Solar Photovoltaic Performance Overview:
An Analysis of Solar-Diesel Microgrid Performance in Eagle, Alaska

Chris Pike, Ben Loeffler, and Erin Whitney
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Abstract
Hundreds of villages in rural Alaska rely on islanded microgrids utilizing diesel generators to provide reliable electricity. As the price of fuel has continued to rise over the last decade, the cost for essential electrical services has continue to rise. Many Alaskan Utilities have installed renewable generation in the form of wind or diesel to supplement the diesel generation and reduce fuel consumption. The village of Eagle, Alaska installed a 24 kW solar PV array in 2015. The solar combined with the existing diesel generation meets the community load which averages 80 kW annually and can drop below 50 kW during the summer. Initially, the inverter did trip off during periods of power quality deviation. The inverter trip settings were widened and the inverter tripping as eliminated and the system functioned as designed. Solar penetrations exceeded 40% for brief periods and solar ramp rates were measured at 5 kW/sec. Overall the system is performing as expected with no maintenance issues.

Keywords
Microgrid; Solar; Alaska; Diesel Generation; High Penetration; Renewable Energy

Introduction
Eagle and Eagle Village, Alaska, are located on the southern bank of the Yukon River near the Canada-Alaska border. A seasonal road provides summer access. The 2010 combined census population was 153 people. One power plant, owned and operated by the Alaska Power and Telephone (AP&T) Company, supplies electricity to both villages. The average load is about 80 kW.

In 2012, the AP&T submitted an application to Round 6 of the Renewable Energy Fund grant program seeking funding from the Alaska Energy Authority (AEA) for a 30 kW solar array to offset the consumption of diesel fuel used to generate electricity. Up to this point, all electricity consumed in Eagle and Eagle Village was generated by the diesel power plant. The application stated that providing “clean, renewable energy may lead to lower electric rates in the long term and will provide a public benefit to these struggling communities.”

The project was awarded by AEA, and the solar array was built by Wolf Solar and commissioned in May 2015 at a total cost of $212,000. The project’s original budget was $165,750, but delays, additional required materials, and civil costs added significantly to the final cost. The final completed project was 24 kW in size.

Eagle Photovoltaic System Description
The completed 24 kW photovoltaic (PV) system is a collection of arrays mounted on 8 poles spaced 18 feet apart. One thousand yards of gravel was mined locally and used to level out the project site. Each pole-mounted array can be manually adjusted to change the tilt angle from 15° to 65° to improve snow shedding and better accommodate seasonal changes in sun angle. The panels are wired as 2 arrays with 4 strings per array. Each string has 12 modules connected in series. The 4 strings of each array are connected in parallel at a combiner box. The combiner output is connected to a 3-phase inverter.
through a disconnect switch. The inverter output is connected to the power plant switchgear bus, as shown in Figure 1.

![Eagle solar array configuration](image)

*Figure 1. Eagle solar array configuration. The eGauge and Shark 200 are power meters and data loggers that record data for this project. The drawing shows locations on the grid where each meter collects data.*

The final solar project details are as follows:

**Panels**
- 96 Sharp Solar 250 watt polycrystalline silicon modules

**Mounting**
- Eight adjustable pole mounts with manually adjustable tilt angles from 15° to 65°. The pole mounts are constructed of 8-inch schedule 80 steel pipe, spaced 18 feet apart and buried 8 feet deep with concrete footings and structural steel stabilizing beams. Each pole mount supports 12 panels.

**Electrical Components**
- Midnight Solar MNPV4HV-Delux Combiner with MNSPD600 Surge Protector
- Square D 600 VDC 60A Disconnect with surge protectors
- Fronius IG Plus V 12.0-3 Inverter
Input volts – 360 VDC
Output volts – 277 VAC 3Ø4 W
DC max power – 13.8 kW

Sharp Solar Module ND-250QCS
Volts per module – 29.8 VDC
Watts per module – 224 W (PTC Rating)
Volts per string – 360 VDC
Total number of modules: 96

Performance Monitoring
- Shark 200 Series meter between PV inverters and the main bus
- eGauge 3010 system meter between inverters and the main bus and between the main bus and the village loads

Existing Power Plant Infrastructure
Cummins 150 kW genset
Cummins 175 kW genset
Cummins 125 kW genset
Engines currently average about 12.5 kWh per gallon of diesel fuel, and all are mechanically governed. Eagle staff indicate that this older power plant is in the process of being replaced with more modern equipment that will better integrate with variable renewable generation sources.

Data Collection Overview
The Alaska Center for Energy and Power (ACEP) is an applied energy research institute based at the University of Alaska Fairbanks. In 2015, ACEP was contracted by the Alaska Energy Authority to collect and analyze high-resolution data from the Eagle solar Renewable Energy Fund project to answer the following questions:

1. What are peak solar ramp rates, when do they occur, and do they impact reliability?
2. Does the solar project impact the frequency of blackouts?
3. Are there power quality impacts caused by integration of the solar array?
4. How does the project performance compare to PVWatts predictions?
Do the tolerance setting adjustments recently made by AP&T, with the permission and assistance of the inverter manufacturer, eliminate inverter trips without unnecessarily increasing the risk of islanding?

Voltage, current, frequency, and real and reactive power data/measurements were collected at 5-second resolution from the PV array as well as from the Eagle load. Measurement locations can be seen in Figure 1.

Data collection began April 20, 2016, and ended May 20, 2017. The following time gaps in the data exist:

- July 2 through July 10
- July 12 through July 27
- July 30 through August 18
- August 23 through October 9
- November 29 through January 5

These data gaps are due to issues with the script that sent the data files to ACEP. While the gaps are an annoyance, they were not deemed a significant issue since the data collected include the solar peaks in the spring and summer that are most important to this analysis.

Five-second resolution data were chosen after it was determined that this was the highest resolution that could reliably be collected with the existing connectivity. In total, 4,505,173 data points were collected. To model the estimated output of the array, PVWatts was used along with the same inputs that the system designers indicated they had used. The PVWatts weather station nearest to Eagle is the Big Delta station located 145 miles southwest of Eagle. This station was the location used as an input for the PVWatts analysis. A thorough description of the PVWatts modeling inputs is given later in this report.

### Solar System Performance

The Eagle PV array appears to be functioning approximately as expected. As shown on the graphs in Figure 3–Figure 7, maximum instantaneous power penetration was just over 40% of the total village load. This peak was observed during spring 2016. The maximum daily energy penetration was approximately 11%, also measured during spring 2016.
Figure 3. Minimum, maximum, and average daily Eagle load information is shown for the 2016–2017 data collection period. The load reaches a minimum in the early summer and peaks in January.

Figure 4. Total daily energy generation. The purple component represents diesel generation, and the red component represents solar generation. The solar energy penetration maximum occurs during spring and early summer when the load is near its seasonal minimum and solar production is near its seasonal maximum.
Figure 5. Extraction of daily solar energy penetration from Figure 4, for clarification. Maximum daily solar energy penetration is just over 11%.

Figure 6. Instantaneous solar power penetration for the data collection period. Peak solar power penetration is 43%.
Solar Production Overview

Figure 3 shows the daily minimum, maximum, and average load used to calculate PV penetration. During summer, minimum loads are near 40 kW; during winter, maximum loads reach almost 140 kW. In general, the maximum load is about twice the minimum load for the corresponding day. Solar energy and power penetration levels are as follows:

Solar energy penetration
- Maximum observed value of 11.3% daily PV energy penetration.
- Average overall daily mean energy penetration was 4.6%.

Solar power penetration
- Maximum PV power penetration was 43.5%.
- Mean solar power penetration for the entire data set was 4%. Mean penetration for solar production periods (when solar production was >0) was 11%.
Capacity Factor
- The overall capacity factor was 14.4%.

Actual Production versus Modeled Production
Figure 8 shows the actual daily PV production versus the production modeled with PVWatts. The weather station available for PVWatts modeling that is nearest to Eagle is in Big Delta, about 145 miles southwest of Eagle. The following inputs were used for modeling:
- 14% losses
- 65° tilt from September–March
- 45° tilt from April–August
- 180° Azimuth

This information was gathered from presentations given by AP&T. Figure 8 shows that the system generally underperforms the expected output on some days and overperforms the expected output on other days. Figure 9 shows the accumulated monthly PV energy production compared with what was modeled in PVWatts for the months when complete production data were available. It appears that for the period measured, the system underperformed the modeled output during the winter months, overperformed during March and April, and performed about as expected during May and June.

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1 This capacity factor should not be considered a representative annual capacity factor without further study. There were gaps in the data during periods of low solar productivity, and this skews the coefficient of performance higher since more production data existed for the more productive times of the year.
Figure 8. Actual daily solar energy production shown in red, overlaid with the modeled solar production shown in blue, generated with PVWatts.

Figure 9. Actual monthly PV energy production shown in blue, alongside modeled monthly energy production in orange.

Ramp Rates Analysis
One of the main goals of this research was to identify the maximum ramp rates that occur for a community scale PV array like the one installed in Eagle. Ramp rates are important because they
influence the integration of variable generation sources into the electrical grid. In a small, islanded grid like the one in Eagle, large ramp rates of variable generation could have negative impacts on grid stability because a diesel generator’s power quality temporarily degrades during steep ramping events. During changes in power demand on a diesel generator, the diesel engine has to increase or decrease the torque provided to the electric generator, while maintaining near-constant engine RPM, which is no issue when the load changes are small, i.e., ramping is slow. If significant load changes occur very fast, the engine has trouble maintaining constant speed, and/or supplying/removing the torque change required, which can result in over and under frequency events. While small excursions from fixed frequency and voltage are a mere nuisance, significant excursions can eventually lead to equipment failure, particularly for sensitive electronics. During severe excursions, blackouts can result.²

Figure 10 shows the daily maximum ramp up and ramp down rates for the data collection period. Not surprisingly, the highest ramp rates, which approach 5 kW/sec, are observed in spring and early summer when irradiance levels are also high.

![Daily Ramp Rates](image)

*Figure 10. Peak daily ramp up and ramp down rates for the Eagle PV system from spring 2016 through spring 2017.*

Figure 11. Daily peak ramp rates compared with daily peak PV penetrations. The graph shows that as daily maximum PV penetrations increase, so do peak ramp rates. This corresponds to the peak solar production periods of spring and summer.

Figure 11 confirms what is seen in Figure 10, that peak ramp rates occur during the periods when PV production is at the highest levels.

The graphs in Figure 12 through Figure 14 use the same inputs that were used to create Figure 10 and Figure 11 to give more detail to the distribution and frequency of high ramp rates on a daily and hourly basis. It seems that ramp rates between 0 and 3 kW/sec occur somewhat regularly, especially during the peak solar season. Ramp rates between 3 and 5 kW/sec are more rare.
Figure 12. Daily peak ramp up and ramp down rates of the Eagle PV array. Since these are daily values, each day with solar PV generation has two values: a peak ramp up value and a peak ramp down value. On the left axis, the sum of the bar heights is normalized so that the height of each bar is equal to the probability of a daily peak ramp rate observation occurring within that bin interval. The heights of all the bars sum to 1. On the right axis is the number of occurrences of the daily peak ramp rates.
Figure 13. Hourly peak ramp up and ramp down rates of the Eagle PV array. Since these are daily values, each day with solar PV generation has two values: a peak ramp up value and a peak ramp down value.

Figure 14. An enlarged version of Figure 13. The y-axis is truncated above 300 occurrences to increase the detail that can be seen in the extreme ramp rates. The 0–0.5 kW/sec ramp rate has 5816 occurrences, and the -0.5–0 kW/sec ramp rate has 5528 occurrences.
Hourly Ramp Rates
Figure 15 through Figure 19 show detail relating peak community load and time of day when high ramp rates occur. Fortunately for system stability, the highest ramp rates occur between noon and 4 p.m. during periods of peak irradiance. This time of peak irradiance and higher ramp rates also corresponds to the time of day when load is at its highest. Local weather, especially with scattered cloud cover, would also affect ramp rates. In many areas, this type of weather is most prevalent in the afternoons, which is the case in Eagle.

![January and June Average Hourly Loads](image)

*Figure 15. Average hourly electric loads in Eagle according to hour of the day in January, when loads are highest, and in June, when electrical loads are the lowest. In both cases, loads are at their daily minimum at approximately 5 a.m. In June, load peaks about 9 a.m. and remains relatively stable until 5 p.m., when it begins to decline. In January, load plateaus at its peak between approximately 4 p.m. and 9 p.m.*
Figure 16. Average hourly community load during the peak solar months of March through July. During this time, load is near 80 kW between 9 a.m. and 5 p.m., but peaks just above 80 kW around noon.

Figure 17. Average hourly solar production for the peak solar months of March through July alongside the hourly load during the same time. The shapes of the curves are similar, although the solar generation curve has a more pronounced mid-day peak than the community load curve.
Figure 18. Time of day for PV ramp down events in excess of 500 W/s. The highest ramp rates occurred between noon and 4 p.m.

Figure 19. Essentially the same as Figure 18, this graph shows time of day for ramp up events in excess of 500 W/s. Peak ramp rates occurred between noon and 4 p.m.
Power Quality

The impact of a solar PV system integrated into a relatively small grid that uses a diesel generator as the prime mover was an area of uncertainty, and there were fears that it could adversely affect grid power quality during times of high penetration and high solar variability. In Eagle, the governors on the generators are set to 60 Hz, and they run in an isochronous mode. Voltage is maintained at nominal or slightly above at the generation bus.

The graphs in Figure 20 and Figure 21 show the impact of PV production on power quality. An important caveat to this information is that the data were collected at 5-second resolution, likely the highest that has been collected from an operational grid-tied PV system in Alaska to date. Load changes will cause momentary power quality changes from nominal frequency and voltage. In addition, there is no communication between the PV array and the generators, so large positive PV ramp rates appear as negative load changes. Due to the sub-second nature of power quality deviations, it is possible that deviations in frequency and voltage caused by the PV system could be hidden in the 5-second data.

Figure 20 and Figure 21 show real, reactive, and apparent power generated by the PV system at 5-second resolution. Figure 21 gives a more thorough understanding of the power factor of the PV array at different production levels.

![Graph](image-url)

Figure 20. Apparent, real, and reactive power of the PV array. Apparent and real power peak near 25 kW, but reactive power is harder to characterize. See Figure 21, which is an enlargement of a shorter period to make the variations in power easier to see.
Figure 21. Essentially an enlarged version of Figure 20, but instead of displaying reactive and apparent power, PV power factor is graphed on the left axis and real power is graphed on the right axis. Power factors are low for short periods first thing in the morning and in the evening, but are above 0.8 during the day.

Figure 22 shows the extent of deviation from the hourly mean of the grid voltage measured against the hourly peak PV penetration. As a reminder, a standard deviation of 1 indicates that 68% of the voltage values measured during the corresponding hour is within 1 volt of the hourly mean. As higher penetration of PVs is achieved, the load voltage does not deviate from the hourly mean in a notable way.
Figure 22. Hourly standard deviation around the mean of the load voltage during different levels of PV penetration. An obvious correlation between increased PV penetration and increased voltage variation is not seen in the data.

Grid frequency is measured against PV penetration and ramp rates in Figure 23 and Figure 24. In general, the frequency remains within 1 Hz of the 60 Hz norm consistently throughout the different PV penetrations.
Figure 23. Frequency deviation from 60 Hz is shown graphed against PV penetration to observe any correlation between grid frequency deviation and PV penetration. The gray box shows the 2 Hz deviation limit. This threshold is set by Alaska statute under 3 AAC 52.460.

Figure 24 shows that frequency does not significantly deviate from 60 Hz at different solar ramp rates in the 5-second dataset obtained for this report. If frequency is affected by high solar ramp rates, one can expect it to modulate from 60 Hz more as higher ramp rates occur.
Figure 24. PV ramp rates are graphed against the grid frequency deviation from 60 Hz to observe any correlation between frequency deviation and high PV ramp rates. While the chart shows that frequency deviation is higher at low ramp rates, this is likely due to there being significantly more data points for lower ramp rates than for higher ramp rates.

To investigate grid stability and power quality during periods of high PV penetration and/or high ramp rates, see Figure 25 where several time periods are shown in greater detail.
Figure 25. Load frequency, voltage, and power along with PV real power and ramp rates are graphed over time on the same set of axis to enable easy comparison. The graph shows about 24 minutes' worth of data on April 12, 2017. Between 15:02 and 15:04, there is a significant drop in PV production from about 23 kW down to less than 10 kW and then back up. This is a classic case of a cloud shading the array. During this time, no significant variation is observed in the 5-second data for frequency and voltage.

Figure 25 shows grid frequency and voltage along with solar production and solar ramp rates on April 12. At 15:02, a significant drop in PV real power production is observed followed by an increase about 2 minutes later. During this period, no effect is seen on frequency or voltage in the data measured.
Figure 26. Frequency deviation from 60 Hz. PV penetration and community load are shown over a 1½-hour period on May 22, when PV penetration ranges from less than 10% to peaks near 40%. One can observe deviations in the grid frequency that approach 0.3 Hz during the largest changes in PV penetration.

Figure 26 shows frequency deviation from 60 Hz along with PV penetration and load. On this day, PV penetration varied significantly, ranging from less than 10% to near 40%. The average 5-second grid frequency does show small deviations, but remains within 0.5 Hz.

Figure 27 shows a significant ramp event on May 25. The graphs show a significant solar ramp down and ramp up rate between 12:45 and 12:46. In the close-up examination of load voltage and frequency during this corresponding period, it appears that during peak ramp rates, load voltage experiences a sudden 2-volt drop, and frequency drops by less than 0.3 Hz. These deviations were not high enough to trip the inverter off.
Inverter Grid Interaction

Grid-tied solar inverters are designed to disconnect from the grid in the event of a power outage or poor grid power quality. Anti-islanding protections are established by IEEE 1547/UL 1741, and utilities usually require that grid-tied inverters interconnected with their systems be compliant with these regulations. Anti-islanding protection requires that the inverter automatically cease to energize the grid within 2 seconds in the event of a fault or power quality deviation. The regulations are designed to protect utility workers and civilians who might believe that a grid is de-energized and safe for maintenance or other work in the event of a power outage. These regulations are constantly evolving, and new inverters are incorporating “ride through” capabilities that allow the inverters to stay connected during very short times of poor power quality. This is especially important where high penetrations of solar energy are present to prevent a small deviation in grid power quality from tripping many inverters offline, thus disconnecting a large source of power generation from the grid and increasing the potential for a grid failure. California and Hawaii, which have seen huge growth in grid-tied solar PV generation, are continuing to draft their own regulations, which allow increased flexibility with power quality and ride-through requirements. In California, this is called Rule 21; in Hawaii, it is known as 14H.
At the beginning of this project, there was concern that the sometimes-variable power quality in a small isolated grid might cause the inverter to trip off. The data show that, indeed, there were times when the inverter tripped offline. Figure 28 and Figure 29 show examples of several events when the inverter likely tripped due to power quality deviations in frequency or voltage outside of programmed parameters. These deviations often do not show up in the data, likely because 5-second resolution data are too coarse to detect small sub-second deviations in voltage or frequency. A pattern of power level or time of day when the inverter trip events occur is not apparent, and these events have not affected grid power quality in a way that can be seen in the data.

At the request of staff from AP&T, Wolf Solar widened the delays and magnitude of under/over frequency and voltage parameters from IEEE 1547 to keep the units online during power fluctuations. The changes were made on May 11, 2016, and special permissions were required from the manufacturer to change the ride-through frequency and voltage parameters. The new inverter settings are shown in Appendix A.

The majority of the inverter trip events occurred at the beginning of the data collection period, with 31 different events occurring in late April and early May 2016. After the inverter settings were changed, the inverter trip events were significantly less frequent and generally were caused by power outages or periods of significant instability.

Figure 28. Examples of the solar inverter tripping offline. When the inverter trips offline, it appears to stay off for 2 minutes before it restarts and ramps up in steps.
Power Outages

Nine power outages were observed in the data set. Power outages were identified by observing periods when both voltage and frequency went nearly to zero or to zero. Power outages occurred during all levels of PV production, and no pattern is discernable. Table 1 shows the date and duration of the outages.

Table 1. Suspected outage date and duration as observed in the data set.

<table>
<thead>
<tr>
<th>Date of Outage</th>
<th>Outage Start Time</th>
<th>Outage End Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>April 25, 2016</td>
<td>13:18</td>
<td>13:20</td>
</tr>
<tr>
<td>March 4, 2017</td>
<td>15:18</td>
<td>15:38</td>
</tr>
<tr>
<td>March 9, 2017</td>
<td>13:06</td>
<td>13:42</td>
</tr>
<tr>
<td>April 11, 2017</td>
<td>19:11</td>
<td>19:12</td>
</tr>
<tr>
<td>April 12, 2017</td>
<td>12:43</td>
<td>12:45</td>
</tr>
<tr>
<td>April 12, 2017</td>
<td>14:38</td>
<td>10 second outage</td>
</tr>
<tr>
<td>May 7, 2017</td>
<td>8:34</td>
<td>8:48</td>
</tr>
<tr>
<td>May 7, 2017</td>
<td>19:57</td>
<td>20:03</td>
</tr>
<tr>
<td>May 8, 2017</td>
<td>6:23</td>
<td>6:29</td>
</tr>
</tbody>
</table>

Figure 29. PV power, grid voltage, and frequency from the morning of May 1, 2016—an example of a voltage and frequency deviation that caused the inverter to trip off. Solar production was just beginning for the day, and PV production was low.
Conclusions

The solar performance data collected in Eagle provide insight into the integration of PV energy into a remote grid. AP&T reports that, after the initial problems related to the solar inverter tripping offline frequently, the system has been fairly trouble-free. The utility does not maintain technical staff in Eagle, so a simple system that is able to operate without constant maintenance is important. The five key questions identified at the beginning of this report are now addressed:

Solar Ramp Rates and Diesel Performance
Peak solar ramp rates approached 5 kW/sec on a few occasions. On a more frequent basis, ramp rates reached 3 kW/sec (see Table 2). The highest ramp rates tend to occur during peak solar periods, during the middle of the day and during the peak solar months. While voltage and frequency deviations were observed during high ramp periods, the grid remained stable through these high ramp events.

The village load was monitored, but this monitoring did not extend into the powerhouse for fuel consumption and output of individual generators. The Eagle powerhouse runs with one of three engines online, any of which can assume the full community load. According to the utility, no operational issues with the generators have been noticed since installation of the PV array. AP&T reports, however, that the diesel units run at low loads at some points in the summer when community load is low and solar output is high, which has raised concerns about exceeding the wet stacking point. At the very least, the operating engine is being operated at an inefficient level during these periods.

<table>
<thead>
<tr>
<th>Peak Ramp Rates (kW/Sec)</th>
<th># of Hours When the Peak Ramp Rates Were Within Range Shown in Left Column</th>
</tr>
</thead>
<tbody>
<tr>
<td>4 to 5</td>
<td>5</td>
</tr>
<tr>
<td>3 to 4</td>
<td>8</td>
</tr>
<tr>
<td>2 to 3</td>
<td>137</td>
</tr>
<tr>
<td>1 to 2</td>
<td>312</td>
</tr>
<tr>
<td>&lt;1</td>
<td>5858</td>
</tr>
</tbody>
</table>

PV and Power Quality
Solar power penetrations exceeded 40% during some brief periods in the data collection; however, solar penetrations that exceeded 20% were much more common (see Figure 7). These high penetrations do not seem to affect grid stability in a way that can be observed in the 5-second data. While there are power quality impacts from the high ramp rates in PV production, the frequency deviations that result from these events are less than 1 Hz as observed in the 5-second data.

Modeled versus Actual PV Performance
The solar array underperformed the PVWatts predictions November through February and outperformed the PVWatts predictions during the spring months of March and April. Output was close to the predicted energy outputs for May and June. It is important to bear in mind that this data set only covers a 1-year period; several years of solar data would be needed to better compare actual PV output.
with what was modeled by PVWatts. In addition, PVWatts uses the nearest TMY data for modeling, which was near Delta Junction, about 145 miles southwest of Eagle.

**Inverter Tolerance Settings**

Inverter trips were frequent at the beginning of the data collection period in late April and early May. Fourteen different events occurred in late April, and 14 events occurred between May 1 and May 16. Toward the end of this period on May 11, the inverter power quality parameters were changed, and this nearly eliminated the issue of the inverter tripping offline because of power quality deviations. Details relating to the actual parameters are found in Appendix A.

**Acknowledgments**

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**Funding Source**

This work was funded by The Alaska Energy Authority as part of the Renewable Energy Fund data collection and analysis effort.
Appendix A

The Current Inverter Voltage and Frequency Settings (changed by Jarret of Wolf Solar 5/11/2016 to prevent dropouts) are shown below:

- V IL Max - 315 vac
- V IL Time - 158 p
- V IL MIN - 244 vac
- V IL Time - 218 p
- V OL Max - 325 vac
- V OL Time - 109 p
- V OL Min - 139 vac
- V OL Time - 109 p
- Freq IL Max - 61.5 hz
- Freq IL Time - 309 p
- Freq IL Min - 58 hz
- Freq IL Time - 309 p
- Freq OL Max - 62 hz
- Freq OL Time - 200 p
- Freq OL Min - 57 hz
- Freq OL Time - 250 p

Start Time - (5 seconds on #1, 10 seconds on #2) Reconnect Time - (5 seconds on #1, 10 seconds on #2)

Note:
- Times are in cycles (P), and not seconds.
- The MIX MODE was converted to BALANCE MODE on both inverters. They are staggered to start up 5 seconds apart upon reconnecting to the grid.
- IL = inner limit
- OL = outer limit