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Ganged-PV System Evaluation

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ABSTRACT

The following report contains data and data summaries collected for the SkySun LLC elevated Ganged PV arrays. These arrays were fabricated as a series of PV panels in various orientations, suspended by cables, at the National Solar Thermal Test Facility (NSTTF) at Sandia National Laboratories (SNL). Starting in February of 2021, Sandia personnel have collected power and accelerometer data for these arrays to assess design and operational efficacy of varying ganged-PV configurations. The purpose of this power data collection was to see how the various array orientations compare in power collection capability depending on the time of day, year, and the specific daily solar direct normal irradiance (DNI). The power data was collected as a measurement of the power output from the various series strings. The project team measured direct current (DC) voltage and current from the respective arrays. The accelerometer data was collected with the purpose of demonstrating potential destructive mode shapes that could take place with each of the arrays when exposed to high winds. This allowed the team to evaluate whether impacts with respect to specific array orientations using suspended cables is a safe design. All data collection was performed during calendar year 2021.

ACKNOWLEDGEMENTS

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TERMS AND DEFINITIONS

Abbreviation	Definition
NSTTF	National Solar Thermal Test Facility
SNL	Sandia National Laboratories
PV	Photovoltaic
SATS	Single Axis Tracking South
SATN	Single Axis Tracking North
FX20 East	Fixed 20 East
FX20 West	Fixed 20 West
FXZS	Fixed Zero South
FXZN	Fixed Zero North
TSAT	Tensile Single Axis Tracking (Saddle)
DNI	Direct Normal Iridescence

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1. Introduction

The SkySun LLC elevated photovoltaic (PV) arrays were designed as a series of PV strings, that were fabricated in various orientations, suspended by cables, at the SNL NSTTF PV evaluation area. Starting in February of 2021, Sandia personnel collected power and accelerometer data for these systems using a ballasted resistor bank and power analyzers. The power data was measured for each of the four arrays. The data was then compared to assess how differing orientations, materials and costs can affect system performance. The accelerometer data was collected on windy days, with accelerometer devices attached strategically on the edges of panels to show how the different arrays are impacted by high wind loads that could impact destructive mode shapes.

The first of the four array systems tested was the Single Axis Tracking (SAT) array. As shown in Figure 1, this array was setup with South-North placement, and consisted of 4 sets of 3 panels. This consisted of two strings that were measured in series. The array used linear actuators to track the sun in an East-West single-axis manner. The arrays were able to tilt up to 45° in either direction. The two SAT arrays was referred to as SAT-South and SAT-North. Each had its own disconnect and connection point for power data recording.

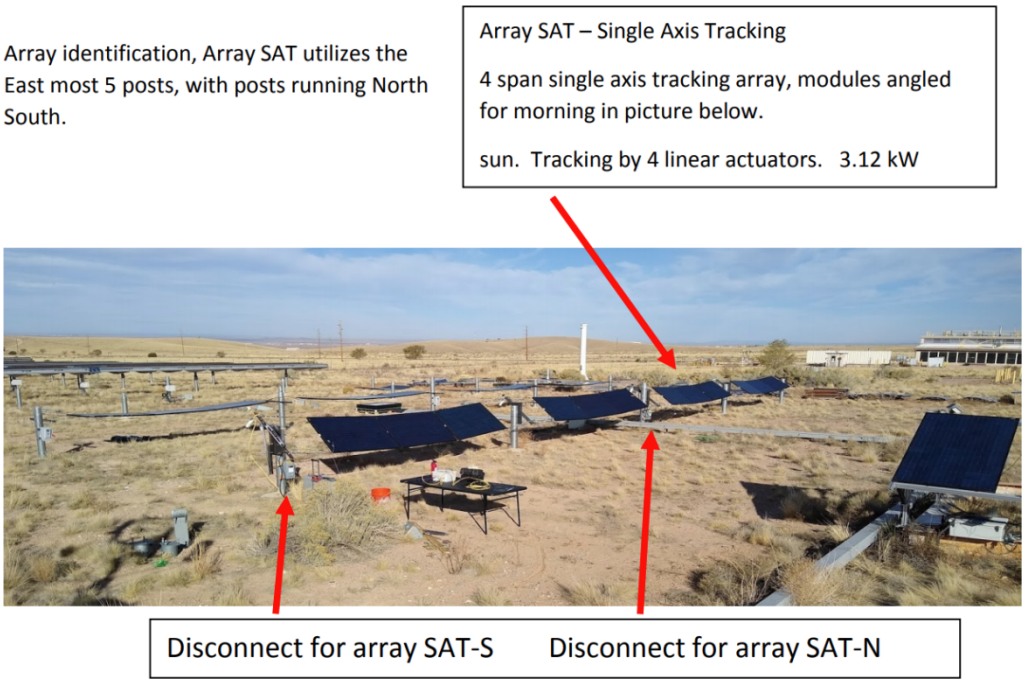


Figure 1: SAT Array Map and Disconnects

Parallel to the SAT array, also running South-North, was the Fixed Zero (FXZ) array. Like the SAT array, the FXZ was comprised of 4 sets of 3 panels. The FXZ array was also split into two series strings, FXZ-North and FXZ-South. However, the FXZ had no sun tracking capabilities. It

was fixed at an angle of zero degrees, facing directly up to provide a baseline comparison against dynamic tracking. This will allow a later techno-economic cost comparison to assess costs against power production.

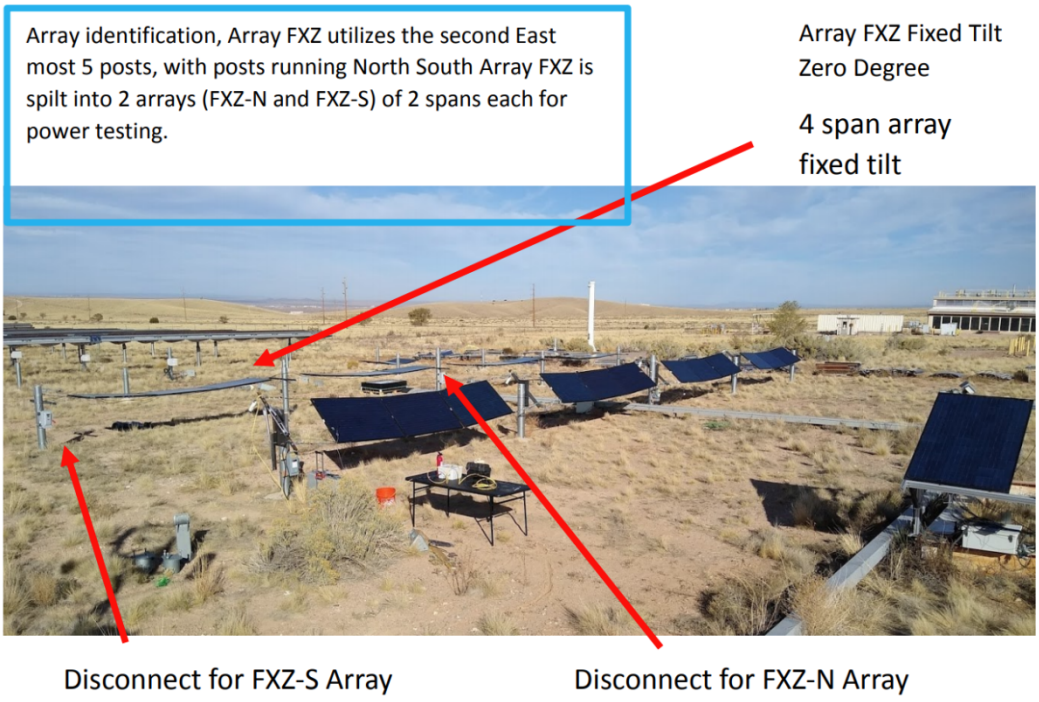


Figure 2: FXZ Array Map and Disconnects

Another arrat system evaluated as part of this project was the Fixed 20 (FX20), which was orientated in an East-West manner. The array was at a fixed angle, facing 20° towards the South. The array was comprised of 2 series of 4 panels. For power data collection, these sets of panels had to be measured individually. The 2 series sets were referred to as FX20-East and FX20-West.

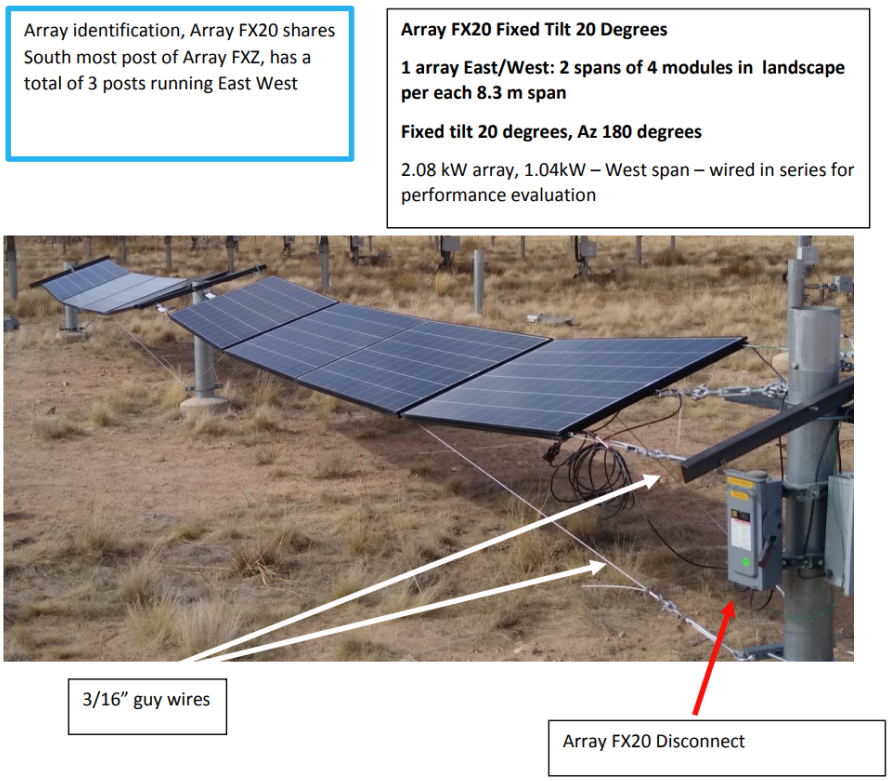


Figure 3: FX20 Array Map and Disconnects

The final array is the Tensile Single axis Tracking (TSAT) array. This array had a single set of 3 panels on 3/8" in. cables running South-North, hanging from cables running East-West. Linear actuators gave the TSAT array a single-axis, sun tracking capability. This array was only used for accelerometer data collection and not for power evaluation.

Array TSAT – Tensile Single axis Tracking

1 span single axis tracking array, modules angled for morning

sun. N/S cables carried by E/W cables. Tracking by 2 linear actuators – tension variation only. 0.78 kW

3rd and 4th rows of posts utilizing the 4 South most posts.

Figure 4: TSAT Array Map and Disconnects

2. Power Data Collection

In this section the data recorded is presented for days when power data was collected. For every collection day data was recorded three times, typically once in the morning, once at noon, and once in the afternoon. Data was collected for each of the three power assessment arrays. This was performed by connecting a 1500-Watt load bank to each respective set of panels, while using a Fluke meter and a Klein Clamp meter to measure DC voltage and current.

The SAT north and SAT south arrays represent strings of six panels wired in series which can track the sun with the use of linear actuators. Before collecting data from these arrays, the angle of the arrays was adjusted East or West to maximize the output. This was done by connecting a 300-Watt load bank to a single panel in the SAT-South array and to a fixed reference panel simultaneously. The voltage and current of the reference panel was recorded, and then the angle of the array was adjusted so that the single panel on the SAT was maximized. The FX20 array was split into an east and west array, each containing 4 panels. The 8 panels comprising the entire FX20 array would overload the 1500-Watt load bank so the system was split.

Each of the following sections contains the data for a specific day. The time of the recording, the angle of the panel (fixed or tracking), the recorded voltage, current, and the calculated power are all reported in the table for each respective test section. The respective plots show the power recordings for each array at each time stamp. The graphs also show the DNI in W/m^2 units recorded for the date, plotted across the 24-hour duration of each day. Solar noon is also marked on each graph with a yellow dashed line. Each set of arrays were paired together by a shared color, with one array denoted by a solid line and the other by a dashed line. The SAT north and south arrays are paired, the FX20 east and west arrays are paired, and the FXZ north and south arrays are paired. Because the FX20 east and west arrays each contain 4 panels, while the SAT and FXZ arrays contain 6, the data for the FX20 arrays is adjusted in the graphs by multiplying the power values by a factor of 6/4.

2.1 February 5th

Table 1: February 5th Power Data

Array	Time	Angle (degrees)	Volts	Amps	Power (Watts)
SAT-South	11:35:00	15 East	124.00	7.97	988.28
	12:23:00	5 West	122.90	6.56	806.224
	13:39:00	30 West	129.30	5.99	774.507
SAT-North	11:36:00	15 East	123.40	7.82	964.988
	12:24:00	5 West	122.70	6.49	796.323
	13:40:00	30 West	131.10	6.05	793.155
FX20-West	11:38:00	Fixed 20	125.50	7.72	968.86
	12:32:00	Fixed 20	125.60	6.46	811.376
	13:43:00	Fixed 20	123.80	5.73	709.374
FX20-East	11:39:00	Fixed 20	126.60	7.71	976.086
	12:33:00	Fixed 20	125.60	6.42	806.352
	13:42:00	Fixed 20	124.50	5.73	713.385
FXZ-South	11:40:00	Fixed 0	120.20	7.39	888.278
	12:33:00	Fixed 0	122.80	6.27	769.956
	13:44:00	Fixed 0	115.60	5.30	612.68
FXZ-North	11:42:00	Fixed 0	118.80	7.24	860.112
	12:35:00	Fixed 0	121.20	5.55	672.66
	13:45:00	Fixed 0	112.70	5.16	581.532

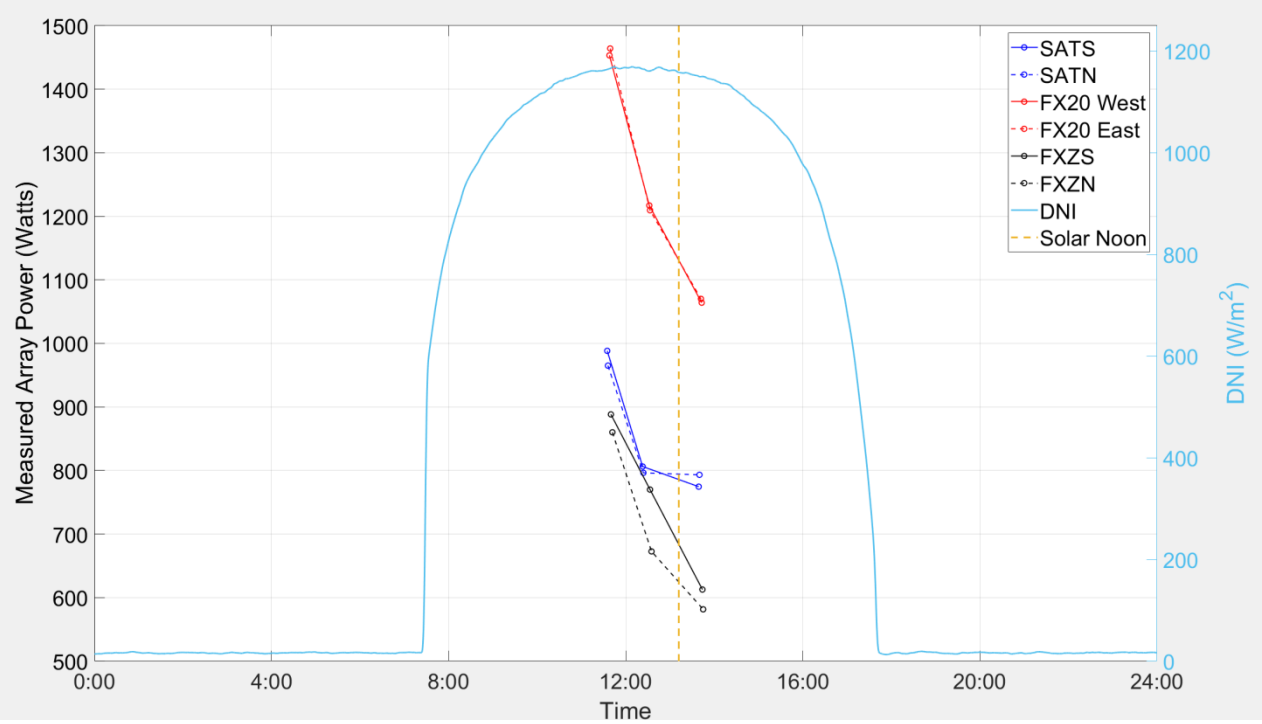


Figure 5: February 5th Power and DNI Plot

Power recordings for each array were maximized at approximately 11:30-11:45 AM. Values recorded after solar noon were found to be significantly lower. However, the SAT north and South arrays did show less of a power reduction during the second and third recordings. The FX20 east and west arrays show the highest overall power values at each time measurement.

2.2 February 8th

Table 2: February 8th Power Data

Array	Time	Angle (degrees)	Volts	Amps	Power (Watts)
SAT-South	12:39:00	10 West	123.30	5.63	694.179
	14:24:00	35 West	142.70	6.50	927.55
SAT-North	12:42:00	10 West	125.30	5.74	719.222
	14:25:00	35 West	142.10	6.53	927.913
FX20-West	12:45:00	Fixed 20	124.00	5.61	695.64
	14:26:00	Fixed 20	121.00	5.50	665.5
FX20-East	12:46:00	Fixed 20	124.70	5.65	704.555
	14:27:00	Fixed 20	121.10	5.55	672.105
FXZ-South	12:50:00	Fixed 0	125.00	5.70	712.5
	14:29:00	Fixed 0	105.90	4.80	508.32
FXZ-North	12:48:00	Fixed 0	124.40	5.68	706.592
	14:30:00	Fixed 0	102.90	4.68	481.572

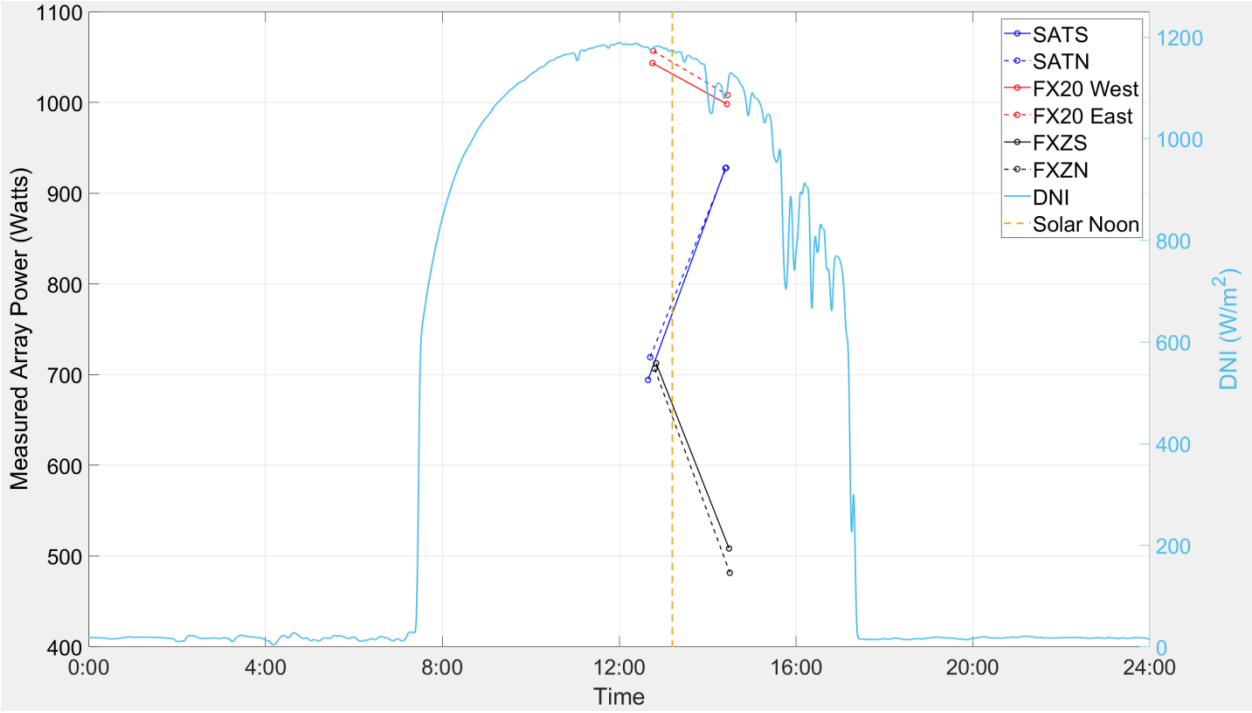


Figure 6: February 8th Power and DNI Plot

For February 8th data was only collected twice, between 12:40-12:50pm and 2:24-2:30pm. In the afternoon, the DNI began to fluctuate with mild cloud coverage. Both the FX20 and FXZ panels saw a

decrease in power between the two collection times while the SAT panels were able to record significantly higher power later in the day. Overall, the FX20 panels had the highest power recordings.

2.3 February 11th

Table 3: February 11th Power Data

Array	Time	Angle (degrees)	Volts	Amps	Power (Watts)
SAT-South	8:56:00	40 East	137.30	6.10	837.53
	11:31:00	15 East	128.90	5.55	715.395
	12:27:00	7.5 West	124.70	5.69	709.543
SAT-North	8:58:00	40 East	130.60	5.83	761.398
	11:32:00	15 East	128.30	5.85	750.555
	12:28:00	7.5 West	125.90	5.76	725.184
FX20-West	9:00:00	Fixed 20	86.80	3.98	345.464
	11:33:00	Fixed 20	124.60	5.52	687.792
	12:30:00	Fixed 20	124.40	5.55	690.42
FX20-East	9:00:00	Fixed 20	90.60	4.00	362.4
	11:34:00	Fixed 20	125.00	5.69	711.25
	12:31:00	Fixed 20	122.70	5.58	684.666
FXZ-South	9:01:00	Fixed 0	64.30	2.83	181.969
	11:35:00	Fixed 0	123.90	5.68	703.752
	12:32:00	Fixed 0	127.50	5.80	739.5
FXZ-North	9:02:00	Fixed 0	65.10	2.77	180.327
	11:37:00	Fixed 0	123.60	5.62	694.632
	12:33:00	Fixed 0	126.10	5.77	727.597

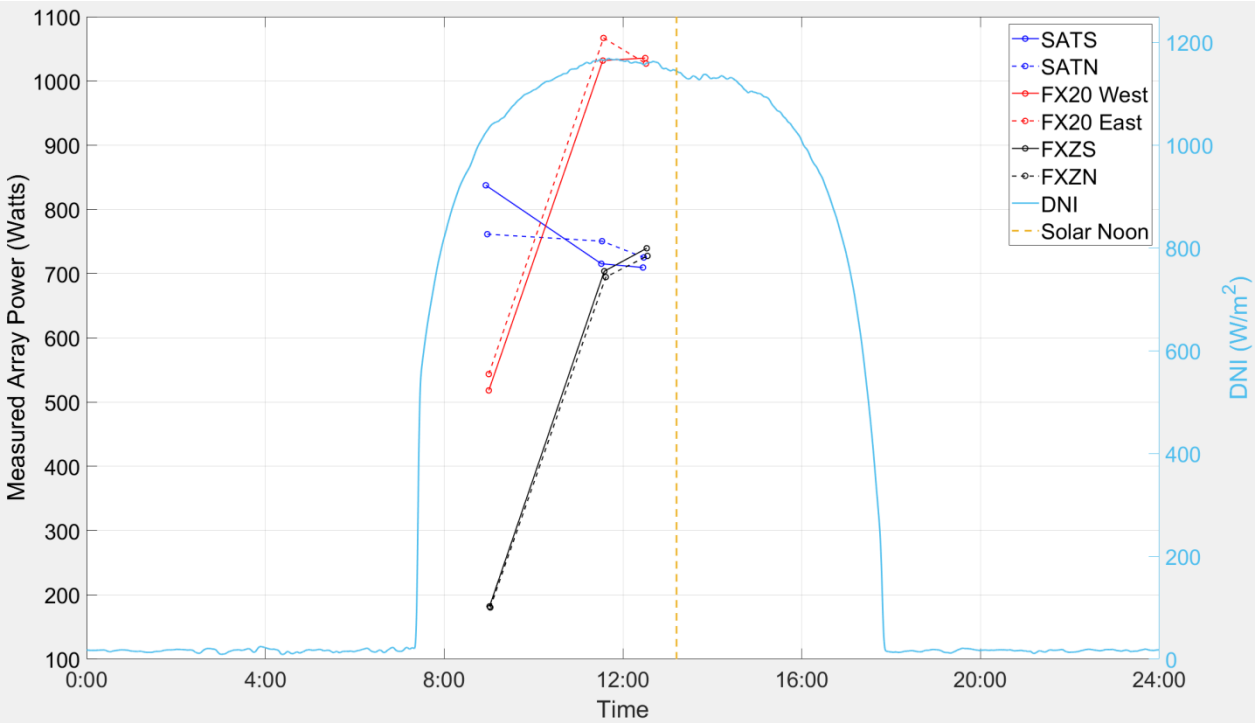


Figure 7: February 11th Power and DNI Plot

On Feb. 11th data was recorded at approximately 9:00am, 11:30am, and 12:30pm. While the FX20 and FXZ panels started with low power recordings which increased as the DNI increased towards solar noon, the SAT panels started much higher and did not see significant power reductions. This is certainly attributed to the SAT tracking capabilities. However, past approximately 10:00am the FX20 panels were found however to have the highest power output.

2.4 February 17th

Table 4: February 17th Power Data

Array	Time	Angle (degrees)	Volts	Amps	Power (Watts)
SAT-South	10:55:00	35 East	160.10	7.25	1160.725
	12:30:00	5 West	174.00	7.80	1357.2
	13:49:00	25 West	122.30	5.51	673.873
SAT-North	10:56:00	35 East	163.30	7.40	1208.42
	12:31:00	5 West	160.70	7.36	1182.752
	13:50:00	25 West	124.40	5.70	709.08
FX20-West	10:59:00	Fixed 20	129.90	5.87	762.513
	12:32:00	Fixed 20	128.60	5.97	767.742
	13:51:00	Fixed 20	111.00	5.12	568.32
FX20-East	11:01:00	Fixed 20	135.20	6.02	813.904
	12:33:00	Fixed 20	130.00	5.92	769.6
	13:52:00	Fixed 20	110.10	5.00	550.5
FXZ-South	11:03:00	Fixed 0	155.00	6.95	1077.25
	12:35:00	Fixed 0	140.20	6.50	911.3
	13:53:00	Fixed 0	97.10	4.36	423.356
FXZ-North	11:04:00	Fixed 0	175.00	7.60	1330
	12:36:00	Fixed 0	178.90	8.25	1475.925
	13:54:00	Fixed 0	103.40	4.67	482.878

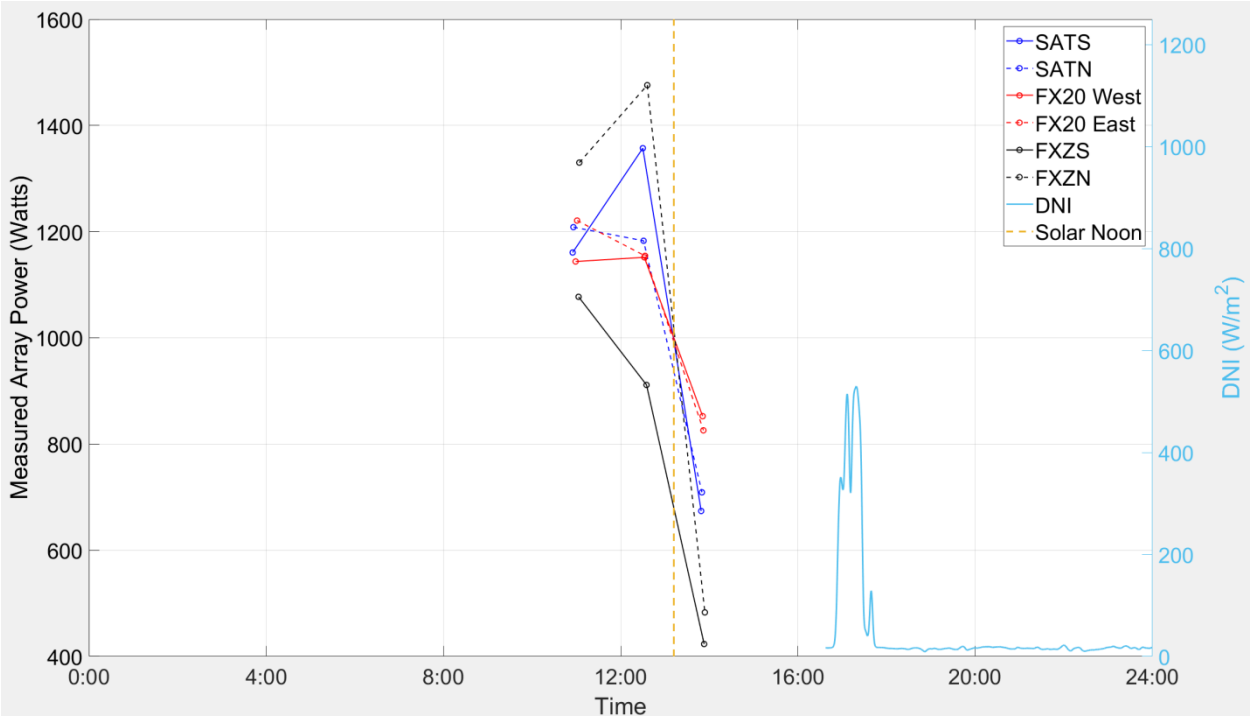


Figure 8: February 17th Power and DNI Plot

On Feb. 17th power was recorded at approximately 11:00am, 12:30pm, and 1:40pm. Unfortunately, local data recording for DNI failed on this day and values were only recorded past 4:00pm. On this day, the ground was significantly snow covered. This resulted in extremely high-power values, especially for the SAT-south and FXZ-north at approximately solar noon. However, the winter weather this day overall made for messy, unpredictable data, with extreme reductions in power for all panels after solar noon.

2.5 February 19th

Table 5: February 19th Power Data

Array	Time	Angle (degrees)	Volts	Amps	Power (Watts)
SAT-South	11:25:00	20 East	140	6.26	876.4
	12:20:00	3.2 West	134.7	6.09	820.323
	13:24:00	25 West	141.3	6.48	915.624
SAT-North	11:27:00	20 East	140.2	6.3	883.26
	12:21:00	3.2 West	136.1	6.17	839.737
	13:25:00	25 West	142	6.52	925.84
FX20-West	11:29:00	Fixed 20	115.6	5.55	641.58
	12:23:00	Fixed 20	126	5.7	718.2
	13:26:00	Fixed 20	123.6	5.68	702.048
FX20-East	11:29:00	Fixed 20	125.4	5.61	703.494
	12:24:00	Fixed 20	126.3	5.68	717.384
	13:27:00	Fixed 20	123.7	5.65	698.905
FXZ-South	11:30:00	Fixed 0	132.3	5.94	785.862
	12:25:00	Fixed 0	137.7	6.28	864.756
	13:27:00	Fixed 0	123.2	6.05	745.36
FXZ-North	11:31:00	Fixed 0	131.8	5.94	782.892
	12:26:00	Fixed 0	136.9	6.21	850.149
	13:28:00	Fixed 0	130.2	6.01	782.502

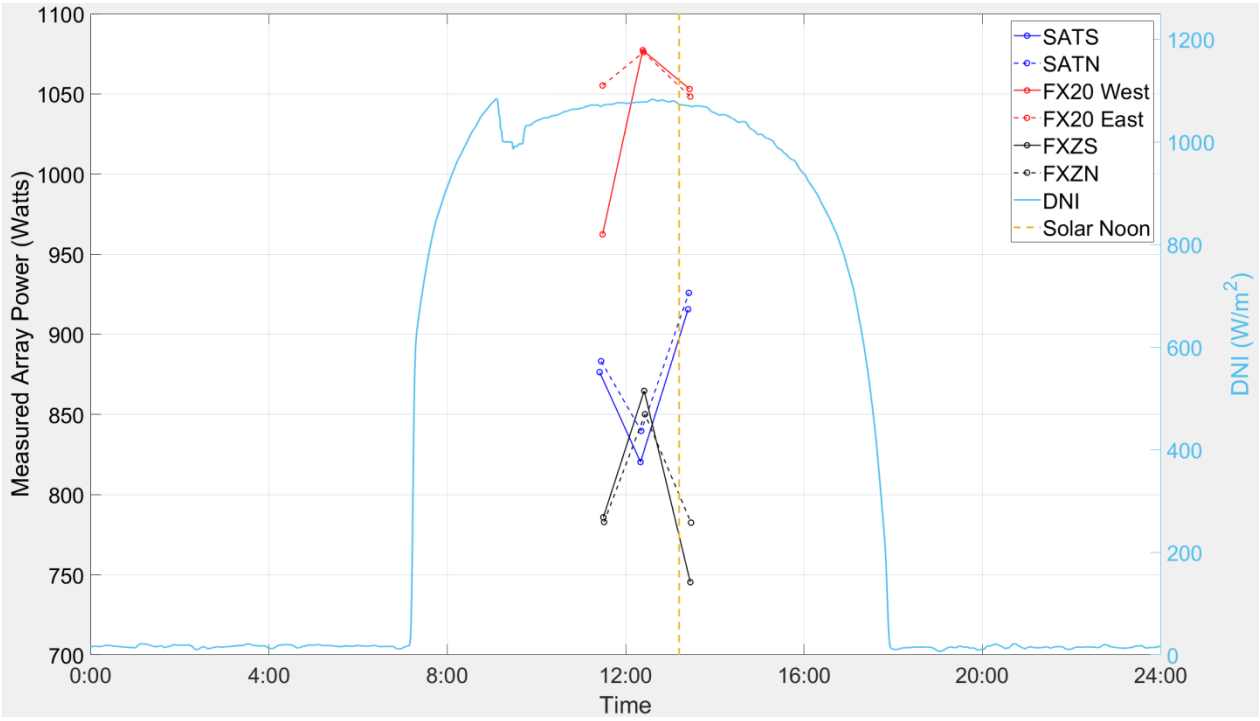


Figure 9: February 19th Power and DNI Plot

On Feb. 19th power was recorded at approximately 11:20am, 12:20pm, and 1:20pm. The SAT panels recorded higher values than the FXZ panels in the morning and afternoon due to tracking. At solar noon when the FXZ and SAT panels were most similar in angle, the FXZ had increased power while the SAT had decreased power, putting the sets of panels all in a similar range. Overall, the FX20 panels recorded the highest power values.

2.6 February 26th

Table 6: February 26th Power Data

Array	Time	Angle (degrees)	Volts	Amps	Power (Watts)
SAT-South	11:25:00	20 East	160.40	7.28	1167.71
	12:22:00	5 West	99.40	4.58	455.25
	13:15:00	15 West	152.10	7.00	1064.70
SAT-North	11:26:00	20 East	161.20	7.38	1189.66
	12:24:00	5 West	99.80	4.58	457.08
	13:15:00	15 West	145.70	6.71	977.65
FX20-West	11:27:00	Fixed 20	128.80	5.85	753.48
	12:25:00	Fixed 20	124.40	5.41	673.00
	13:16:00	Fixed 20	124.50	5.58	694.71
FX20-East	11:27:00	Fixed 20	129.40	5.80	750.52
	12:25:00	Fixed 20	126.20	5.76	726.91
	13:16:00	Fixed 20	124.90	5.70	711.93
FXZ-South	11:29:00	Fixed 0	129.40	5.80	750.52
	12:27:00	Fixed 0	129.70	5.95	771.72
	13:17:00	Fixed 0	141.50	6.63	938.15
FXZ-North	11:30:00	Fixed 0	143.60	6.57	943.45
	12:29:00	Fixed 0	133.33	6.12	815.98
	13:18:00	Fixed 0	142.00	6.45	915.90

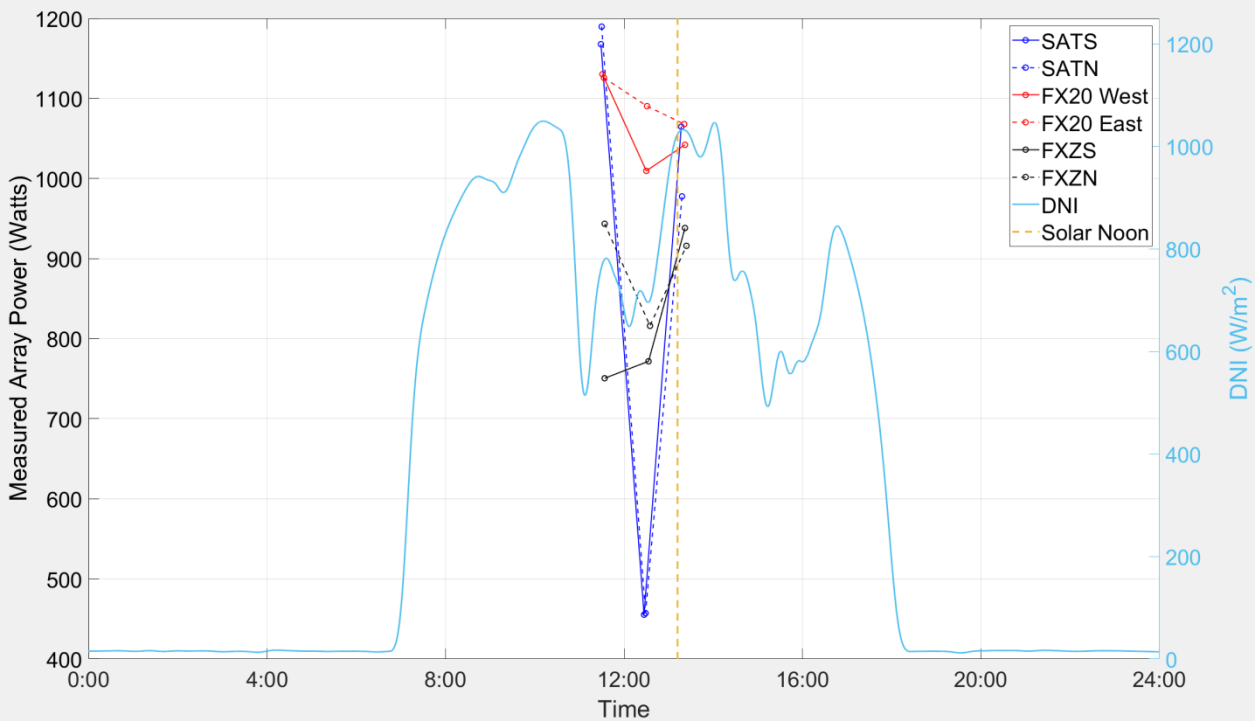


Figure 10: February 26th Power and DNI Plot

On Feb. 26th power was recorded at approximately 11:20am, 12:20pm, and 1:20pm. This day was very cloudy, as reflected in the DNI data. The FX20 saw a significant drop in power reading near solar noon, likely due to cloud coverage. In the afternoon all panels performed similarly, but overall the FX20 panels recorded the highest power values at solar noon and afterwards.

2.7 March 1st

Table 7: March 1st Power Data

Array	Time	Angle (degrees)	Volts	Amps	Power (Watts)
SAT-South	11:27:00	30 East	145.10	6.46	937.346
	12:24:00	5 West	144.60	6.67	964.482
	13:15:00	20 West	148.90	6.91	1028.899
SAT-North	11:28:00	30 East	147.80	6.71	991.738
	12:25:00	5 West	145.40	6.66	968.364
	13:16:00	20 West	149.00	6.96	1037.04
FX20-West	11:30:00	Fixed 20	123.80	5.61	694.518
	12:27:00	Fixed 20	123.60	5.56	687.216
	13:17:00	Fixed 20	125.10	5.89	736.839
FX20-East	11:30:00	Fixed 20	124.50	5.59	695.955
	12:28:00	Fixed 20	124.10	5.66	702.406
	13:17:00	Fixed 20	125.80	5.87	738.446
FXZ-South	11:31:00	Fixed 0	142.30	6.45	917.835
	12:28:00	Fixed 0	147.20	6.75	993.6
	13:19:00	Fixed 0	141.50	6.56	928.24
FXZ-North	11:32:00	Fixed 0	140.80	6.38	898.304
	12:29:00	Fixed 0	143.60	6.53	937.708
	13:19:00	Fixed 0	139.90	6.55	916.345

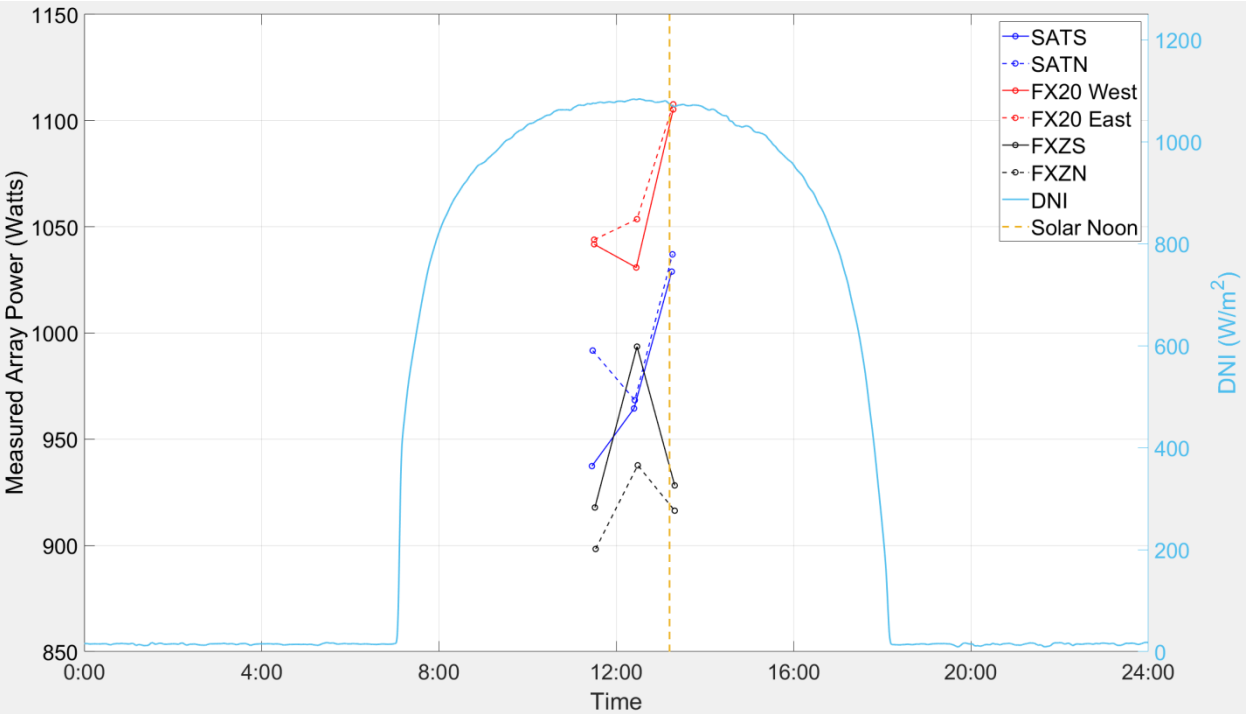


Figure 11: March 1st Power and DNI Plot

On March 1st power was recorded at approximately 11:20am, 12:20pm, and 1:20pm. The FX20 panels recorded the highest values overall, though the FX20 west had a drop off possibly due to brief cloud coverage. The SAT panels recorded higher values than the FXZ panels in the morning and afternoon due to tracking. At solar noon when the FXZ and SAT panels were most similar in angle, the FXZ had increased power while the SAT had decreased power, causing the sets of panels to all operate in a similar range.

2.8 March 5th

Table 8: March 5th Power Data

Array	Time	Angle (degrees)	Volts	Amps	Power (Watts)
SAT-South	11:29:00	20 East	148.40	6.73	998.732
	12:24:00	9 West	145.80	6.60	962.28
	13:21:00	20 West	151.60	7.00	1061.2
SAT-North	11:30:00	20 East	149.30	6.75	1007.775
	12:25:00	9 West	146.40	6.60	966.24
	13:21:00	20 West	151.80	6.96	1056.528
FX20-West	11:32:00	Fixed 20	125.00	5.61	701.25
	12:26:00	Fixed 20	122.10	5.55	677.655
	13:23:00	Fixed 20	122.00	5.26	641.72
FX20-East	11:32:00	Fixed 20	125.80	5.58	701.964
	12:27:00	Fixed 20	123.30	5.56	685.548
	13:23:00	Fixed 20	122.50	5.63	689.675
FXZ-South	11:33:00	Fixed 0	143.80	6.48	931.824
	12:28:00	Fixed 0	148.40	6.75	1001.7
	13:24:00	Fixed 0	142.00	6.55	930.1
FXZ-North	11:34:00	Fixed 0	141.80	6.38	904.684
	12:28:00	Fixed 0	144.70	6.57	950.679
	13:25:00	Fixed 0	138.90	6.44	894.516

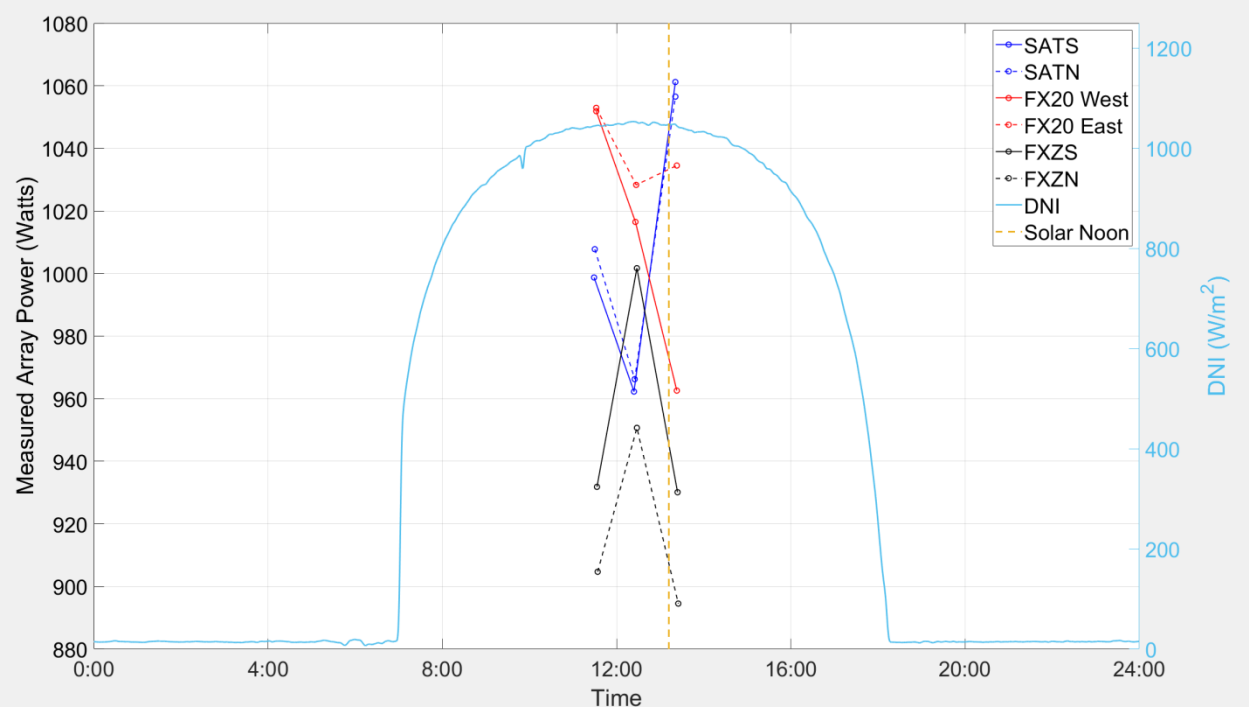


Figure 12: March 5th Power and DNI Plot

On March 5th power was recorded at approximately 11:30am, 12:20pm, and 1:20pm. The SAT panels recorded higher values than the FXZ panels in the morning and afternoon due to tracking. The SATS panel was lower than would be expected in the morning, likely due to brief interference by cloud coverage or similar. At solar noon when the FXZ and SAT panels were most similar in angle, the FXZ had increased power while the SAT had decreased power, allowing all the panel sets to operate in a similar range. Overall, the FX20 panels recorded the highest power values.

2.9 March 10th

Table 9: March 10th Power Data

Array	Time	Angle (degrees)	Volts	Amps	Power (Watts)
SAT-South	11:31:00	20 East	154.10	6.92	1066.372
	12:20:00	2.0 West	151.50	6.96	1054.44
	13:24:00	16 West	156.70	7.23	1132.941
SAT-North	11:32:00	20 East	154.60	6.97	1077.562
	12:21:00	2.0 West	153.00	7.02	1074.06
	13:25:00	16 West	155.90	7.26	1131.834
FX20-West	11:34:00	Fixed 20	125.30	5.62	704.186
	12:23:00	Fixed 20	126.30	5.77	728.751
	13:26:00	Fixed 20	127.10	5.91	751.161
FX20-East	11:34:00	Fixed 20	125.60	5.59	702.104
	12:25:00	Fixed 20	127.80	5.81	742.518
	13:26:00	Fixed 20	127.80	5.92	756.576
FXZ-South	11:35:00	Fixed 0	149.10	6.64	990.024
	12:26:00	Fixed 0	153.60	7.00	1075.2
	13:28:00	Fixed 0	145.70	6.74	982.018
FXZ-North	11:36:00	Fixed 0	145.65	7.15	1041.3975
	12:27:00	Fixed 0	150.30	6.79	1020.537
	13:28:00	Fixed 0	143.20	6.64	950.848

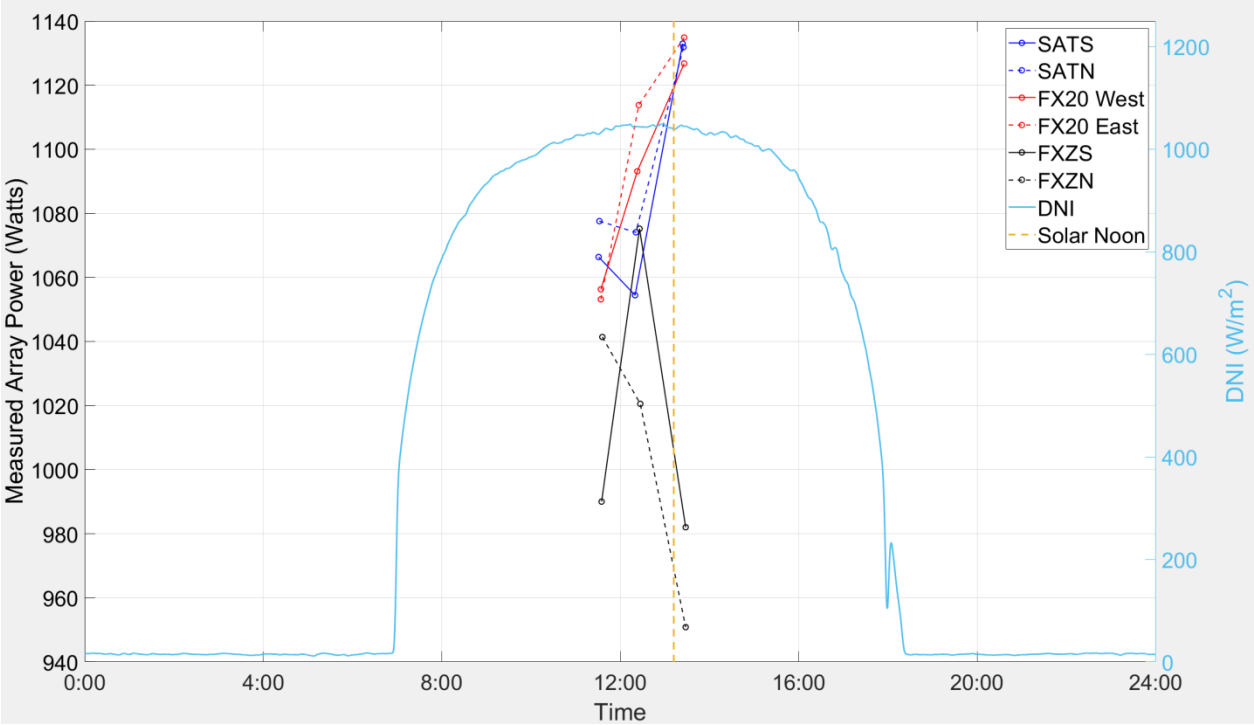


Figure 13: March 10th Power and DNI Plot

On March 10th power was recorded at approximately 11:30am, 12:20pm, and 1:20pm. The SAT panels recorded higher values than the FXZ and FX20 panels in the morning due to tracking. At solar noon when the FXZ and SAT panels were most similar in angle, the FXZ had increased power while the SAT had decreased power, putting the sets of panels all in a similar range. The FXZ north had a drop off at solar noon which was likely due to clouds or interference. Overall, the FX20 panels recorded the highest power values at solar noon, but in the afternoon the SAT and FX20 panels recorded similar power outputs.

2.10 March 11th

Table 10: March 11th Power Data

Array	Time	Angle (degrees)	Volts	Amps	Power (Watts)
SAT-South	11:23:00	25 East	156.20	7.18	1121.516
	12:26:00	10 West	152.40	7.21	1098.804
	13:26:00	21 West	159.90	7.08	1132.092
SAT-North	11:24:00	25 East	157.60	7.25	1142.6
	12:27:00	10 West	153.10	7.32	1120.692
	13:27:00	21 West	160.40	7.49	1201.396
FX20-West	11:25:00	Fixed 20	125.90	5.80	730.22
	12:27:00	Fixed 20	124.30	5.84	725.912

	13:31:00	Fixed 20	125.20	5.77	722.404
FX20-East	11:25:00	Fixed 20	126.40	5.80	733.12
	12:28:00	Fixed 20	124.40	5.81	722.764
	13:33:00	Fixed 20	125.30	5.74	719.222
FXZ-South	11:26:00	Fixed 0	150.30	6.90	1037.07
	12:29:00	Fixed 0	155.40	7.32	1137.528
	13:33:00	Fixed 0	147.10	6.74	991.454
FXZ-North	11:27:00	Fixed 0	146.50	6.78	993.27
	12:30:00	Fixed 0	152.20	7.17	1091.274
	13:33:00	Fixed 0	145.20	6.70	972.84

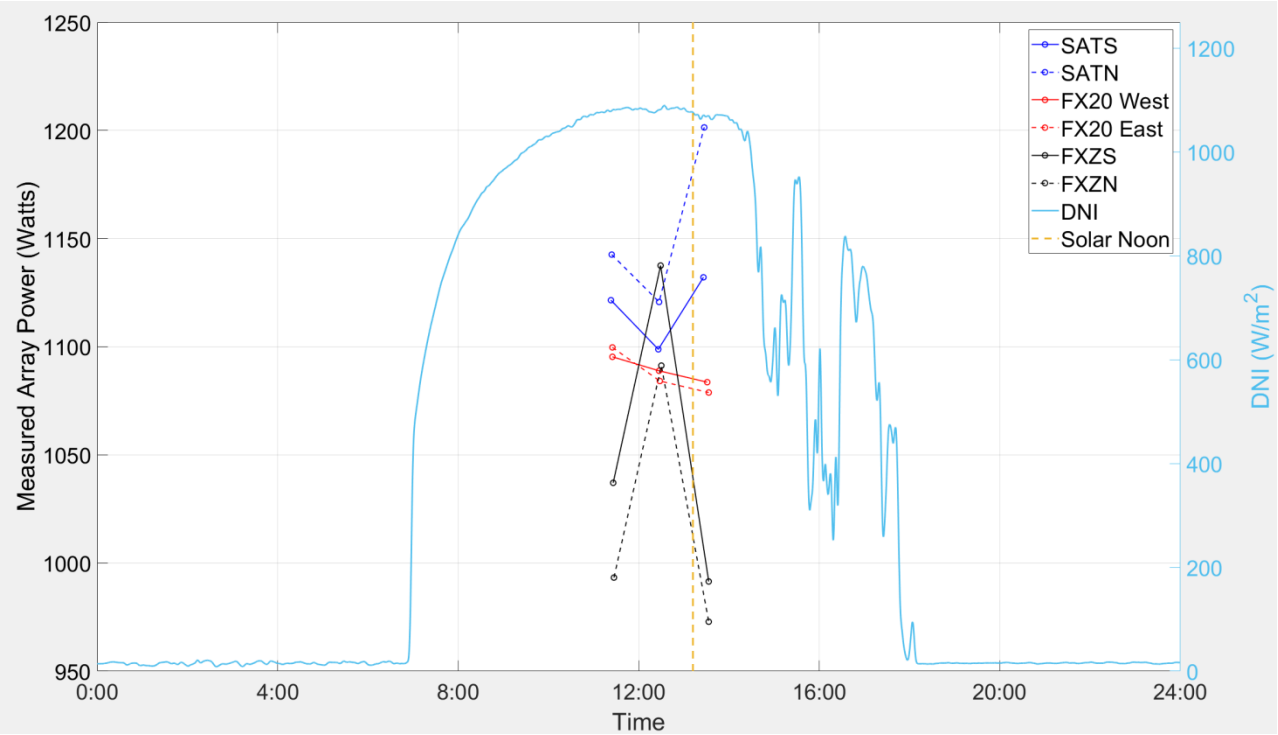


Figure 14: March 11th Power and DNI Plot

On March 11th day power was recorded at approximately 11:20am, 12:20pm, and 1:20pm. The SAT panels recorded higher values than the FXZ and FX20 panels in the morning and afternoon due to tracking. At solar noon when the FXZ and SAT panels were most similar in angle, the FXZ had increased power while the SAT had decreased power, putting the sets of panels all in a similar range. The FX20 panels recorded better power than the FXZ in the morning and afternoon, however the SAT panels had the highest overall power values for this day.

2.11 March 25th

Table 11: March 25th Power Data

Array	Time	Angle (degrees)	Volts	Amps	Power (Watts)
SAT-South	11:34:00	16 East	170.30	7.65	1302.795
	12:33:00	0	174.80	8.29	1449.092
	13:06:00	15 West	104.10	4.03	419.523
SAT-North	11:36:00	16 East	165.60	7.36	1218.816
	12:34:00	0	169.30	8.01	1356.093
	13:07:00	15 West	101.20	4.62	467.544
FX20-West	11:38:00	Fixed 20	127.30	5.77	734.521
	12:36:00	Fixed 20	127.10	5.83	740.993
	13:08:00	Fixed 20	111.90	5.23	585.237
FX20-East	11:39:00	Fixed 20	128.70	5.84	751.608
	12:36:00	Fixed 20	128.40	5.91	758.844
	13:08:00	Fixed 20	102.70	5.45	559.715
FXZ-South	11:41:00	Fixed 0	163.90	7.40	1212.86
	12:37:00	Fixed 0	162.60	7.53	1224.378
	13:09:00	Fixed 0	114.10	5.37	612.717
FXZ-North	11:41:00	Fixed 0	160.40	7.28	1167.712
	12:37:00	Fixed 0	140.20	6.05	848.21
	13:10:00	Fixed 0	86.50	3.95	341.675

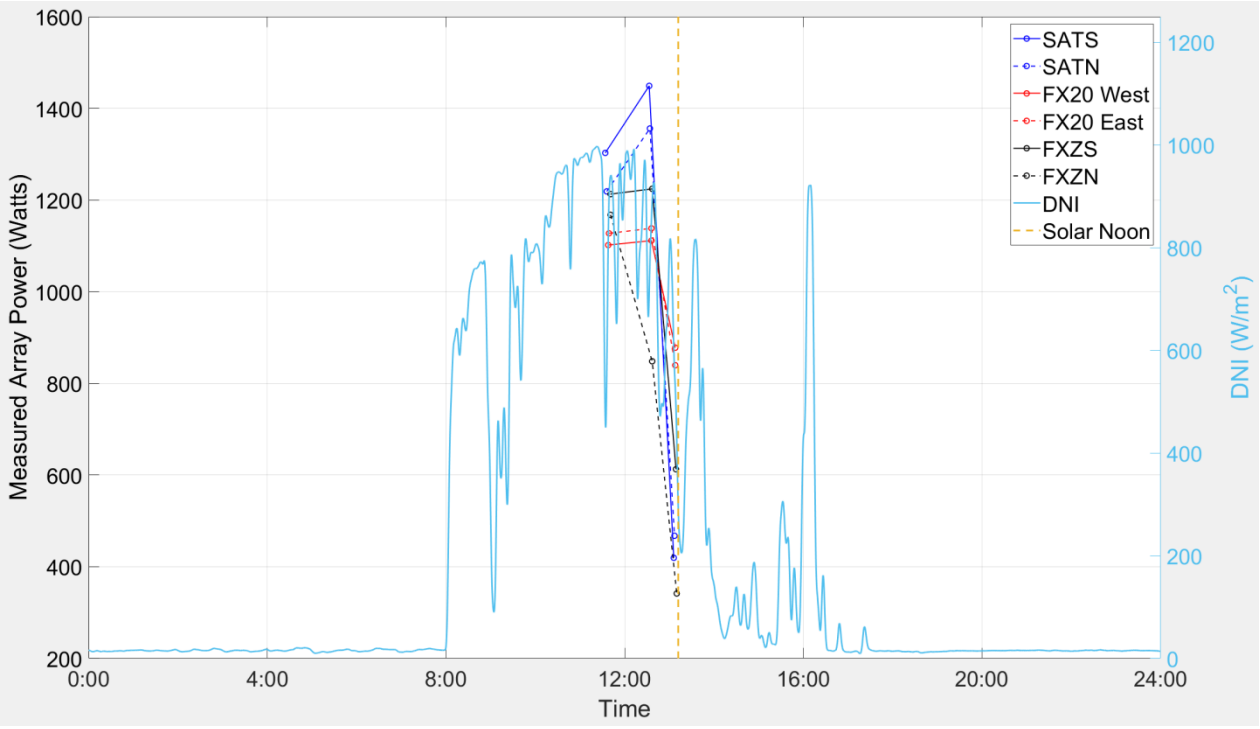


Figure 15: March 25th Power and DNI Plot

On March 25th power was recorded at approximately 11:30am, 12:30pm, and 1:00pm. Solar noon has now moved an hour ahead due to daylight savings. The SAT panels recorded higher values than the FXZ and FX20 panels in the morning at noon due to tracking. At solar noon all panels recorded significant drops in power due to inclement weather.

2.12 March 31st

Table 12: March 31st Power Data

Array	Time	Angle (degrees)	Volts	Amps	Power (Watts)
SAT-South	11:27:00	25 East	170.7	7.86	1341.702
	12:34:00	5 East	169.9	7.78	1321.822
	13:24:00	5 West	167.1	7.75	1295.025
SAT-North	11:28:00	25 East	169.9	7.86	1335.414
	12:35:00	5 East	167.1	7.78	1300.038
	13:24:00	5 West	167.4	7.79	1304.046
FX20-West	11:32:00	Fixed 20	123.3	5.61	691.713
	12:36:00	Fixed 20	124.4	5.81	722.764
	13:26:00	Fixed 20	123.3	5.72	705.276
FX20-East	11:33:00	Fixed 20	123.4	5.56	686.104
	12:36:00	Fixed 20	124.3	5.8	720.94
	13:27:00	Fixed 20	123.8	5.76	713.088
FXZ-South	11:33:00	Fixed 0	156.1	7.1	1108.31
	12:37:00	Fixed 0	165.5	7.72	1277.66
	13:27:00	Fixed 0	167.3	7.84	1311.632
FXZ-North	11:34:00	Fixed 0	153.1	6.99	1070.169
	12:38:00	Fixed 0	165.3	7.65	1264.545
	13:28:00	Fixed 0	167.1	7.68	1283.328

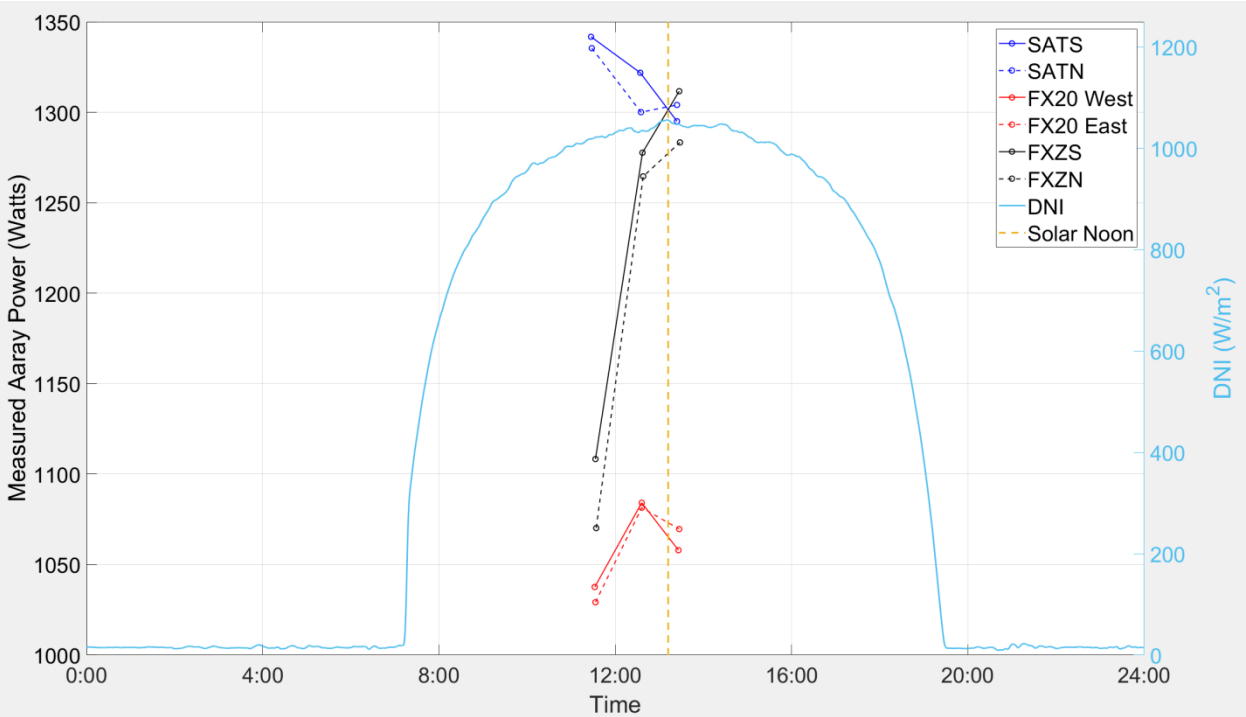


Figure 16: March 31st Power and DNI Plot

On March 31st power was recorded at approximately 11:30am, 12:30pm, and 1:20pm. The SAT panels had the highest data recordings in the morning and at noon. At solar noon when the sun was at a near optimal angle for the FXZ panels, the FXZ had increased power while the SAT had decreased power, putting the sets of panels all in a similar range. The FX20 panels peaked at 12:30pm, but overall recorded the lowest values.

2.13 April 1st

Table 13: April 1st Power Data

Array	Time	Angle (degrees)	Volts	Amps	Power (Watts)
SAT-South	8:25:00	40 East	144.00	6.37	917.28
	9:13:00	30 East	157.60	7.29	1148.904
	10:18:00	20 East	161.10	7.24	1166.364
SAT-North	8:26:00	40 East	142.90	6.19	884.551
	9:14:00	30 East	155.00	7.20	1116
	10:19:00	20 East	160.30	7.29	1168.587
FX20-West	8:28:00	Fixed 20	50.40	2.12	106.848
	9:15:00	Fixed 20	88.20	4.03	355.446
	10:21:00	Fixed 20	118.70	5.43	644.541

FX20-East	8:28:00	Fixed 20	54.70	2.25	123.075
	9:16:00	Fixed 20	89.80	4.10	368.18
	10:22:00	Fixed 20	119.00	5.40	642.6
FXZ-South	8:29:00	Fixed 0	47.30	1.85	87.505
	9:16:00	Fixed 0	84.00	3.85	323.4
	10:23:00	Fixed 0	125.20	5.73	717.396
FXZ-North	8:30:00	Fixed 0	47.90	2.04	97.716
	9:17:00	Fixed 0	83.40	3.81	317.754
	10:24:00	Fixed 0	125.00	5.69	711.25

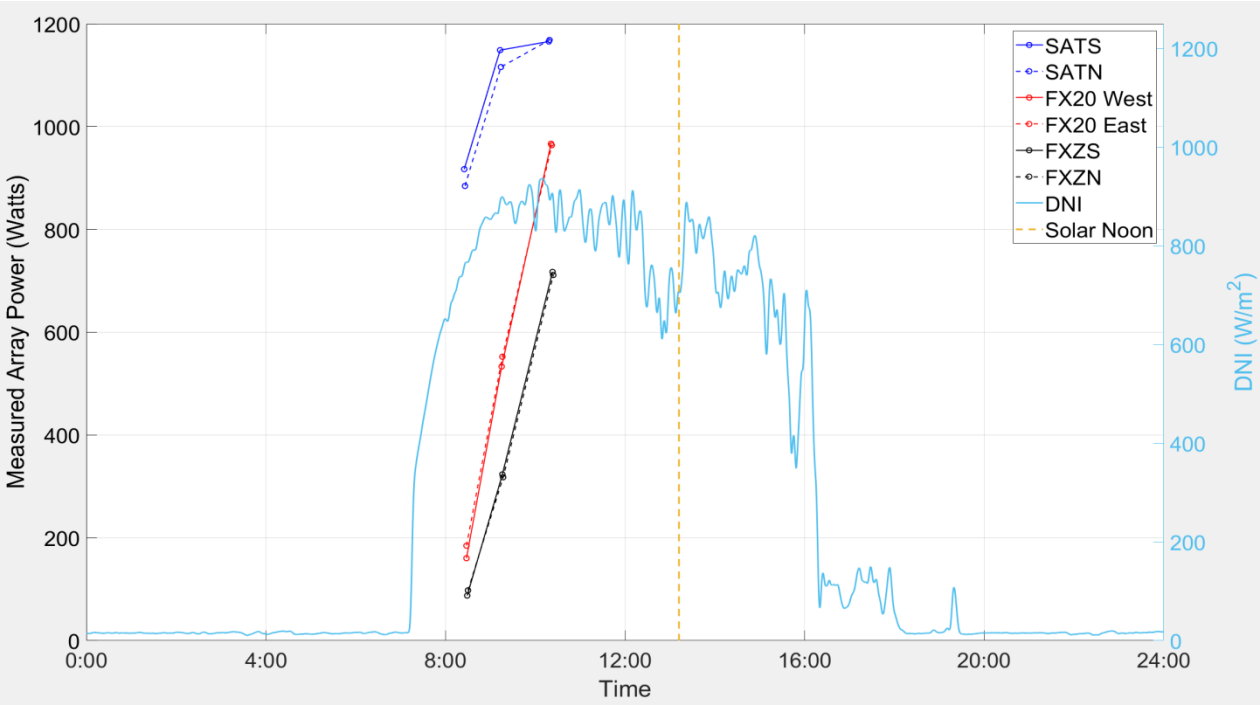


Figure 17: April 1st Power and DNI Plot

On April 1st power data was 8:20am, 9:15am, and 10:20am to show how the panels performed in the early morning. The SAT panels were the best overall at every time, attributed to their ability to track the sun while the other panels were not at optimal angles so early in the day. The FX20 panels out-performed the FXZ panels this early, but neither sets were close to the SAT panels, especially earlier in the morning.

2.14 April 6th

Table 14: April 6th Power Data

Array	Time	Angle (degrees)	Volts	Amps	Power (Watts)
SAT-South	10:40:00	20 East	171.20	7.96	1362.752
	12:15:00	10 East	171.00	7.86	1344.06
	13:05:00	0	38.20	1.72	65.704
SAT-North	10:41:00	20 East	169.30	7.86	1330.698
	12:16:00	10 East	172.50	7.91	1364.475
	13:06:00	0	33.90	1.53	51.867
FX20-West	10:43:00	Fixed 20	123.10	5.68	699.208
	12:17:00	Fixed 20	124.80	5.74	716.352
	13:07:00	Fixed 20	37.60	1.76	66.176
FX20-East	10:44:00	Fixed 20	123.30	5.68	700.344
	12:18:00	Fixed 20	125.00	5.79	723.75
	13:07:00	Fixed 20	36.80	1.72	63.296
FXZ-South	10:45:00	Fixed 0	139.00	6.35	882.65
	12:19:00	Fixed 0	167.90	7.75	1301.225
	13:08:00	Fixed 0	32.80	1.46	47.888
FXZ-North	10:45:00	Fixed 0	138.20	6.30	870.66
	12:20:00	Fixed 0	168.10	7.73	1299.413
	13:08:00	Fixed 0	32.50	1.05	34.125

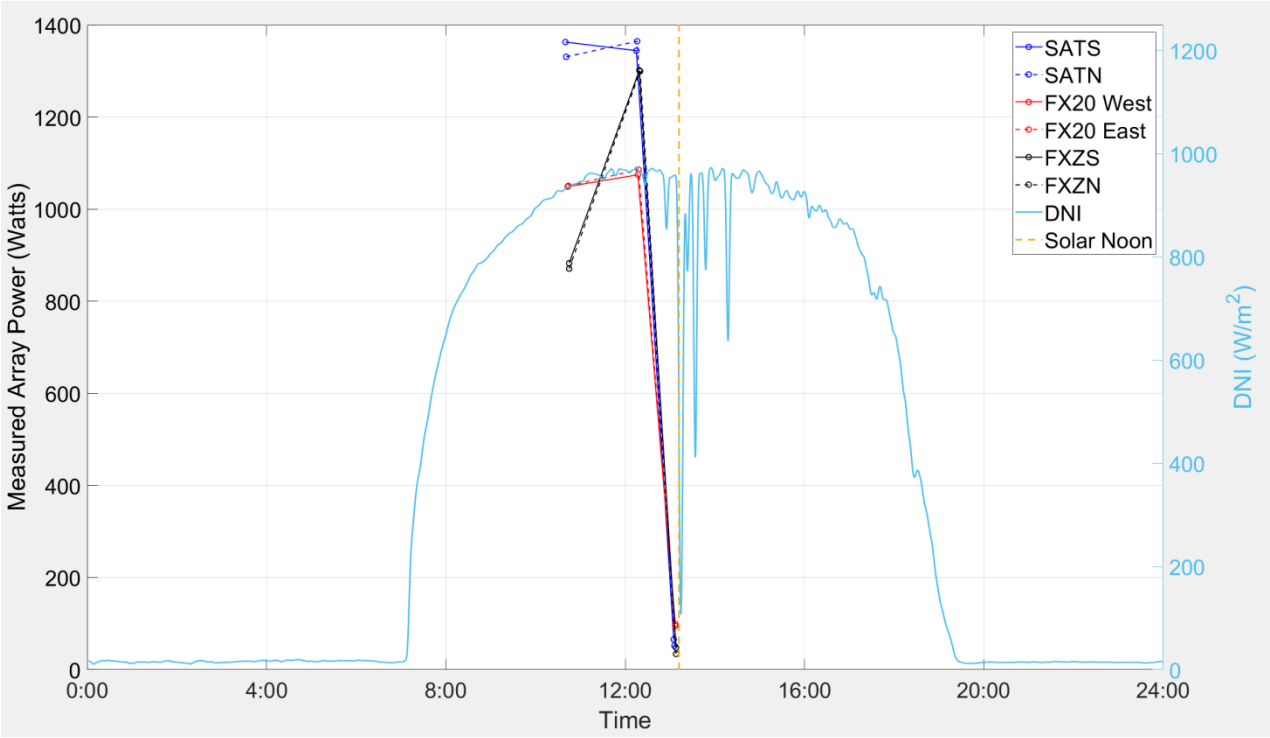


Figure 18: April 6th Power and DNI Plot

On April 6th power was recorded at approximately 10:40am, 12:20pm, and 1:00pm. The SAT panels performed the best in the morning and at noon. The FXZ panels had an increase at noon putting the power output near that of the SAT panels. However, at solar noon inclement weather arrived and all panels recorded large drops in power output.

2.15 May 10th

Table 15: May 10th Power Data

Array	Time	Angle (degrees)	Volts	Amps	Power (Watts)
SAT-South	12:39:00	4 East	167.60	7.62	1277.11
	13:07:00	8 West	166.30	7.67	1275.52
	13:58:00	10 East	166.80	7.72	1287.70
SAT-North	12:40:00	4 East	168.30	7.60	1279.08
	13:09:00	8 West	166.50	7.09	1180.49
	13:59:00	10 East	166.30	7.69	1278.85
FX20-West	12:42:00	Fixed 20	122.00	5.50	671.00
	13:10:00	Fixed 20	121.80	5.56	677.21
	14:00:00	Fixed 20	120.40	5.52	664.61
FX20-East	12:43:00	Fixed 20	123.10	5.44	669.66
	13:11:00	Fixed 20	121.50	5.56	675.54
	14:01:00	Fixed 20	120.70	5.50	663.85
FXZ-South	12:45:00	Fixed 0	168.30	7.50	1262.25
	13:12:00	Fixed 0	165.40	7.60	1257.04
	14:02:00	Fixed 0	165.00	7.62	1257.30
FXZ-North	12:46:00	Fixed 0	168.90	7.53	1271.82
	13:13:00	Fixed 0	167.10	7.79	1301.71
	14:03:00	Fixed 0	164.10	7.60	1247.16

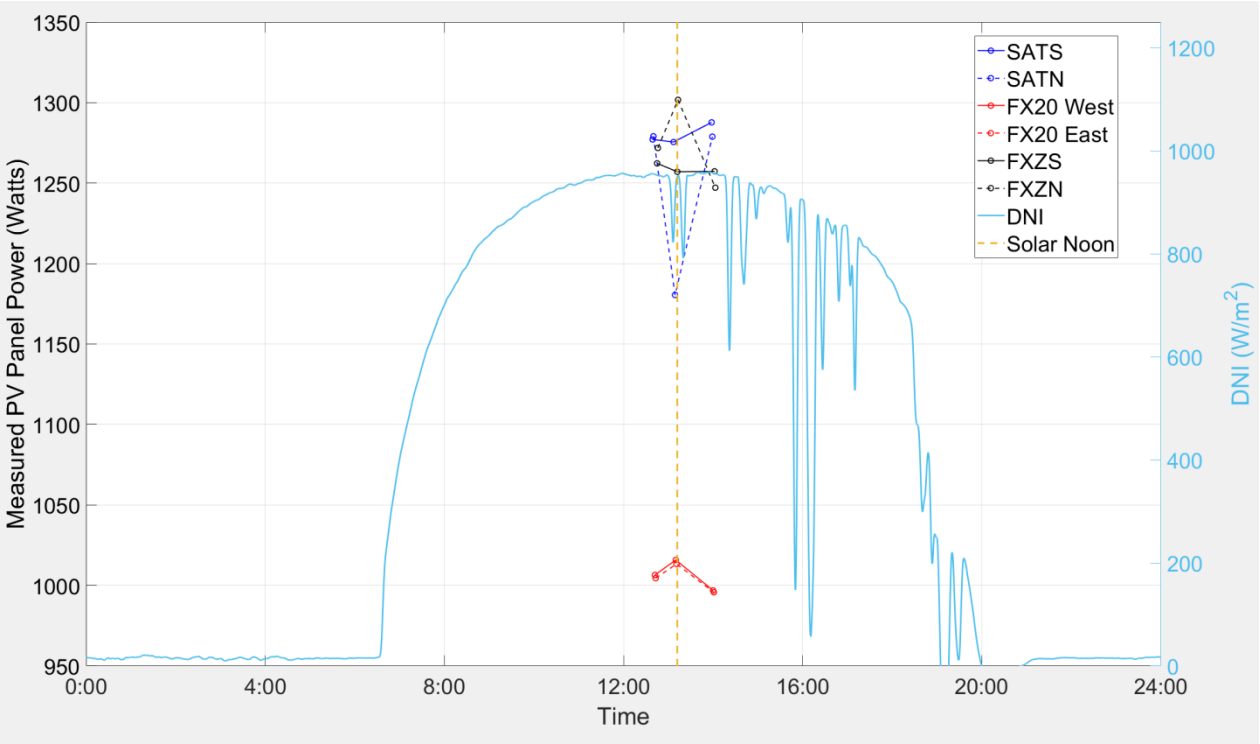


Figure 19: May 10th Power and DNI Plot

On May 10th power was recorded at approximately 12:40pm, 1:10pm, and 2:00pm. The SAT panels performed the best after solar noon. At solar noon cloud coverage started affecting the data and results became more sporadic, with the SATN panel dropping in power while the FXZN panel increased to nearly 1300 W. The adjusted power of the FX20 panels stayed consistently between 1000W and 1050 W.

2.16 May 19th

Table 16: May 19th Power Data

Array	Time	Angle (degrees)	Volts	Amps	Power (Watts)
SAT-South	10:32:00	15 East	165.40	7.58	1253.73
	10:55:00	22 East	168.40	7.73	1301.73
	12:31:00	1 East	162.40	7.64	1240.74
SAT-North	10:33:00	15 East	163.60	7.49	1225.36
	10:56:00	22 East	167.20	7.67	1282.42
	12:32:00	1 East	162.10	7.47	1210.89
FX20-West	10:34:00	Fixed 20	118.90	5.40	642.06
	10:57:00	Fixed 20	118.00	5.33	628.94
	12:33:00	Fixed 20	116.00	5.37	622.92
FX20-East	10:35:00	Fixed 20	119.60	5.41	647.04
	10:58:00	Fixed 20	118.60	5.32	630.95
	12:31:00	Fixed 20	117.30	5.41	634.59
FXZ-South	10:36:00	Fixed 0	145.70	6.60	961.62
	11:00:00	Fixed 0	152.00	6.95	1056.40
	12:34:00	Fixed 0	161.40	7.47	1205.66
FXZ-North	10:37:00	Fixed 0	145.40	6.63	964.00
	11:01:00	Fixed 0	153.70	6.93	1065.14
	12:35:00	Fixed 0	163.60	7.49	1225.36

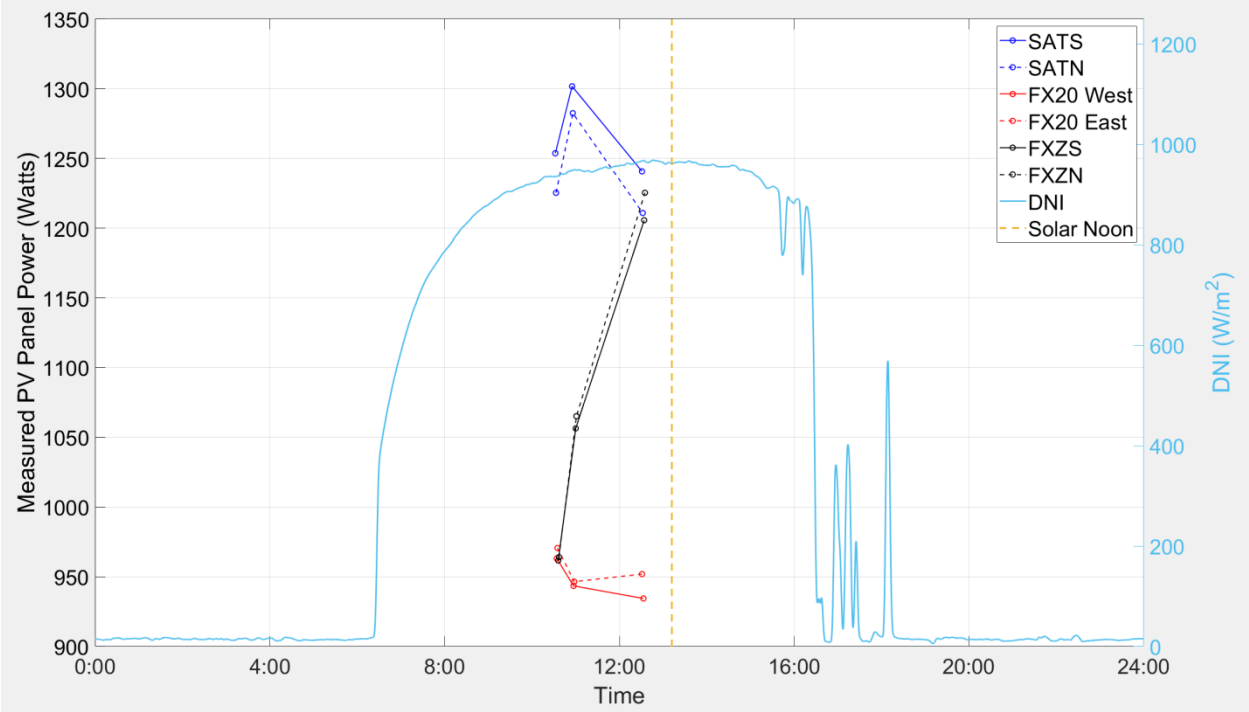


Figure 20: May 19th Power and DNI Plot

On May 19th power was recorded at approximately 10:30am, 11:00am, and 12:30pm. The SAT panels performed the best overall, peaking at 11:00am. The FXZ panels started low, with similar power to the FX20s. But by noon the FXZ panels were similar in power output to the SAT panels. The adjusted power of the FX20 panels stayed consistently around 950 W.

2.17 May 27th

Table 17: May 27th Power Data

Array	Time	Angle (degrees)	Volts	Amps	Power (Watts)
SAT-South	9:56:00	35 East	167.50	7.62	1276.35
	11:02:00	15 East	164.50	7.44	1223.88
	13:28:00	10 West	163.00	7.47	1217.61
SAT-North	9:57:00	35 East	165.00	7.57	1249.05
	11:04:00	15 East	161.25	7.47	1204.54
	13:28:00	10 West	164.00	7.44	1220.16
FX20-West	9:57:00	Fixed 20	116.60	5.30	617.98
	11:04:00	Fixed 20	117.20	5.32	623.50
	13:30:00	Fixed 20	118.10	5.36	633.02
FX20-East	10:00:00	Fixed 20	116.80	5.16	602.69
	11:05:00	Fixed 20	116.50	5.36	624.44
	13:31:00	Fixed 20	117.10	5.34	625.31
FXZ-South	10:01:00	Fixed 0	126.30	5.80	732.54
	11:06:00	Fixed 0	159.00	7.21	1146.39
	13:32:00	Fixed 0	161.45	7.36	1188.27
FXZ-North	10:02:00	Fixed 0	138.90	6.23	865.35
	11:07:00	Fixed 0	145.20	7.20	1045.44
	13:33:00	Fixed 0	158.50	7.33	1161.81

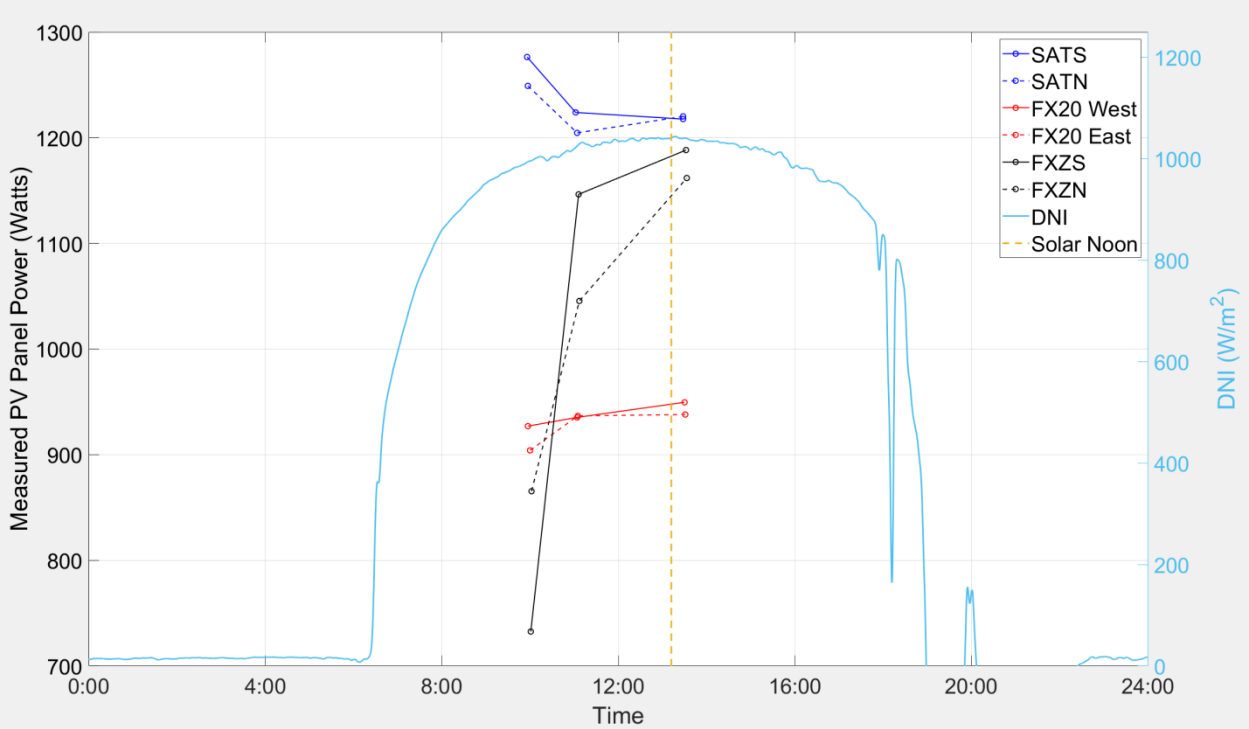


Figure 21: May 27th Power and DNI Plot

On May 27th power was recorded at approximately 10:00am, 11:00am, and 1:30pm. The SAT panels performed the best overall, peaking at 10:00am. The FXZ panels started low, with power lower than even the FX20s. But by solar noon the FXZ panels were similar in power output to the SAT panels, though not as high. The adjusted power of the FX20 panels stayed consistently around 950 W, though the power was higher at solar noon.

2.18 May 28th

Table 18: May 28th Power Data

Array	Time	Angle (degrees)	Volts	Amps	Power (Watts)
SAT-South	10:38:00	30 East	166.90	7.57	1263.43
	11:12:00	13 East	163.20	7.44	1214.21
	14:28:00	7 West	162.90	7.47	1216.86
SAT-North	10:40:00	30 East	166.20	7.51	1248.16
	11:14:00	13 East	162.90	7.47	1216.86
	14:29:00	7 West	162.40	7.44	1208.26
FX20-West	10:41:00	Fixed 20	117.50	5.29	621.58
	11:14:00	Fixed 20	117.20	5.32	623.50
	14:30:00	Fixed 20	117.40	5.36	629.26
FX20-East	10:42:00	Fixed 20	118.10	5.23	617.66
	11:15:00	Fixed 20	117.90	5.36	631.94
	14:31:00	Fixed 20	117.60	5.34	627.98
FXZ-South	10:43:00	Fixed 0	125.40	6.34	795.04
	11:16:00	Fixed 0	158.60	7.21	1143.51
	14:32:00	Fixed 0	161.30	7.36	1187.17
FXZ-North	10:44:00	Fixed 0	153.00	6.93	1060.29
	11:17:00	Fixed 0	159.30	7.20	1146.96
	14:33:00	Fixed 0	161.20	7.33	1181.60

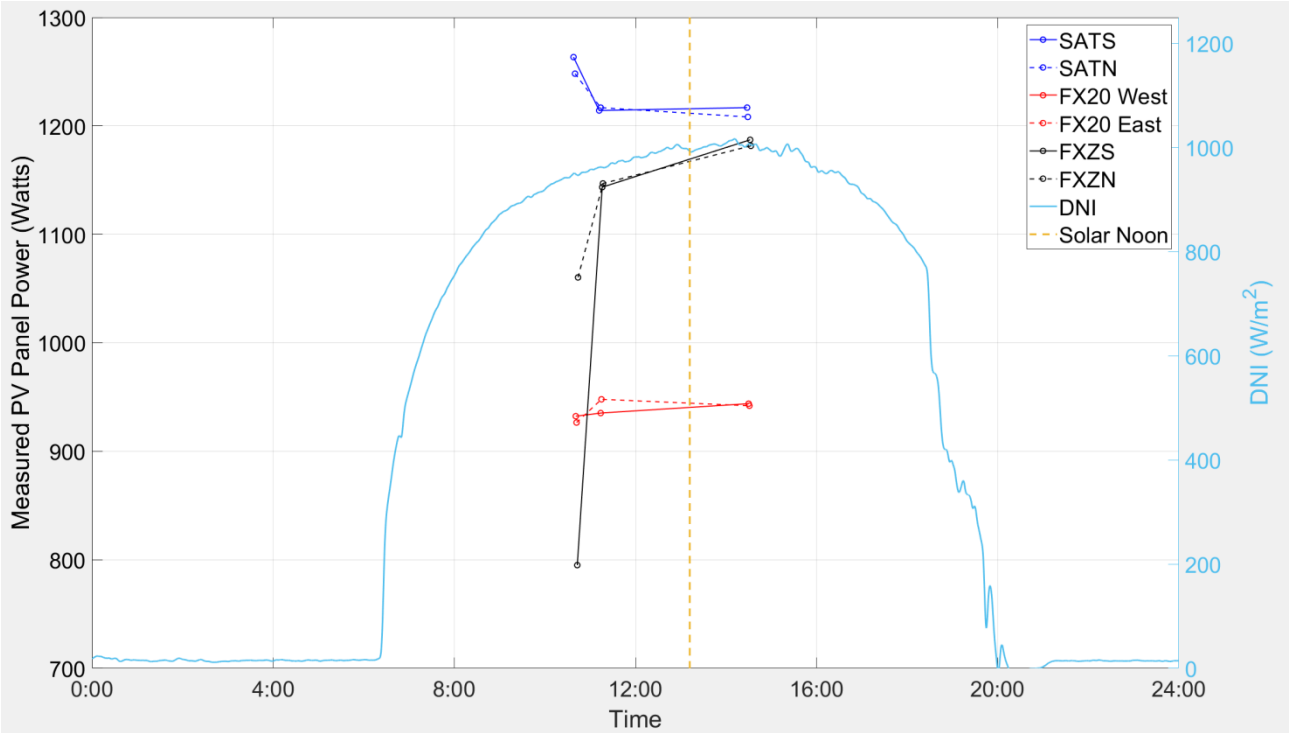


Figure 22: May 28th Power and DNI Plot

On May 28th power was recorded at approximately 10:40am, 11:20am, and 2:30pm. The SAT panels performed the best overall, peaking at 10:40am. The FXZS panels started low, possibly due to momentary cloud interference, while the FXZN panel was above 1100Watts which is typical for this time of day and DNI. By solar noon the FXZ panels were similar in power output to the SAT panels, though not as high. The adjusted power of the FX20 panels stayed consistently around 950 W.

2.19 June 17th

Table 19: June 17th Power Data

Array	Time	Angle (degrees)	Volts	Amps	Power (Watts)
SAT-South	9:02:00	40 East	156.10	7.20	1123.92
	10:32:00	32 East	155.40	7.05	1095.57
	12:06:00	1 East	164.10	7.23	1186.44
SAT-North	9:03:00	40 East	156.50	6.96	1089.24
	10:33:00	32 East	155.90	6.95	1083.51
	12:07:00	1 East	161.50	7.15	1154.73
FX20-West	9:05:00	Fixed 20	94.20	3.25	306.15
	10:35:00	Fixed 20	115.60	4.75	549.10
	12:08:00	Fixed 20	118.40	5.24	620.42
FX20-East	9:06:00	Fixed 20	96.30	3.28	315.86
	10:35:00	Fixed 20	114.80	4.93	565.96
	12:10:00	Fixed 20	118.90	5.18	615.90
FXZ-South	9:08:00	Fixed 0	96.50	3.89	375.39
	10:36:00	Fixed 0	138.00	5.78	797.64
	12:11:00	Fixed 0	156.40	7.12	1113.57
FXZ-North	9:09:00	Fixed 0	95.20	3.91	372.23
	10:37:00	Fixed 0	137.60	5.72	787.07
	12:12:00	Fixed 0	155.90	7.22	1125.60

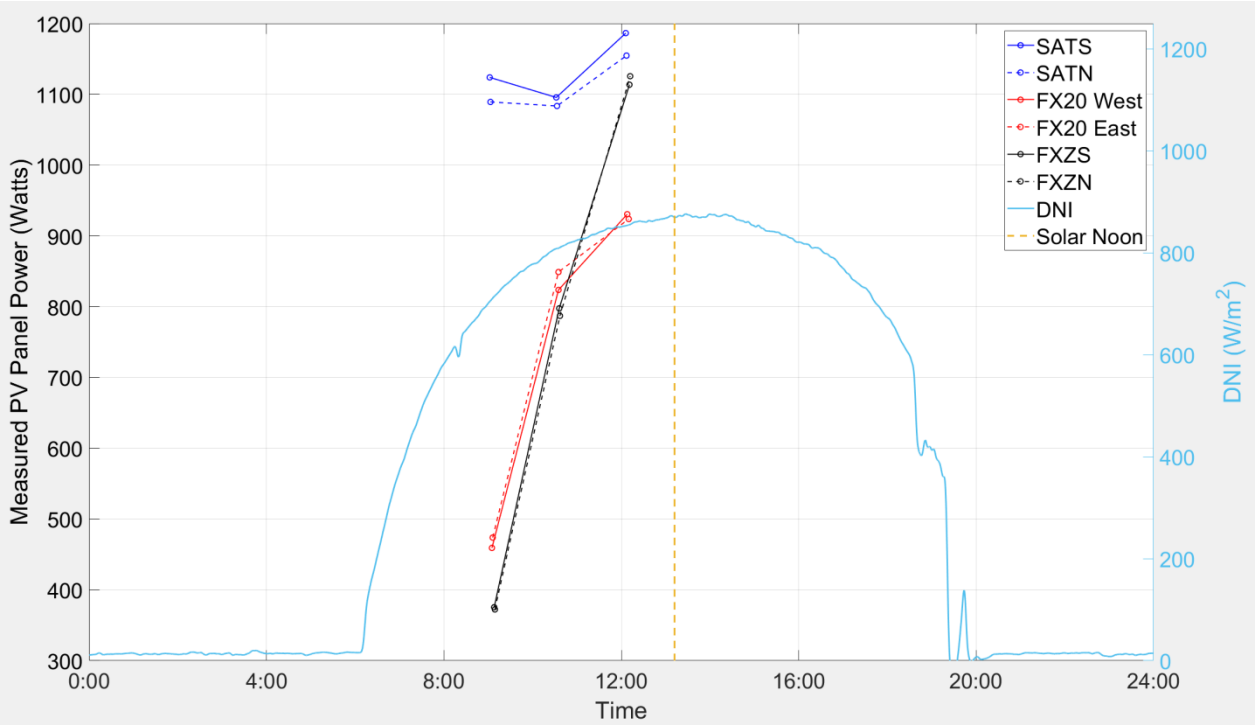


Figure 23: June 17th Power and DNI Plot

On June 17th power was recorded at approximately 9:00am, 10:30am, and 12:00pm. The DNI for this day was low compared to days data was recorded in May. The peak DNI was just above 800 W/m². The SAT panels performed the best overall, peaking at 12:00pm. The FXZ panels started very low, though the corresponding DNI was just approximately 700 W/m². By solar noon the FXZ panels were similar in power output to the SAT. The FX20 panels also started very low, but continuously increased until reaching a peak output of approximately 900 W by 12:00pm. 900 W is a fairly typical output for the FX20 panels in the afternoon and at DNI of 800W/m² or higher.

2.20 June 23rd

Table 20: June 23rd Power Data

Array	Time	Angle (degrees)	Volts	Amps	Power (Watts)
SAT-South	8:48:00	45 East	158.80	7.20	1143.36
	10:04:00	45 East	156.10	7.14	1114.55
	11:03:00	26.5 East	162.50	7.33	1191.13
SAT-North	8:50:00	45 East	156.40	6.99	1093.24
	10:05:00	45 East	156.10	7.07	1103.63
	11:04:00	26.5 East	162.80	7.26	1181.93

FX20-West	8:54:00	Fixed 20	74.80	3.15	235.62
	10:07:00	Fixed 20	107.00	4.83	516.81
	11:06:00	Fixed 20	116.40	5.22	607.61
FX20-East	8:55:00	Fixed 20	74.20	3.15	233.73
	10:08:00	Fixed 20	108.20	4.85	524.77
	11:07:00	Fixed 20	115.80	5.21	603.32
FXZ-South	8:56:00	Fixed 0	90.00	3.73	335.70
	10:09:00	Fixed 0	125.60	5.68	713.41
	11:08:00	Fixed 0	155.10	7.00	1085.70
FXZ-North	8:57:00	Fixed 0	91.40	3.75	342.75
	10:10:00	Fixed 0	124.20	5.72	710.42
	11:09:00	Fixed 0	156.10	6.98	1089.58

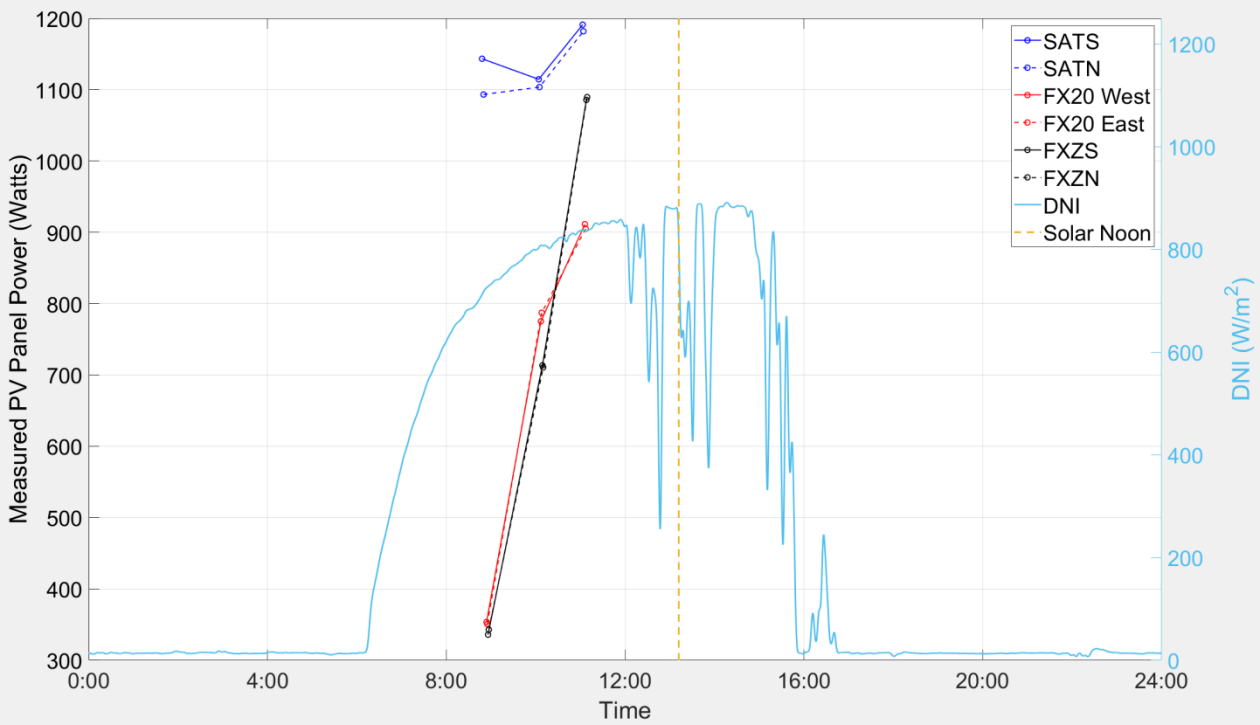


Figure 24: June 23rd Power and DNI Plot

On June 23rd power was recorded at approximately 9:00am, 10:00am, and 11:00am. The DNI for this day was low compared to days data was recorded in April and May, and by the afternoon there was heavy cloud coverage. The SAT panels performed the best overall, peaking at 11:00am. The FXZ panels started very low, though the corresponding DNI was only approximately 750 W/m2. By solar noon the FXZ panels were similar in power output to the SAT panels. The FX20 panels also started very low, but continuously increased until reaching a peak output of approximately 900Watts by 11:00am. 900 W is a

fairly typical output for the FX20 panels in the afternoon and at DNI of 800W/m2 or higher.

2.21 Maximum Power Output vs Date

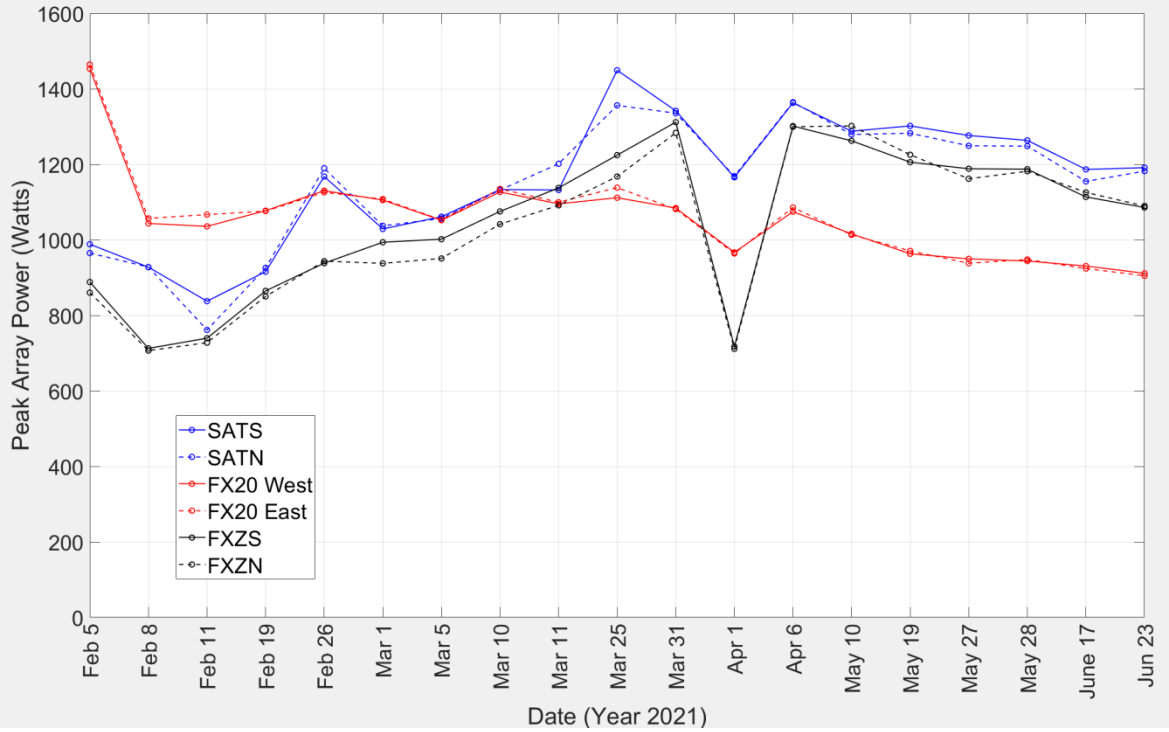


Figure 25: Maximum Daily Power Output by Array

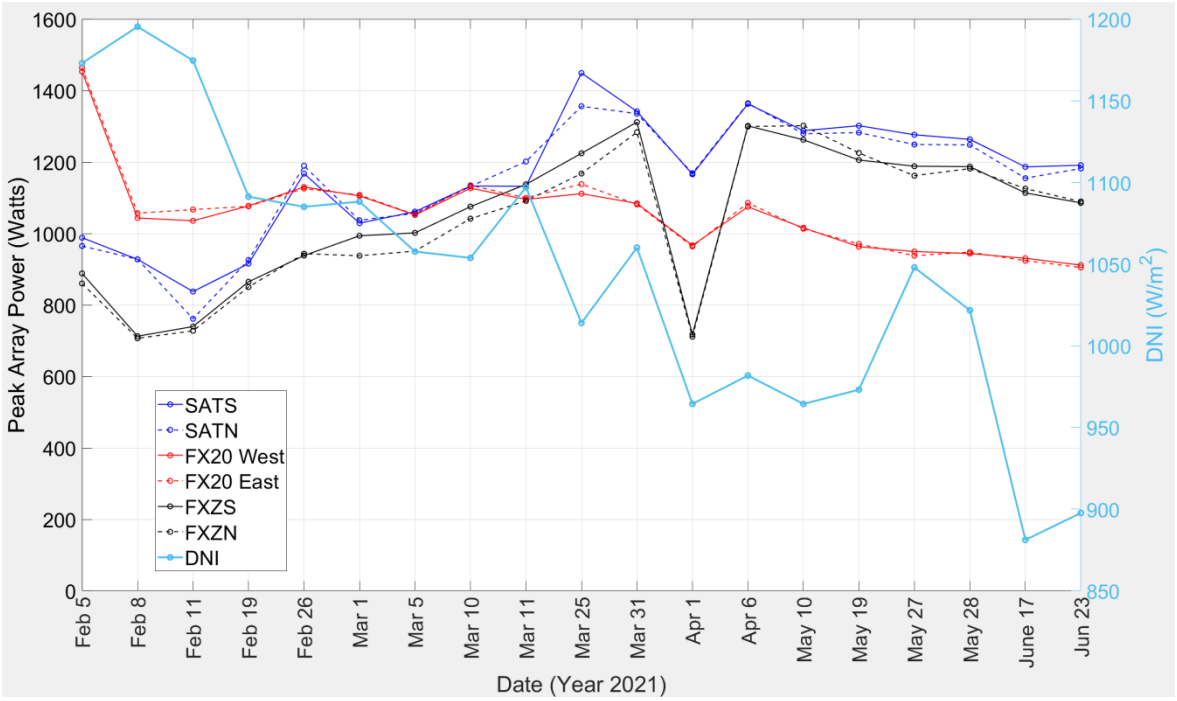


Figure 26: Maximum Daily Power Output by Array VS DNI

The figures above show the maximum power value recorded by each panel set on each day data was collected. The first graph shows the power data alone, while the second graph shows the power data plotted against the maximum DNI recorded each day. In February and early March, the FX20 panels performed the best. However, by March 10th-11th the FXZ and SAT panels exceeded the FX20 panels. From this date on, the sun tracking SAT panels had the highest power output. However, the FX20 did not experience any significant drop in power output throughout the year. For most days data was collected, the FX20 panels output 900-1100 W, regardless of the daily peak DNI which varied between 800-1200W/m^2. This is in stark contrast to the FXZ and SAT panels, which had maximum power outputs between 800-1000 W in February and slowly increased to outputs between 1200-1400Watts in March through June. The FXZ panels tend to closely follow the trends of the SAT panels throughout the year. However, the FXZ panels never surpassed the SAT panels in power output. The peak daily power of the FXZ panels was always lower than the SAT panels. In addition, the FXZ panels never maintained powers similar to the SAT panels for a long duration. While the SAT panels would stay above 1100-1200 W output for most of the day, the FXZ panels would only reach similar values between 12:00-2:00pm.

3. Accelerometer Data

The following graphs are the accelerometer data collected from the Ganged PV array. The accelerometers used are ADXL335 by SparkFun. These accelerometers take analog voltage measurements in the X, Y, and Z direction. Each one of the accelerometers had to be calibrated with the capturing system (Arduino Mega 2560). To calibrate the accelerometers each were placed on all six sides to get a -1G to 1G reading.

After calibration and development of the interface software, 10 accelerometers were placed under the panels and data was taken at 10hz over a 5-minute period. This data was then processed using a Fast Fourier Transform (FFT). Wind data was collected from the field wind speed, where it is recorded every 5 seconds.

Because wind data was not producing significant frequencies for the fast fourier transform, it was then decided to take data the same way that was used for the “Dynamic Load Mechanical Modeling of a Ganged Heliostat” did. The methods used in the paper were to produce multiple frequencies with different techniques. The first required a side to side motion input, with the

second producing a roll by lifting one cable and pushing down the other, the last required pushing each steel suspension cable up and down continuously and equally. The saddle produced the most wave forms relative to the wind data. The data on the legend represents each axis from 5 accelerometers.

3.1 Accelerometer Data with First Style of Accelerometer Placement
3.2

The first set of data was taken the same way as the "Dynamic Load Mechanical Modeling of a Ganged Heliostat".

The next images show the accelerometer placement when using this vibration technique.

Figure 27: FXZ and SAT Array Accelerometer Second Placement

Figure 28: FX20 Array Accelerometer Placement

Figure 29: Saddle Accelerometer Placement

The following images show the collected data. It can be seen that the wind data does not have much effect on the system when compared to an even more harsh environment.

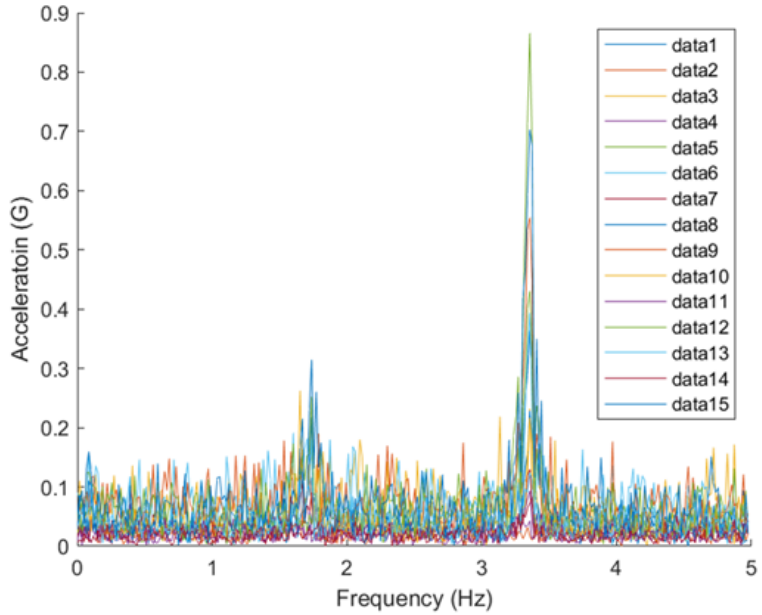


Figure 30: Saddle First Technique

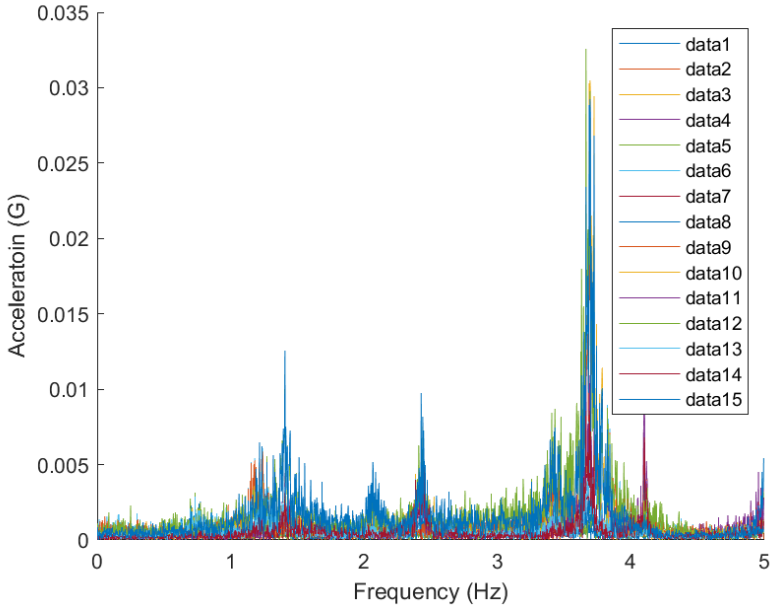


Figure 31: Saddle 1/19/21 (35 mph wind)

The saddle shows a decrease in activity at 35 MPH wind speeds compared to the extreme environment testing, but there are still significant amounts of mode frequencies displayed. All graphs will be attached at the end for reference. The SAT showed minimal amounts of mode

shapes, but more than the fixed counter parts.

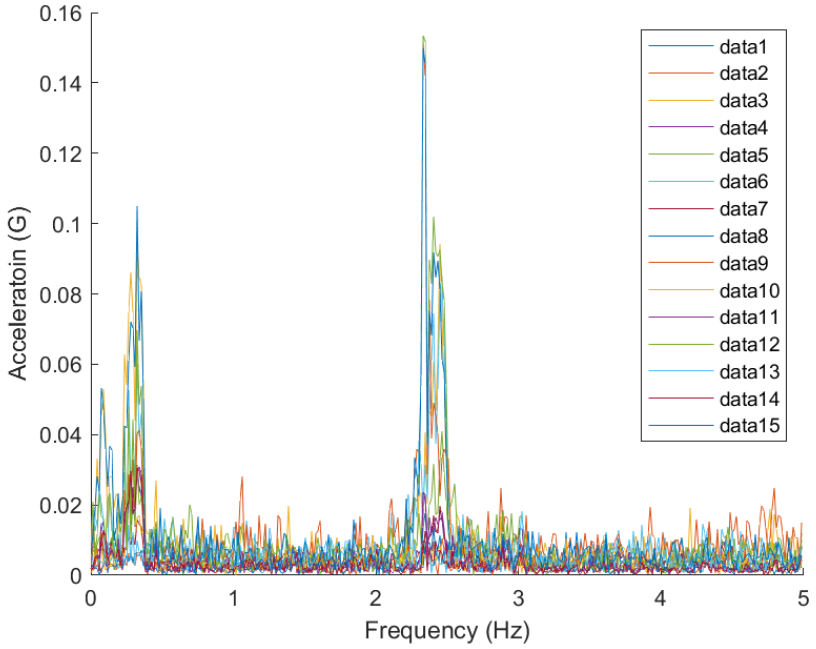


Figure 32: SAT-N First Technique

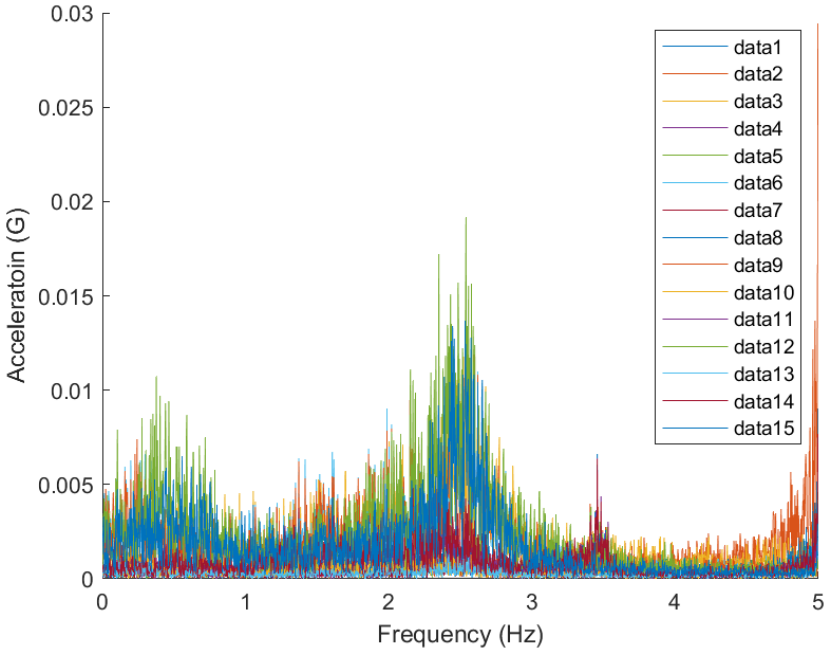


Figure 33: SAT-N 1/19/21 (35 mph wind)

The same mode shape is seen, but the magnitude of the vibration is much less. These tests were done at the "stowed," position with the panels at 0 degrees. Also, FXZ-N and FXZ-20 both

showed even less movement than SAT because of the added structural rigidity from not being able to rotate.

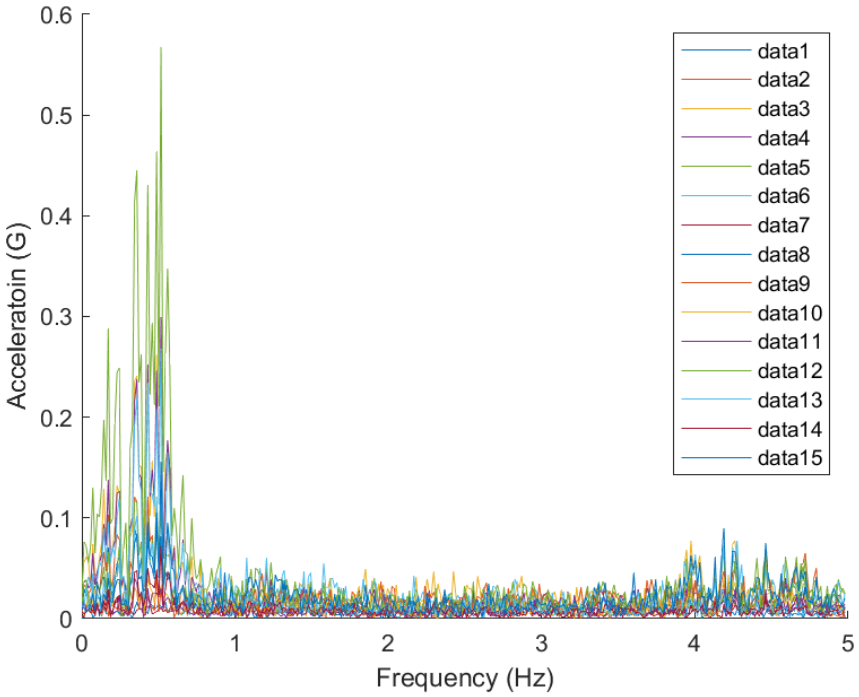


Figure 34: FX-20 Second Technique

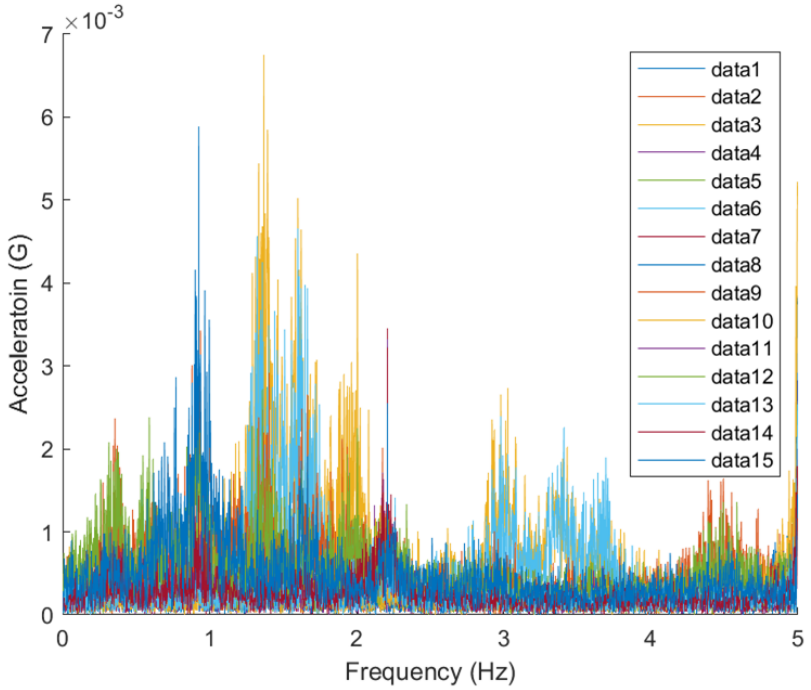


Figure 35: FX-20 East 1/19/21 (35 mph wind)

The second technique saw the largest peak accelerations but with little frequency.

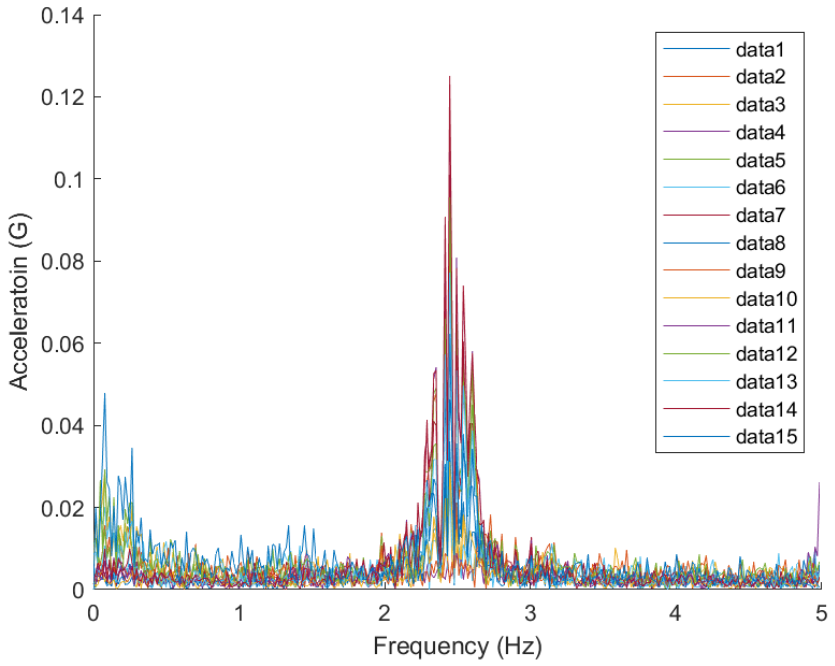


Figure 36: FXZ-N First Technique

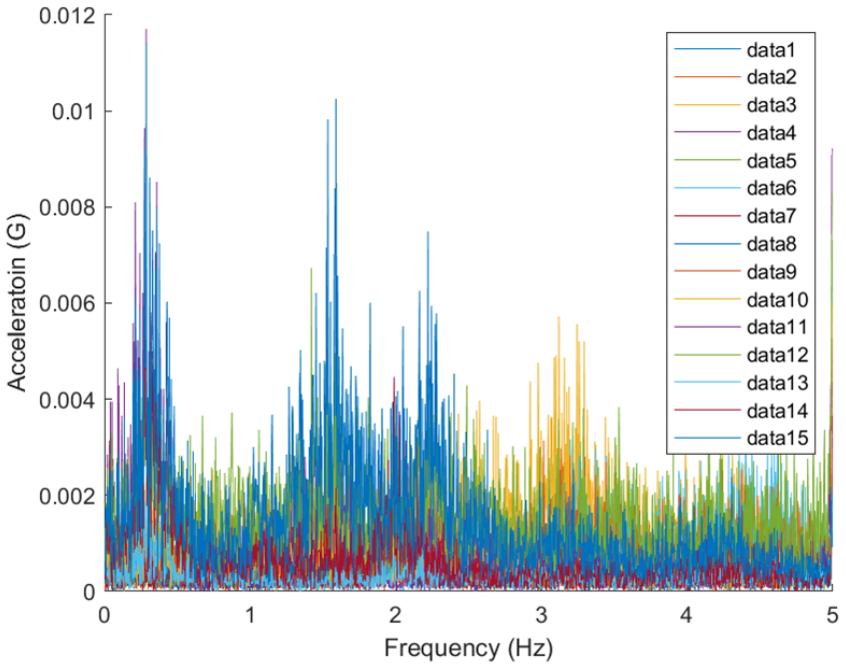


Figure 37: FXZ-North 1/19/21 (35 mph wind)

Peaks from SAT-N South 1/19/21 come from the accelerometer falling off the panel itself.

3.3 Accelerometer Data with Second Style of Accelerometer Placement

A second arrangement of accelerometers was also used for collecting data. Below are the placements of the accelerometers when taking wind data.

Figure 38: FXZ and SAT Array Accelerometer Placement

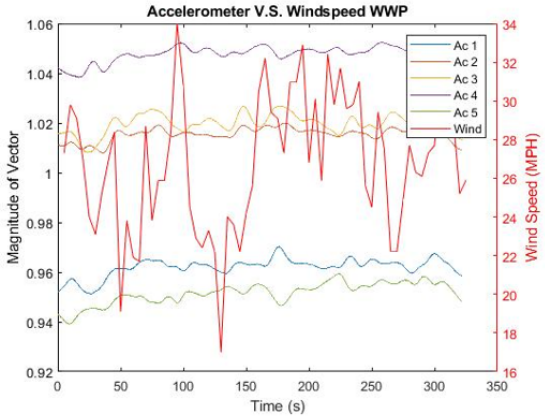
Figure 39: FX20 Array Accelerometer Placement

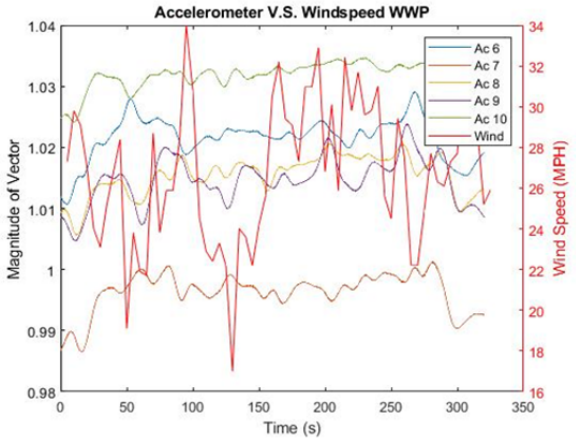
Figure 40: Saddle Accelerometer Placement

The following images show the data collected from this method.

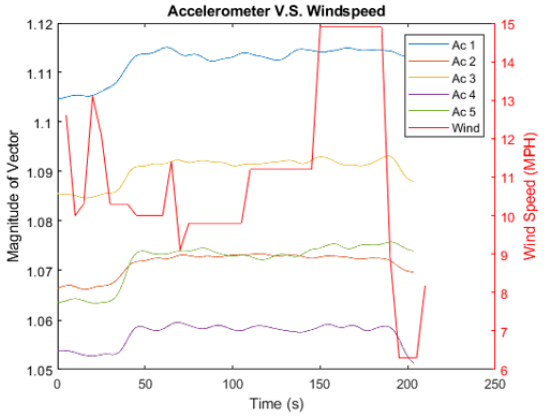
Date

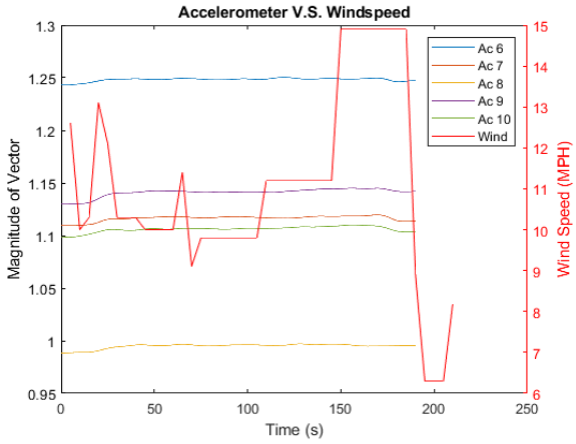
1/19/21



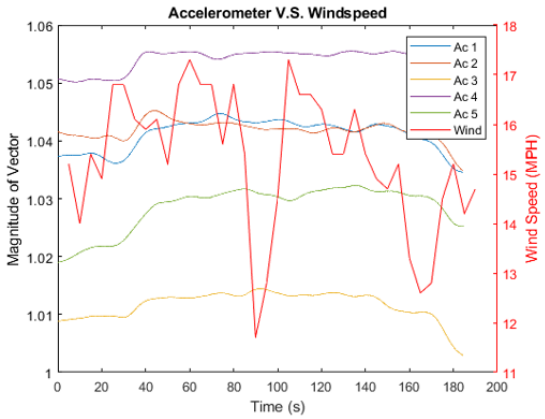


3/11/21





3/25/21



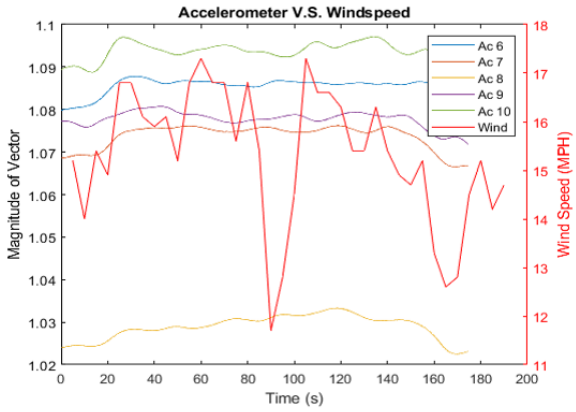
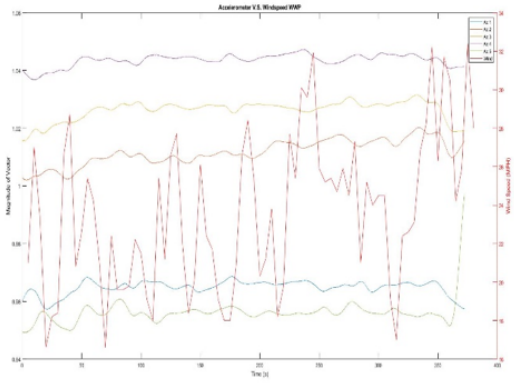
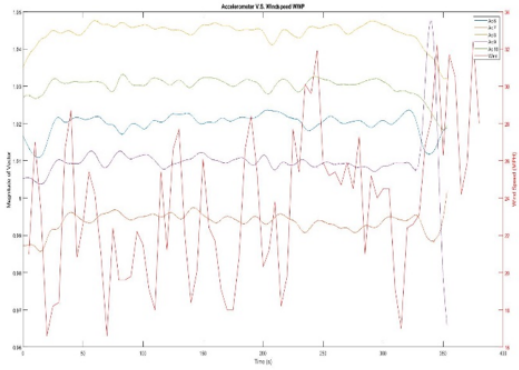


Figure 41: SAT-S South Panel Accelerometer VS Windspeed Data by Date

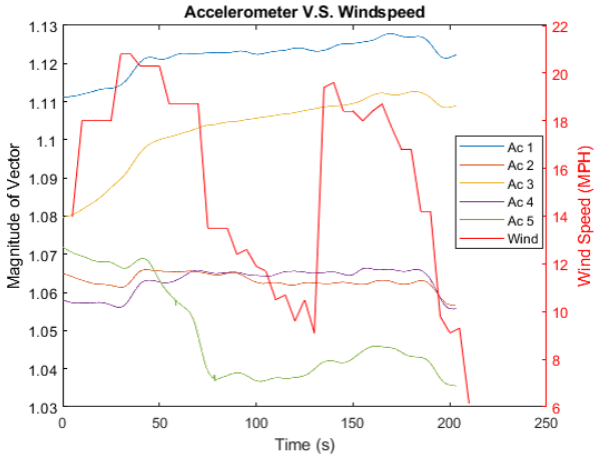
Date

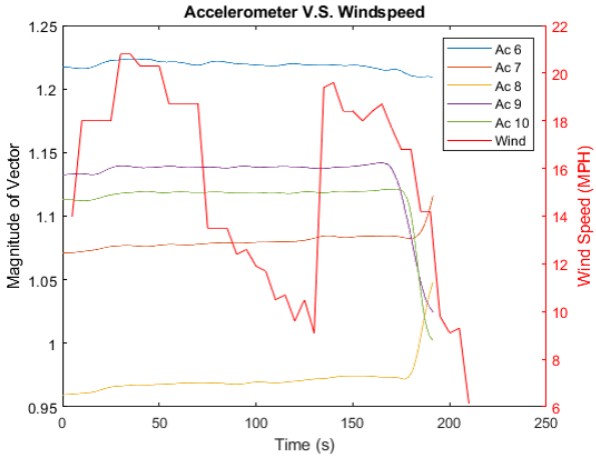
1/19/21



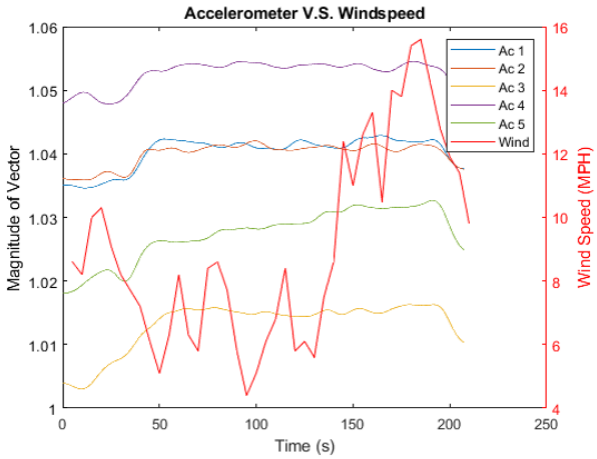


3/11/21





3/25/21



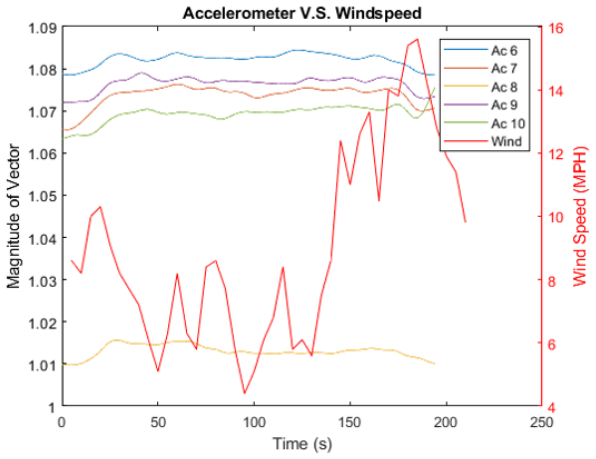
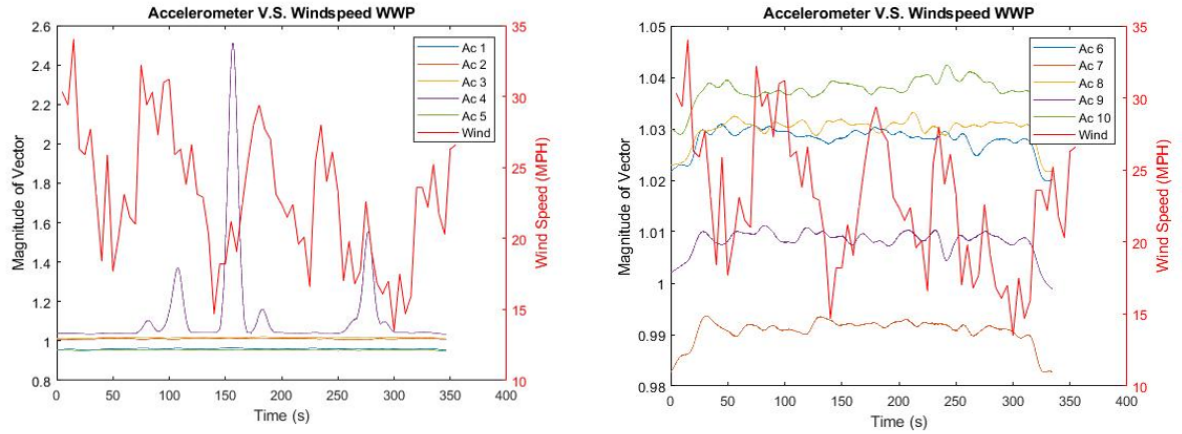


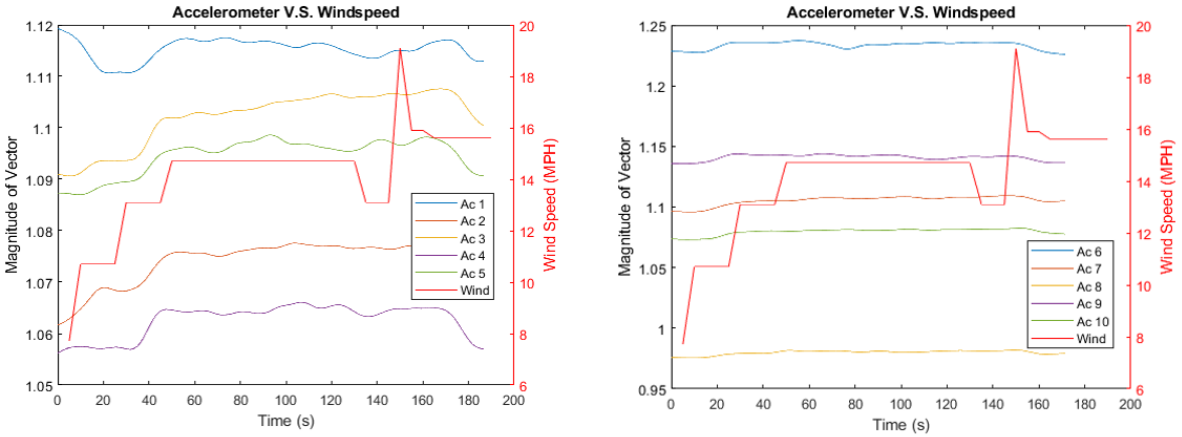
Figure 42: SAT-S North Panel Accelerometer VS Windspeed Data by Date

Date

1/19/21



3/11/21



3/25/21

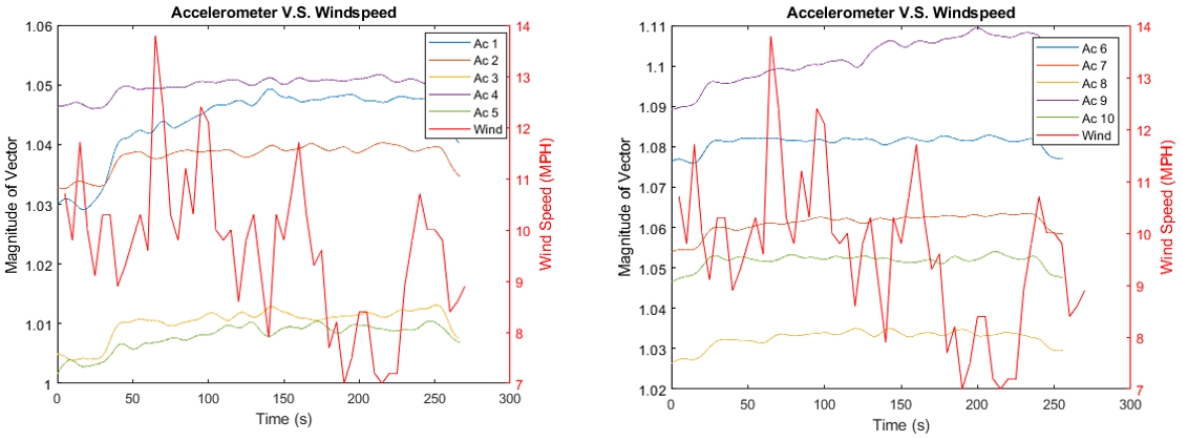
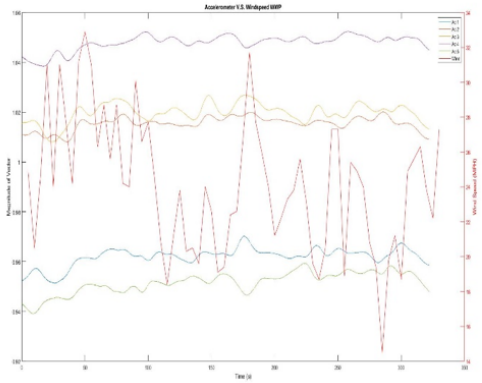
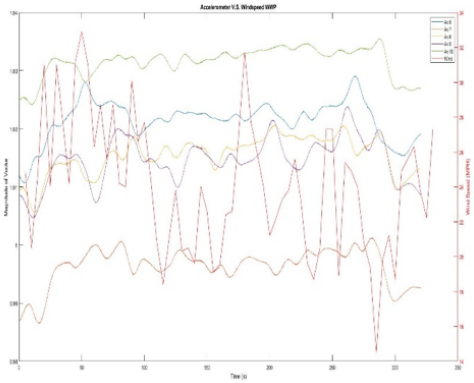


Figure 43: SAT-N South Panel Accelerometer VS Windspeed Data by Date

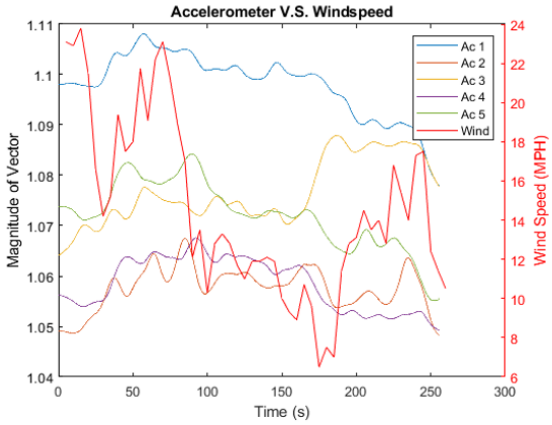
Date

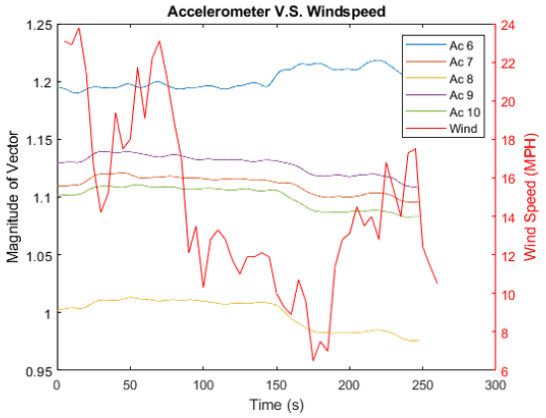
1/19/21



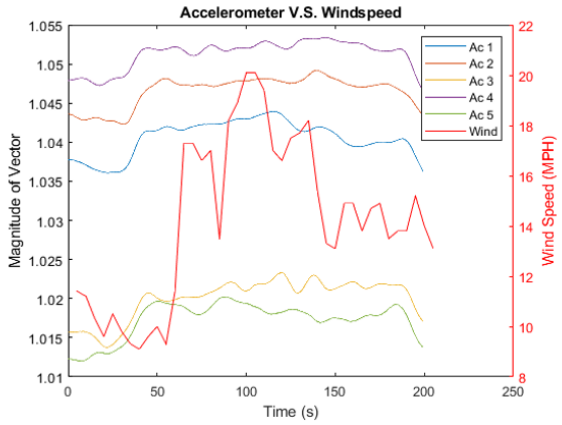


3/11/21





3/25/21



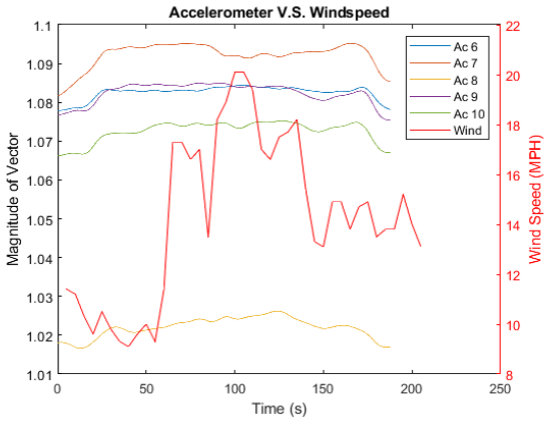
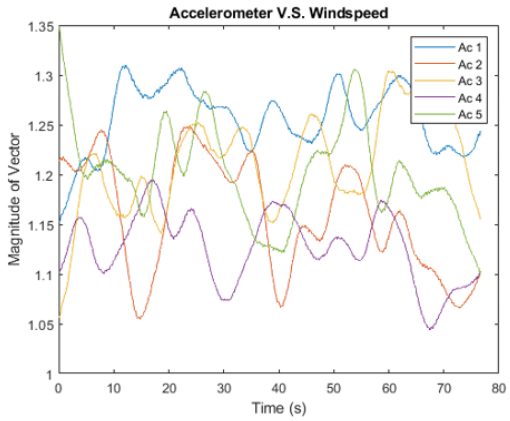
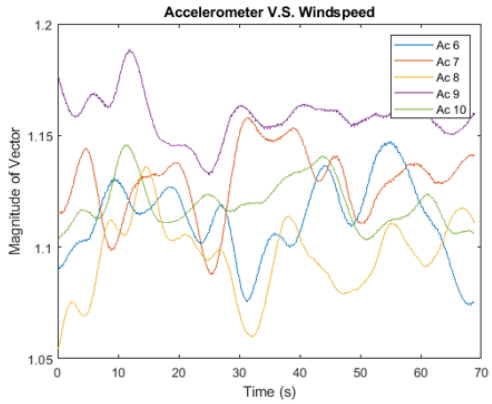


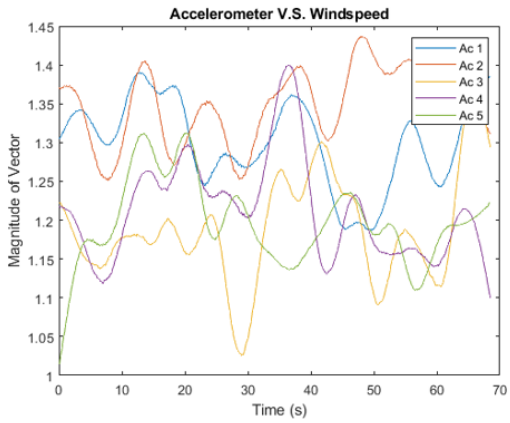
Figure 44: SAT-N North Panel Accelerometer VS Windspeed Data by Date

SAT S
4/15/21





SAT N
4/15/21



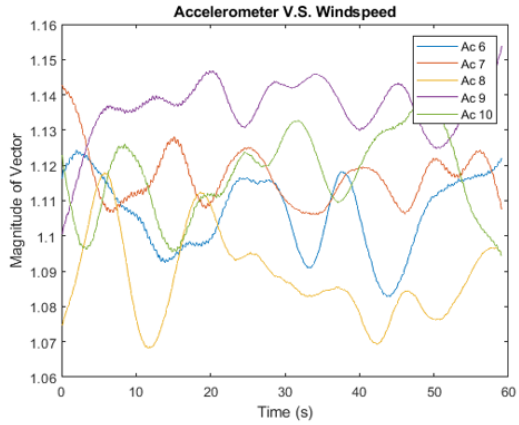
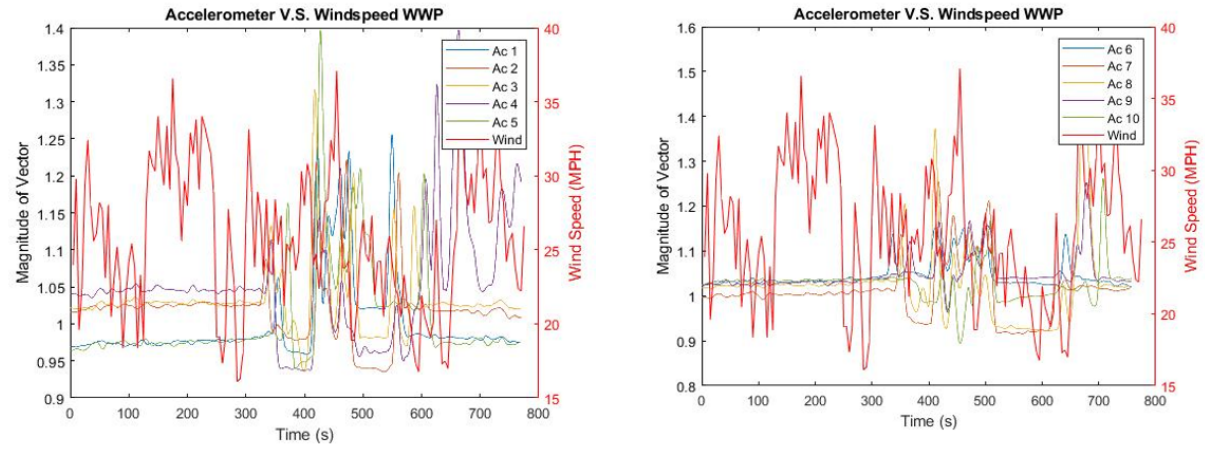


Figure 45: SAT-S/N Panel Accelerometer VS Windspeed Data by Date

Date

1/19/21



2/22/21

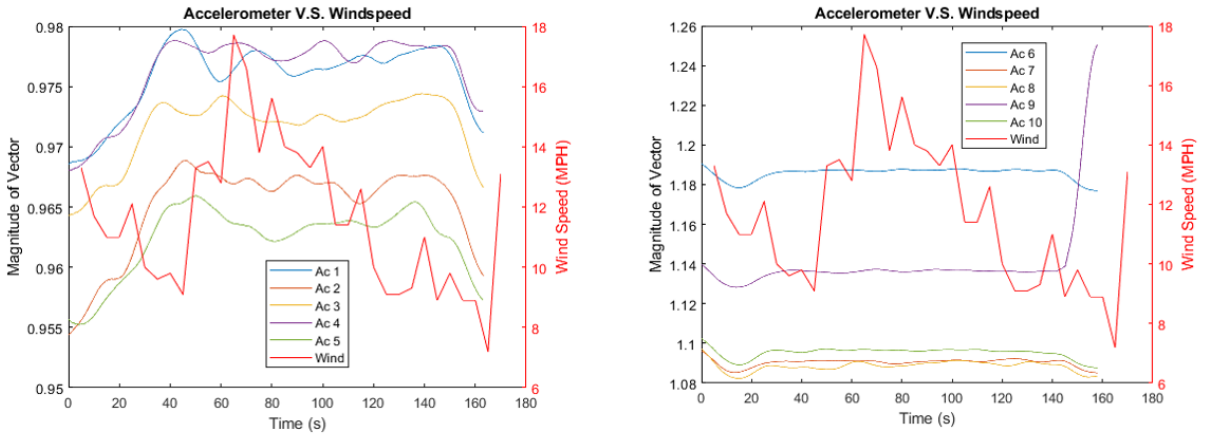
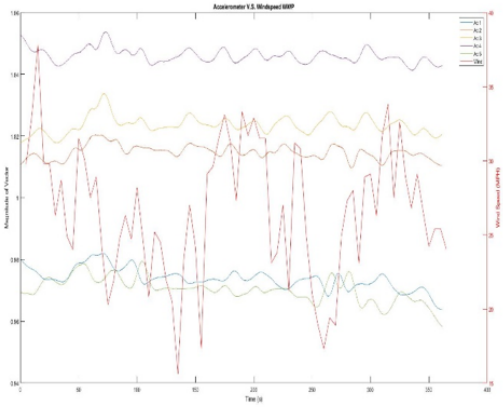


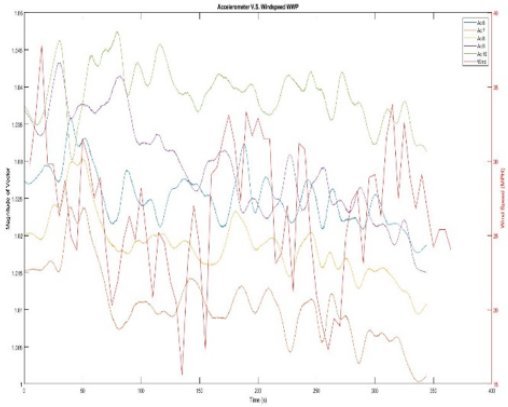
Figure 46: FXZ-S South Panel Accelerometer VS Windspeed Data by Date

1/19/21 shows the program not shutting off correctly and the accelerometers being moved to the next set of panels.

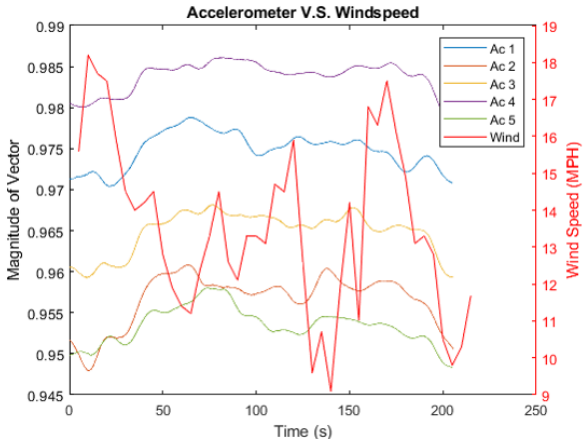
Date

1/19/21





2/22/21



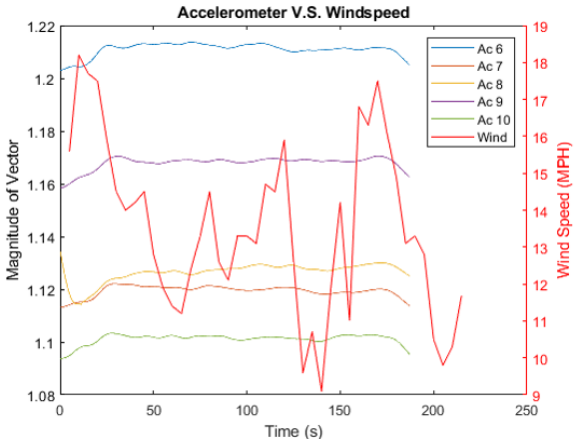
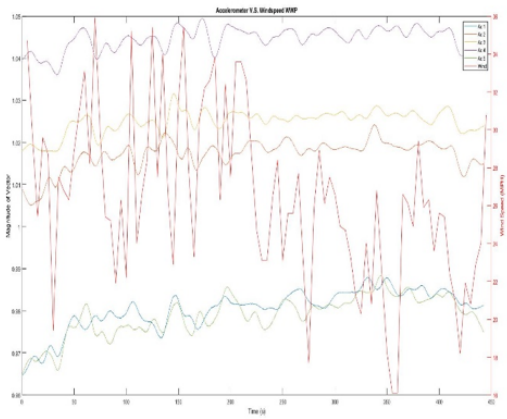
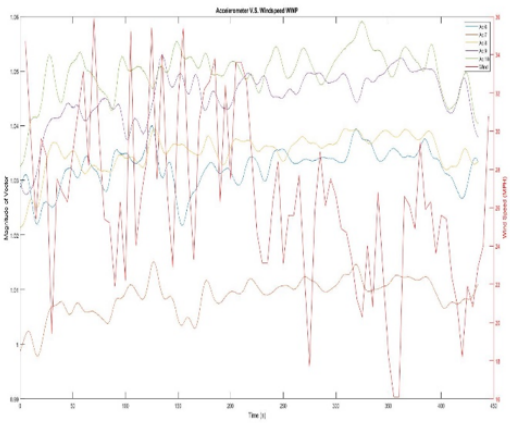


Figure 47: FXZ-S North Panel Accelerometer VS Windspeed Data by Date

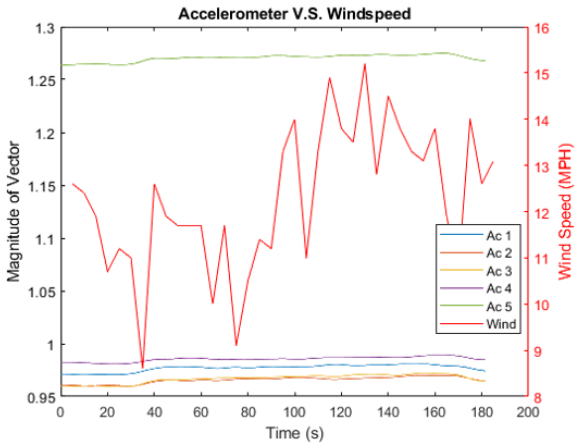
Date

1/19/21





2/22/21



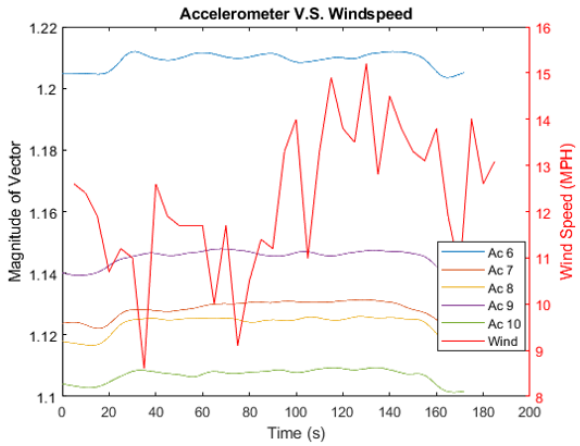
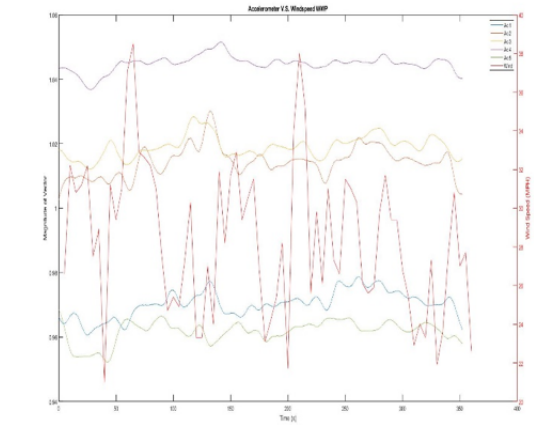
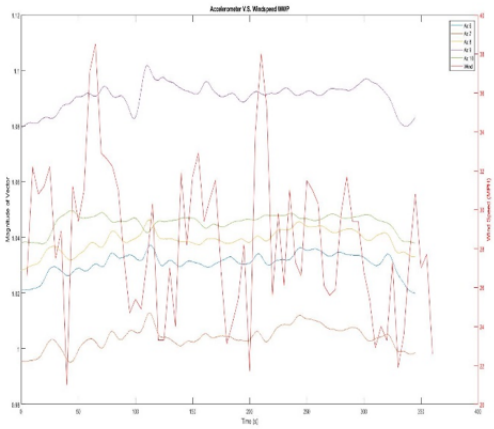


Figure 48: FXZ-N South Panel Accelerometer VS Windspeed Data by Date

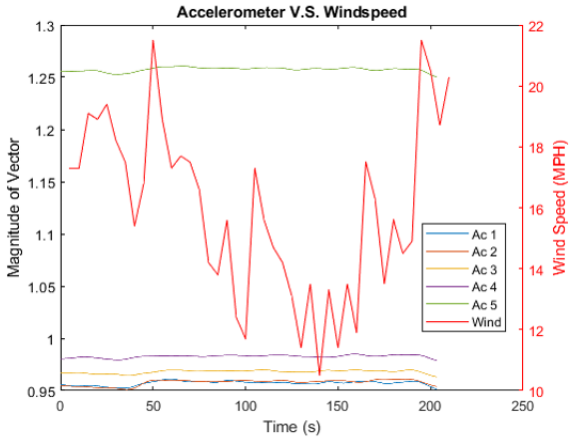
Date

1/19/21





2/22/21



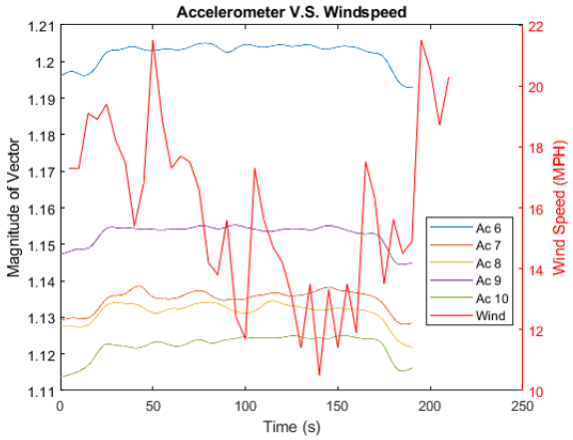


Figure 49: FXZ-N North Panel Accelerometer VS Windspeed Data by Date

FXZ-N 4/15/21

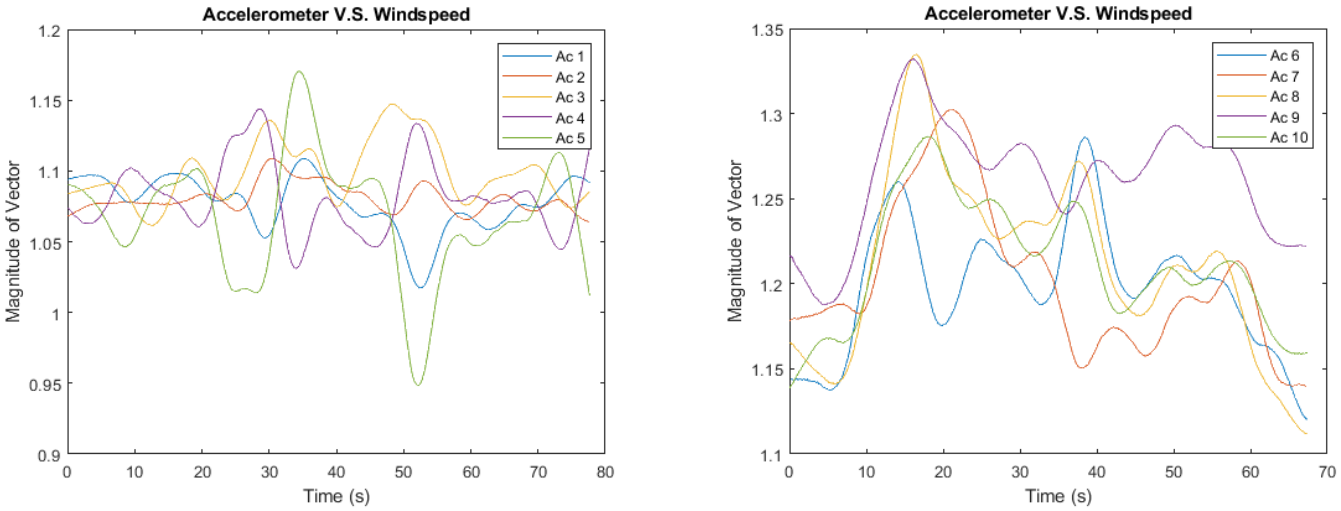
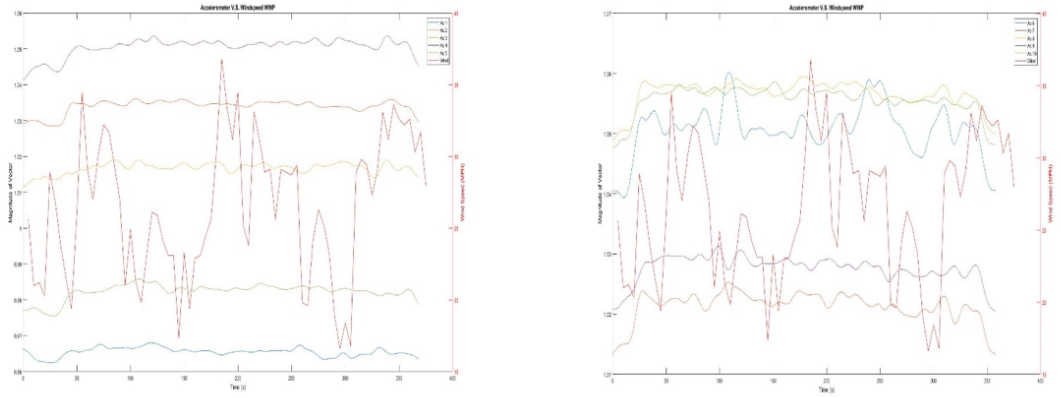


Figure 50: Entire FXZ-N Array Accelerometer VS Windspeed Data by Date

Date

1/19/21



2/22/21

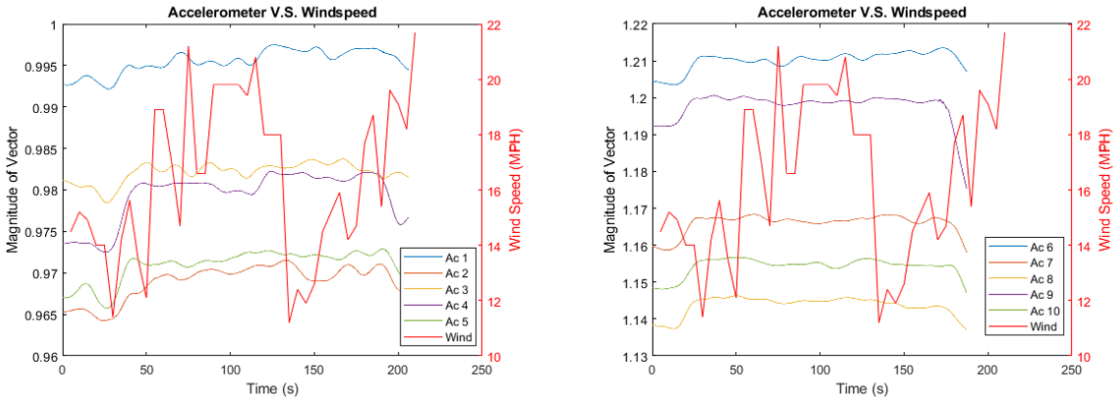
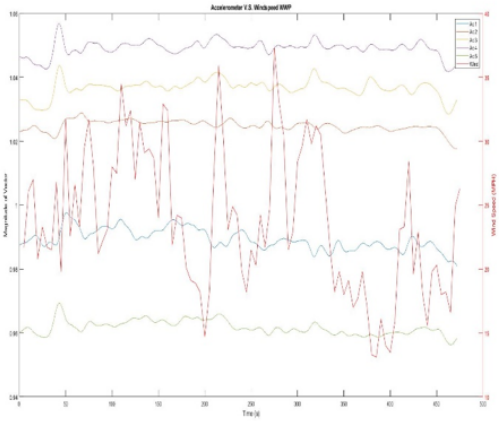
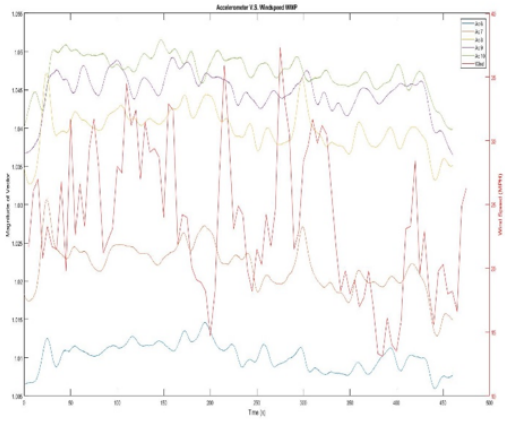


Figure 51: FX20 East Accelerometer VS Windspeed Data by Date

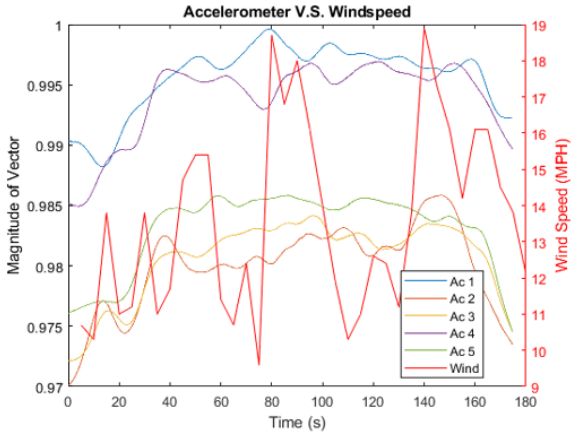
Date

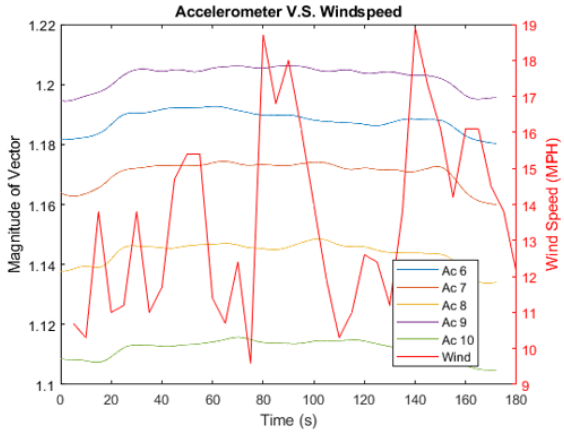
1/19/21



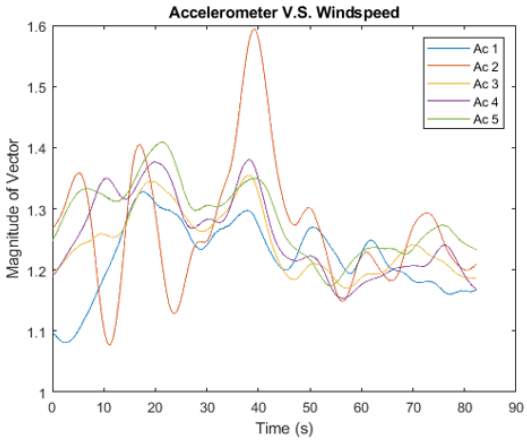


2/22/21





4/15/21



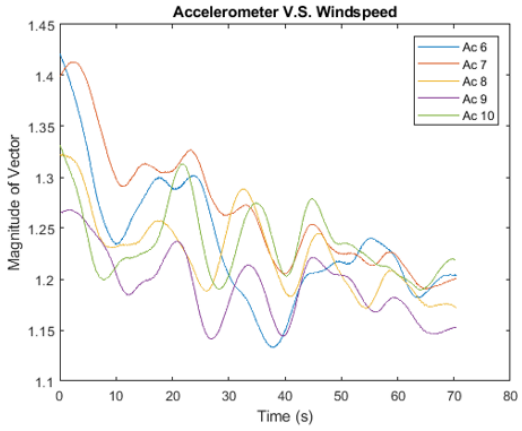
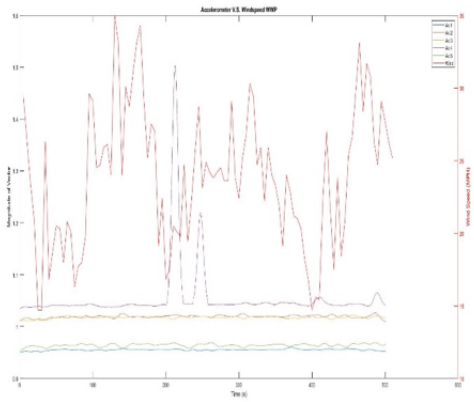
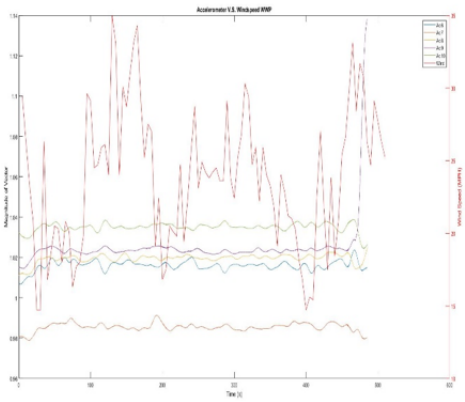


Figure 52: FX20 West Accelerometer VS Windspeed Data by Date

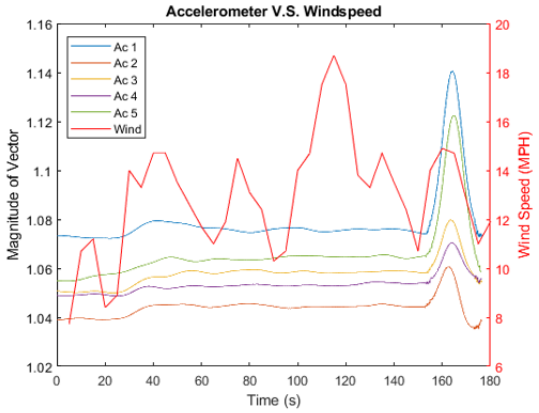
Date

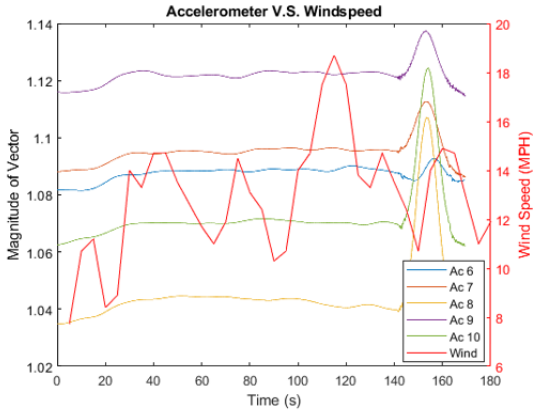
1/19/21



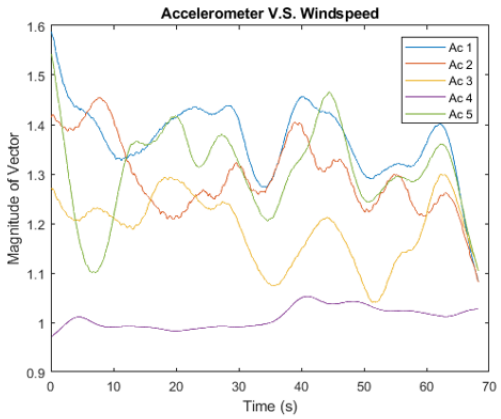


3/25/21





4/15/21



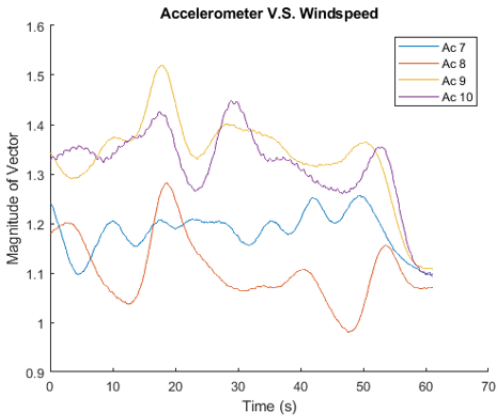


Figure 53: Saddle Accelerometer VS Windspeed Data by Date

The spikes at the end of 3/25/21 come from a force exerted on one corner of the array to witness changes in acceleration.

Accelerometer 6 is missing from 4/15/21 because it malfunctioned during the test resulting in

wrong data.

3.4 Comparison of Accelerometer Data from Force Movement of the Arrays

As previously mentioned, three types of forced movement were introduced to the arrays, replicating the methods of the paper “Dynamic Load Mechanical Modeling of a Ganged Heliostat”, in order to collect good and consistent accelerometer data of the arrays in motion that could not be replicated with wind. The following figures contain the data for each motion type and each set of panels. Not all arrays were subjected to the force motions as only some sets of panels could be properly accessed.

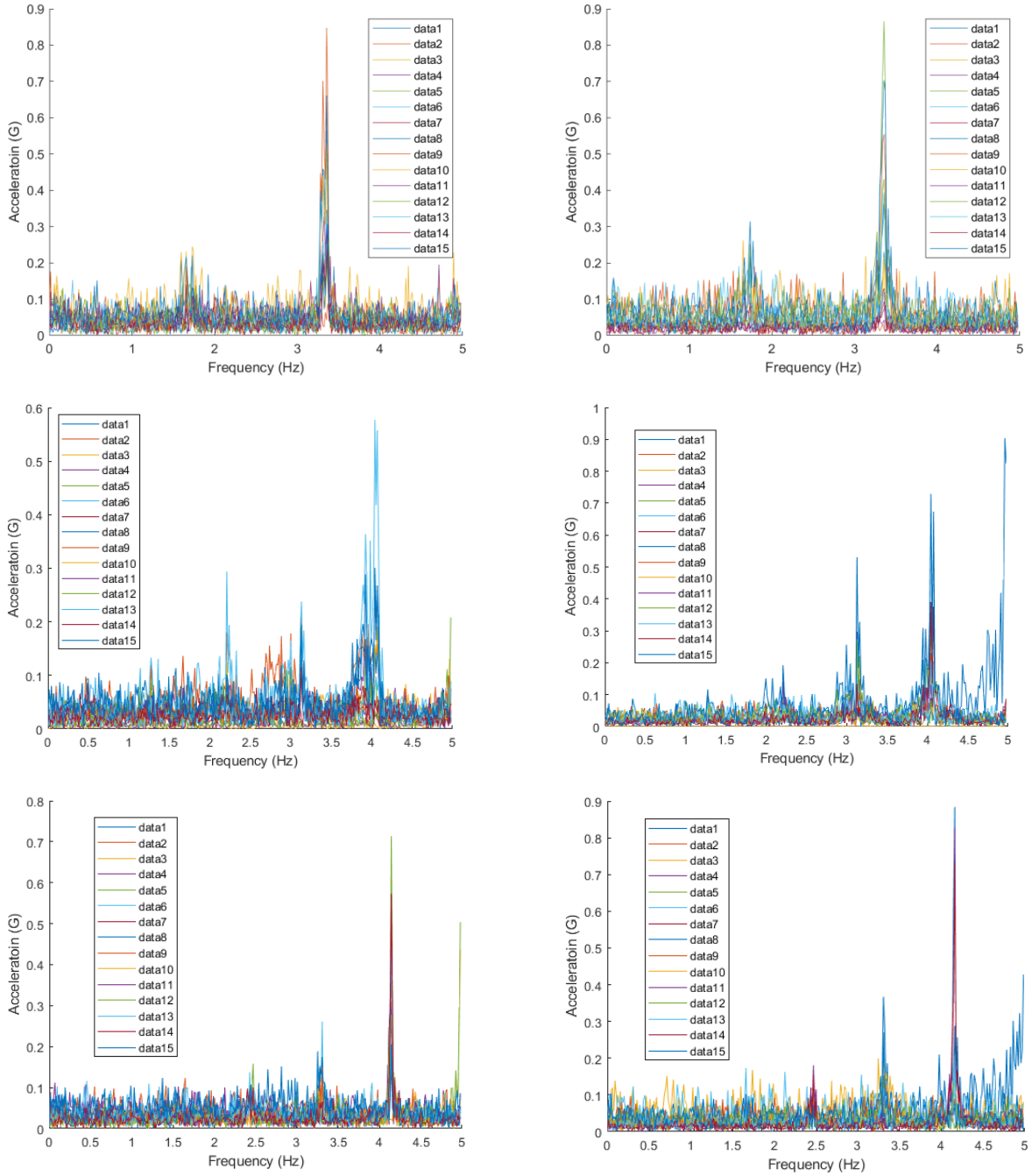


Figure 54: Saddle at high input (First row is the first technique, second row second technique, third row third techniqu)

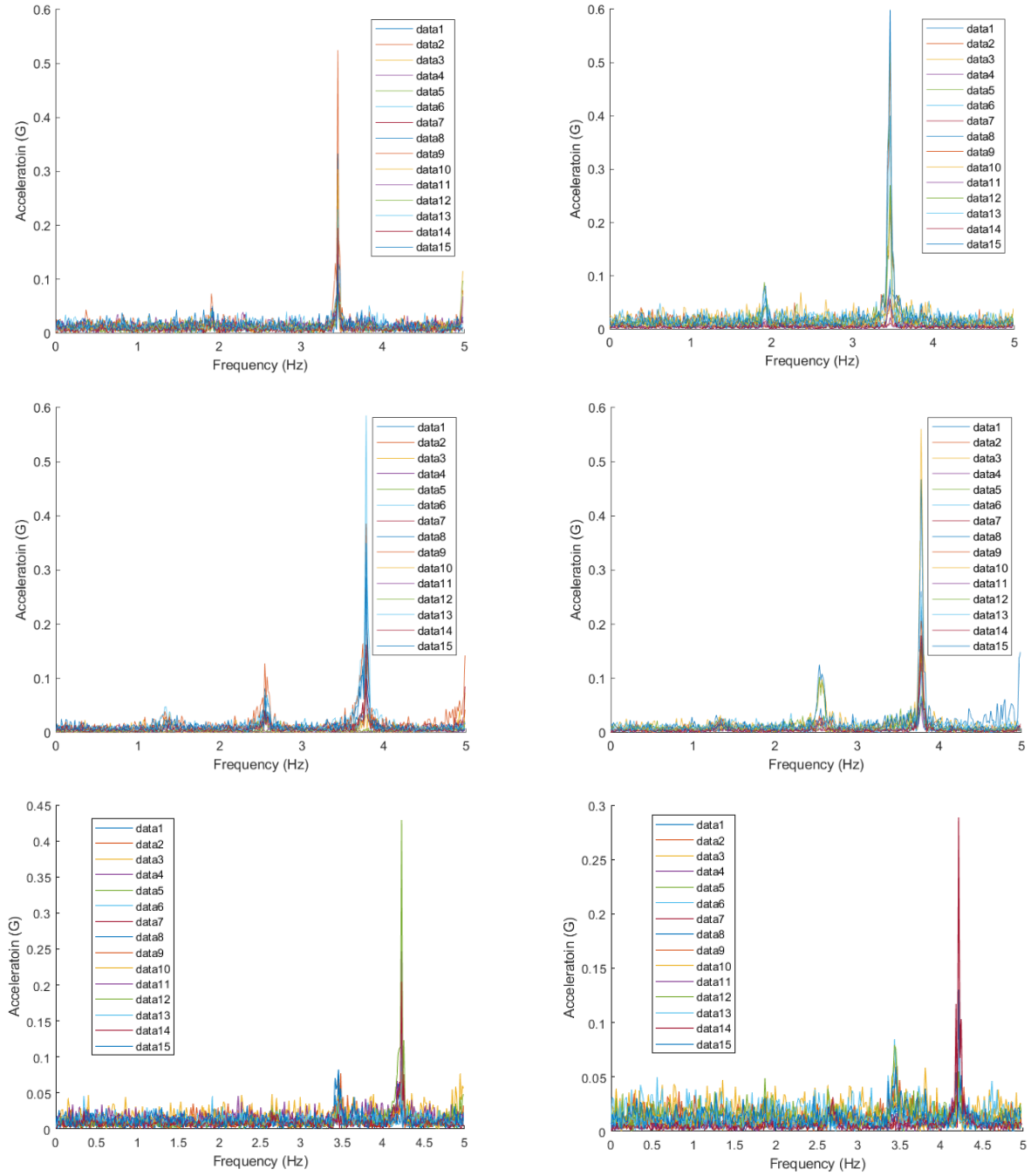


Figure 55: Saddle at low input (First row is the first technique, second row second technique, third row third technique)

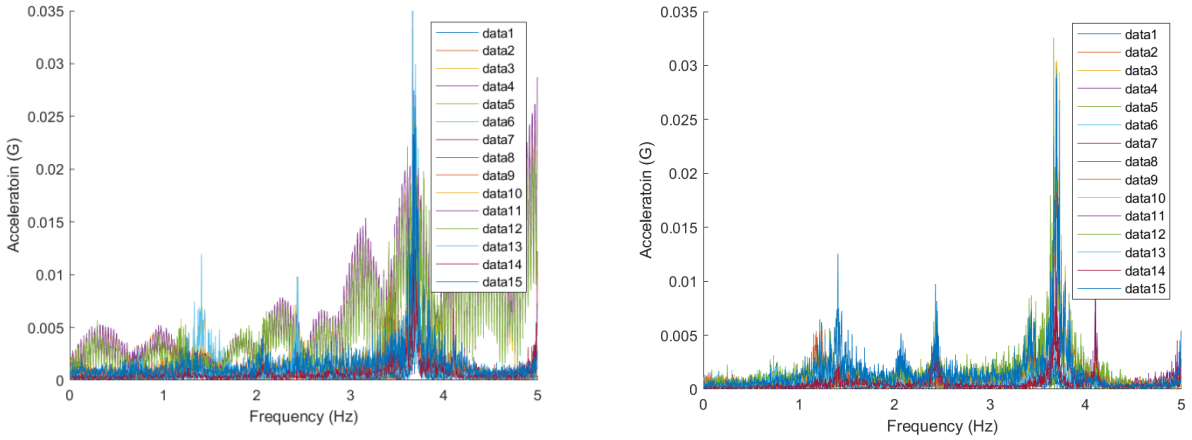


Figure 56: Saddle Data at 35 mph wind. The first set shows data errors with the accelerometers due to external force.

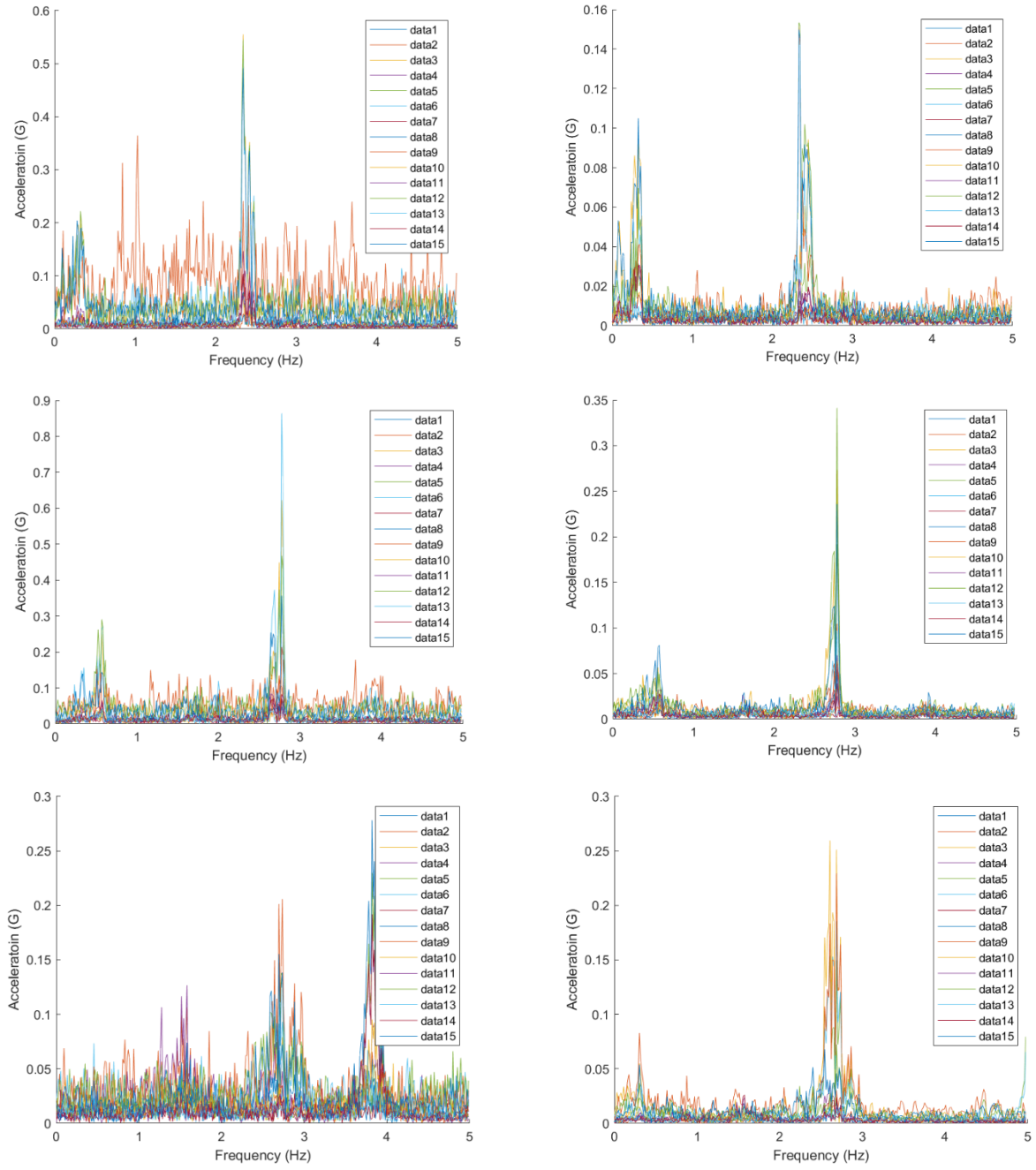


Figure 57: SATN at high input (First row is the first technique, second row second technique, third row third technique)

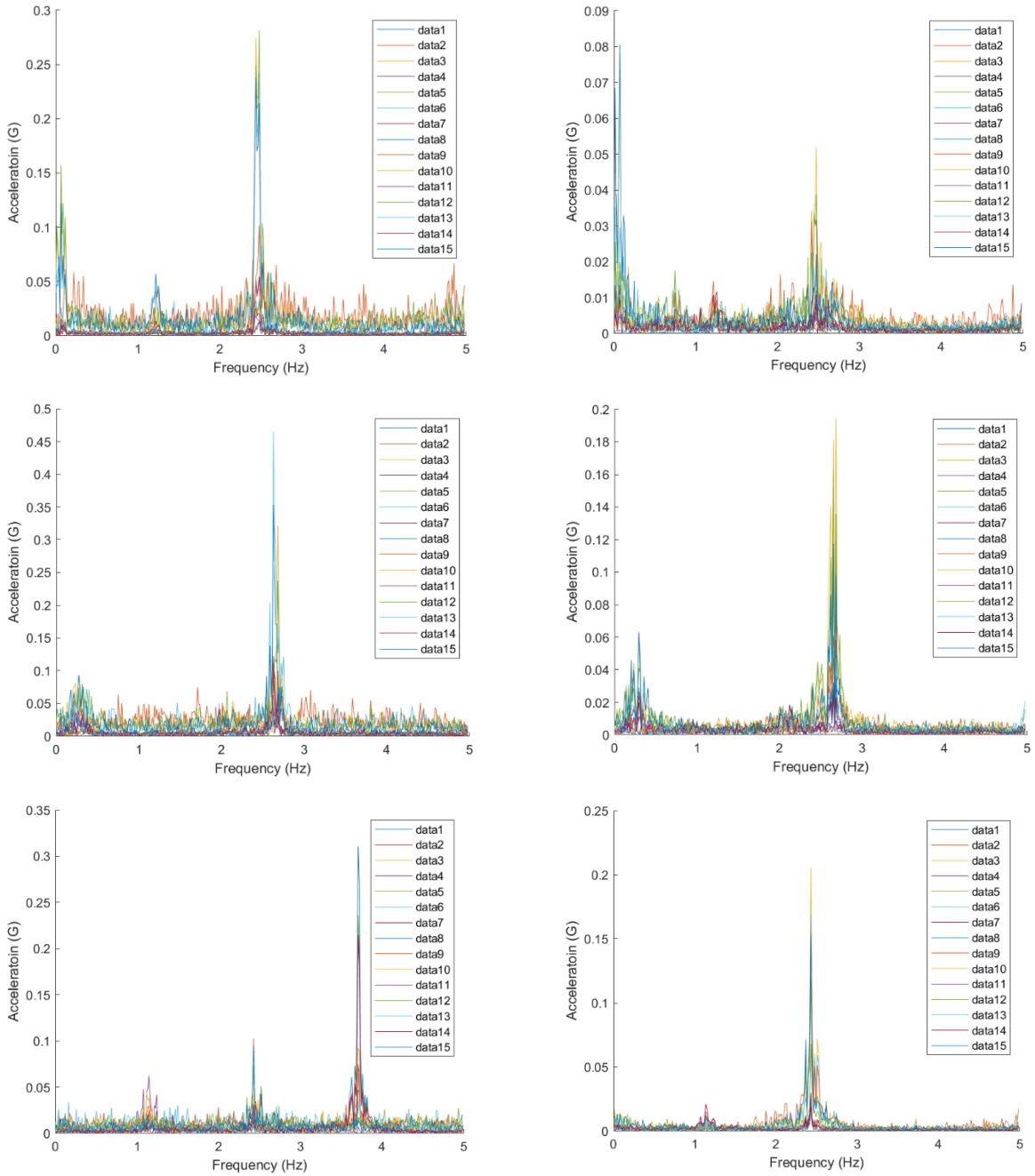


Figure 58: SATN at low input (First row is the first technique, second row second technique, third row third technique)

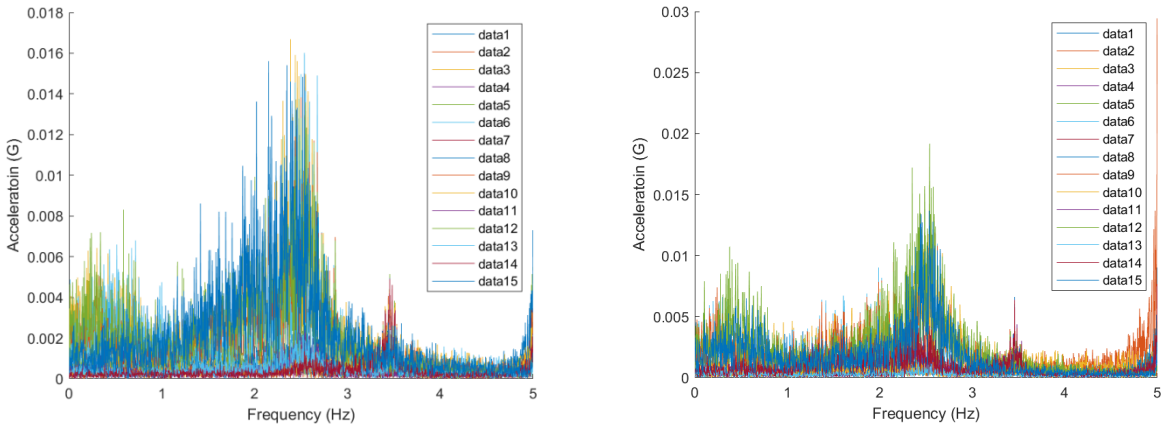


Figure 59: SATN Data at 35mph wind

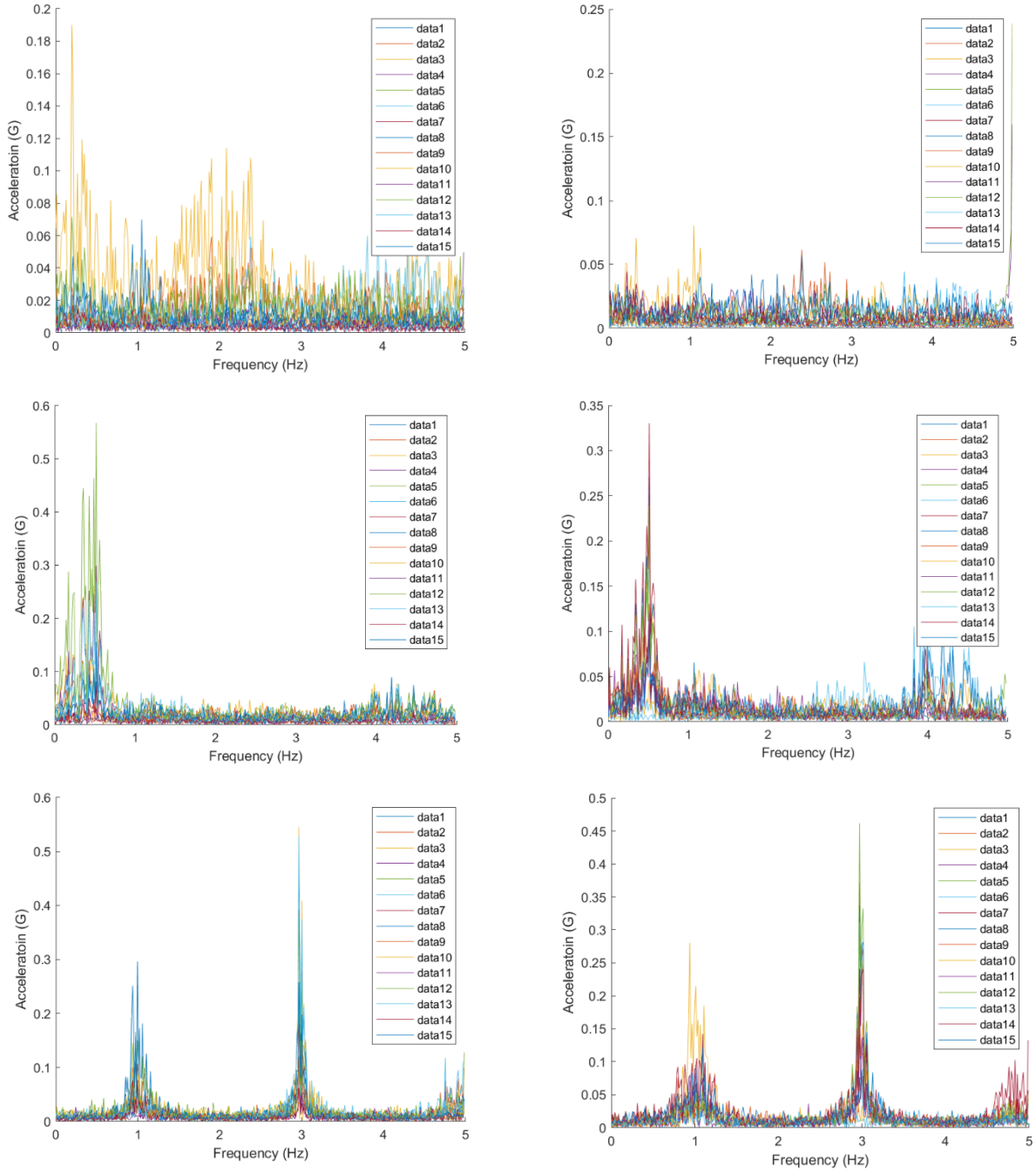


Figure 60: FX20 East at high input (First row is the first technique, second row second technique, third row third technique)

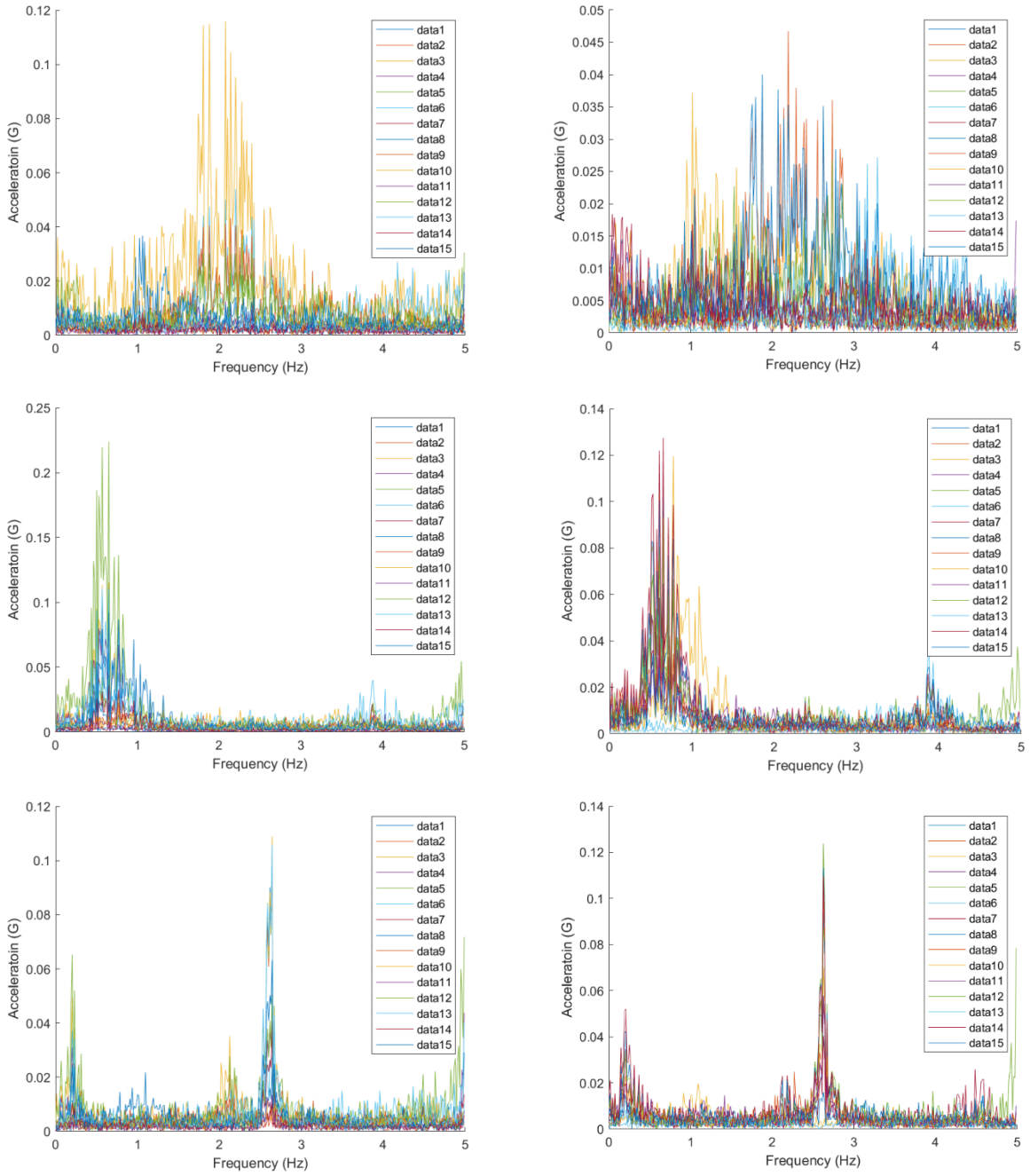


Figure 61: FX20 East at low input (First row is the first technique, second row second technique, third row third technique)

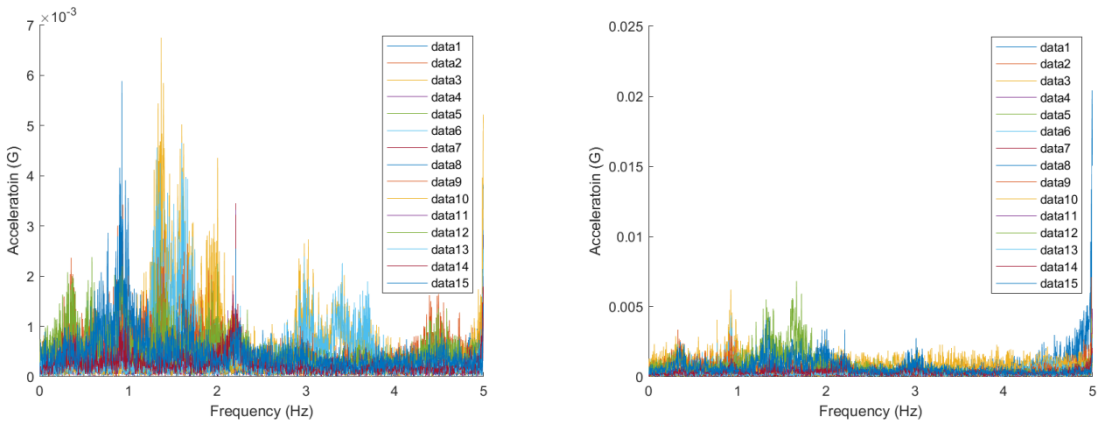


Figure 62: FX-20 East Data at 35 mph wind.

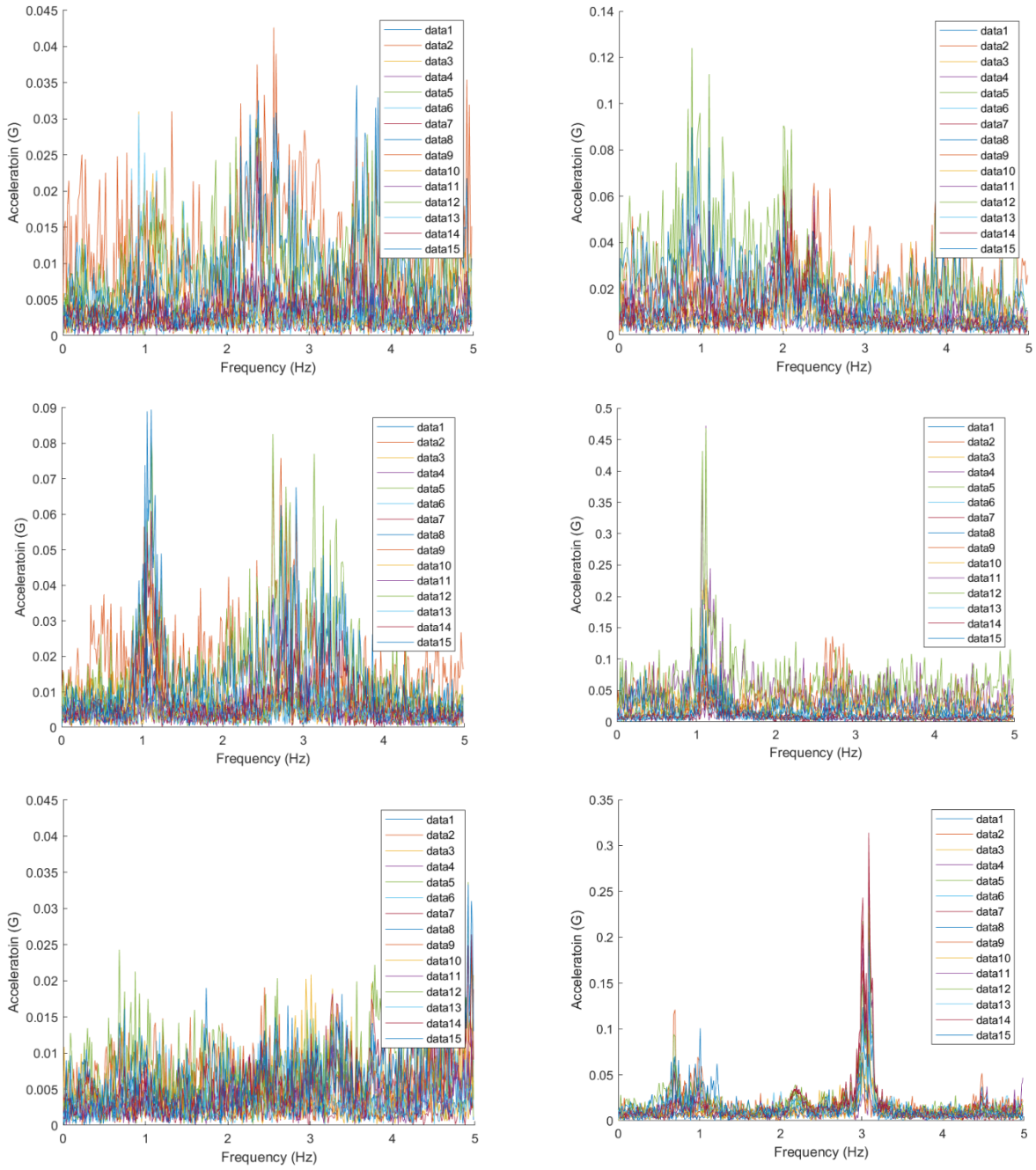


Figure 63: FXZ North at high input (First row is the first technique, second row second technique, third row third technique)

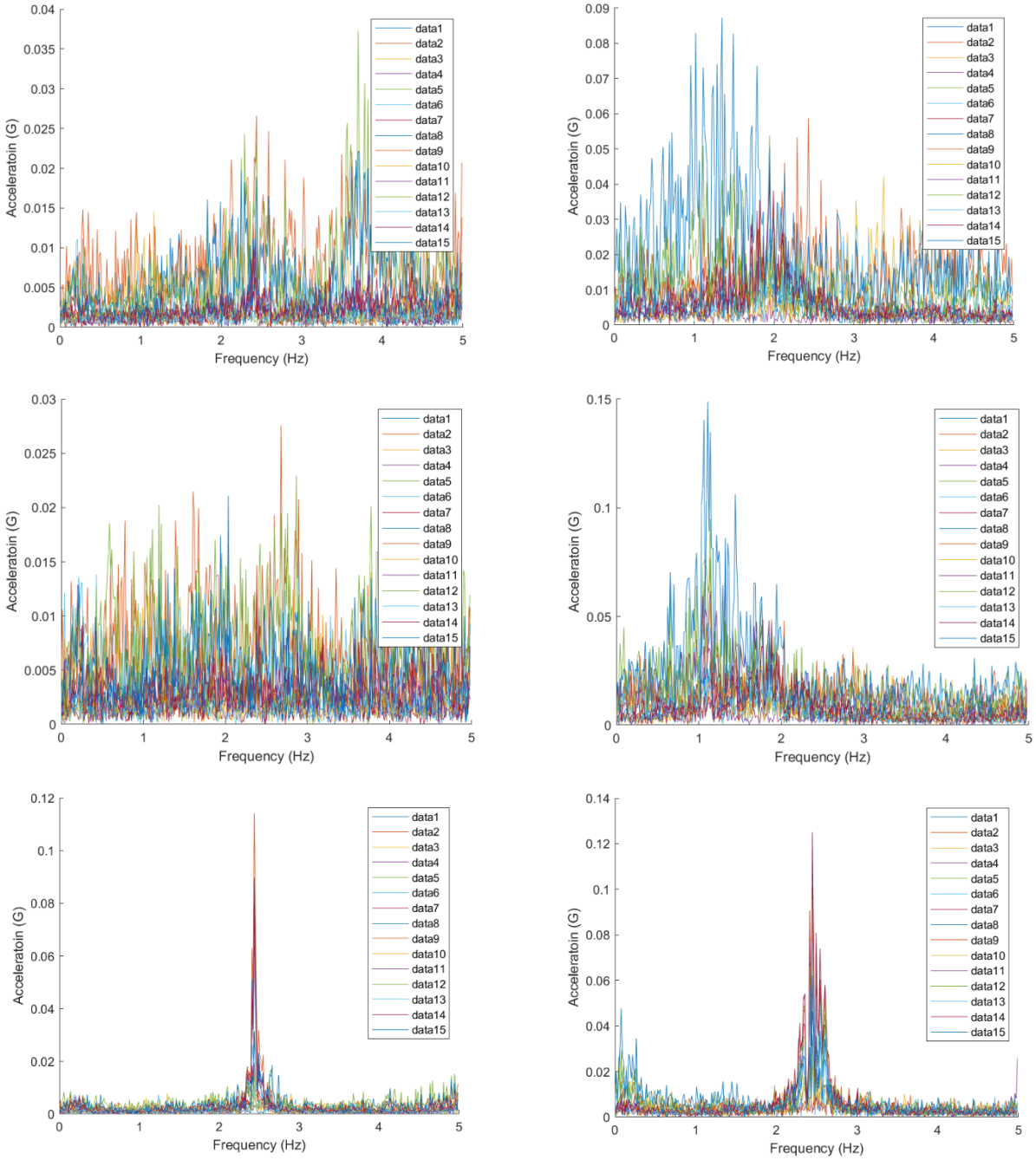


Figure 64: FXZ North at low input (First row is the first technique, second row second technique, third row third technique)

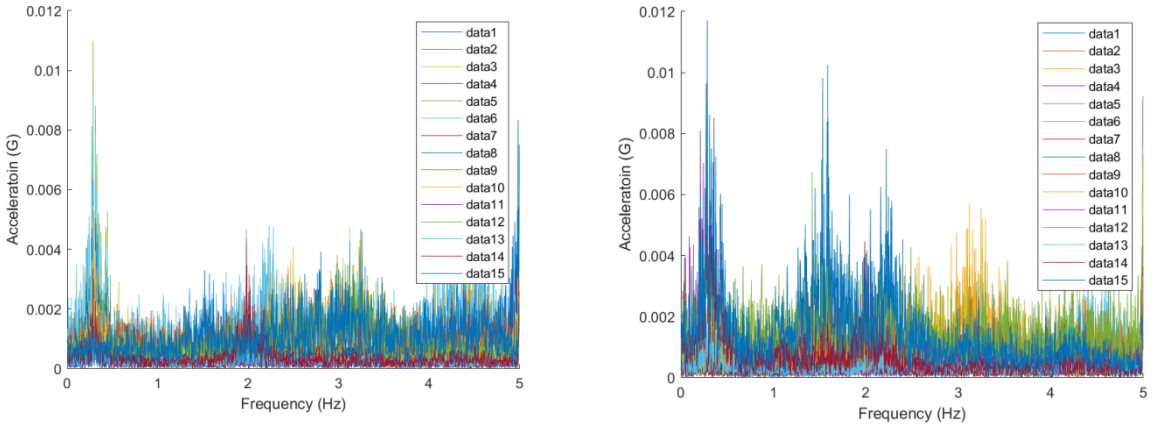


Figure 65: FXZ-North Data at 35 mph wind

REFERENCES

[1] Armijo, Kenneth et al. *Dynamic Load Mechanical Modeling of a Ganged Heliostat.* AIP Conference Proceedings 2126, 26 July 2019

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