kNm]	

Calibrations

(15) Bridge Voltage	2.98E-05	[mV]	
(16) Analog Signal Voltage	0.00	[V]	
(17) Gain	9.77E+06	[kNm/V/V]	

Shunt Calibration Test

Test Case	Simulated	DAS	Error (%)
(18) e+ s+	0.00E+00	0.00E+00	0.0%
(19) e+ s-	5.00E-04	5.04E-04	-0.8%
(20) e- s+	0.00E+00	1.93E-06	0.0%
(21) e- s-	-5.00E-04	-5.01E-04	-0.2%

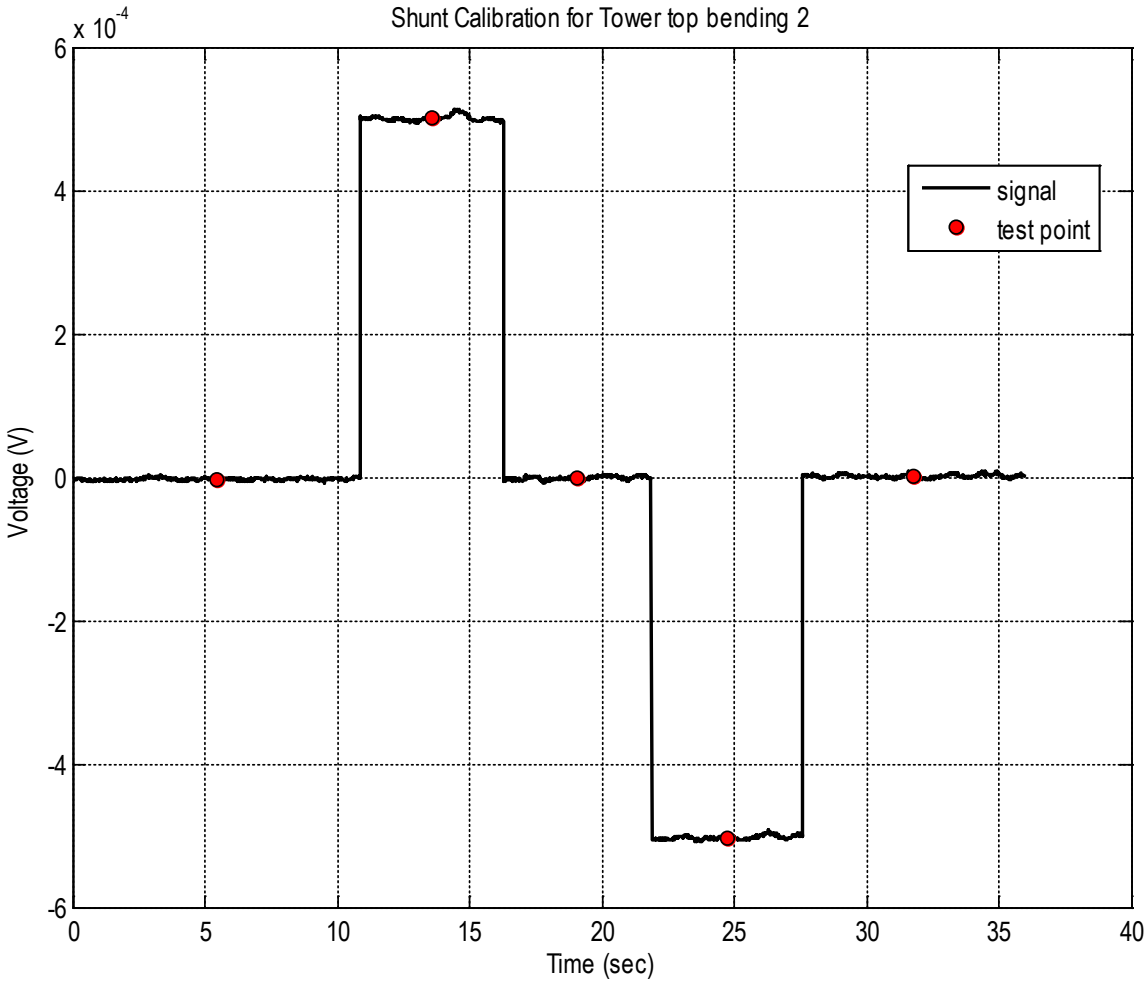


Figure 265. Tower-top 2 bending shunt calibration

Table 98. Tower-Top Torque Bending Shunt Calibration Results

Client	National Renewable Energy Laboratory		
Turbine	DOE/GE 1.5sle		
Location	National Wind Technology Center, Golden , CO		
Signal	Tower Top Torsion		

Input Data

	Value	Units	Approved
(1) Outer Diameter	2564	[mm]	RS
(2) Inner Diameter	2540	[mm]	RS
(3) Modulus of Elasticity	2.10E+05	[N/mm^2]	RS
(4) Pissons Ratio	0.3	[]	RS
(5) Strain Gage Type	S		RS
(6) Strain Gage Resistance	350	[Ω]	RS
(7) Gage Factor	2.02	[]	RS
(8) Shunt Resistance	174.65	[kΩ]	RS
(9) Excitation	5	[]	RS
(10) Calibration Date	2/10/2011		RS

Calculations

(11) Polar Moment	1.22E+08	[mm^3]	
(12) Voltage Ratio	-5.00E-04	[kNm]	
(13) strain	-247.52	[microstrain]	
(14) Shear Modulus	80769.23	[N/mm^2]	
(15) Torque	-4886	[kNm]	

Calibrations

(15) Bridge Voltage	-2.50	[mV]	
(16) Analog Signal Voltage	-2.50	[mV]	
(17) Gain	9.77E+06	[kNm/V/V]	

Shunt Calibration Test

Test Case	Simulated	DAS	Error (%)
(18) e+ s+	5.000E-04	5.038E-04	-0.8%
(19) e+ s-	-5.000E-04	-5.048E-04	-1.0%
(20) e- s+	5.000E-04	5.038E-04	-0.8%
(21) e- s-	-5.000E-04	-5.048E-04	-1.0%

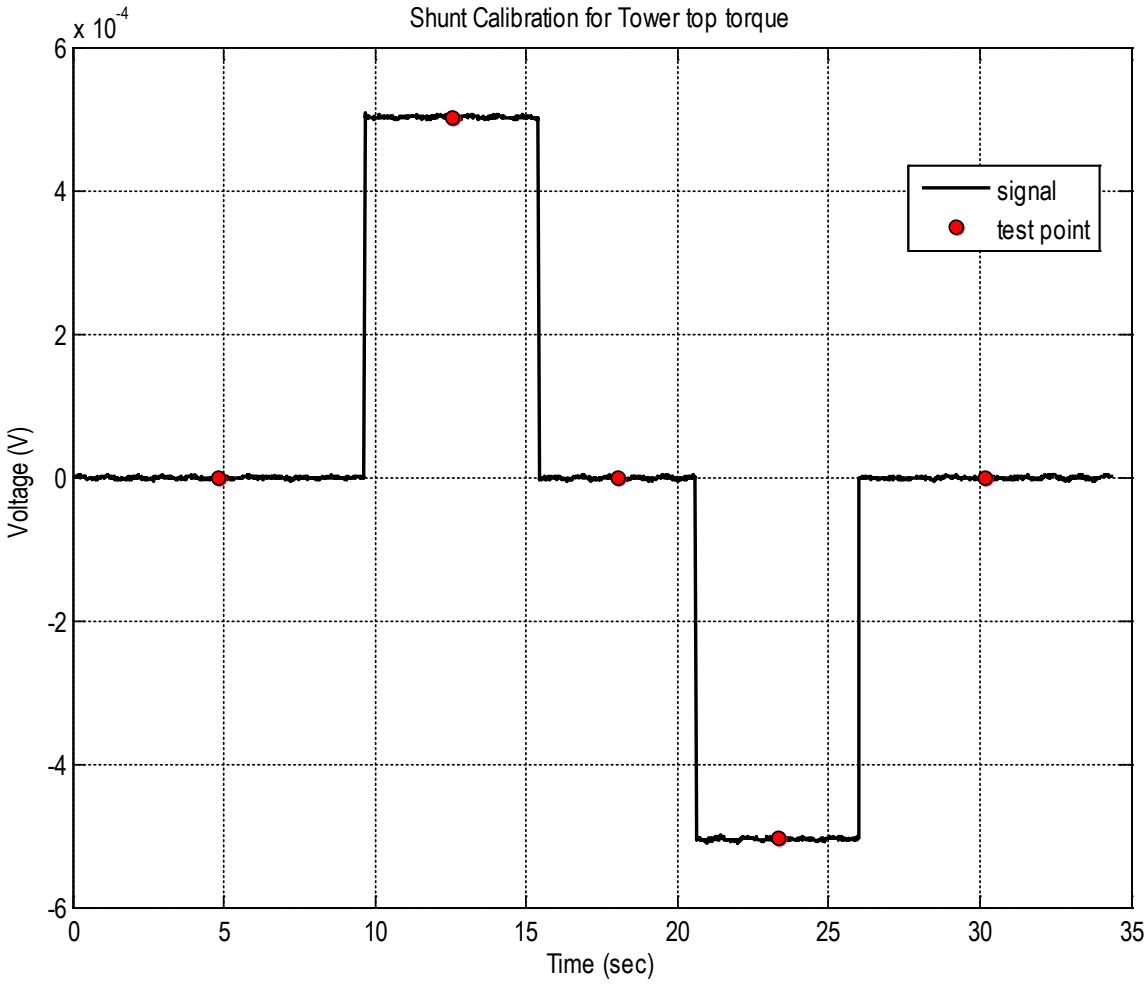


Figure 266. Tower-top torque shunt calibration

Table 99. Tower-Base 1 Bending Shunt Calibration Results

Client	National Renewable Energy Laboratory
Turbine	DOE/GE 1.5sle
Location	National Wind Technology Center, Golden , CO
Signal	Tower Base Bending 1

Input Data	Value	Units	Approved
(1) Outer Diameter	4297	[mm]	RS
(2) Inner Diameter	4255	[mm]	RS
(3) Modulus of Elasticity	2.10E+05	[N/mm^2]	RS
(4) Pissons Ratio	0.3	[]	RS
(5) Strain Gage Type	T		RS
(6) Strain Gage Resistance	350	[Ω]	RS
(7) Gage Factor	2.02	[]	RS
(8) Excitation Voltage	5	[V]	RS
(8) Shunt Resistance	174.65	[kΩ]	RS
(9) Calibration Date	2/10/2011		RS

Calculations			
(11) Section Modulus	3.00E+08	[mm^3]	
(12) Voltage Ratio	-5.00E-04	[V/V]	
(12) Simulated Strain	-380.81	microstrain	
(13) Simulatred Stress	-79.97	[N/mm^2]	
(14) Simulated Moment	-23999	[kNm]	

Calibrations			
(15) Bridge Voltage	-2.50	[mV]	
(16) Analog Signal Voltage	-2.50	[V]	
(17) Gain	4.80E+07	[kNm/V/V]	

Shunt Calibration Test			
Test Case	Simulated	DAS	Error (%)
(18) e+ s+	5.000E-04	5.058E-04	-1.2%
(19) e+ s-	-5.000E-04	-5.058E-04	-1.2%
(20) e- s+	5.000E-04	5.058E-04	-1.2%
(21) e- s-	-5.000E-04	-5.058E-04	-1.2%

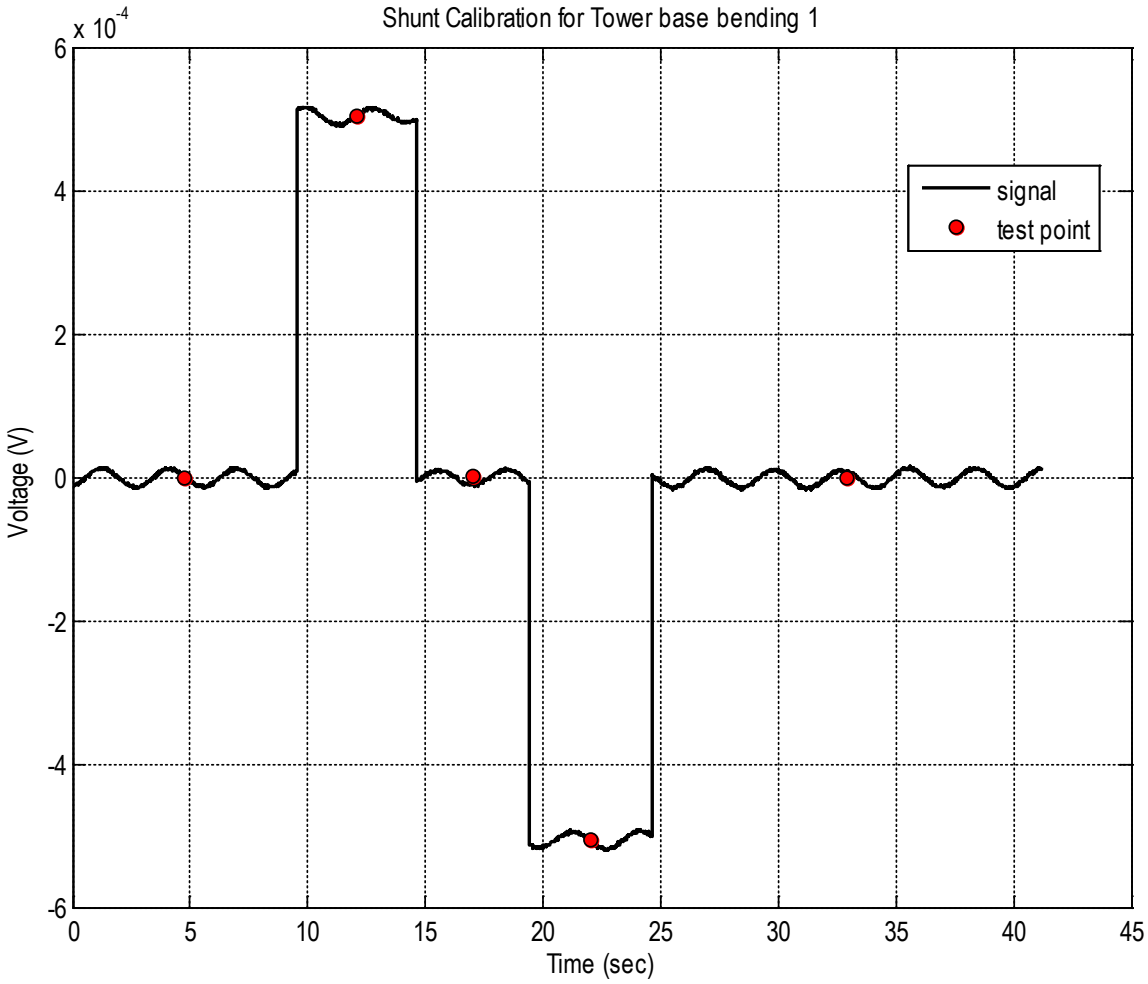


Figure 267. Tower-base 1 bending shunt calibration

Table 100. Tower-Base 2 Bending Shunt Calibration Results

Client	National Renewable Energy Laboratory		
Turbine	DOE/GE 1.5sle		
Location	National Wind Technology Center, Golden , CO		
Signal	Tower Base Bending 2		

Input Data	Value	Units	Approved
(1) Outer Diameter	4297	[mm]	RS
(2) Inner Diameter	4255	[mm]	RS
(3) Modulus of Elasticity	2.10E+05	[N/mm^2]	RS
(4) Pissons Ratio	0.3	[]	RS
(5) Strain Gage Type	T		RS
(6) Strain Gage Resistance	350	[Ω]	RS
(7) Gage Factor	2.02	[]	RS
(8) Excitation Voltage	5	[V]	RS
(8) Shunt Resistance	174.65	[kΩ]	RS
(9) Calibration Date	2/10/2011		RS

Calculations			
(11) Section Modulus	3.00E+08	[mm^3]	
(12) Voltage Ratio	-5.00E-04	[V/V]	
(12) Simulated Strain	-380.81	microstrain	
(13) Simulatred Stress	-79.97	[N/mm^2]	
(14) Simulated Moment	-23999	[kNm]	

Calibrations			
(15) Bridge Voltage	-2.50	[mV]	
(16) Analog Signal Voltage	-2.50	[V]	
(17) Gain	4.80E+07	[kNm/V/V]	

Shunt Calibration Test			
Test Case	Simulated	DAS	Error (%)
(18) e+ s+	5.000E-04	5.057E-04	-1.1%
(19) e+ s-	-5.000E-04	-5.057E-04	-1.1%
(20) e- s+	5.000E-04	5.057E-04	-1.1%
(21) e- s-	-5.000E-04	-5.057E-04	-1.1%

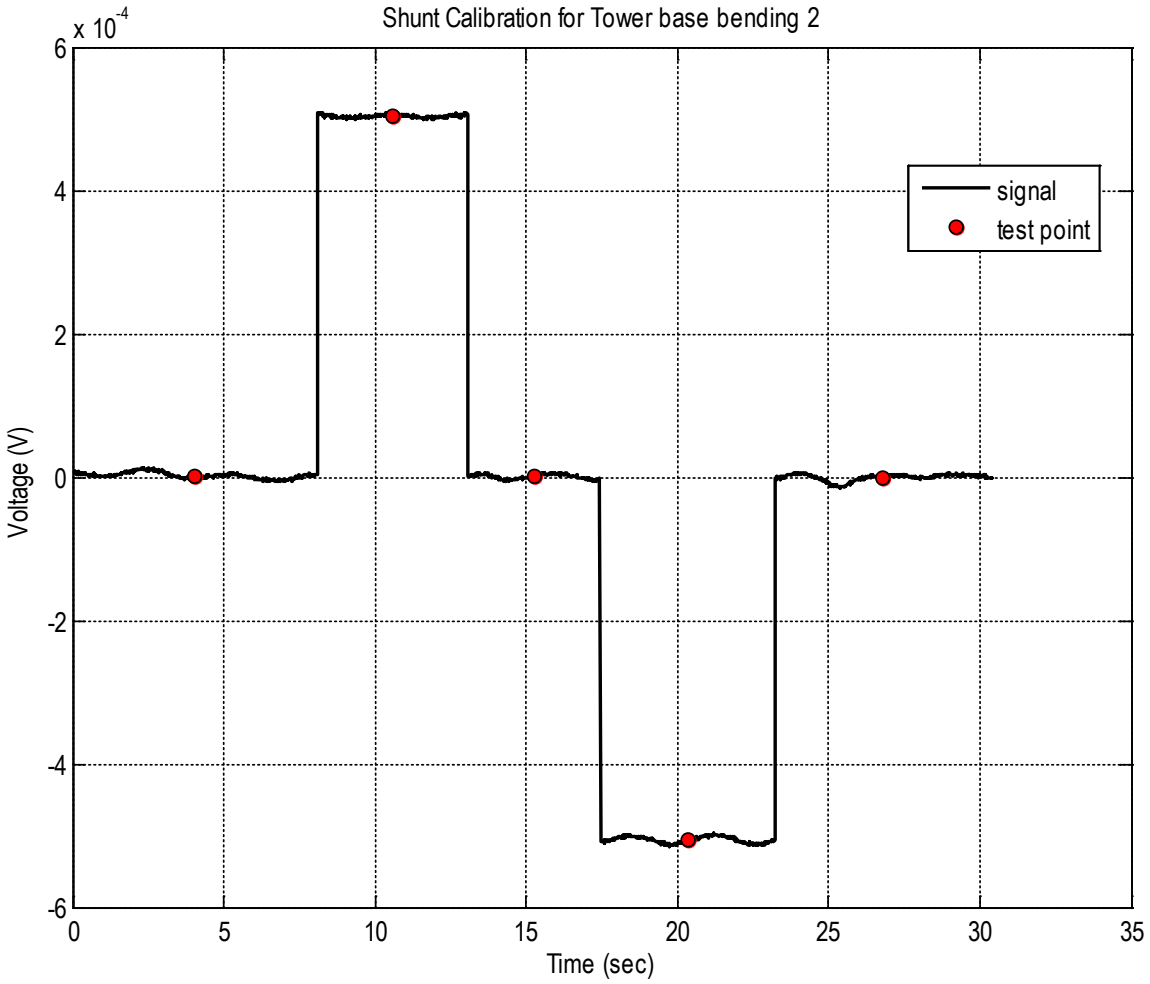


Figure 268. Tower-base 2 bending shunt calibration

Appendix G. Instrument Calibration Sheets

Met One Instruments, Inc.
1600 NW Washington Blvd.
Grants Pass, Oregon 97526
Telephone 541-471-7111
Facsimile 541-541-7116

Regional Service
3206 Main St. Suite 106
Rowlett, Texas 75088
Telephone 972-412-4715
Facsimile 972-412-4716

Test Certificate

Model: SS201 **Sensor Serial No:** K16684

Job Number: **Customer:**

Test Date: 12/10/2010 **Tested by:** D. Hoagland

Room Temperature: 24.6 °C **Room Relative Humidity:** 42.9 %

Recommended calibration interval is 12 months from the first day of use.

Calibration Standards

Standards	Manufacturer	Model	SN	Cal Due
DMM	HEWLETT PACKARD	3468B	2231A01057	April 7, 2011
TEMPERATURE	ROSEMONT	T-200	1171688	January 12, 2011
RH Sensor	Met One Instruments	083D-1-35	W3673	June 26, 2011
BAROMETRIC PRESSURE	MET ONE INSTRUMENTS	090B	H6507	July 2, 2011

Test Data

TEST	UUT	SPEC	NOTES
OUTPUT Vpp	10.6 Vpp	8.0 Vpp Min	
SYMMETRY %Duty	55.90%	50 ±10%	
CURRENT DRAIN	3.5 mA	5.0 mA TYP.	
STARTING TORQUE	0.324 GM-CM	1.0 GM-CM MAX	
SHAFT END PLAY	0.0145 in	0.006 to 0.020 in	
SHAFT & HUB RUNOUT	0.0005 in	0.000 to 0.005 in	

Test Procedure # 42061-6101, 53645-6101

The standards used for this calibration have accuracies equal to or greater than the instruments tested. These standards are on record and traceable to NIST to the extent allowed by the institute's calibration facility. Unless otherwise stated hereon, all instruments are calibrated to meet the manufacturer's published specifications. The Calibration system complies with MIL-STD-45662A.

SS201-9600 Rev B

Figure 269. Calibration sheet for reference anemometer

DEUTSCHER KALIBRIERDIENST **DKD**

Kalibrierlaboratorium / Calibration laboratory
Akkreditiert durch die / *accredited by the*
Akkreditierungsstelle des Deutschen Kalibrierdienstes

Deutsche WindGuard
Wind Tunnel Services GmbH
Varel

Deutscher Akkreditierungs Rat
DKD-K- 36801

Kalibrierzeichen *Calibration label*	09/5843
	DKD-K-36801
	09/2009

Kalibrierschein
Calibration Certificate

Gegenstand *Object*	Cup Anemometer
Hersteller *Manufacturer*	Thies Clima D-37083 Göttingen
Typ *Type*	4.3351.10.000
Fabrikat/Serien-Nr. *Serial number*	Body: 0909219 Cup: 0909219
Auftraggeber *Customer*	Sky Power International LLC USA - Liberty, SC 29657
Auftragsnummer *Order No.*	VT09556
Anzahl der Seiten des Kalibrierscheines *Number of pages of the certificate*	3
Datum der Kalibrierung *Date of calibration*	26.09.2009

Dieser Kalibrierschein dokumentiert die Rückführung auf nationale Normale zur Darstellung der Einheiten in Übereinstimmung mit dem Internationalen Einheitensystem (SI).
Der DKD ist Unterzeichner der multi- lateralen Übereinkommen der European co-operation for Accreditation (EA) und der International Laboratory Accreditation Cooperation (ILAC) zur gegenseitigen Anerkennung der Kalibrierscheine.
Für die Einhaltung einer angemessenen Frist zur Wiederholung der Kalibrierung ist der Benutzer verantwortlich.
This calibration certificate documents the traceability to national standards, which realize the units of measurement according to the International System of Units (SI).
The DKD is signatory to the multilateral agreements of the European co-operation for Accreditation (EA) and of the International Laboratory Accreditation Cooperation (ILAC) for the mutual recognition of calibration certificates.
The user is obliged to have the object recalibrated at appropriate intervals.

Dieser Kalibrierschein darf nur vollständig und unverändert weiterverbreitet werden. Auszüge oder Änderungen bedürfen der Genehmigung sowohl der Akkreditierungsstelle des DKD als auch des ausstellenden Kalibrierlaboratoriums. Kalibrierscheine ohne Unterschrift und Stempel haben keine Gültigkeit.
This calibration certificate may not be reproduced other than in full except with the permission of both the Accreditation Body of the DKD and the issuing laboratory. Calibration certificates without signature and seal are not valid.

Stempel *Seal*	Datum *Date*	Leiter des Kalibrierlaboratoriums *Head of the calibration laboratory*	Bearbeiter *Person in charge*
Deutscher DKD-K-36801 Kalibrierdienst	26.09.2009	Dipl. Phys. D. Westermann	Dipl.-Ing. (FH) M. Meyer zu Himmern

Deutsche WindGuard Wind Tunnel Services GmbH
Oldenburger Str. 65
26316 Varel ; Tel. ++49 (0)4451 9515 0

Figure 270. Calibration sheet for primary anemometer

Met One Instruments, Inc.
1600 NW Washington Blvd.
Grants Pass, Oregon 97526
Telephone 541-471-7111
Facsimile 541-541-7116

Regional Service
3206 Main St. Suite 106
Rowlett, Texas 75088
Telephone 972-412-4715
Facsimile 972-412-4716

Test Certificate

Model: SD201 **Sensor Serial No:** K16689

Job Number: **Customer:**

Test Date: 12/10/2010 **Tested by:** D. Hoagland

Room Temperature: 24.6 °C **Room Relative Humidity:** 42.9 %

Recommended calibration interval is 12 months from the first day of use.

Calibration Standards

Standards	Manufacturer	Model	SN	Cal Due
DMM	HEWLETT PACKARD	3468B	2231A01057	April 7, 2011
TEMPERATURE	ROSEMONT	T-200	1171688	January 12, 2011
RH Sensor	Met One Instruments	083D-1-35	W3673	June 26, 2011
BAROMETRIC PRESSURE	MET ONE INSTRUMENTS	090B	H6507	July 2, 2011

Test Data

TEST	OUTPUT VOLTS	INDICATED °	ERROR °	SPEC	NOTES
0°	0.001	0.1	0.1	±5°	
30°	0.299	29.9	-0.1	±5°	
60°	0.601	60.1	0.1	±5°	
90°	0.905	90.5	0.5	±5°	
120°	1.204	120.4	0.4	±5°	
150°	1.503	150.3	0.3	±5°	
180°	1.804	180.4	0.4	±5°	
210°	2.109	210.9	0.9	±5°	
240°	2.416	241.6	1.6	±5°	
270°	2.723	272.3	2.3	±5°	
300°	3.030	303.0	3.0	±5°	
330°	3.337	333.7	3.7	±5°	

END PLAY	0.005
TORQUE	0.040

NOISE CW	N/A
NOISE CCW	N/A

Test Procedure #42062-6200

The standards used for this calibration have accuracies equal to or greater than the instruments tested. These standards are on record and traceable to NIST to the extent allowed by the institute's calibration facility. Unless otherwise stated hereon, all instruments are calibrated to meet the manufacturer's published specifications. The Calibration system complies with MIL-STD-45662A.

SD210-9600 Rev B

Figure 271. Calibration sheet of wind vane K16689

Branch #: 5000 sheet: 1 of: 1

NREL METROLOGY LABORATORY

Test Report

Test Instrument: Pressure Transmitter DOE #: 03466C

Model # : PTB101B S/N : B2130018

Calibration Date: 09/22/2010 Due Date: 09/22/2011

No	Function Tested	Nominal Value (kPa)	Measured Output Voltage (VDC)		( )Mfr. Specs. OR (X)Data only (mb)
			As Found	As Left	
*	Absolute Pressure				
		65	0.265		
		70	0.538		
		75	0.809		
		80	1.081		
		85	1.352		
		90	1.624		
		95	1.895		
		100	2.167		
		103	2.330		

Notes:
1. Expanded Uncertainty of the nominal value is ± 0.2 kPa, with k = 2.
2. Calibration was performed at 24°C and 39% RH.
3. Calibration was performed using standards that are traceable to NIST. DOE numbers: 128120, and 02301C.

Calibrated By: P. Morse
Date: 09/22/2010

Approved By: D. Myers
Date: 09/22/2010

Figure 272. Calibration sheet for pressure transducer

Branch #: 5000 sheet: 1 of: 1

NREL METROLOGY LABORATORY

Test Report

Test Instrument: RTD DOE #: 03507C

Model # : 78N01N00N04 S/N : 0673552

Calibration Date: 09/23/2010 Due Date: 09/23/2011

No	Function Tested	Nominal Value (°C)	Measured Values (Ω)		( )Mfr. Specs. OR (X)Data only
			AS Found	AS Left	
*	Temperature:	-15	94.118	Same	
		0	100.005	"	
		15	105.854	"	
		30	111.680	"	
		45	117.481	"	

Notes:
- Calibration was performed using instruments that are traceable to NIST. DOE#s 124272, 108603, and 108604.
- Calibration was performed at temperature = 23°C and relative humidity = 40%.
- Uncertainty of Nominal Values = ± 0.02 °C, k = 2.

Calibrated By: P. Morse
Date: 9/23/2010

Approved By: D. Myers
Date: 9/23/2010

Figure 273. Calibration sheet for temperature sensor

NATIONAL INSTRUMENTS

Certificate of Calibration

Board Information:
Serial Number: 158B4F4
NI Part Number: 198857A-01L
Description: NI 9239

Certificate Information:
Certificate Number: 1981620
Date Printed: 16-MAR-11

Calibration Date: 10-JAN-11
Recommended Calibration Due Date: 10-JAN-12*

Ambient Temperature: 23 °C
Relative Humidity: 35 %

National Instruments certifies that at the time of test, the above product was calibrated in accordance with applicable National Instrument procedures. These procedures are designed to assure that the product listed above meets or exceeds National Instruments specifications.

We further certify that the environment in which this product was calibrated is maintained within the operating specifications of the instrument and standards. The measurement standards and instruments used during the calibration of this product are traceable to NIST and/or other International Measurement Institutes (NMI's) that are signatories of the International Committee of Weights and Measure (CIPM) Mutual Recognition Agreement (MRA).

The information shown on this certificate applies only to the instrument identified above and this certificate may not be reproduced, except in full, without the prior written consent of National Instruments.

For questions or comments, please contact National Instruments Technical Support.

NI Hungary Software és
Hardware Gyártó Kft.
4031 Debrecen, Határ út
1/A.
HUNGARY

Signed,

Andrew Krupp
Vice President, Quality
and Continuous
Improvement

* Recommended calibration due date is based on a combination of calibration interval and, when applicable, calibration shelf life. This date may vary depending on your

Figure 274. Calibration sheet for signal conditioning module 158B4F4

NATIONAL INSTRUMENTS

Certificate of Calibration

Board Information:
Serial Number: 158B478
NI Part Number: 198857A-01L
Description: NI 9239

Certificate Information:
Certificate Number: 1981879
Date Printed: 16-MAR-11

Calibration Date: 10-JAN-11
Recommended Calibration Due Date: 10-JAN-12*

Ambient Temperature: 23 °C
Relative Humidity: 35 %

National Instruments certifies that at the time of test, the above product was calibrated in accordance with applicable National Instrument procedures. These procedures are designed to assure that the product listed above meets or exceeds National Instruments specifications.

We further certify that the environment in which this product was calibrated is maintained within the operating specifications of the instrument and standards. The measurement standards and instruments used during the calibration of this product are traceable to NIST and/or other International Measurement Institutes (NMI's) that are signatories of the International Committee of Weights and Measure (CIPM) Mutual Recognition Agreement (MRA).

The information shown on this certificate applies only to the instrument identified above and this certificate may not be reproduced, except in full, without the prior written consent of National Instruments.

For questions or comments, please contact National Instruments Technical Support.

NI Hungary Software és
Hardware Gyártó Kft.
4031 Debrecen, Határ út
1/A.
HUNGARY

Signed,

Andrew Krupp
Vice President, Quality
and Continuous
Improvement

* Recommended calibration due date is based on a combination of calibration interval and, when applicable, calibration shelf life. This date may vary depending on your

Figure 275. Calibration sheet for signal conditioning module 158B478

Davis Calibration

ACLASS ACCREDITED CALIBRATION

Certificate of Calibration

4415599

Certificate Page 1 of 1

Instrument Identification

Company ID: 120205
NATIONAL RENEWABLE ENERGY LAB
BEV KAY/SRRL
16253 DENVER WEST PARKWAY
GOLDEN, CO 80401

PO Number: CC-BEVERLY KAY

Instrument ID: **03889C**
Manufacturer: NATIONAL INSTRUMENTS
Description: 4-CH 100 OHM 24-BIT RTD ANALOG INPUT

Model Number: NI 9217
Serial Number: 12BD192

Accuracy: Mfr. Specifications

Certificate Information

Reason For Service: CALIBRATION
Type of Cal: ACCREDITED 17025 WITH UNCERTAINTIES
As Found Condition: IN TOLERANCE
As Left Condition: LEFT AS FOUND
Procedure: NATIONAL INSTRUMENTS CAL EXECUTIVE 3.4

Technician: COREY CLAXTON
Cal Date 21Aug2010
Cal Due Date: 21Aug2011
Interval: 12 MONTHS
Temperature: 23.0 C
Humidity: 55.0 %

Remarks: *CALIBRATED WITH DATA, REFER TO ATTACHED DATA FOR BEFORE AND AFTER READINGS.*

The instrument on this certification has been calibrated against standards traceable to the National Institute of Standards and Technology (NIST) or other recognized national metrology institutes, derived from ratio type measurements, or compared to nationally or internationally recognized consensus standards.

A test uncertainty ratio (T.U.R.) of 4:1 [K=2, approx. 95% Confidence Level] was maintained unless otherwise stated.

Davis Calibration Laboratory is certified to ISO 9001:2008 by Eagle Registrations (certificate # 3046). Lab Operations meet the requirements of ANSI/NCSL Z540-1-1994 (R2002), ISO 10012:2003, 10CFR50 AppxB, and 10CFR21.

ISO/IEC 17025-2005 accredited calibrations are per ACLASS certificate # AC-1187 within the scope for which the lab is accredited.
When uncertainty measurement calculations have been calculated per customer request, reported condition statements do not take into account uncertainty of measurement.
All results contained within this certification relate only to item(s) calibrated. Any number of factors may cause the calibration item to drift out of calibration before the instrument's calibration interval has expired.

This certificate shall not be reproduced except in full, without written consent of Davis Calibration Laboratory.

Approved By: COREY CLAXTON
Service Representative

Calibration Standards

NIST Traceable#	Inst. ID#	Description	Model	Cal Date	Date Due
3730238	15-0247	REFERENCE MULTIMETER	8508A	02Dec2009	02Dec2010

Davis Calibration • 2324 Ridgepoint Drive, Suite D • Austin, TX 78754 • Phone: 800-365-0147 • Fax: 512-926-8450

Figure 276. Calibration sheet for signal conditioning module 12BD192

Davis Calibration

ACLASS ACCREDITED CALIBRATION

Certificate of Calibration

4415656

Certificate Page 1 of 1

Instrument Identification

Company ID: 120205
NATIONAL RENEWABLE ENERGY LAB
BEV KAY/SRRL
16253 DENVER WEST PARKWAY
GOLDEN, CO 80401

PO Number: CC-BEVERLY KAY

Instrument ID: **03886C**
Manufacturer: NATIONAL INSTRUMENTS
Description: 32-CH ±200 MV TO ±10 V, 16-BIT, 250 KS/S ANALOG INPUT MODULE

Model Number: NI 9205
Serial Number: 12E9CD3

Accuracy: Mfr Specifications

Certificate Information

Reason For Service: CALIBRATION
Type of Cal: ACCREDITED 17025 WITH UNCERTAINTIES
As Found Condition: IN TOLERANCE
As Left Condition: LEFT AS FOUND
Procedure: NATIONAL INSTRUMENTS CAL EXECUTIVE 3.4

Technician: COREY CLAXTON
Cal Date 21Aug2010
Cal Due Date: 21Aug2011
Interval: 12 MONTHS
Temperature: 23.0 C
Humidity: 55.0 %

Remarks: *CALIBRATED WITH DATA, REFER TO ATTACHED DATA FOR BEFORE AND AFTER READINGS.*

The instrument on this certification has been calibrated against standards traceable to the National Institute of Standards and Technology (NIST) or other recognized national metrology institutes, derived from ratio type measurements, or compared to nationally or internationally recognized consensus standards.

A test uncertainty ratio (T.U.R.) of 4:1 [K=2, approx. 95% Confidence Level] was maintained unless otherwise stated.

Davis Calibration Laboratory is certified to ISO 9001:2008 by Eagle Registrations (certificate # 3046). Lab Operations meet the requirements of ANSI/NCSL Z540-1-1994 (R2002), ISO 10012:2003, 10CFR50 AppxB, and 10CFR21.

ISO/IEC 17025-2005 accredited calibrations are per ACLASS certificate # AC-1187 within the scope for which the lab is accredited.
When uncertainty measurement calculations have been calculated per customer request, reported condition statements do not take into account uncertainty of measurement.
All results contained within this certification relate only to item(s) calibrated. Any number of factors may cause the calibration item to drift out of calibration before the instrument's calibration interval has expired.
This certificate shall not be reproduced except in full, without written consent of Davis Calibration Laboratory.

Approved By: COREY CLAXTON
Service Representative

Calibration Standards

NIST Traceable#	Inst. ID#	Description	Model	Cal Date	Date Due
4291519	15-0271	MULTIFUNCTION CALIBRATOR	5700A	07Jul2010	05Oct2010

Davis Calibration • 2324 Ridgepoint Drive, Suite D • Austin, TX 78754 • Phone: 800-365-0147 • Fax: 512-926-8450

Figure 277. Calibration sheet for signal conditioning module 12E9CD3

Certificate of Calibration

Certificate Number:	960930	**Date:**	
Serial Number:	1342666	**Part Number:**	
Description:	CCA,NI 9237,4 CHANNEL BRIDGE INPUT		
Calibration Date:	19-FEB-2008	**Shelf Life:**	
Calibration Due Date*:	-	**Recommended Calibration Interval:**	
Temperature:	21 °C	**Humidity:**	

Standards Used

Manufacturer	Model	Tracking Number	Calibratior
VAISALA	HMP35E	5018	31-JUL-07
National Instruments	PXI-4110	6059	08-MAY-07
NATIONAL INSTRUMENTS	PXI-4070	6769	27-AUG-07
NATIONAL INSTRUMENTS	PXI-6120	6815	20-MAR-07

National Instruments certifies that at the time of test, the above product was calibrated in accordance with a procedures are designed to ensure that the product listed above meets or exceeds National Instruments specificatio

We further certify that the environment in which this product was calibrated is maintained within the operating spe measurement standards used during calibration are traceable to NIST and/or other International Measurement Instit Committee of Weights and Measure (CIPM) Mutual Recognition Agreement (MRA).

The information shown on this certificate applies only to the instrument identified above and this certificate may written consent of National Instruments.

*Optional field, ***Calibration Due Date***, may be established by combining the *Recommended Calibration Interval*, *Ca Shelf Life*. Shelf life defines how long an instrument may be stored, after calibration, without impact to its specificatic

The instrument's Calibration Due Date can be calculated using the following methods:

a) If date placed in service is within *Calibration Date* + *Shelf Life*: *Calibration Due Date* = date placed in

b) If date placed in service is outside *Calibration Date* + *Shelf Life*: *Calibration Due Date* = *Calibration D Interval*

For questions or comments, please contact National Instruments Technical Support.

Figure 278. Calibration sheet for signal conditioning module 1342666

Certificate of Calibration

Certificate Number:	1004899	**Date:**	
Serial Number:	1357162	**Part Number:**	
Description:	CCA,NI 9237,4 CHANNEL BRIDGE INPUT		
Calibration Date:	26-MAR-2008	**Shelf Life:**	
Calibration Due Date*:	-	**Recommended Calibration Interval:**	
Temperature:	22 °C	**Humidity:**	

Standards Used

Manufacturer	Model	Tracking Number	Calibratior
VAISALA	HMP35E	5018	31-JUL-07
NATIONAL INSTRUMENTS	PXI-6120	6846	24-MAY-07
NATIONAL INSTRUMENTS	PXI-4110	6897	21-MAY-07
NATIONAL INSTRUMENTS	PXI-4070	7001	06-DEC-07

National Instruments certifies that at the time of test, the above product was calibrated in accordance with a procedures are designed to ensure that the product listed above meets or exceeds National Instruments specificatio

We further certify that the environment in which this product was calibrated is maintained within the operating spe measurement standards used during calibration are traceable to NIST and/or other International Measurement Instit Committee of Weights and Measure (CIPM) Mutual Recognition Agreement (MRA).

The information shown on this certificate applies only to the instrument identified above and this certificate may written consent of National Instruments.

*Optional field, ***Calibration Due Date***, may be established by combining the *Recommended Calibration Interval*, *Ca Shelf Life*. Shelf life defines how long an instrument may be stored, after calibration, without impact to its specificatic

The instrument's Calibration Due Date can be calculated using the following methods:

a) If date placed in service is within *Calibration Date* + *Shelf Life*: *Calibration Due Date* = date placed in

b) If date placed in service is outside *Calibration Date* + *Shelf Life*: *Calibration Due Date* = *Calibration D Interval*

For questions or comments, please contact National Instruments Technical Support.

Figure 279. Calibration sheet for signal conditioning module 1357162

Certificate of Calibration

Certificate Number:	1004852	**Date:**	
Serial Number:	1357177	**Part Number:**	
Description:	CCA,NI 9237,4 CHANNEL BRIDGE INPUT		
Calibration Date:	26-MAR-2008	**Shelf Life:**	
Calibration Due Date*:	-	**Recommended Calibration Interval:**	
Temperature:	22 °C	**Humidity:**	

Standards Used

Manufacturer	Model	Tracking Number	Calibratior
VAISALA	HMP35E	5018	31-JUL-07
NATIONAL INSTRUMENTS	PXI-6120	6846	24-MAY-07
NATIONAL INSTRUMENTS	PXI-4110	6897	21-MAY-07
NATIONAL INSTRUMENTS	PXI-4070	7001	06-DEC-07

National Instruments certifies that at the time of test, the above product was calibrated in accordance with a procedures are designed to ensure that the product listed above meets or exceeds National Instruments specificatio

We further certify that the environment in which this product was calibrated is maintained within the operating spe measurement standards used during calibration are traceable to NIST and/or other International Measurement Instit Committee of Weights and Measure (CIPM) Mutual Recognition Agreement (MRA).

The information shown on this certificate applies only to the instrument identified above and this certificate may written consent of National Instruments.

*Optional field, ***Calibration Due Date***, may be established by combining the *Recommended Calibration Interval*, *Ca Shelf Life*. Shelf life defines how long an instrument may be stored, after calibration, without impact to its specificatic

The instrument's Calibration Due Date can be calculated using the following methods:

a) If date placed in service is within *Calibration Date + Shelf Life*: *Calibration Due Date* = date placed in

b) If date placed in service is outside *Calibration Date + Shelf Life*: *Calibration Due Date = Calibration D Interval*

For questions or comments, please contact National Instruments Technical Support.

Figure 280. Calibration sheet for signal conditioning module 1357177

Certificate of Calibration

Certificate Number:	1039322	**Date:**	
Serial Number:	136D7A2	**Part Number:**	
Description:	CCA,NI 9237,4 CHANNEL BRIDGE INPUT		
Calibration Date:	14-MAY-2008	**Shelf Life:**	
Calibration Due Date*:	-	**Recommended Calibration Interval:**	
Temperature:	23 °C	**Humidity:**	

Standards Used

Manufacturer	Model	Tracking Number	Calibratior
VAISALA	HMP35E	5018	31-JUL-07
National Instruments	PXI-4110	6059	08-APR-08
NATIONAL INSTRUMENTS	PXI-4070	6769	27-AUG-07
NATIONAL INSTRUMENTS	PXI-6120	6815	20-MAR-06

National Instruments certifies that at the time of test, the above product was calibrated in accordance with a procedures are designed to ensure that the product listed above meets or exceeds National Instruments specificatio

We further certify that the environment in which this product was calibrated is maintained within the operating spe measurement standards used during calibration are traceable to NIST and/or other International Measurement Instit Committee of Weights and Measure (CIPM) Mutual Recognition Agreement (MRA).

The information shown on this certificate applies only to the instrument identified above and this certificate may written consent of National Instruments.

*Optional field, ***Calibration Due Date***, may be established by combining the *Recommended Calibration Interval*, *Ca Shelf Life*. Shelf life defines how long an instrument may be stored, after calibration, without impact to its specificatic

The instrument's Calibration Due Date can be calculated using the following methods:

a) If date placed in service is within *Calibration Date* + *Shelf Life*: *Calibration Due Date* = date placed in

b) If date placed in service is outside *Calibration Date* + *Shelf Life*: *Calibration Due Date* = *Calibration D Interval*

For questions or comments, please contact National Instruments Technical Support.

Figure 281. Calibration sheet for signal conditioning module 136D7A2

Appendix H. Coordinate System

Blade Coordinate System

The blade coordinate system has its origin at the center of the blade flange and is fixed to the blade, in essence, it rotates with both the azimuth and the pitching of the blade. The z-axis points towards the blade tip, the y-axis points along the zero pitch line toward the trailing edge, and the x-axis is perpendicular in accordance with the right-hand rule, as shown in Figure 282.

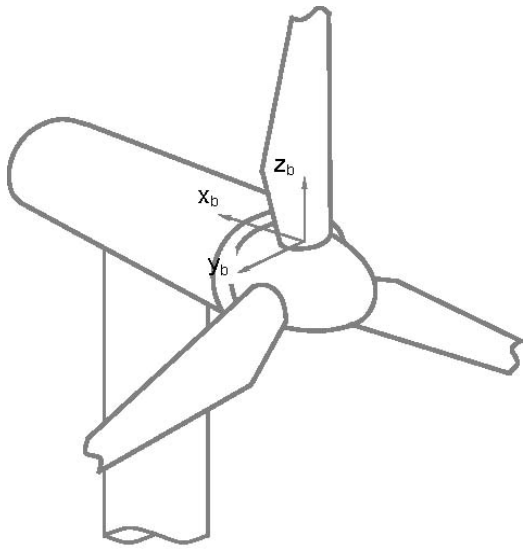


Figure 282. Blade coordinate system [1]

Rotor Coordinate System

The rotor coordinate system has its origin in the center of the rotor plane and rotates with the rotor. The x-axis points in the direction along the main shaft in the downwind direction, the z-axis is perpendicular in the direction of the reference blade (blade 1), and the y-axis is perpendicular in accordance with the right-hand rule (see Figure 283).

Nacelle Coordinate System

The nacelle coordinate system has its origin at the intersection of the tower axis and the center of the main shaft. The x-axis points horizontally downwind, the z-axis vertically upwards, and the y-axis is perpendicular in accordance with the right-hand rule (see Figure 283).

Tower Coordinate System

The tower coordinate system has its origin at the tower center at ground level. The z-axis points upward, the x-axis points downwind, and the y-axis is perpendicular in accordance with the right-hand rule. Downwind and crosswind are determined by the nacelle yaw position (see Figure 283).

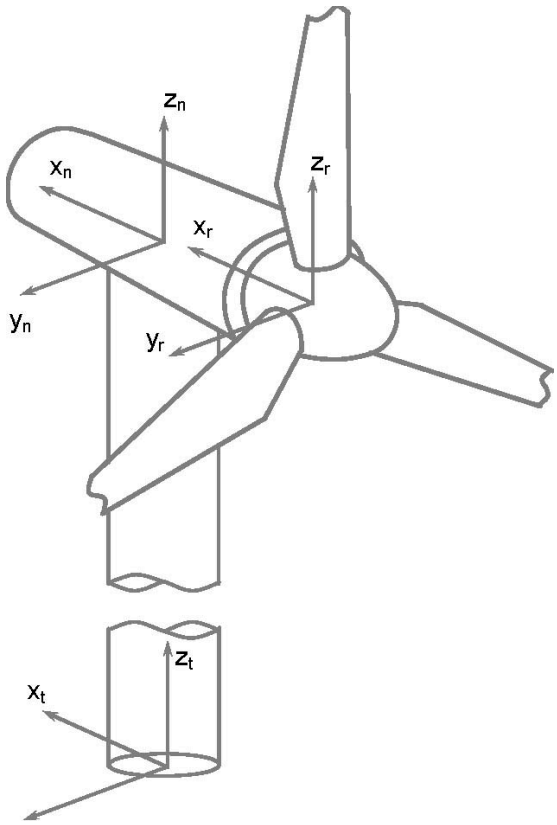


Figure 283. Rotor, nacelle, and tower coordinate systems [1]

Yaw Error

The yaw error, which is the direction of the wind and the direction of waves, is considered positive with the right-hand screw of the tower z-axis as shown in Figure 284.

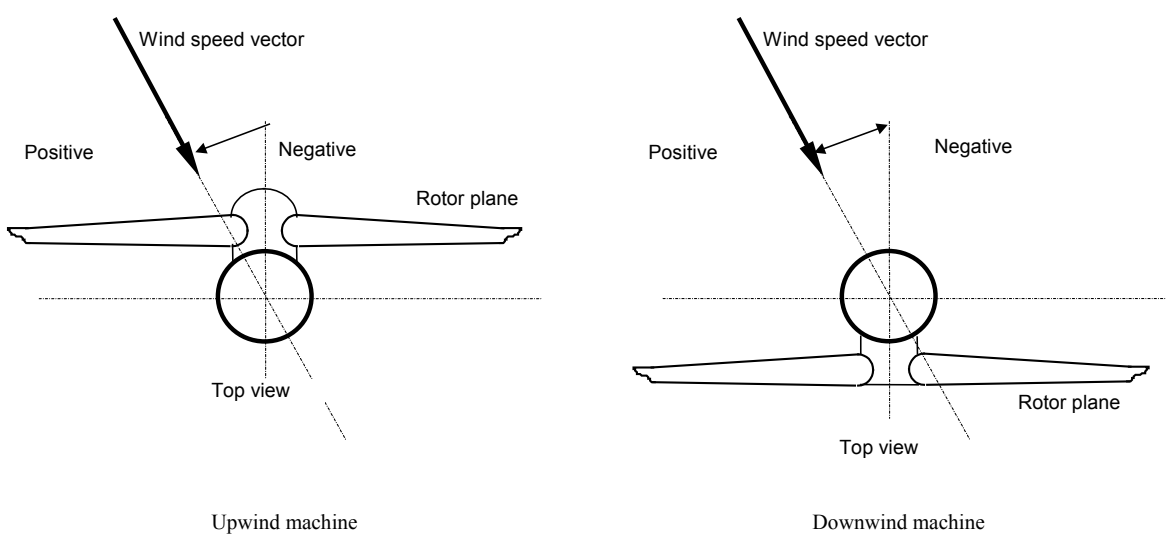


Figure 284. Yaw error [1]

Appendix I. Post-Test Calibration Sheets

Tektronix
Service Solutions

ACLASS ACCREDITED CALIBRATION

Certificate of Calibration

5051265

Certificate Page 1 of 1

Instrument Identification

Company ID: 120205
NATIONAL RENEWABLE ENERGY LAB
BEV KAY/SRRL
16253 DENVER WEST PARKWAY
GOLDEN, CO 80401

PO Number: CC-BEVERLY KAY

Instrument ID: **04179C**
Manufacturer: NATIONAL INSTRUMENTS
Description: 4-CHANNEL, ±25 MV/V, 24-BIT SIMULTANEOUS BRIDGE MODULE
Accuracy: Mfr. Specifications

Model Number: NI-9237
Serial Number: 136D7A2

Certificate Information

Reason For Service: CALIBRATION
Type of Cal: ACCREDITED 17025 WITH UNCERTAINTIES
As Found Condition: IN TOLERANCE
As Left Condition: LEFT AS FOUND
Procedure: NATIONAL INSTRUMENTS CAL EXECUTIVE 3.4

Technician: WAYNE GETCHELL
Cal Date 15Apr2011
Cal Due Date: 15Apr2012
Interval: 12 MONTHS
Temperature: 23.0 C
Humidity: 44.0 %

Remarks: *Reference attached Calibration Data with Measurement Uncertainties.*

The instrument on this certification has been calibrated against standards traceable to the National Institute of Standards and Technology (NIST) or other recognized national metrology institutes, derived from ratio type measurements, or compared to nationally or internationally recognized consensus standards.

A test uncertainty ratio (T.U.R.) of 4:1 [K=2, approx. 95% Confidence Level] was maintained unless otherwise stated.

Tektronix Service Solutions is registered to ISO 9001:2008. Lab Operations meet the requirements of ANSI/NCSL Z540-1-1994 (R2002), ISO 10012:2003, 10CFR50 AppxB, and 10CFR21.

ISO/IEC 17025-2005 accredited calibrations are per ACLASS certificate # AC-1187 within the scope for which the lab is accredited.
When uncertainty measurement calculations have been calculated per customer request, reported condition statements do not take into account uncertainty of measurement.
All results contained within this certification relate only to item(s) calibrated. Any number of factors may cause the calibration item to drift out of calibration before the instrument's calibration interval has expired.
This certificate shall not be reproduced except in full, without written consent of Tektronix Service Solutions.

Approved By: WAYNE GETCHELL
Service Representative

Calibration Standards

NIST Traceable#	Inst. ID#	Description	Manufacturer	Model	Cal Date	Date Due
4881917	15-0271	MULTIFUNCTION CALIBRATOR	FLUKE	5700A	20Jan2011	20Apr2011
4176293	A144598	DMM	HEWLETT PACKARD	3458A	24May2010	24May2011

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Figure 285. Post-test calibration sheet for signal conditioning module 136D7A2

Tektronix
Service Solutions

ACLASS ACCREDITED CALIBRATION

Certificate of Calibration

5051240

Certificate Page 1 of 1

Instrument Identification

Company ID: 120205
NATIONAL RENEWABLE ENERGY LAB
BEV KAY/SRRL
16253 DENVER WEST PARKWAY
GOLDEN, CO 80401

PO Number: CC-BEVERLY KAY

Instrument ID: **04180C**
Manufacturer: NATIONAL INSTRUMENTS
Description: 4-CHANNEL, ±25 MV/V, 24-BIT SIMULTANEOUS BRIDGE MODULE

Model Number: NI-9237
Serial Number: 1357177

Accuracy: Mfr. Specifications

Certificate Information

Reason For Service: CALIBRATION
Type of Cal: ACCREDITED 17025 WITH UNCERTAINTIES
As Found Condition: IN TOLERANCE
As Left Condition: LEFT AS FOUND
Procedure: NATIONAL INSTRUMENTS CAL EXECUTIVE 3.4

Technician: WAYNE GETCHELL
Cal Date 15Apr2011
Cal Due Date: 15Apr2012
Interval: 12 MONTHS
Temperature: 23.0 C
Humidity: 44.0 %

Remarks: *Reference attached Calibration Data with Measurement Uncertainties.*

The instrument on this certification has been calibrated against standards traceable to the National Institute of Standards and Technology (NIST) or other recognized national metrology institutes, derived from ratio type measurements, or compared to nationally or internationally recognized consensus standards.

A test uncertainty ratio (T.U.R.) of 4:1 [K=2, approx. 95% Confidence Level] was maintained unless otherwise stated.

Tektronix Service Solutions is registered to ISO 9001:2008. Lab Operations meet the requirements of ANSI/NCSL Z540-1-1994 (R2002), ISO 10012:2003, 10CFR50 AppxB, and 10CFR21.

ISO/IEC 17025-2005 accredited calibrations are per ACLASS certificate # AC-1187 within the scope for which the lab is accredited.
When uncertainty measurement calculations have been calculated per customer request, reported condition statements do not take into account uncertainty of measurement.
All results contained within this certification relate only to item(s) calibrated. Any number of factors may cause the calibration item to drift out of calibration before the instrument's calibration interval has expired.

Approved By: WAYNE GETCHELL
Service Representative

Calibration Standards

NIST Traceable#	Inst. ID#	Description	Manufacturer	Model	Cal Date	Date Due
4881917	15-0271	MULTIFUNCTION CALIBRATOR	FLUKE	5700A	20Jan2011	20Apr2011
4176293	A144598	DMM	HEWLETT PACKARD	3458A	24May2010	24May2011

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Figure 286. Post-test calibration sheet for signal conditioning module 1357177

Tektronix
Service Solutions

ACLASS ACCREDITED CALIBRATION

Certificate of Calibration

5051312

Certificate Page 1 of 1

Instrument Identification

Company ID: 120205
NATIONAL RENEWABLE ENERGY LAB
BEV KAY/SRRL
16253 DENVER WEST PARKWAY
GOLDEN, CO 80401

PO Number: CC-BEVERLY KAY

Instrument ID: **04176C**
Manufacturer: NATIONAL INSTRUMENTS
Description: 4-CHANNEL, ±25 MV/V, 24-BIT SIMULTANEOUS BRIDGE MODULE

Model Number: NI-9237
Serial Number: 1357162

Accuracy: Mfr. Specifications

Certificate Information

Reason For Service: CALIBRATION
Type of Cal: ACCREDITED 17025 WITH UNCERTAINTIES
As Found Condition: IN TOLERANCE
As Left Condition: LEFT AS FOUND
Procedure: NATIONAL INSTRUMENTS CAL EXECUTIVE 3.4

Technician: WAYNE GETCHELL
Cal Date 15Apr2011
Cal Due Date: 15Apr2012
Interval: 12 MONTHS
Temperature: 23.0 C
Humidity: 44.0 %

Remarks: *Reference attached Calibration Data with Measurement Uncertainties.*

The instrument on this certification has been calibrated against standards traceable to the National Institute of Standards and Technology (NIST) or other recognized national metrology institutes, derived from ratio type measurements, or compared to nationally or internationally recognized consensus standards.

A test uncertainty ratio (T.U.R.) of 4:1 [K=2, approx. 95% Confidence Level] was maintained unless otherwise stated.

Tektronix Service Solutions is registered to ISO 9001:2008. Lab Operations meet the requirements of ANSI/NCSL Z540-1-1994 (R2002), ISO 10012:2003, 10CFR50 AppxB, and 10CFR21.

ISO/IEC 17025-2005 accredited calibrations are per ACLASS certificate # AC-1187 within the scope for which the lab is accredited.
When uncertainty measurement calculations have been calculated per customer request, reported condition statements do not take into account uncertainty of measurement.
All results contained within this certification relate only to item(s) calibrated. Any number of factors may cause the calibration item to drift out of calibration before the instrument's calibration interval has expired.
This certificate shall not be reproduced except in full, without written consent of Tektronix Service Solutions.

Approved By: WAYNE GETCHELL
Service Representative

Calibration Standards

NIST Traceable#	Inst. ID#	Description	Manufacturer	Model	Cal Date	Date Due
4881917	15-0271	MULTIFUNCTION CALIBRATOR	FLUKE	5700A	20Jan2011	20Apr2011
4176293	A144598	DMM	HEWLETT PACKARD	3458A	24May2010	24May2011

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Figure 287. Post-test calibration sheet for signal conditioning module 1357162

Tektronix
Service Solutions

ACLASS ACCREDITED CALIBRATION

Certificate of Calibration

5051336

Certificate Page 1 of 1

Instrument Identification

Company ID: 120205
NATIONAL RENEWABLE ENERGY LAB
BEV KAY/SRRL
16253 DENVER WEST PARKWAY
GOLDEN, CO 80401

PO Number: CC-BEVERLY KAY

Instrument ID: **04177C**
Manufacturer: NATIONAL INSTRUMENTS
Description: 4-CHANNEL, ±25 MV/V, 24-BIT SIMULTANEOUS BRIDGE MODULE

Model Number: NI-9237
Serial Number: 1342666

Accuracy: Mfr. Specifications

Certificate Information

Reason For Service: CALIBRATION
Type of Cal: ACCREDITED 17025 WITH UNCERTAINTIES
As Found Condition: IN TOLERANCE
As Left Condition: LEFT AS FOUND
Procedure: NATIONAL INSTRUMENTS CAL EXECUTIVE 3.4

Technician: WAYNE GETCHELL
Cal Date 15Apr2011
Cal Due Date: 15Apr2012
Interval: 12 MONTHS
Temperature: 23.0 C
Humidity: 44.0 %

Remarks: *Reference attached Calibration Data with Measurement Uncertainties.*

The instrument on this certification has been calibrated against standards traceable to the National Institute of Standards and Technology (NIST) or other recognized national metrology institutes, derived from ratio type measurements, or compared to nationally or internationally recognized consensus standards.

A test uncertainty ratio (T.U.R.) of 4:1 [K=2, approx. 95% Confidence Level] was maintained unless otherwise stated.

Tektronix Service Solutions is registered to ISO 9001:2008. Lab Operations meet the requirements of ANSI/NCSL Z540-1-1994 (R2002), ISO 10012:2003, 10CFR50 AppxB, and 10CFR21.

ISO/IEC 17025-2005 accredited calibrations are per ACLASS certificate # AC-1187 within the scope for which the lab is accredited.
When uncertainty measurement calculations have been calculated per customer request, reported condition statements do not take into account uncertainty of measurement.
All results contained within this certification relate only to item(s) calibrated. Any number of factors may cause the calibration item to drift out of calibration before the instrument's calibration interval has expired.
This certificate shall not be reproduced except in full, without written consent of Tektronix Service Solutions.

Approved By: WAYNE GETCHELL
Service Representative

Calibration Standards

NIST Traceable#	Inst. ID#	Description	Manufacturer	Model	Cal Date	Date Due
4881917	15-0271	MULTIFUNCTION CALIBRATOR	FLUKE	5700A	20Jan2011	20Apr2011
4176293	A144598	DMM	HEWLETT PACKARD	3458A	24May2010	24May2011

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Figure 288. Post-test calibration sheet for signal conditioning module 1342666