UH Green Award Update

Open Power Quality
Feb 7 · Unlisted

The goal of the Open Power Quality (OPQ) “Agile Monitoring” project is to help the UH Manoa campus achieve net zero energy by providing useful instrumentation and data for understanding the impact of solar panel installation and other energy conservation measures. This involves the design and deployment of custom OPQ hardware and software, as well as the availability of data from building energy sensors, as well as the installation of on campus solar panels.

During the past year, all three of these factors have (finally) come into place on the UH Manoa campus: the parking structure solar panel installation contract has been completed, the third generation of OPQ hardware and software has been implemented, and UH Manoa building-level energy meters are in place and collecting data.

In October, 2019, we deployed 15 OPQ Boxes across the UH Campus Microgrid and have been analyzing the data collected by these boxes on a weekly basis. These weekly reports are provided in this document. These reports indicate the following:

- OPQ provides useful, complementary information about the UH Microgrid not available from building-level utility meters. For example, OPQ can distinguish between power quality events that are local (i.e. arise and are contained within) a single building versus power quality events that are “grid-local” (i.e. are present within a subset of buildings on campus) vs. “grid wide” power quality events (i.e. occur throughout the UH campus and mostly likely originated from the external Oahu grid).
- OPQ meters are accurate and precise. We performed a variety of validity tests by comparing OPQ data to build-level utility meters. OPQ data correlates well to building-level utility meters.

- The UH Microgrid, at least since October 2019, has been generally stable. That said, the OPQ deployment has found interesting cyclical phenomena in the grid that are so far unexplained and may warrant further investigation.

We currently have a balance of $3232 remaining. We request the use of these funds to replace aging developer hardware in our laboratory, which will enable us to continue analysis of the data from the UH Microgrid.

The remainder of this document provides the set of reports we created with detailed analysis of the UH Microgrid in reverse chronological order.

Micro-report on the UHM micro-grid: 01/28 to 02/04

Open Power Quality
Feb 5 · Unlisted

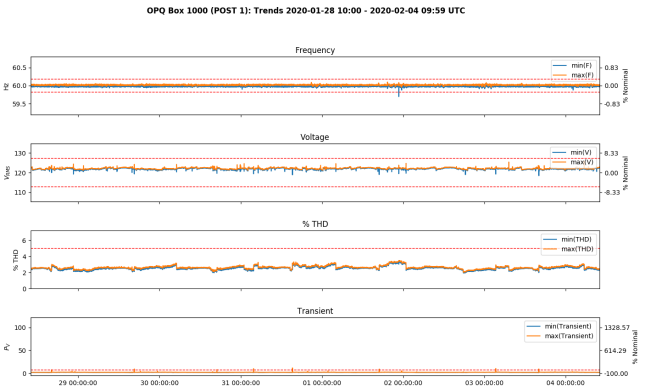
General Summary

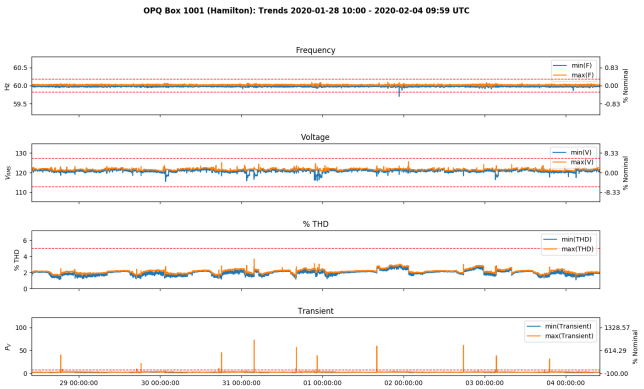
University of Hawaii at Manoa micro-grid report on data from 01–28–2020 10:00 to 02–04–2020 10:00 UTC.

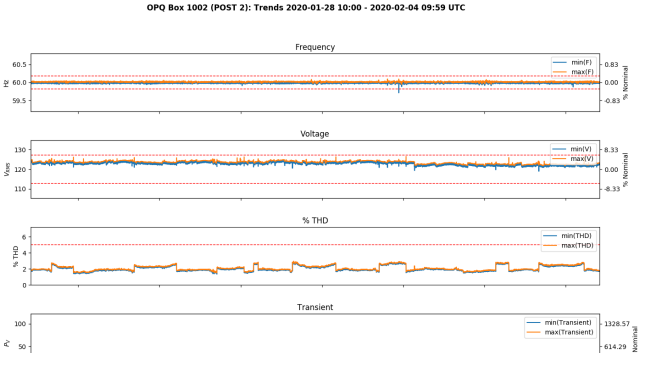
Trends Summary

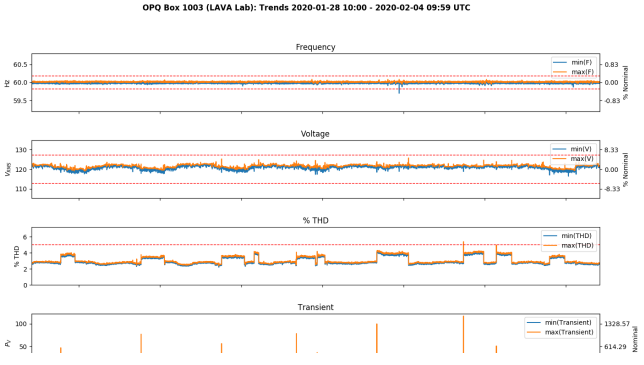
Weekly trends measure the minimum, average, and maximum values for Voltage, Frequency, THD, and transients for each OPQ Box at a rate of 1 Hz.

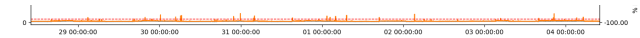
The following figures show Trends for each Box between 2020–01–28 10:00:00 and 2020–02–04 10:00:00.

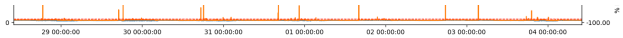




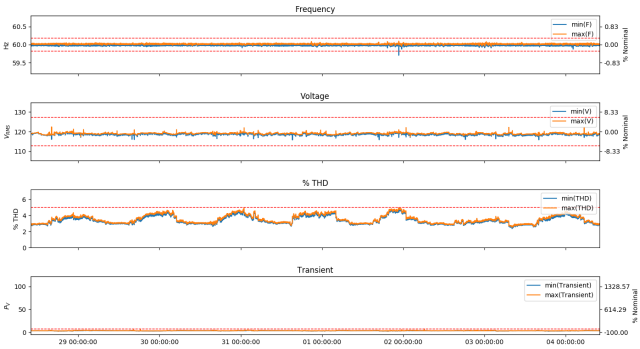




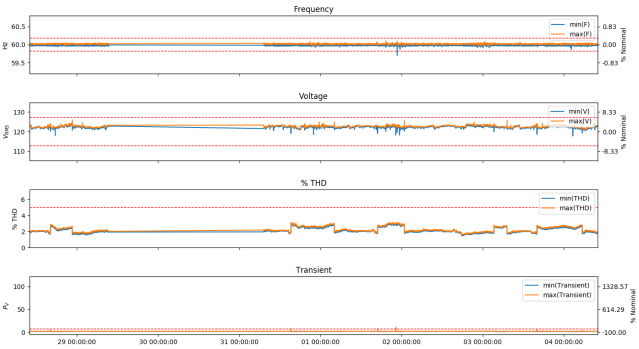




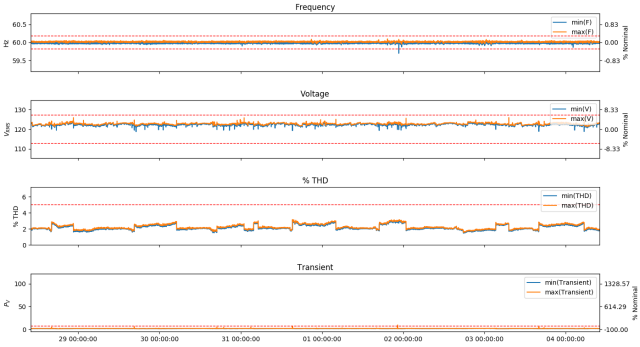
OPQ Box 1005 (Parking Structure Ph II): Trends 2020-01-28 10:00 - 2020-02-04 09:59 UTC



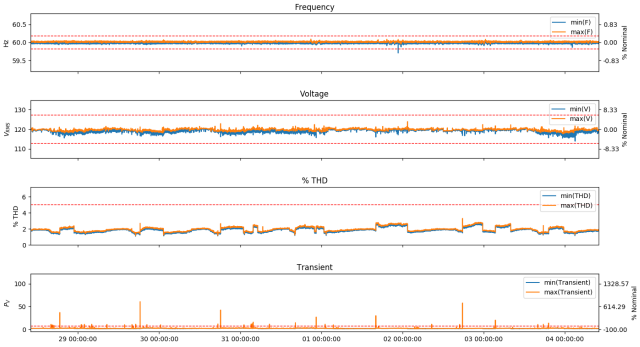
OPQ Box 1006 (Frog 1): Trends 2020-01-28 10:00 - 2020-02-04 09:59 UTC



OPQ Box 1007 (Frog 2): Trends 2020-01-28 10:00 - 2020-02-04 09:59 UTC

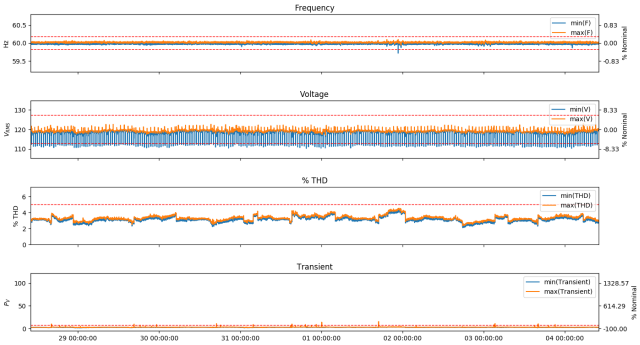


OPQ Box 1008 (Mile's Office): Trends 2020-01-28 10:00 - 2020-02-04 09:59 UTC

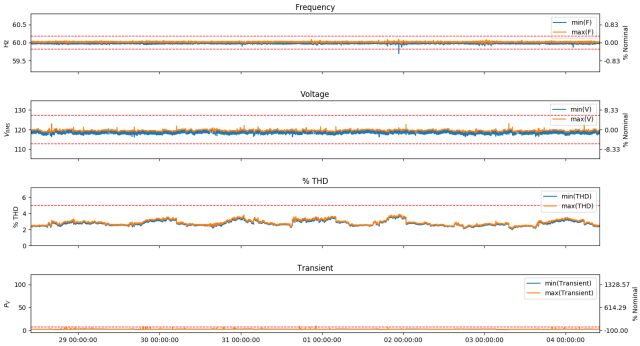


OPQ Box 1010 (Holmes): Trends 2020-01-28 10:00 - 2020-02-04 09:59 UTC

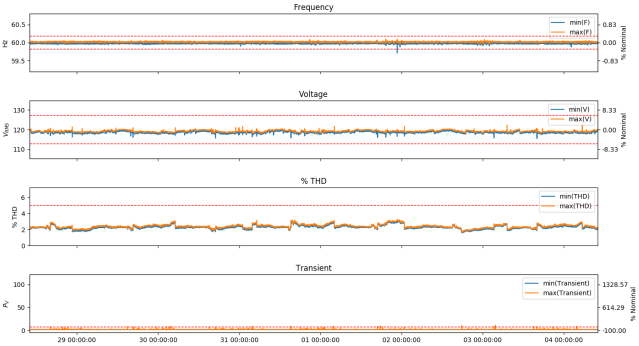
OPQ Box 1021 (Marine Science Building): Trends 2020-01-28 10:00 - 2020-02-04 09:59 UTC



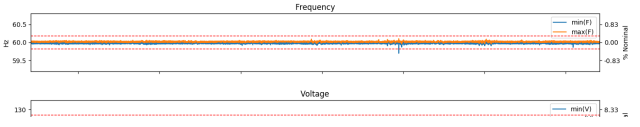
OPQ Box 1022 (Ag. Engineering): Trends 2020-01-28 10:00 - 2020-02-04 09:59 UTC



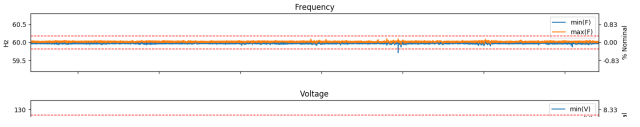
OPQ Box 1023 (Law Library): Trends 2020-01-28 10:00 - 2020-02-04 09:59 UTC

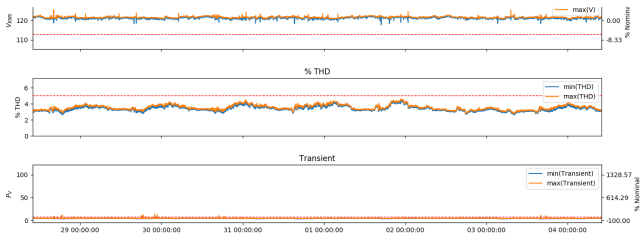


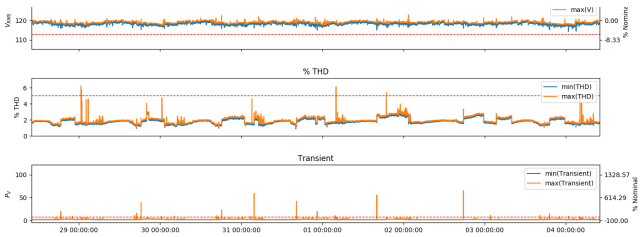
OPQ Box 1024 (IT Building): Trends 2020-01-28 10:00 - 2020-02-04 09:59 UTC



OPQ Box 1025 (Kennedy Theater): Trends 2020-01-28 10:00 - 2020-02-04 09:59 UTC







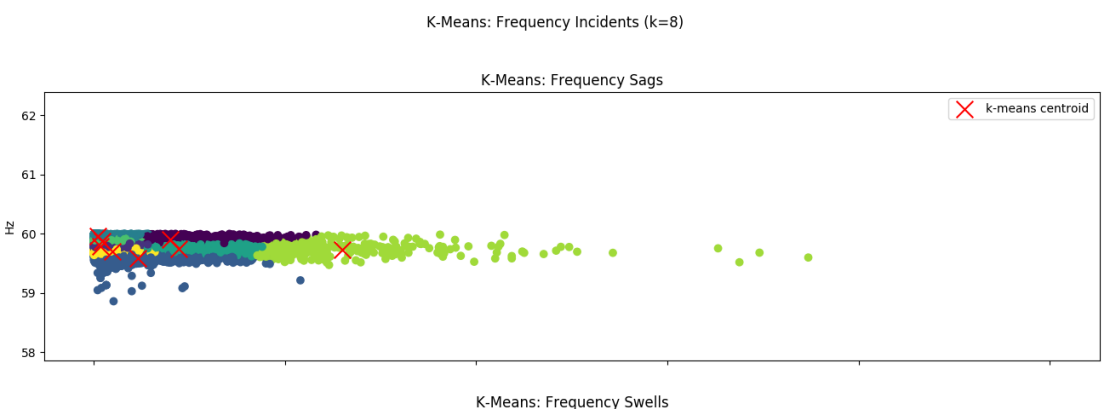
Trends over the past week have been close to nominal with a few exceptions. First, there is a small Frequency sag in the trend data that was observed by all sensors late in the evening January 1 UTC. Second, Kennedy Theater continues to observe spiked in THD that is not observed at other locations. It is show season at the theater, so I speculate that this may be caused by equipment in the theater. It would be interesting to investigate the cause of the THD spikes in more detail to determine the source. Finally, Box 1009 continues to be offline. This Box is located in a colleagues office in Watanabe. Unfortunately, the colleague is currently on academic travel in Japan and we do not have access to the office to restart the Box. The Box will be restarted when the colleague returns from Japan.

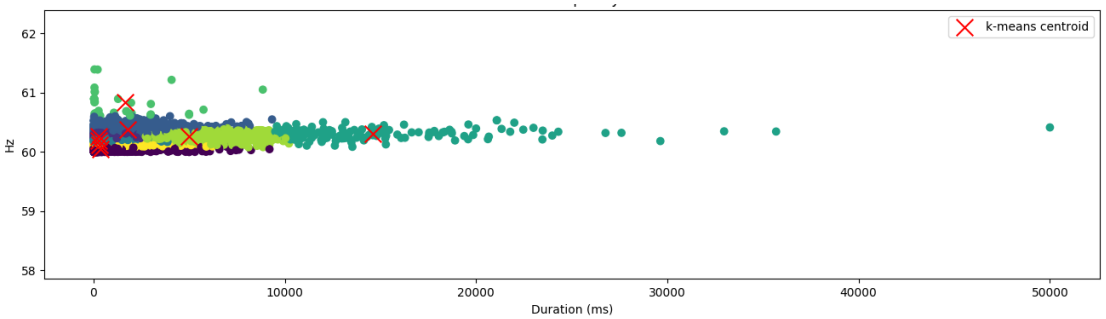
Phenomena

Phenomena are an abstract concept for Anthony's PhD dissertation that provide actionable insights and context on top of classified Incidents. In terms of PQ monitoring, Phenomena provide added context on top of PQ Incidents.

This past week I've focused on improving dynamic generation of Similarity Phenomena. This allows OPQ to determine similarity between Incidents for a specified time range rather than over the entire data set. Results of these updates are provided bellow.

Frequency Incident Similarity Phenomena





The figure above shows Frequency Incident groupings as determined by the k-means algorithm for frequency Incidents collected over this week's report period. The top panel shows groupings of frequency sags while the bottom panel shows groupings of frequency swells.

Similar to last week's report, this figure shows Incidents grouped close to nominal and short in duration, short in duration but further from nominal, and longer duration and further from nominal.

The main take away from these results is that we can now discuss classes of frequency Incidents rather than individual frequency Incidents. This is especially important because OPQ identified close to 40K frequency swell Incidents and 30K frequency sag Incidents, but we need a way of classifying these Incidents as interesting or non-interesting.

I define non-interesting frequency Incidents as Incidents that are "closer to nominal" and less than one second in duration. I admit that "closer to nominal" is not a very rigorous definition and I am currently eye balling the data to determine if Incident clusters are close to nominal or not. I intend to define a more rigorous definition for future reports. Given this classification, 9168 (~41%) frequency sag Incidents would be considered non-interesting and 20027 (~62%) frequency swell Incidents would be considered non-interesting.

Here is the break down of the remaining frequency Incident clusters. First, let's examine frequency sags.

- 5138 (~23.4%) frequency sags with a mean duration of 360 ms and a mean deviation of 59.8 Hz (short duration further from nominal)

- 3025 (~13.7%) frequency sags with a mean duration of 976 ms and a mean deviation of 59.7 Hz (short duration further from nominal)
- 2281 (~10.3%) frequency sags with a mean duration of 2.3 s and a mean deviation of 59.59 Hz (medium duration further from nominal)
- 772 (~3.5%) frequency sags with a mean duration of 4 s and a mean deviation of 59.91 Hz (medium duration and closer to nominal)
- 1292 (~5.8%) frequency sags with a mean duration of 4.4 s and a mean deviation of 59.75 Hz (medium duration and further from nominal)
- 287 (~1.3%) frequency sags with a mean duration of 13 s and a mean deviation of 59.73 (long duration and somewhat close to nominal, but still beyond the threshold)

Next, let's examine the breakdown of frequency swells.

- 9499 (~30%) frequency swells with a mean duration of 270 ms and a mean deviation of 60.27 Hz (short duration further from nominal)
- 31 (~0.1%) frequency swells with a mean duration of 1.6 s and a mean deviation of 60.84 Hz (medium duration and further from nominal)
- 1421 (~4.4%) frequency swells with a mean duration of 1.7 s and a mean deviation of 60.37 Hz (medium duration and further from nominal)
- 968 (~3%) frequency swells with a mean duration of 5 s and a mean deviation of 60.27 Hz (medium duration somewhat closer to nominal)
- 159 (~0.5%) frequency swells with a mean duration of 15 s and a mean deviation of 60.31 Hz (long duration and further from nominal)

These results allow us to focus our analysis on more interesting Incidents and provide a way to make sense of the large number of generated frequency Incidents.

Voltage Incident Similarity Phenomena

Similarity Phenomena with respect to Voltage Incidents are being finalized and were not completed for this week's report. The main issue being that deviations from nominal are not accurately being stored by Voltage Incident plugins (the plugins are still correct, but

they are simply not storing a metric that is required by Similarity Phenomena). This issue is close to being addressed and testing of Voltage similarity is scheduled to begin in the next couple of days. These changes should make it into production in time for next week's report.

Incidents Summary

Incidents are classified PQ issues that were found in the previously provided Events. Incidents are classified by OPQ Mauka according to various PQ standards. OPQ Mauka provides classifications for Outages, Voltage, Frequency, and THD related issues.

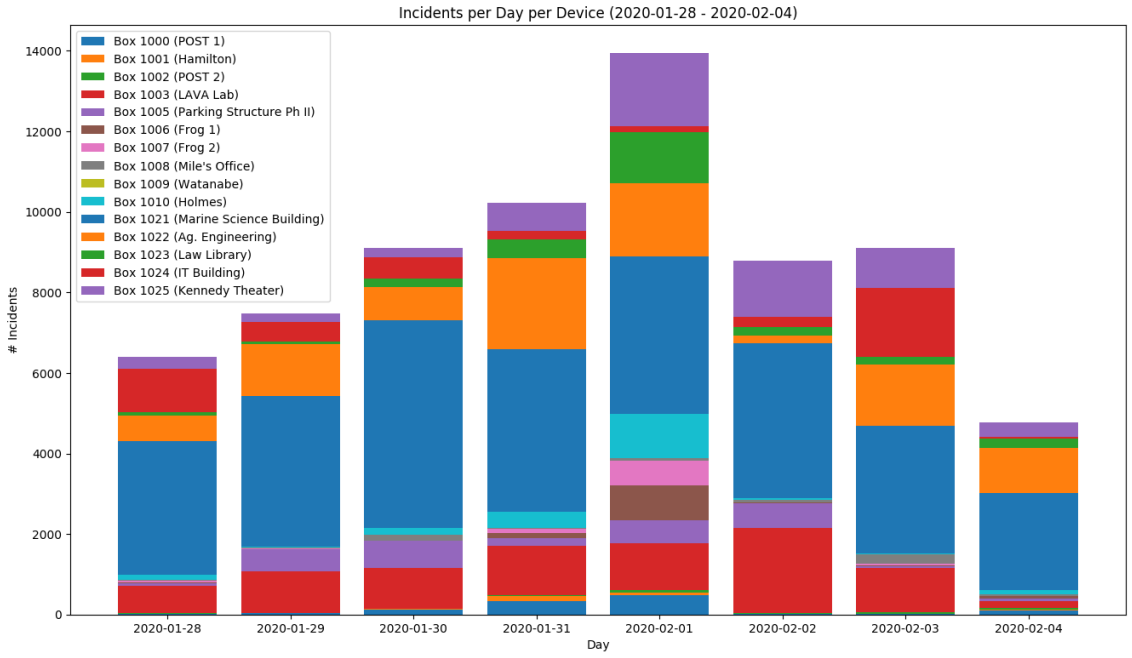
A total of 69866 Incidents were processed.

A breakdown of Incidents per Box is provided in the following table.

Box	Cnt	FSag	FSwell	THD	Outage
1021	29584	6825	22738	20	1
1022	9644	4233	5406	4	1
1003	8537	3928	4593	15	1
1025	6021	5358	630	32	1
1024	4450	2262	2179	8	1
1023	2762	1716	1045	0	1
1005	2732	1317	1398	17	0
1010	2006	744	1252	9	1
1000	1190	629	560	0	1
1006	1107	805	301	0	1
1007	863	607	256	0	0
1008	572	396	161	14	1
1001	219	200	4	14	1
1002	179	71	106	1	1
Total	**69866**	**29091**	**40629**	**134**	**12**

Incidents 2020-01-28 to 2020-02-04

The following figure shows Incidents per Box per day.



Events Summary

Events are ranges of PQ data that may (or may not) have PQ issues within them. Events are generated by two methods. The first method uses Voltage, Frequency, and THD thresholds as defined by IEEE. The second method uses the Napali Trigger which was developed by Sergey as part of his dissertation research. The Napali trigger uses statistical methods to determine when Boxes may contain PQ issues. This summary of Events examines the number of times that Boxes were triggered due to possible PQ issues.

There were a total of 48510 Events processed.

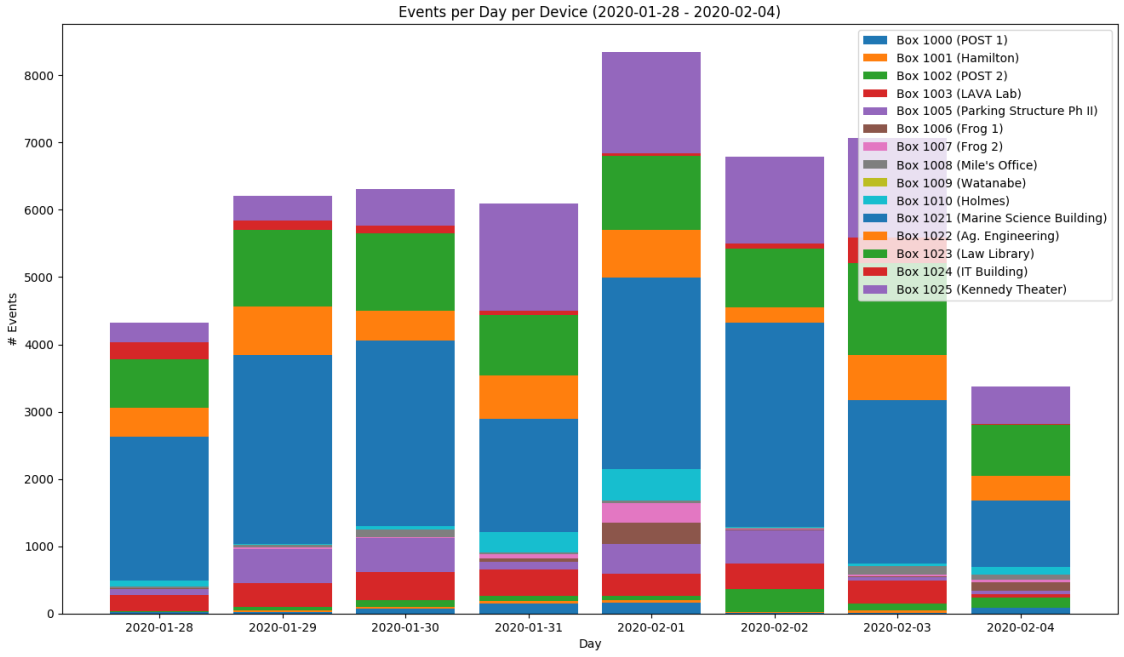
The following table shows Events generated per Box.

OPQ Box	Location	Events Generated
1021	Marine Science Building	18644
1023	Law Library	8015
1025	Kennedy Theater	7637

1022	Ag. Engineering	4220
1003	LAVA Lab	2499
1005	Parking Structure Ph II	2253
1010	Holmes	1100
1024	IT Building	1062
1002	POST 2	881
1000	POST 1	558
1006	Frog 1	543
1007	Frog 2	468
1008	Mile's Office	443
1001	Hamilton	187
Total		**48510**

Events 2020-01-28 to 2020-02-04

The following figure shows Events per Box per day.



Conclusion

This week's report provides fairly nominal trend activity with a single global Frequency sag observed in the trends and we continue to see THD spikes at Kennedy Theater. We also examine improvements to Similarity Phenomena with relation to Frequency Incidents and for the first time utilize Similarity Phenomena over the report period rather than the entire data set.

Unlisted

Micro-report on the UHM micro-grid: 01/14 to 01/28

Open Power Quality
Jan 28 · Unlisted

General Summary

University of Hawaii at Manoa micro-grid report on data from 01–14–2020 10:00 to 01–28–2020 10:00 UTC.

Trends Summary

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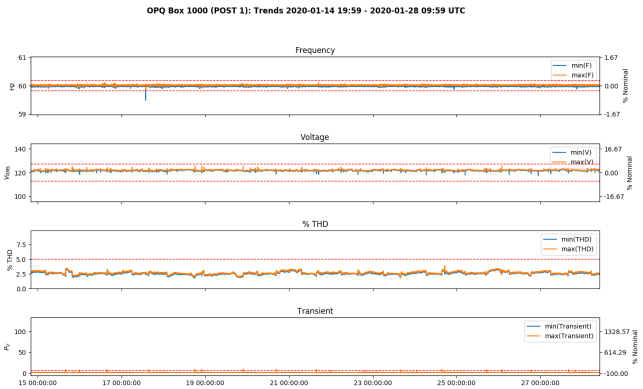
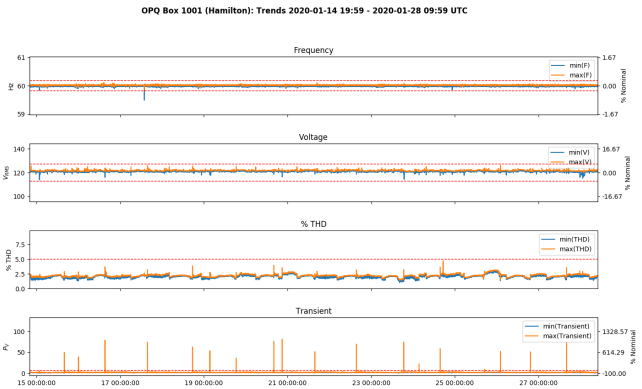
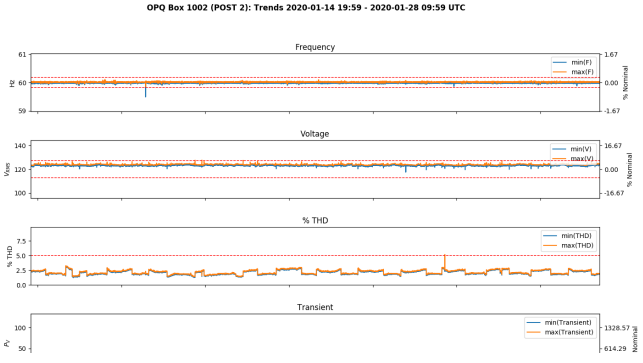
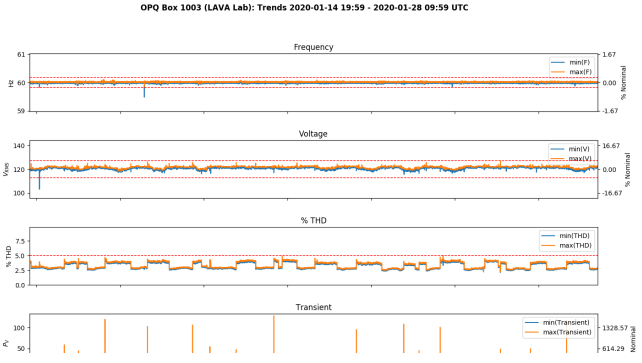
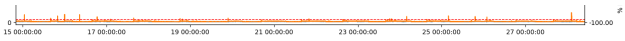
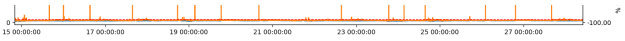




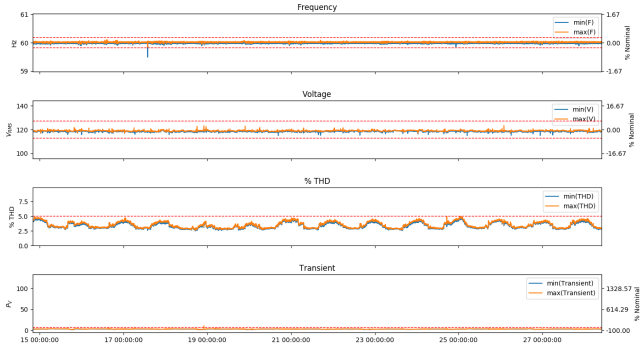








OPQ Box 1005 (Parking Structure Ph II): Trends 2020-01-14 19:59 - 2020-01-28 09:59 UTC



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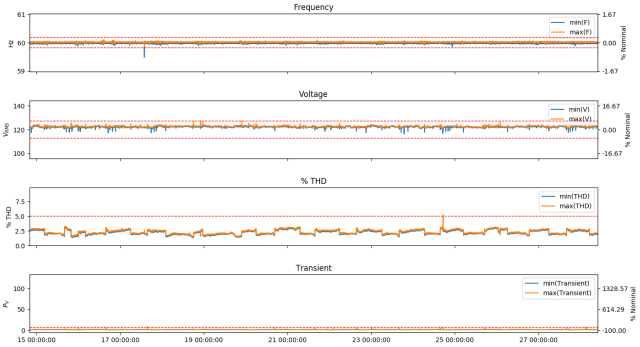
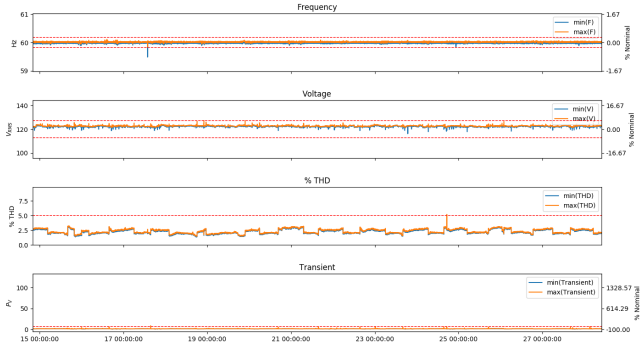


OPQ Box 1007 (Frog 2): Trends 2020-01-14 19:59 - 2020-01-28 09:59 UTC



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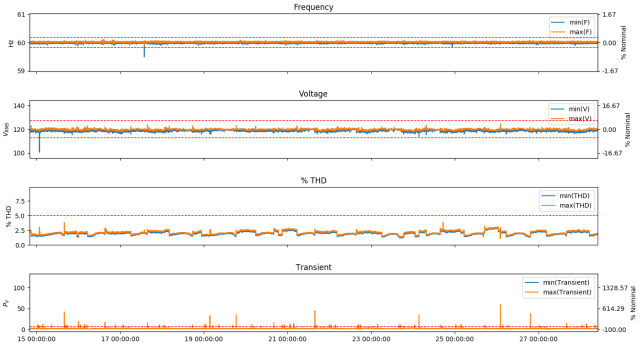

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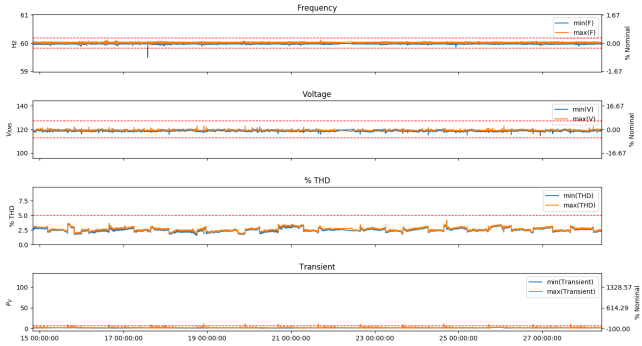
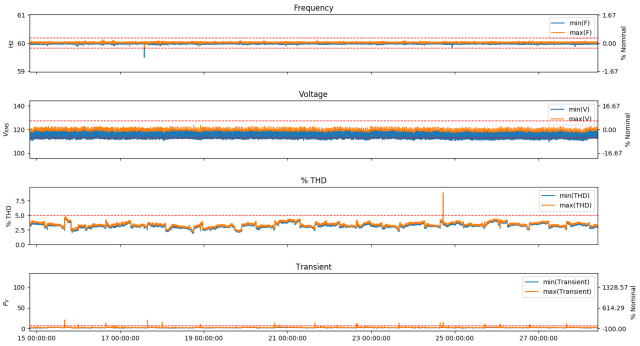
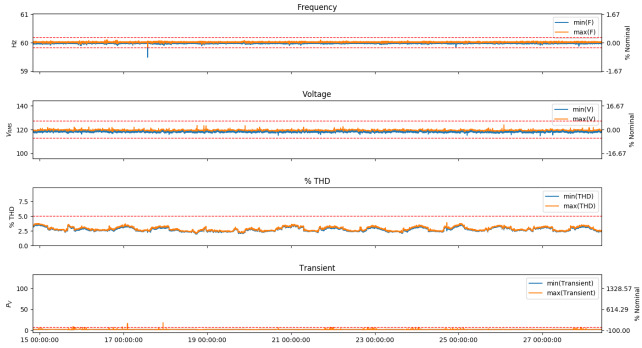


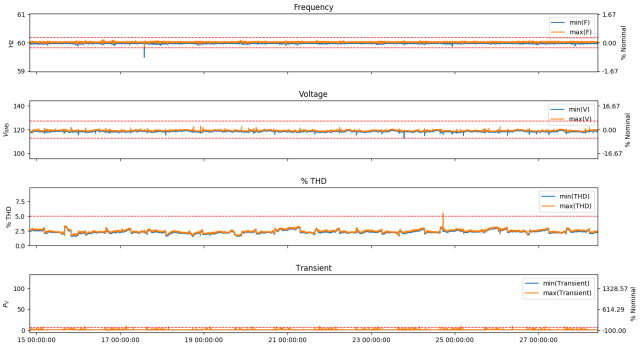
OPQ Box 1021 (Marine Science Building): Trends 2020-01-14 19:59 - 2020-01-28 09:59 UTC



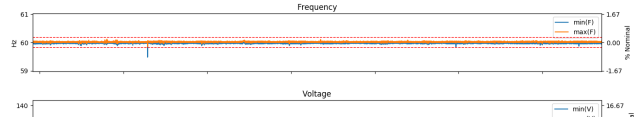
OPQ Box 1022 (Ag. Engineering): Trends 2020-01-14 19:59 - 2020-01-28 09:59 UTC



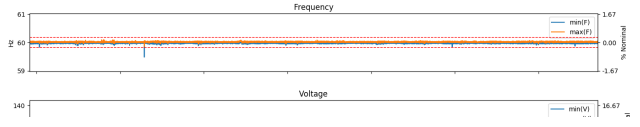
OPQ Box 1023 (Law Library): Trends 2020-01-14 19:59 - 2020-01-28 09:59 UTC

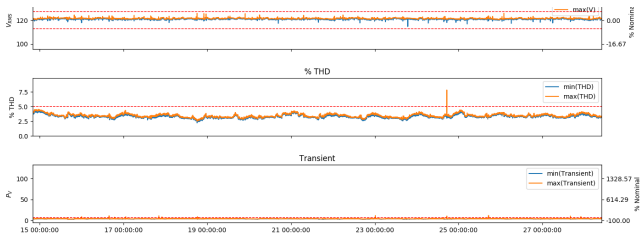


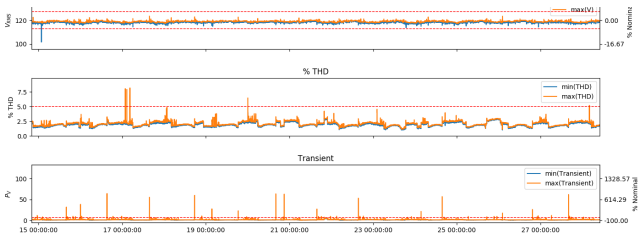
OPQ Box 1024 (IT Building): Trends 2020-01-14 19:59 - 2020-01-28 09:59 UTC



OPQ Box 1025 (Kennedy Theater): Trends 2020-01-14 19:59 - 2020-01-28 09:59 UTC







Trends for the past two weeks have remained fairly nominal. Of interest is a Frequency sag that was observed by all Boxes on January 17th and a few small Voltage sags. The periodic signals at Box 1021 are still present. You'll note that Box 1009 is missing. This Box has stopped sending data within the past couple of weeks and I am working to contact the Box caretaker to restart this Box.

Phenomena

Phenomena are an abstract concept for Anthony's PhD dissertation that provide actionable insights and context on top of classified Incidents. In terms of PQ monitoring, Phenomena provide added context on top of PQ Incidents.

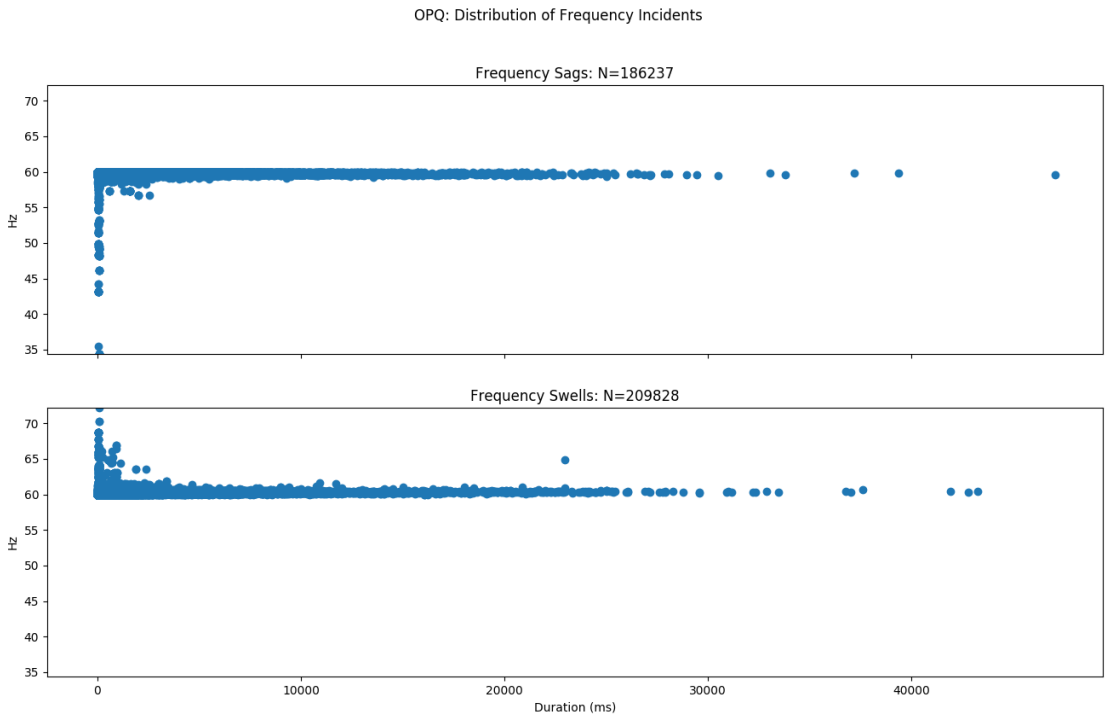
The largest change in relation to Phenomena since the last report is the introduction of Similarity Phenomena. Similarity Phenomena attempt to add context to Incidents by grouping sets of related Incidents together. These groupings allow us to discuss Incidents as Incidents that belong to a particular group rather than individual Incidents. For example, frequency Incidents dominate in count compared to all other Incidents types. This makes it difficult to discuss frequency Incidents and to separate the proverbial wheat from the chaff. Similarity Phenomena were designed to provide a way of providing additional context on top of large numbers of Incidents.

Similarity Phenomena are still computed using a batch process. This is due to the fact that not all metrics required by this Phenomena are present in the database. Instead, metrics are computed using a batch process and then fed into the Similarity Phenomena. The frequency and similarity plugins are being updated to provide Similarity Phenomena in a dynamic nature rather than through a batch process. Unfortunately, I'm still working out a few bugs in dynamic generation of these Phenomena. Because of this limitation, for this week's report, I will provide results of grouping all Frequency Incidents that OPQ has recorded. Future reports will provide groupings generated during the report period.

Two approaches were taken to find similar groups of frequency Incidents with varying success. I initially attempted to utilize hierarchical clustering, but had issues due to the high memory requirements required for performing agglomerative clustering. In agglomerative clustering, point-wise distances are found which ends up providing a memory overhead of $O(N^2)$. This memory overhead is too large to be useful on our cloud based OPQ server with a large number of Incidents. I tried to perform agglomerative clustering on a development machine with 32 GB of memory, but still ran into memory issues. Because of these memory issues, I attempted to focus my efforts on k-means clustering which provides memory overhead of closer to $O(N + k * d)$. K-means clustering was used to find groups of related clusters with an empirically found k value.

I focused my Similarity Phenomena on frequency Incidents due to the large amount of frequency Incidents present in the OPQ system. Frequency Incidents were compared using a distance metric comprised of the duration of the Incident and the maximum deviation from nominal of the Incident.

The following figure shows the distribution of all Frequency Incidents.

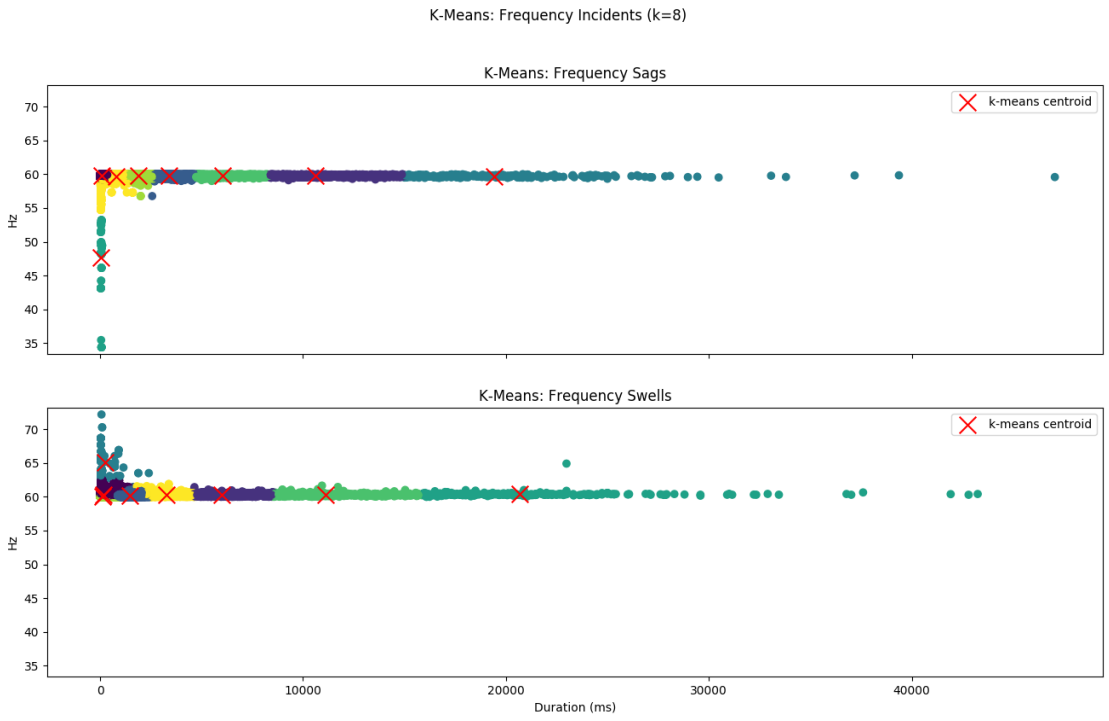


From this distribution, we can gain a pretty good idea of the makeup of OPQ's frequency Incidents. Most frequency Incidents are relatively short in duration (less than 1 second).

Large deviations from nominal tend to only occur over short durations. This is expected since frequency tends to self-correct rather quickly on power grids. There is a long tail of sags and swells that don't deviate too far from nominal with durations over 40 seconds.

The distance metrics provided were normalized in both the x and y directions to perform k-means, and then denormalized for display of the results. I empirically found that k=8 provides a nice set of clusters that characterize both the durations and the deviations from nominal. Smaller values of k do not provide enough resolution in the y-direction while larger values of k provide too many clusters in the x-direction. The only negative aspect of selecting k=8, is that long duration Incidents are generally classified together. This is acceptable because long duration Incidents are much more rare than short duration Incidents.

The following figure shows groupings of related frequency Incidents (with sags on the top and swells on the bottom). The centroid of each grouping is marked by a red X.



The above Figure shows clusters for short duration Incidents that are close to nominal, clusters for short duration Incidents that are further from nominal, and clusters for Incidents that are close to nominal, but have longer durations.

Further analysis allows us to determine the exact makeup of these clusters.

The following table shows the clusters found for frequency sags.

Cluster	Incidents	Mean Duration	Std Duration	Mean Value	Std Value
5	79	56.19	17.33	47.70	5.21
1	116769	98.91	93.97	59.84	0.08
6	35957	809.18	261.35	59.73	0.21
3	20059	1908.64	354.46	59.77	0.13
0	8931	3447.78	575.45	59.75	0.12
7	3121	6132.47	1016.73	59.74	0.13

First, we can gather that 152,805 (82%) frequency sag Incidents all have mean durations less than 1 second. Next, we can observe that cluster 5 captures the outlying short duration voltage sags that have larger deviations from nominal (47 Hz). The rest of the clusters show mean frequency sag values near 59.75 Hz, but vary in duration. You will also note that the standard deviation on the duration increases as the duration increases. This is caused by the smaller number of Incidents that are created at longer durations.

The following table shows the clusters found for frequency swells.

Cluster	Incidents	Mean Duration	Std Duration	Mean Value	Std Value
7	78577	138.63	176.19	60.10	0.06
0	95488	158.29	175.95	60.27	0.08
3	136	245.82	398.53	65.14	1.89
5	21972	1469.80	433.48	60.21	0.12
2	8954	3298.74	633.05	60.29	0.12
1	3422	6046.04	1072.05	60.31	0.11
6	1027	11297.67	2003.82	60.32	0.13
4	252	21019.67	4684.53	60.39	0.32

Clusters of frequency swells provide similar results to clusters of frequency sags. For instance, 174,201 (83%) frequency swell Incidents are less than 1 second in duration. Cluster 3 contains frequency swell Incidents that are further from nominal while other clusters vary in duration and remain closer to nominal.

This combination of Similarity Phenomena for frequency sag and swell Incidents creates a total of 16 Similarity Phenomena within the OPQ network, 8 for each frequency Incident type.

Similarity Phenomena can be used to “ignore” non-interesting Frequency Incidents, saving storage and analysis resources. My dissertation defines non-interesting Frequency Incidents as those that are less than a second in duration and closer to nominal.

If all non-interesting Frequency Incidents were removed, it would provide a data savings of close 1.7 GB and minimize the set of total Frequency Incidents by 326,791 Incidents, making it easier to identify interesting Frequency Incidents.

Future reports will examine Similarity Phenomena over the report period, rather than Similarity Phenomena generated over the entire OPQ deployment. Future reports will also expand the Similarity Phenomena to other Incident types other than just Frequency Incidents.

Incidents Summary

Incidents are classified PQ issues that were found in the previously provided Events. Incidents are classified by OPQ Mauka according to various PQ standards. OPQ Mauka provides classifications for Outages, Voltage, Frequency, and THD related issues.

A total of 142717 Incidents were processed.

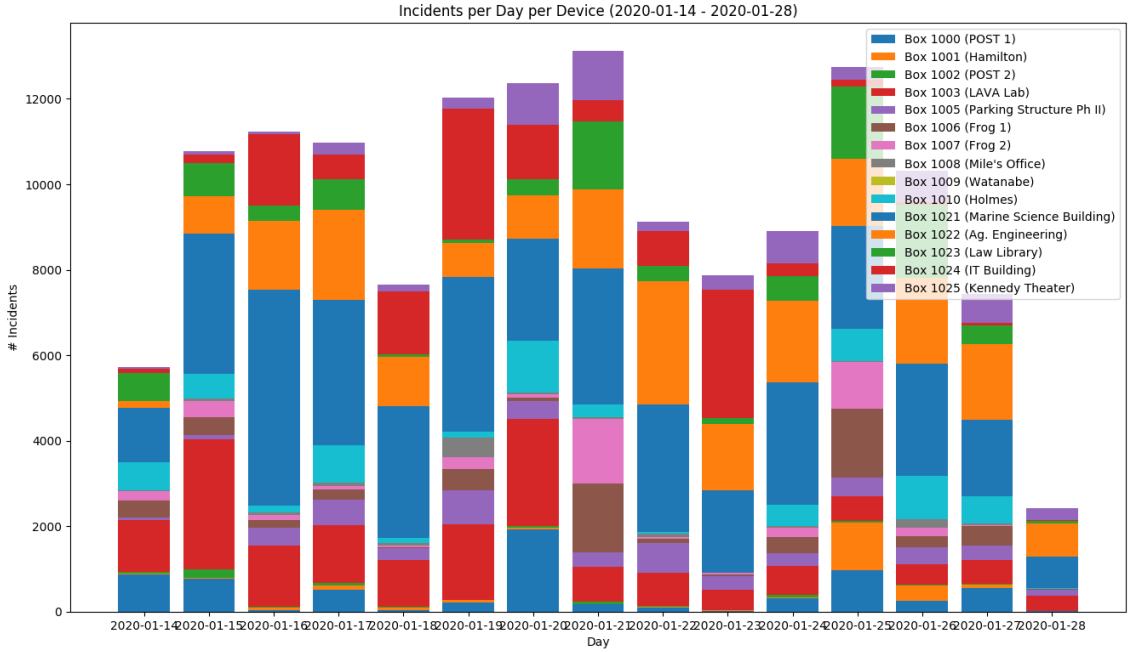
A breakdown of Incidents per Box is provided in the following table.

Box	Cnt	FSwell	FSag	THD	VSag	Outage
1021	40630	31445	9141	43	0	1
1022	21951	8828	13113	9	0	1
1003	17091	9517	7537	33	3	1
1024	13221	6349	6847	23	0	2
1023	9651	5082	4565	3	0	1
1010	6978	4042	2896	11	0	29
1000	6839	3348	3485	5	0	1
1025	6315	654	5589	68	3	1
1006	6299	1310	4980	6	0	3

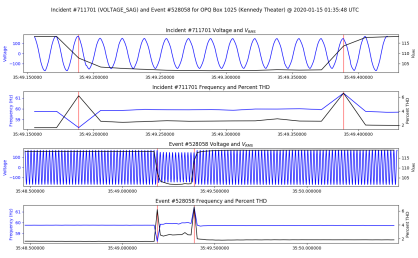
1006	6299	1310	4980	6	0	3
1005	5650	2986	2632	31	0	1
1007	4309	1231	3073	4	0	1
1001	1906	524	1343	37	0	2
1008	1226	303	895	24	3	1
1002	651	373	274	3	0	1
Total	**142717**	**75992**	**66370**	**300**	**9**	**46**

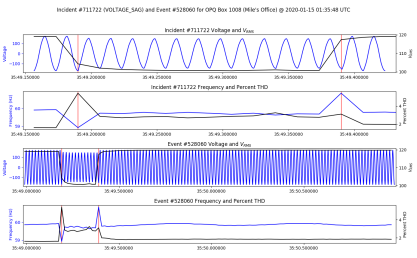
Incidents 2020-01-14 to 2020-01-28

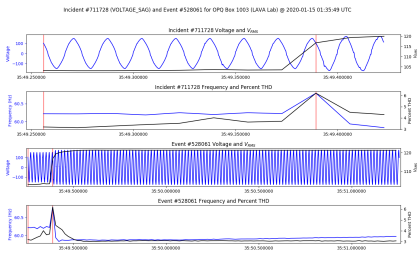
The following figure shows Incidents per Box per day.



Several voltage sags were recording and observed by multiple Boxes (1003, 1008, 1025). These Voltage sags are displayed below.







Events Summary

Events are ranges of PQ data that may (or may not) have PQ issues within them. Events are generated by two methods. The first method uses Voltage, Frequency, and THD thresholds as defined by IEEE. The second method uses the Napali Trigger which was developed by Sergey as part of his dissertation research. The Napali trigger uses statistical methods to determine when Boxes may contain PQ issues. This summary of Events examines the number of times that Boxes were triggered due to possible PQ issues.

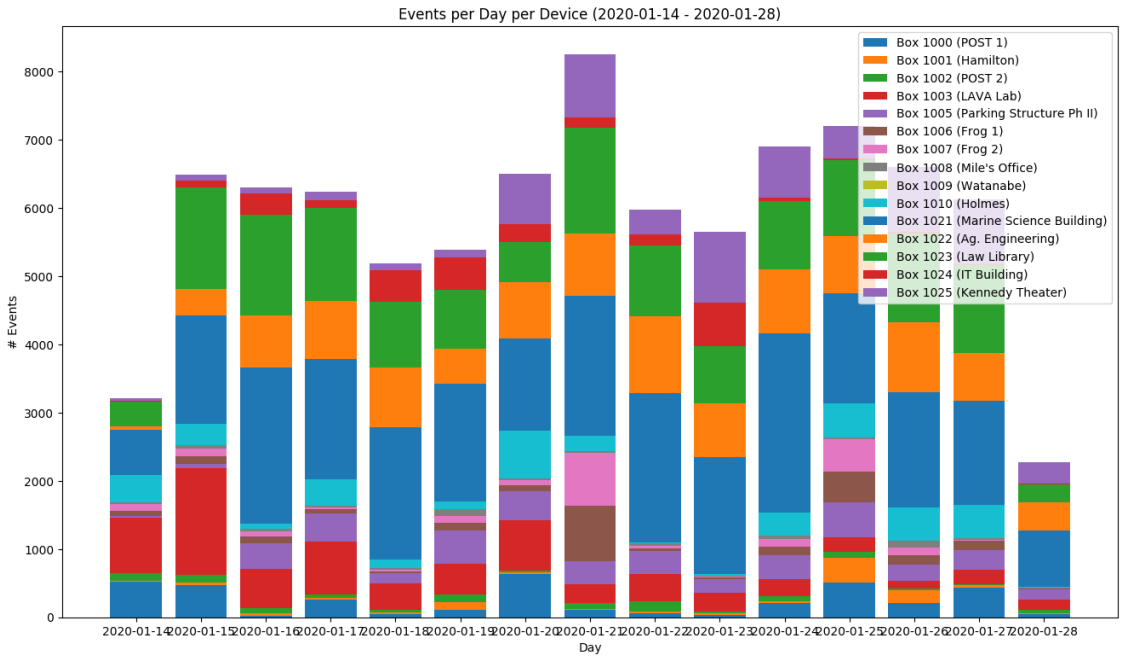
There were a total of 88314 Events processed.

The following table shows Events generated per Box.

OPQ Box	Location	Events Generated
1021	Marine Science Building	25563
1023	Law Library	15503
1022	Ag. Engineering	10983
1003	LAVA Lab	7198
1025	Kennedy Theater	7046
1005	Parking Structure Ph II	4361
1010	Holmes	4190
1000	POST 1	3719
1024	IT Building	2824
1006	Frog 1	2270
1007	Frog 2	2075
1002	POST 2	1039
1001	Hamilton	967
1008	Mile's Office	576
Total		**88314**

Events 2020-01-14 to 2020-01-28

The following figure shows Events per Box per day.



Conclusion

This report examines two weeks worth of data. Trend data continues to be mostly nominal, however a global frequency sag was observed as well as several voltage sags. This report introduces the concept of Similarity Phenomena and analyzes frequency Incidents using these Phenomena.

Unlisted

Micro-report on the UHM micro-grid: 12/31 to 01/07

Open Power Quality
Jan 10 · Unlisted

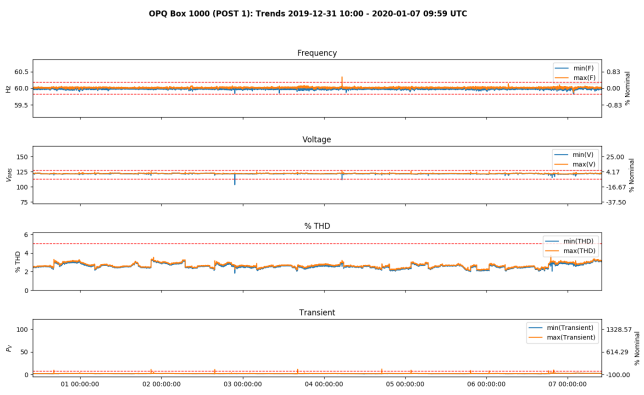
General Summary

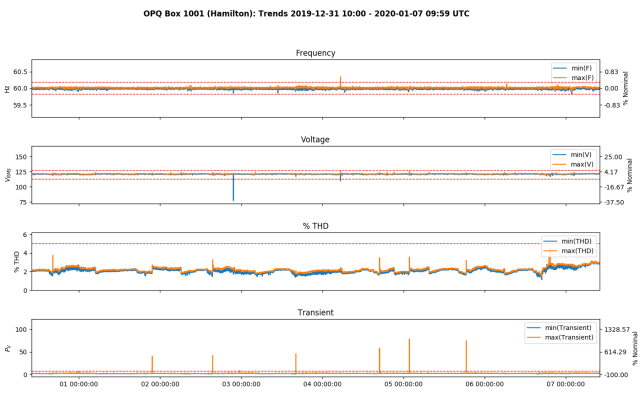
University of Hawaii at Manoa micro-grid report on data from 12–31–2019 10:00 to 01–07–2020 10:00 UTC.

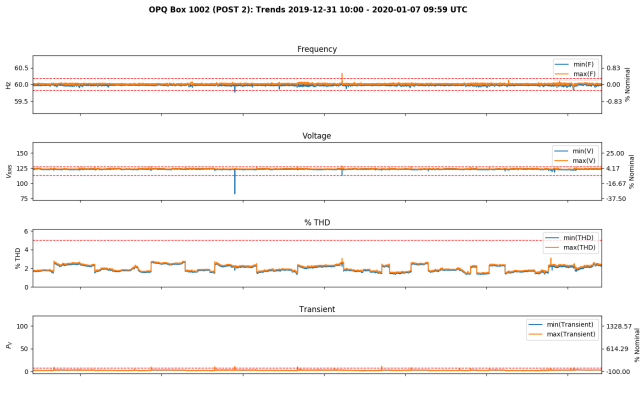
Trends Summary

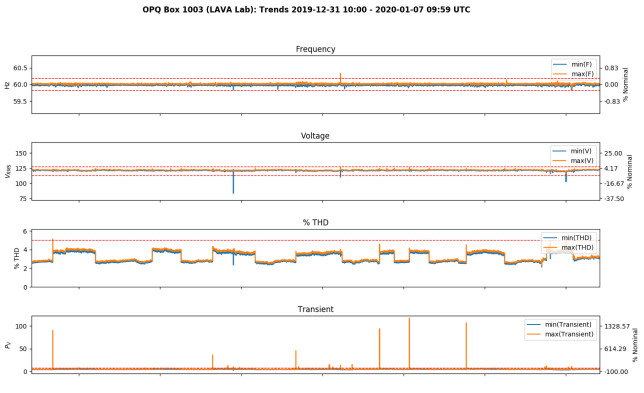
Weekly trends measure the minimum, average, and maximum values for Voltage, Frequency, THD, and transients for each OPQ Box at a rate of 1 Hz.

The following figures show Trends for each Box between 2019–12–31 10:00:00 and 2020–01–07 10:00:00.

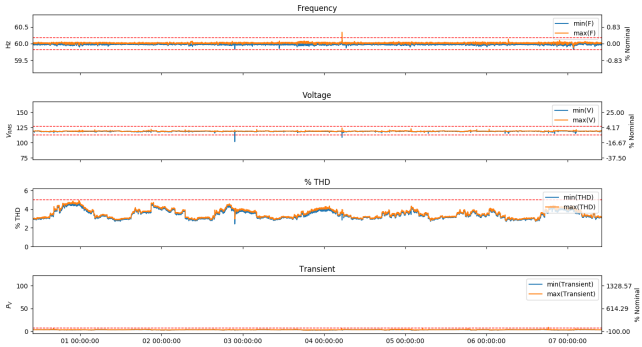


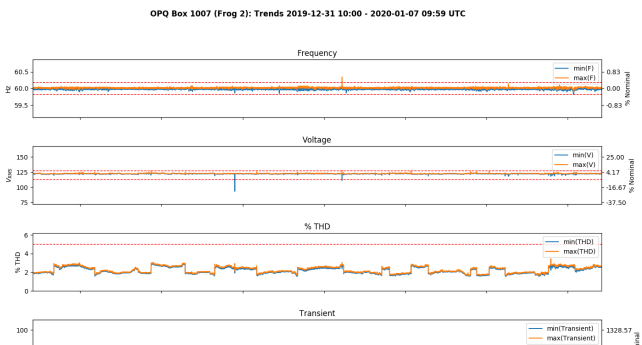




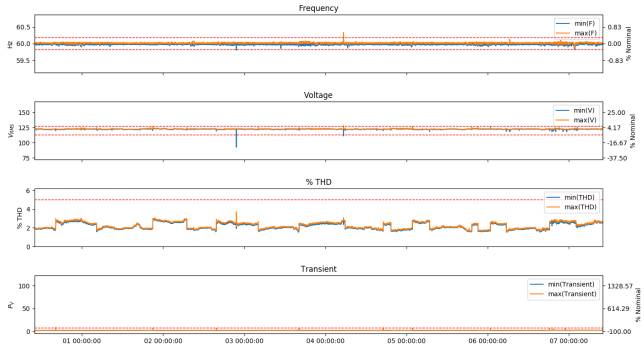


OPQ Box 1005 (Parking Structure Ph II): Trends 2019-12-31 10:00 - 2020-01-07 09:59 UTC



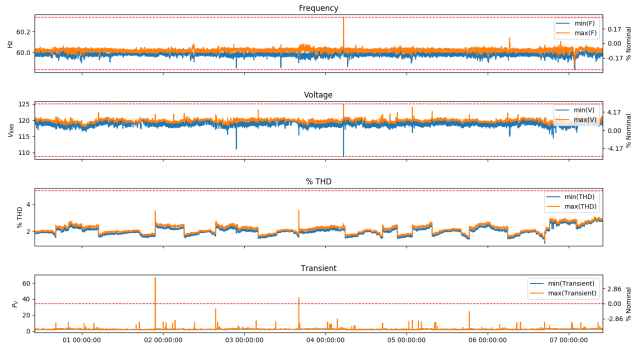


OPQ Box 1006 (Frog 1): Trends 2019-12-31 10:00 - 2020-01-07 09:59 UTC

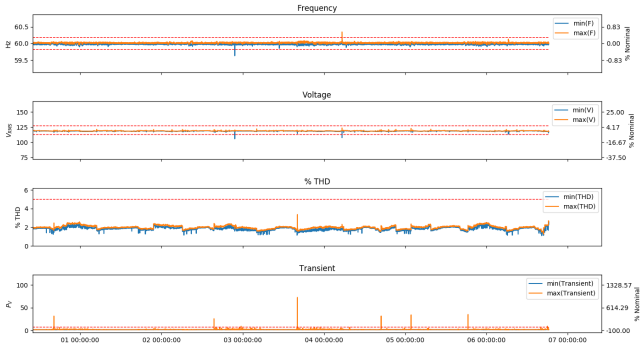


OPQ Box 1007 (Frog 2): Trends 2019-12-31 10:00 - 2020-01-07 09:59 UTC

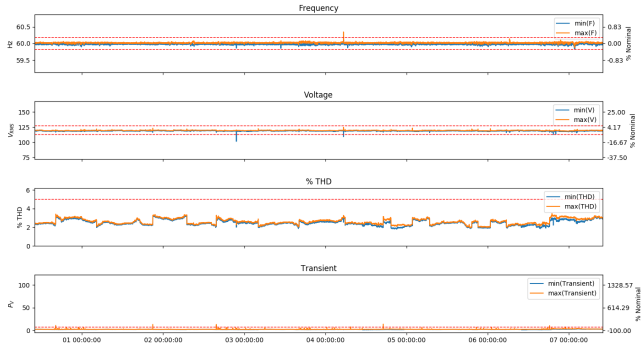
OPQ Box 1008 (Mile's Office): Trends 2019-12-31 10:00 - 2020-01-07 09:59 UTC



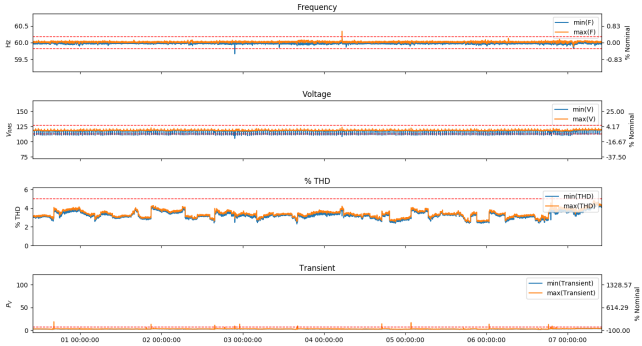
OPQ Box 1009 (Watanabe): Trends 2019-12-31 10:00 - 2020-01-06 18:23 UTC



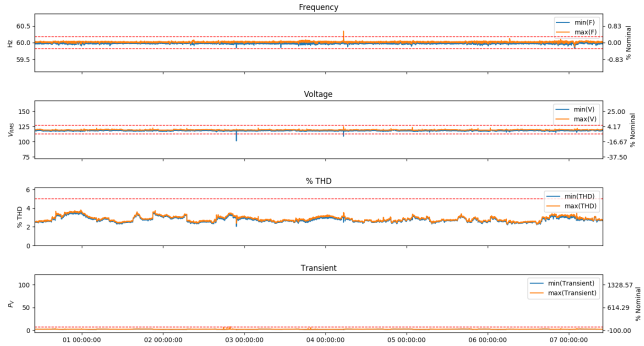
OPQ Box 1010 (Holmes): Trends 2019-12-31 10:00 - 2020-01-07 09:59 UTC



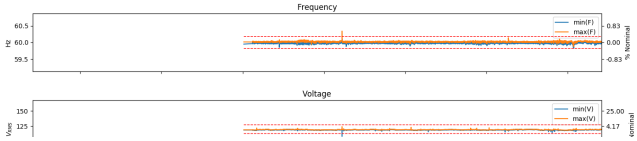
OPQ Box 1021 (Marine Science Building): Trends 2019-12-31 10:00 - 2020-01-07 09:59 UTC



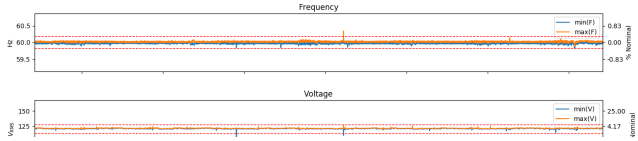
OPQ Box 1022 (Ag. Engineering): Trends 2019-12-31 10:00 - 2020-01-07 09:59 UTC

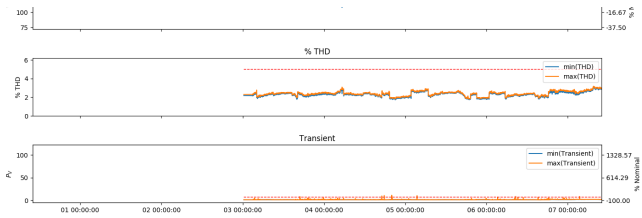


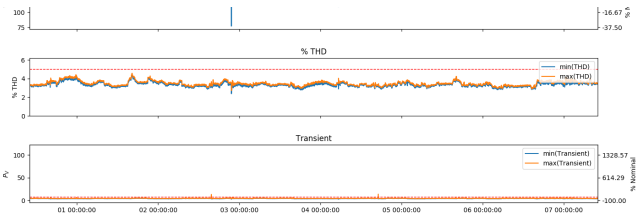
OPQ Box 1023 (Law Library): Trends 2020-01-03 00:20 - 2020-01-07 09:59 UTC



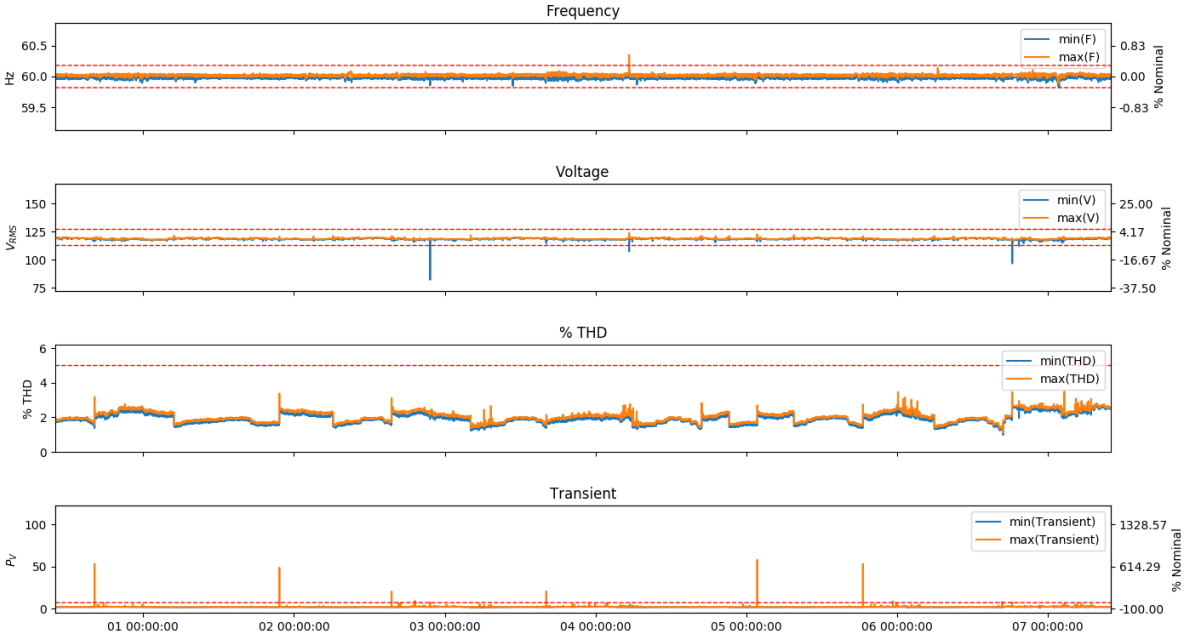
OPQ Box 1024 (IT Building): Trends 2019-12-31 10:00 - 2020-01-07 09:59 UTC







OPQ Box 1025 (Kennedy Theater): Trends 2019-12-31 10:00 - 2020-01-07 09:59 UTC



Trends for this past week exhibit a couple of interesting features.

1. A large Voltage sag that was observed across most of the OPQ Boxes in our deployment near January 2 at 21:40 UTC.

2. A Frequency spike that was observed across all deployed OPQ Boxes early on January 4th UTC.

3. Missing data from Box 1023 from the first third of the last week's report period.

I'm not really sure how to explain the large data gap at Box 1023. Going back into the data, it appears that the data gap started before Christmas and ended near January 3rd. This sensor is placed inside the special texts section of the UH Law Library and has very limited access. I can only guess that either the Box was temporarily unplugged, the Law

Library experienced network issues over the holidays, or a bug in acquisition some how caused Measurements and Trends not to be saved for that device over that time period.

Phenomena

Phenomena are an abstract concept for Anthony's PhD dissertation that provide actionable insights and context on top of classified Incidents. In terms of PQ monitoring, Phenomena provide added context on top of PQ Incidents.

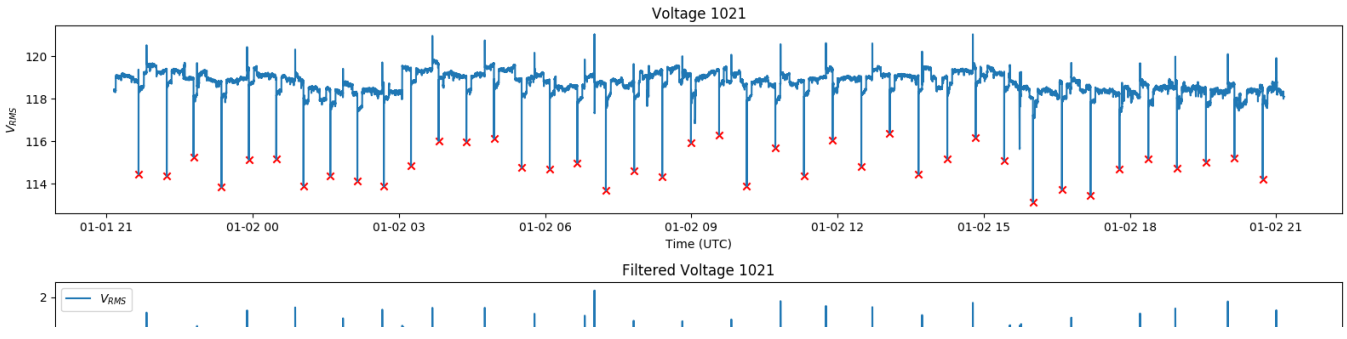
The goal of Phenomena is to provide added actionable context to large numbers of Events and Incidents. There has been a lot of progress since the last report on this front. Periodic Phenomena have been updated to automatically find Events and Incidents that occurred during the periodic signal of interest. Future Phenomena have been added which utilize Periodic Phenomena to predict future signals of interest and adjust the underlying detection capabilities. Annotation Phenomena have been updated to include groupings of sensors, Events, and Incidents that have been properly annotated.

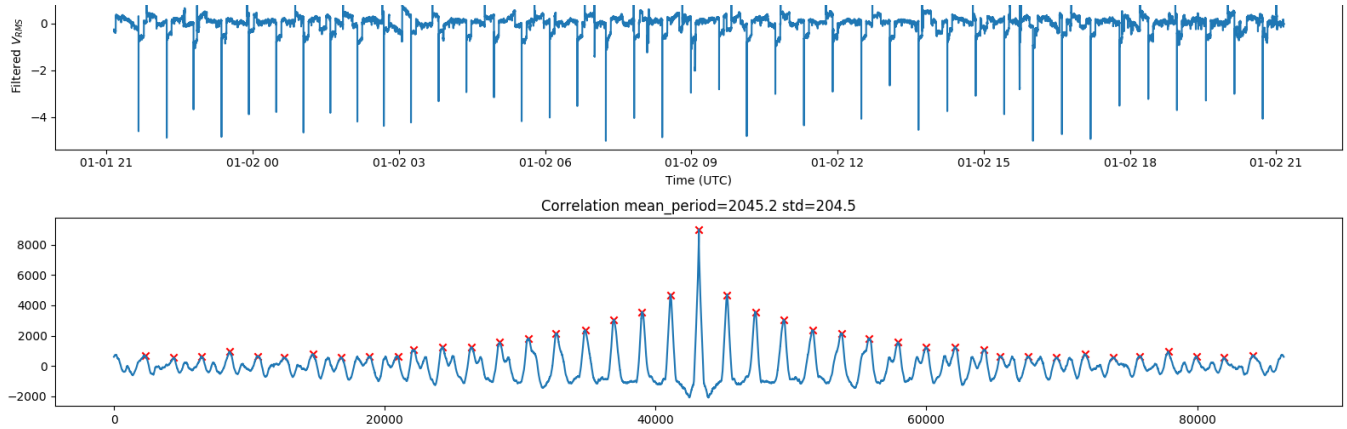
Updates to Periodic Phenomena

Periodic Phenomena have been updated to search for Events and Incidents that occur during windows defined by the periodic signals. To accomplish this, the mean period and mean standard deviation extracted from the peaks found from autocorrelation are used to parameterize and find the peaks of the signal of interest in the original signal.

The timestamps and deviations from nominal are extracted from the peaks found in the original signal. This information is used to inform the Periodicity plugin of which time ranges should be searched for Events and Incidents that match the characteristics of the periodic signal.

As discussed in previous reports, Box 1021 observes regular periodic Voltage sags about 34 minutes apart. An example of this is shown in the following figure.





Over this report duration, the Periodicity plugin was able to identify 375 Events and 4 Incidents that were created due to this periodic signal.

Not only has this Phenomena provided us the ability to group related Incidents and Events, but the plugin provides the ability to optimize itself over time. The original period for this signal was on the order of 40 minutes with a standard deviation of close to 8 minutes. As the plugin observed the signal over time, it was able to identify a period of 34 minutes with a standard deviation of close to 8 seconds. This increases our ability to identify periodic signals of interest and Events and Incidents that are related to those periodic signals.

Updates to Annotation Phenomena

Annotation Phenomena have been updated to provide groupings of Events, Incidents, and OPQ Boxes. Now, when an Annotation is created, a list of related Event Ids and Incident Ids can be specified. These values are used to find all related Event Ids, Incident Ids, and OPQ Boxes affected by the Annotation.

As an example, an Annotation was created for the Voltage sags observed in the trend data. The Annotation has the description “UHM Semi-Global Voltage Sags” and groups 60 related Incident and Event Ids that were identified as part of these Voltage sags. The TTLs for all data making up this Annotation Phenomena were also extended to last for as long as the Annotation, ensuring that this contextualized data lives long enough to be observed and useful.

A total of 5 Annotations currently exist in the database (one of which we will see in next week’s report).

Future Phenomena

Future Phenomena were implemented to predict future signals of interest. Future Phenomena make use of Periodic Phenomena by utilizing the mean period, standard deviation of the period, and timestamps of periodic signals to predict Events and Incidents 4 hours into the future.

When a Future Phenomena is created, the system sets timers to adjust triggering and detection thresholds over the Future Phenomena window. At the start of a Future Phenomena window, the detection thresholds are decreased and the data rates are increased for the Box predicted to see a signal. This increases the fidelity of feature streams coming from the Box and makes it easier for Mauka to detect signals of interest that might have otherwise not passed the detection thresholds. When the Future Phenomena window ends, the triggering and detection thresholds are reset to the default values.

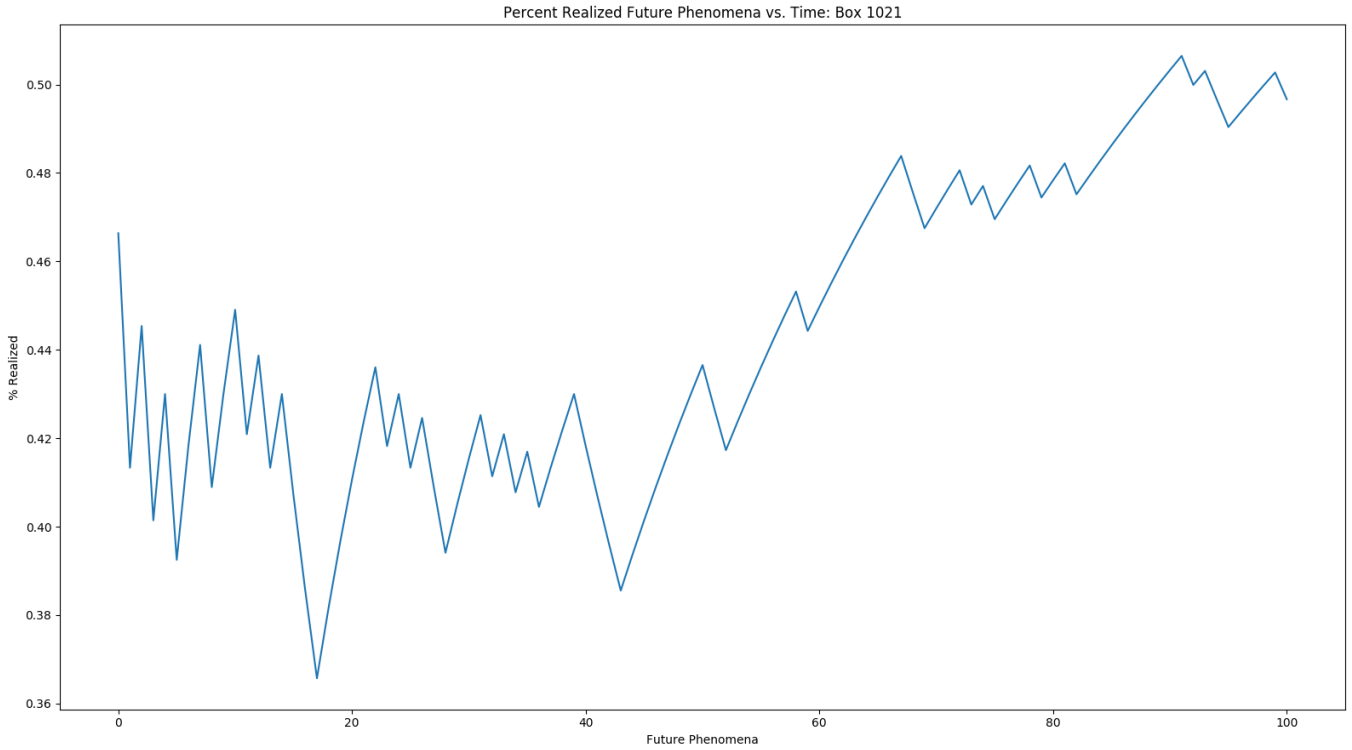
Future Phenomena also periodically check for Events and Incidents that were identified during the period of the Phenomena. I call a Future Phenomena "realized" if it contains Events or Incidents and "unrealized" if it doesn't.

Considering the Periodic Phenomena identified for Box 1021, 403 Future Phenomena were created over the last report period. Of those, 213 (~53%) contained Events or Incidents while 190 did not.

Because Future Phenomena lower detection thresholds, it's able to detect signals of interest and create Events from data that would have otherwise been missed. I call these "sub-threshold" Events and Incidents.

The Future Phenomena and Periodic Phenomena are somewhat symbiotic. The results of Periodic Phenomena inform the results of Future Phenomena and vice versa so that these Phenomena optimize each other and improve over time. This is accomplished for a couple of reasons. As Periodic Phenomena become more accurate over time, the standard deviation decreases. This provides Future Phenomena the ability to become more accurate and make better predictions. Future Phenomena, by increasing the data rate provides higher fidelity data over periodic signal periods. This increases the quality of the Periodicity Phenomena. And so the cycle continues…

I've already shown evidence that the Periodic Phenomena become more accurate over time. Can we do something similar with Future Phenomena? It turns out we can. If we plot the percentage of realized Future Phenomena against unrealized Phenomena, we can actually see that it improves over time as show in the following figure.



Here, the amount of realized Future Phenomena is just over 50%.

In the Pipeline

I am currently implementing Similarity Phenomena. This Phenomena is responsible for identifying similar Incidents both within individual Boxes and between Boxes. Clustering techniques are being used to implement this Phenomena using distance metrics found by comparing the signals deviations from nominal to their length.

More to come in next week's report.

Incidents Summary

Incidents are classified PQ issues that were found in the previously provided Events. Incidents are classified by OPQ Mauka according to various PQ standards. OPQ Mauka provides classifications for Outages, Voltage, Frequency, and THD related issues.

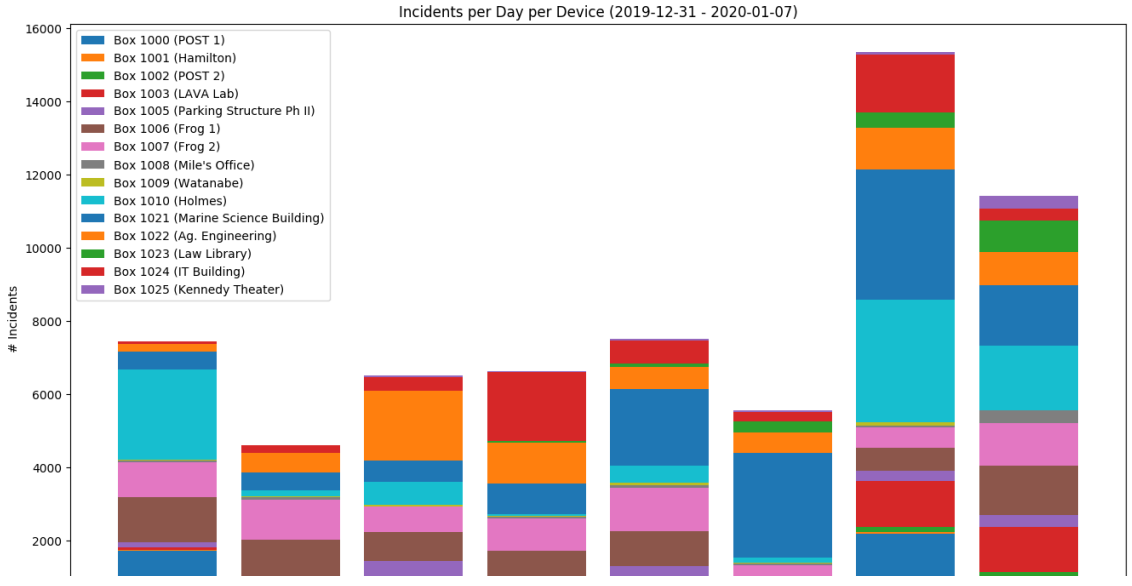
A total of 64984 Incidents were processed.

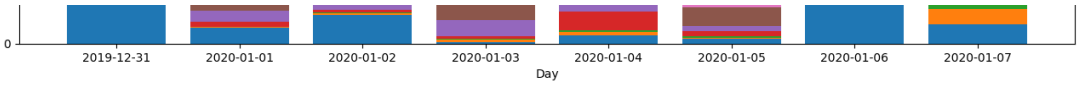
A breakdown of Incidents per Box is provided in the following table.

Box	Cnt	FSag	FSwell	THD	Outage	VSag	IticND
1021	12561	3025	9480	43	9	4	0
1010	8973	3372	5586	12	0	3	0
1006	7642	6640	989	9	0	4	0
1022	7009	3507	3482	16	0	4	0
1007	6874	5847	1017	8	0	2	0
1000	6072	2850	3200	8	9	5	0
1024	5241	2686	2525	19	0	9	2
1003	3458	2031	1399	23	0	5	0
1005	2545	1405	1112	24	0	4	0
1023	1731	944	782	4	1	0	0
1001	755	506	213	28	0	8	0
1008	698	534	156	8	0	0	0
1025	635	534	70	22	1	8	0
1002	489	258	212	8	8	3	0
1009	301	75	205	11	6	4	0
Total	**64984**	**34214**	**30428**	**243**	**34**	**63**	**2**

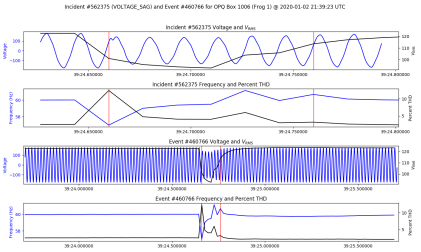
Incidents 2019-12-31 to 2020-01-07

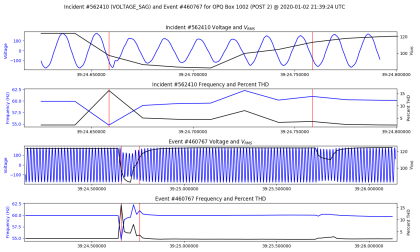
The following figure shows Incidents per Box per day.

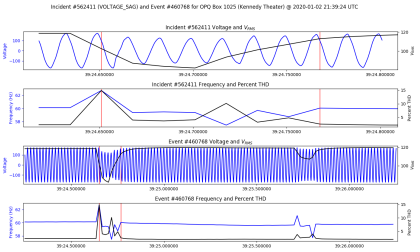


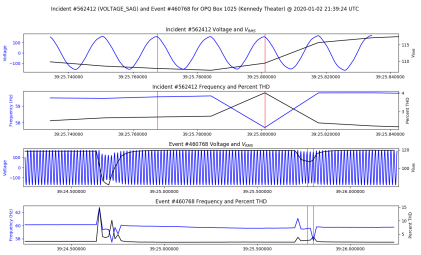


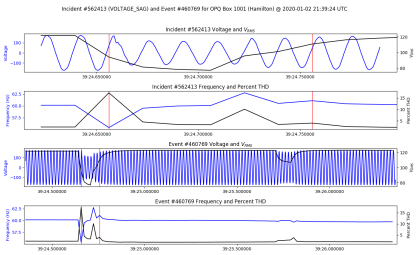
The Voltage sags observed on January 2 were picked up nicely by Mauka's Incidents. The following figures show the Voltage sag Incidents.

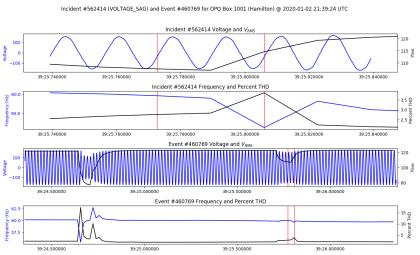


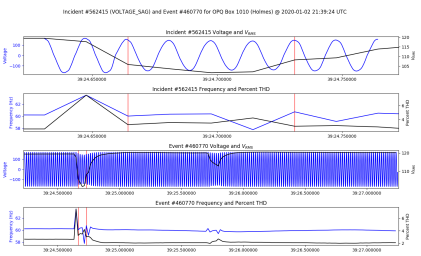


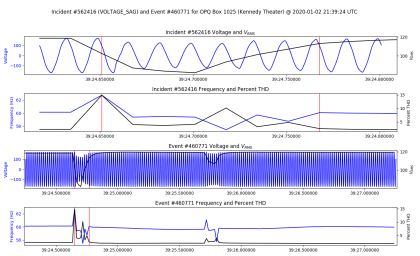


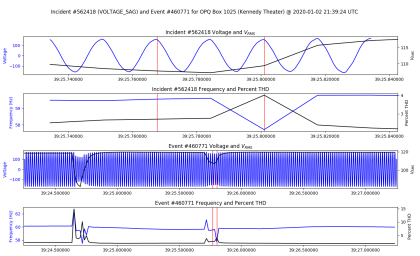


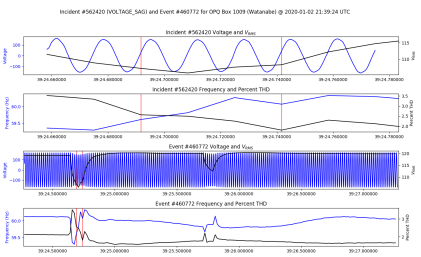


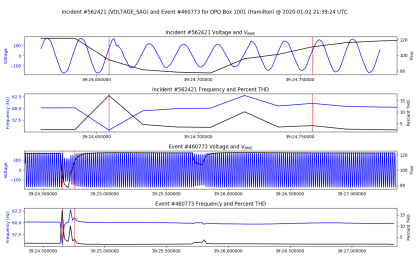


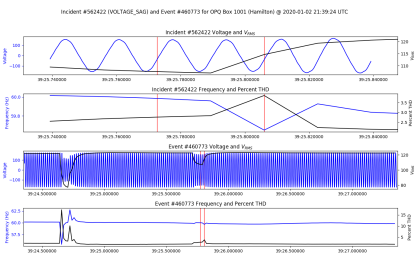


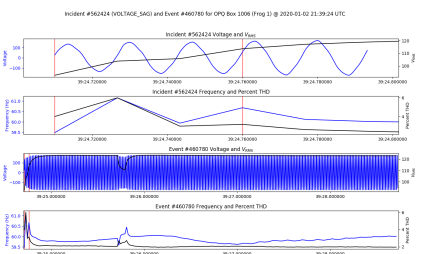


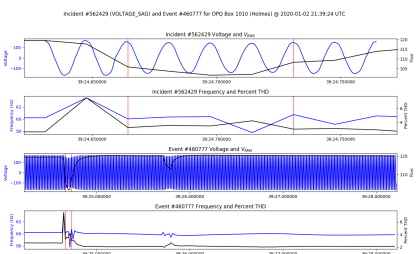


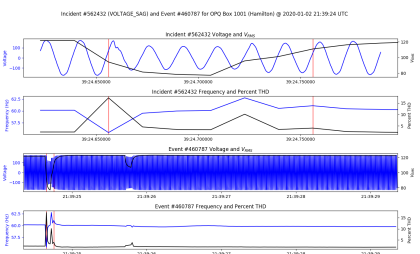


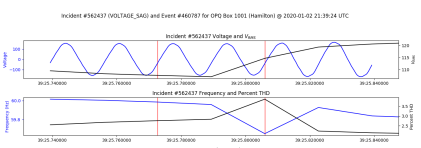


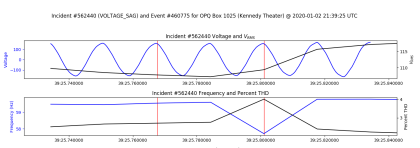


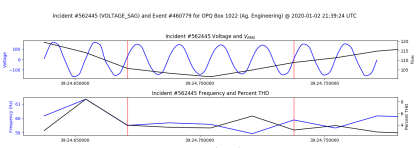


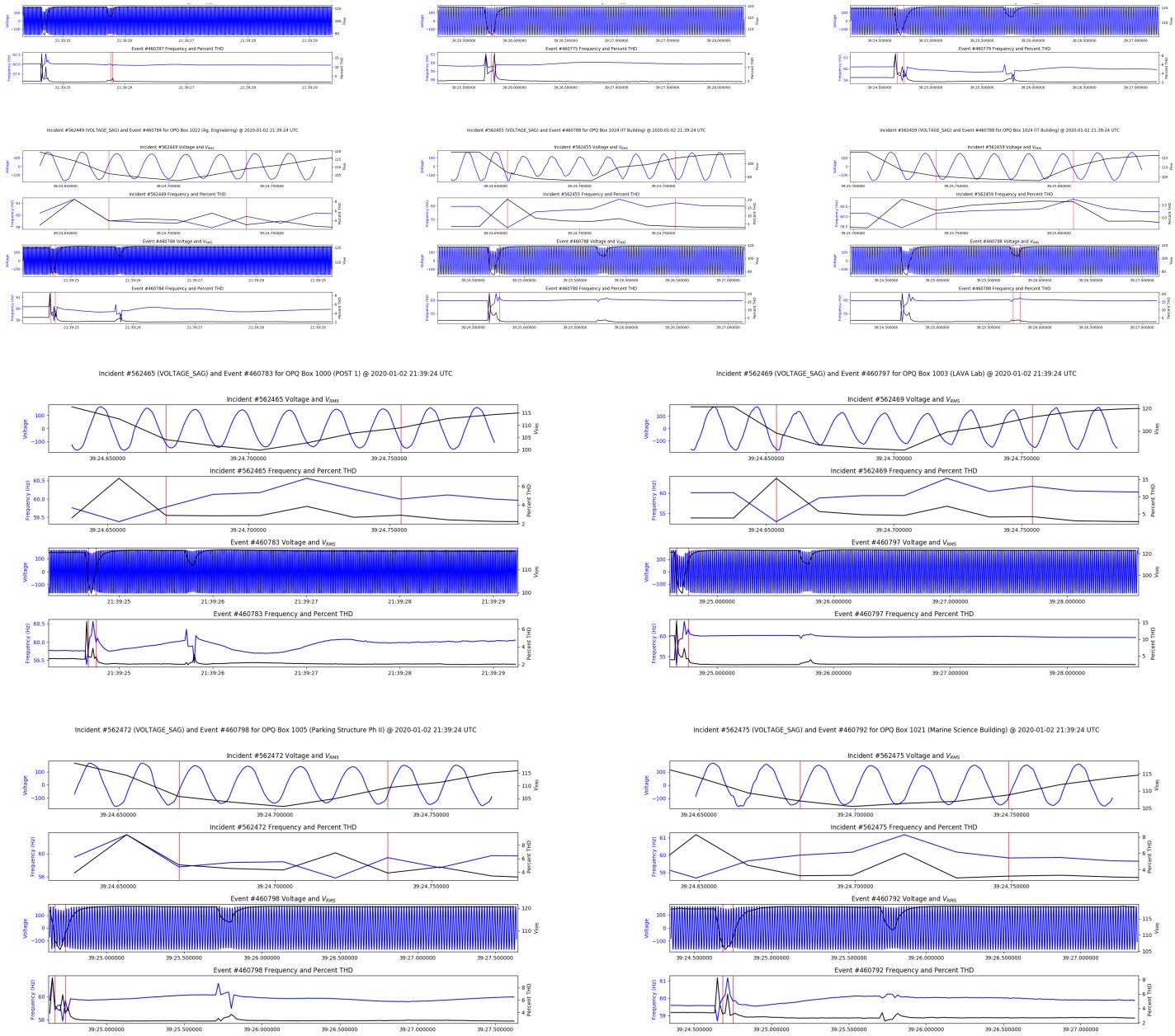




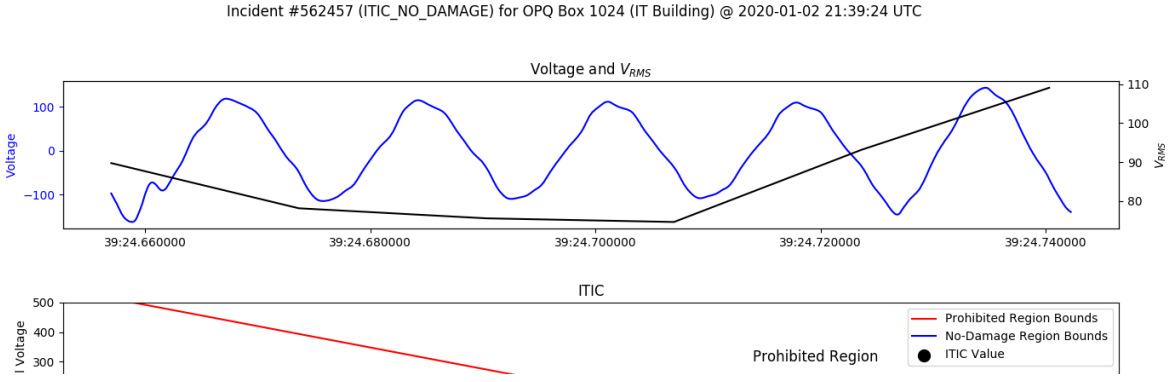


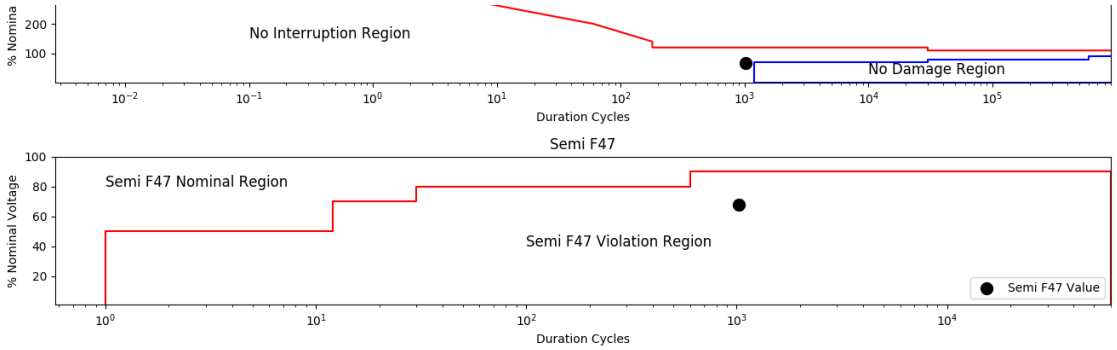






The Voltage sag observed by Box 1023 was large enough in deviation and long enough in duration to be classified by Mauka as both an ITIC “No Damage” Incident and a Semi-F47 Violation Incident.





The Frequency spikes were also well characterized by Mauka.

Events Summary

Events are ranges of PQ data that may (or may not) have PQ issues within them. Events are generated by two methods. The first method uses Voltage, Frequency, and THD thresholds as defined by IEEE. The second method uses the Napali Trigger which was developed by Sergey as part of his dissertation research. The Napali trigger uses statistical methods to determine when Boxes may contain PQ issues. This summary of Events examines the number of times that Boxes were triggered due to possible PQ issues.

There were a total of 29111 Events processed.

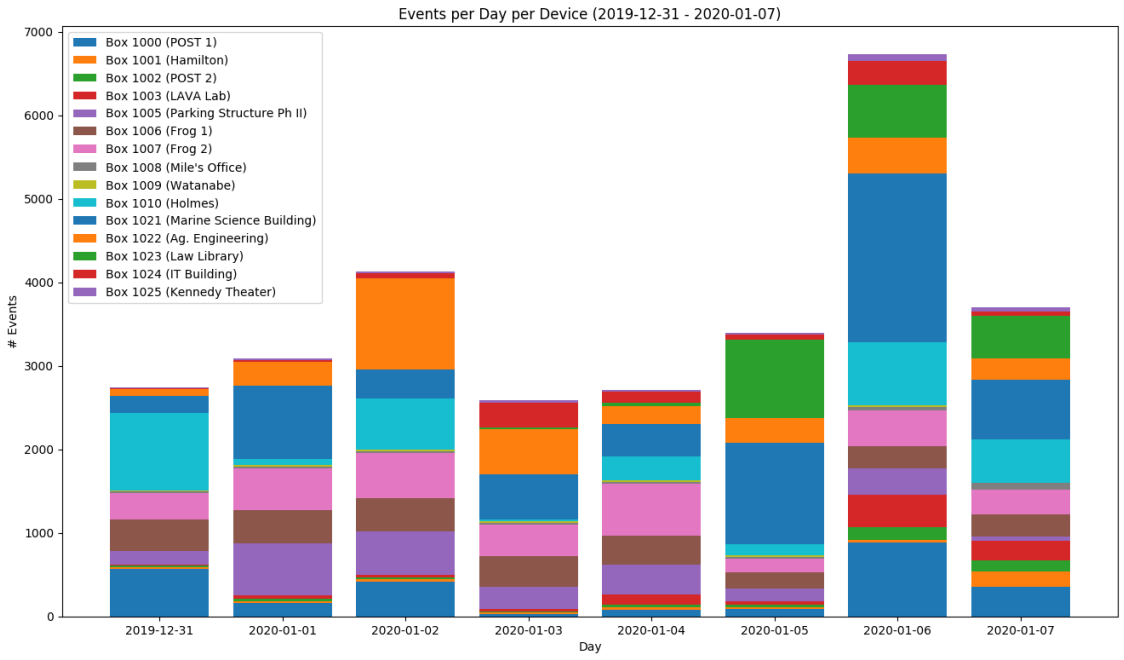
The following table shows Events generated per Box.

OPQ Box	Location	Events Generated
1021	Marine Science Building	6305
1010	Holmes	3320
1007	Frog 2	3241
1022	Ag. Engineering	3184
1006	Frog 1	2609
1000	POST 1	2600
1005	Parking Structure Ph II	2454
1023	Law Library	2152
1024	IT Building	921
1003	LAVA Lab	887
1002	POST 2	440

1001	Hamilton	348
1008	Mile's Office	273
1025	Kennedy Theater	261
1009	Watanabe	116
Total		**29111**

Events 2019-12-31 to 2020-01-07

The following figure shows Events per Box per day.



Conclusion

In this week's report, we examine a large Voltage sag that was observed across most OPQ Boxes and discuss updates to Periodic, Future, and Annotation Phenomena.

Unlisted

Data Science

Micro-report on the UHM micro-grid: 12/10 to 12/17

Open Power Quality
Dec 20, 2019 · Unlisted

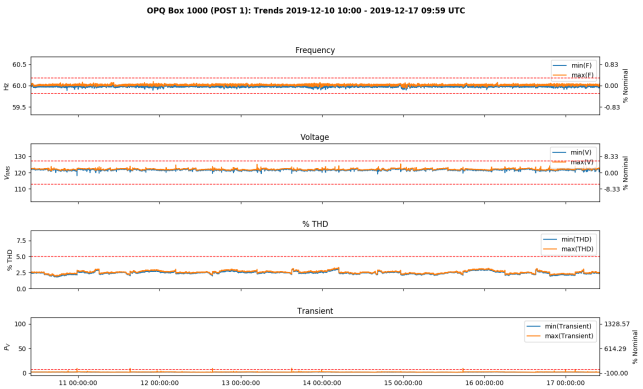
General Summary

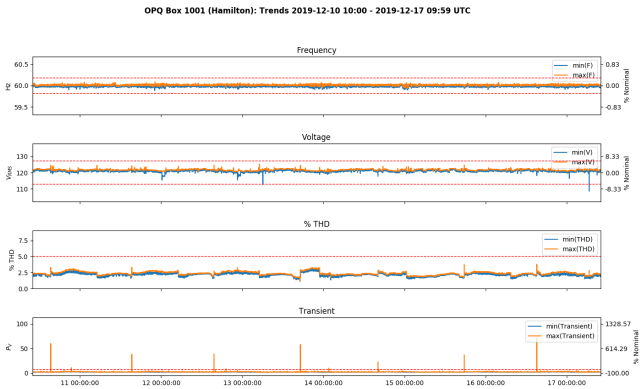
University of Hawaii at Manoa micro-grid report on data from 12–10–2019 10:00 to 12–17–2019 10:00 UTC.

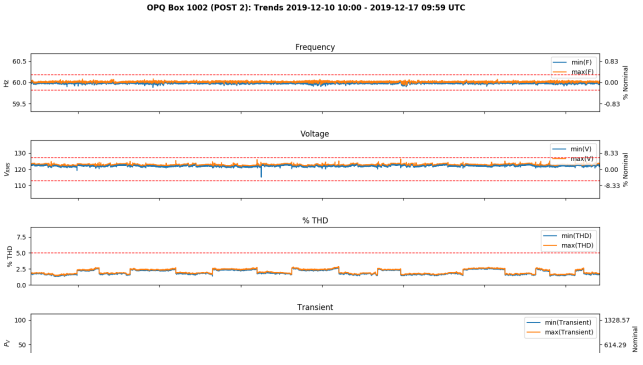
Trends Summary

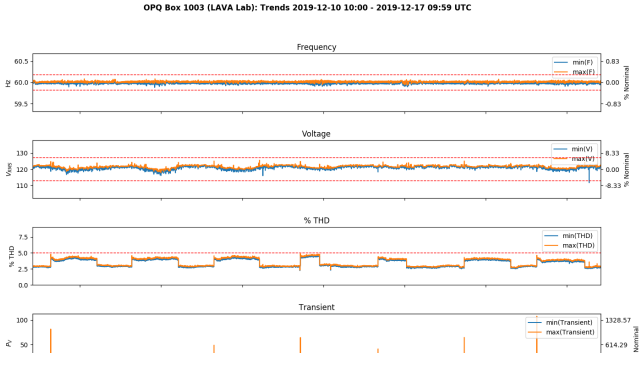
Weekly trends measure the minimum, average, and maximum values for Voltage, Frequency, THD, and transients for each OPQ Box at a rate of 1 Hz.

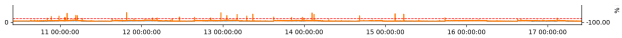
The following figures show Trends for each Box between 2019–12–10 10:00:00 and 2019–12–17 10:00:00

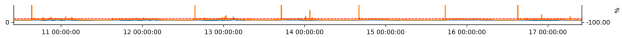




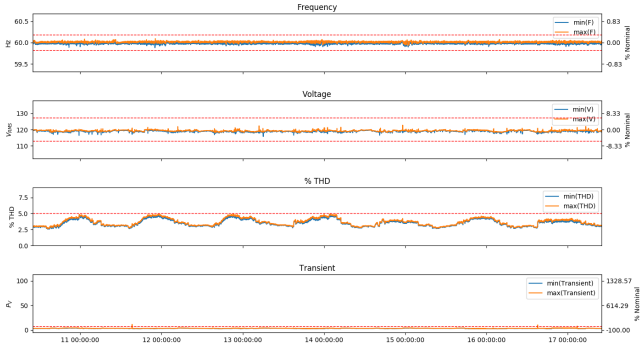




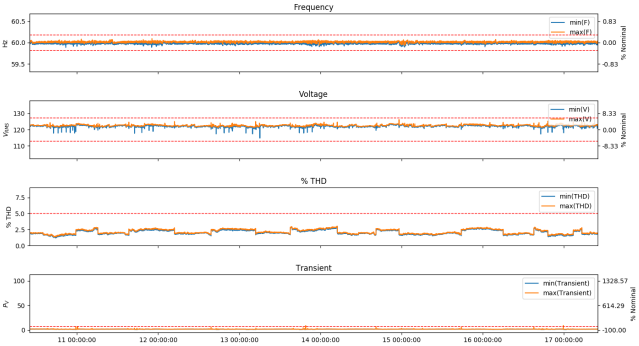




OPQ Box 1005 (Parking Structure Ph II): Trends 2019-12-10 10:00 - 2019-12-17 09:59 UTC

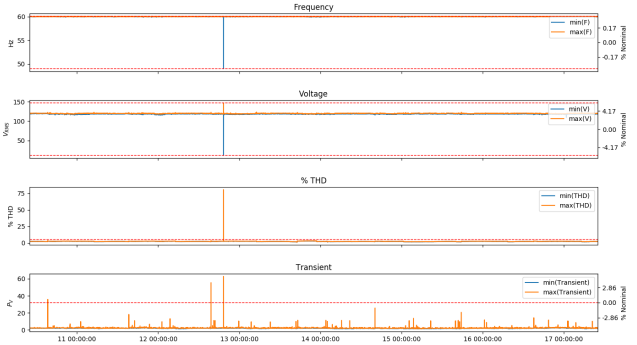


OPQ Box 1006 (Frog 1): Trends 2019-12-10 10:00 - 2019-12-17 09:59 UTC

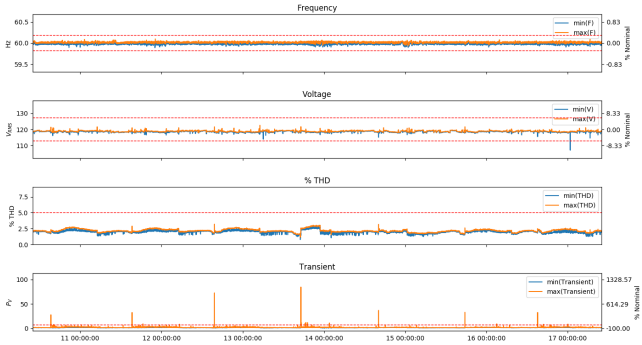


OPQ Box 1007 (Frog 2): Trends 2019-12-10 10:00 - 2019-12-17 09:59 UTC

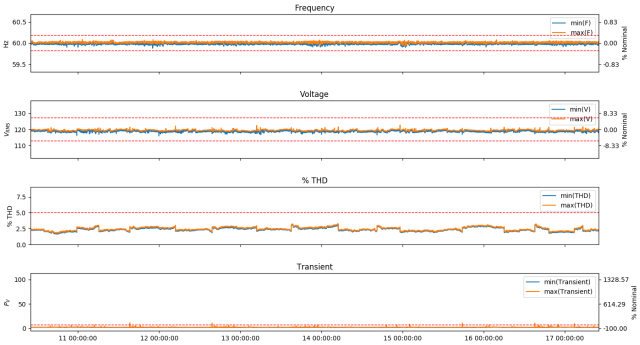
OPQ Box 1008 (Mile's Office): Trends 2019-12-10 10:00 - 2019-12-17 09:59 UTC



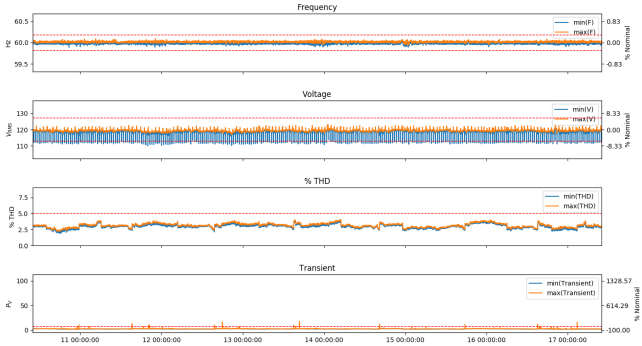
OPQ Box 1009 (Watanabe): Trends 2019-12-10 10:00 - 2019-12-17 09:59 UTC



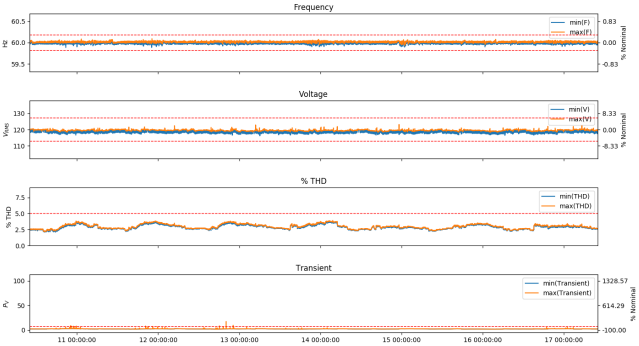
OPQ Box 1010 (Holmes): Trends 2019-12-10 10:00 - 2019-12-17 09:59 UTC



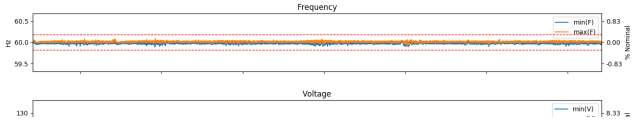
OPQ Box 1021 (Marine Science Building): Trends 2019-12-10 10:00 - 2019-12-17 09:59 UTC



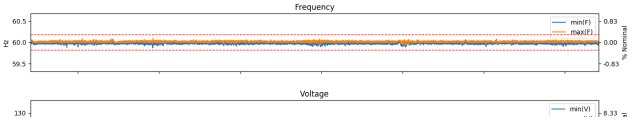
OPQ Box 1022 (Ag. Engineering): Trends 2019-12-10 10:00 - 2019-12-17 09:59 UTC

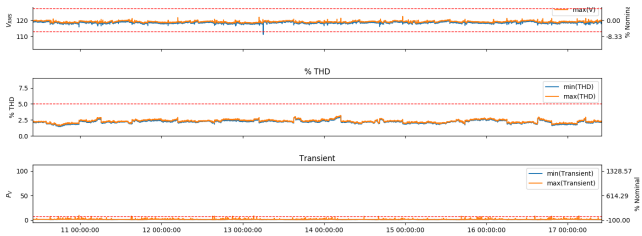


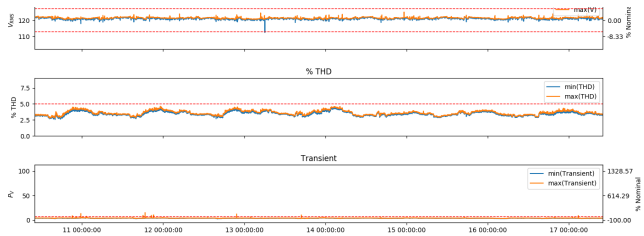
OPQ Box 1023 (Law Library): Trends 2019-12-10 10:00 - 2019-12-17 09:59 UTC

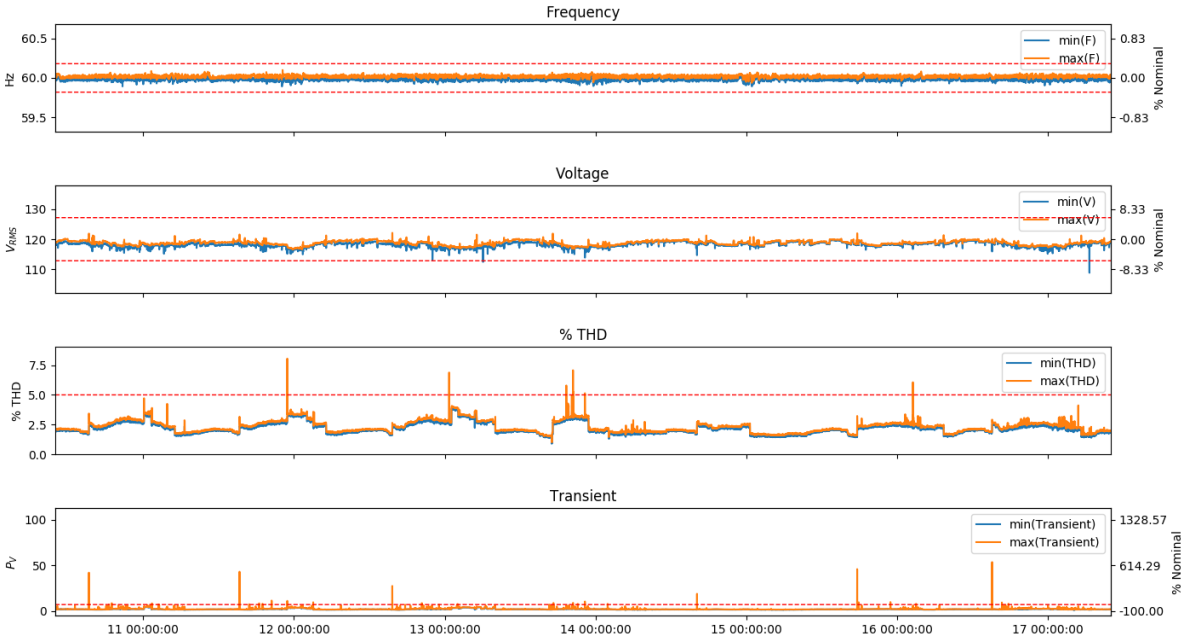


OPQ Box 1024 (IT Building): Trends 2019-12-10 10:00 - 2019-12-17 09:59 UTC









Trends this week are rather interesting because a large spike in magnitude difference at Box 1008 completely dwarfs the rest of the trends. This caused our y-axis to be so large for the other Boxes that we couldn't decipher if there was anything meaningful taking place. We regenerated the Trends ignoring the min and max y-values from 1008. Please be aware that Box 1008 is using a different y-axis scaling compared to every other Box.

After applying this correction, we can see that the Trend data is completely nominal except for Box 1008 and Box 1025 which observed several spikes in THD.

This provides an interesting observation. Some (rather large) local Event occurred at Box 1008 and was not observed on any of the other Boxes.

Phenomena

Phenomena are an abstract concept for Anthony's PhD dissertation that provide actionable insights and context on top of classified Incidents. In terms of PQ monitoring, Phenomena provide added context on top of PQ Incidents.

This past week has focused on developing Phenomena that are able to categorize groups of related Incidents. We've made progress on two fronts regarding this.

First, Annotation Phenomena have been implemented. Annotations provide user defined labels that provide context to classified PQ signals of interest. Annotations are able to group sets of Measurements, Trends, Events, and Incidents.

Each Annotation Phenomena stores the duration of the Annotation as well as a list of related Incident Ids, Event Ids, affected OPQ Boxes, and a description of the Annotation itself.

When an Annotation is created, all Measurements, Trends, and Incidents that are owned by the Annotation have their TTLs updated to that of the Annotation (default 2 years for Phenomena).

Now, instead of discussing Events and Incidents as individual things, we can refer to them as a grouping of Events and Incidents all owned by an Annotation.

So far, I've created Annotations for a power outage that will be discussed in next week's report and for previous PQ events such as the large storm we observed in our first report. I am continuing to add and refine Annotations to provide groupings of related Events and Incidents.

Second, I'm exploring several different approaches to implementing Similarity Phenomena. I expect this Phenomena to have the biggest impact on being able to automatically group sets of related Incidents. To do this, I've arranged all Incidents (grouped by Incident type) in 2D space with the duration of an Incident on the x-axis and the distance from nominal on the y-axis.

I'm next looking to cluster these items either using k-means clustering or hierarchical clustering. I'm experimenting with different distance metrics such as Euclidean Distance and the Jaccard Distance and also playing with whether points in 2D space should belong to more than one cluster or not.

Once I have a robust model of clusters, I will create clusters for Incidents related to individual Boxes and also create clusters including all Boxes. This should provide views of both similar local Incidents and similar global Incidents.

Incidents Summary

Incidents are classified PQ issues that were found in the previously provided Events. Incidents are classified by OPQ Mauka according to various PQ standards. OPQ Mauka provides classifications for Outages, Voltage, Frequency, and THD related issues.

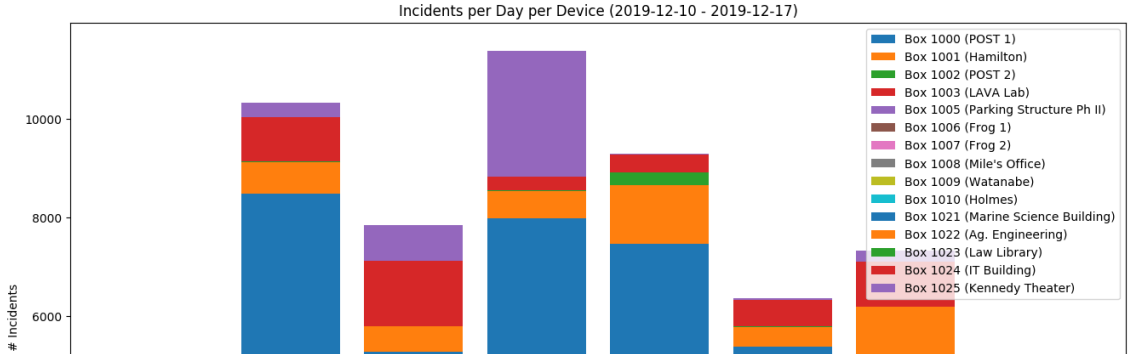
A total of 61156 Incidents were processed.

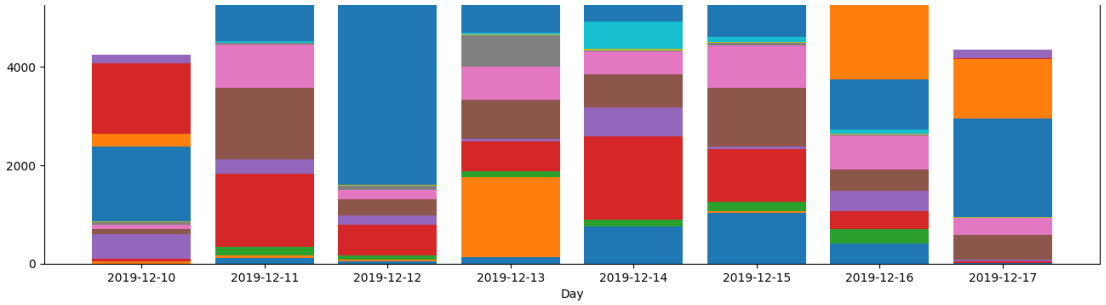
A breakdown of Incidents per Box is provided in the following table.

Box	Cnt	FSwell	FSag	THD	Outage	VSag	SemiF47	IticND	VInt	VSwell
1021	18774	16063	2695	16	0	0	0	0	0	0
1022	7225	4638	2578	9	0	0	0	0	0	0
1003	5926	3546	2367	13	0	0	0	0	0	0
1024	5793	3294	2489	10	0	0	0	0	0	0
1006	5501	511	4990	0	0	0	0	0	0	0
1007	4179	582	3594	2	1	0	0	0	0	0
1025	4170	2273	1858	39	0	0	0	0	0	0
1000	2517	1429	1086	1	1	0	0	0	0	0
1005	2089	1308	769	12	0	0	0	0	0	0
1001	1799	790	994	15	0	0	0	0	0	0
1002	1002	839	162	1	0	0	0	0	0	0
1008	921	400	465	31	1	13	1	1	1	8
1010	823	598	209	8	8	0	0	0	0	0
1023	306	176	128	2	0	0	0	0	0	0
1009	131	72	44	13	0	2	0	0	0	0
Total	**61156**	**36519**	**24428**	**172**	**11**	**15**	**1**	**1**	**1**	**8**

Incidents 2019-12-10 to 2019-12-17

The following figure shows Incidents per Box per day.





In general, the rate of Incidents remains similar to past reports. We can see the Incidents generated by the spikes in Box 1008. Attempting to plot these Incidents has so far failed because the reported Frequency is so far from nominal that the Frequency extraction algorithm failed to converge. We are looking to address this issue in our report plotting so that we can at least observe the other metrics.

Events Summary

Events are ranges of PQ data that may (or may not) have PQ issues within them. Events are generated by two methods. The first method uses Voltage, Frequency, and THD thresholds as defined by IEEE. The second method uses the Napali Trigger which was developed by Sergey as part of his dissertation research. The Napali trigger uses statistical methods to determine when Boxes may contain PQ issues. This summary of Events examines the number of times that Boxes were triggered due to possible PQ issues.

There were a total of 29389 Events processed.

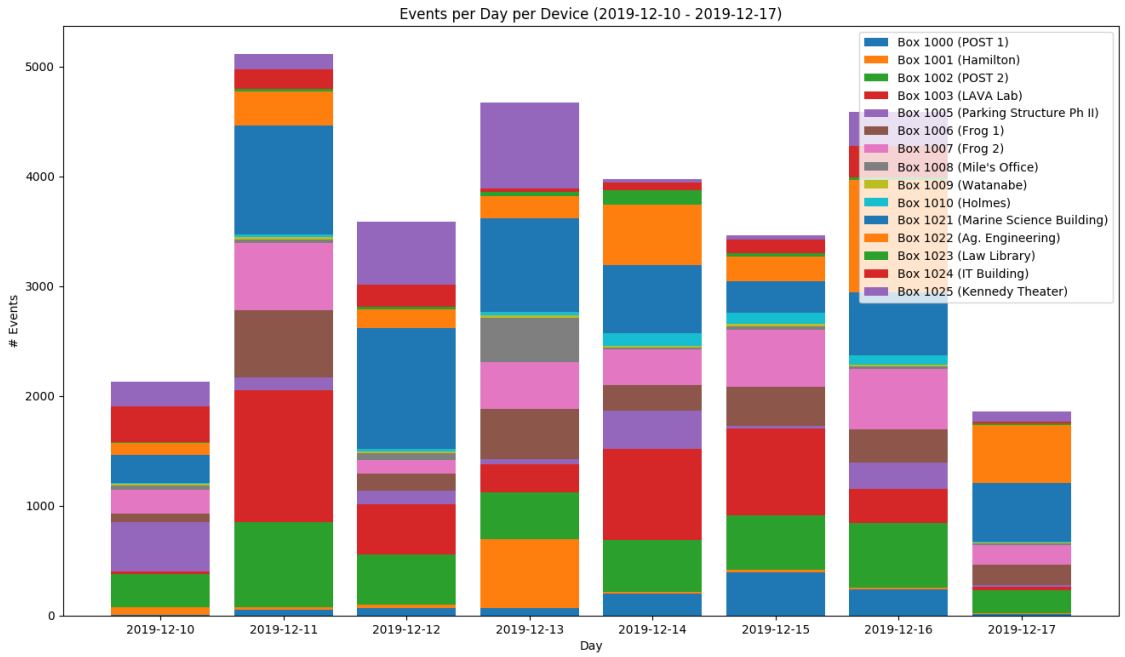
The following table shows Events generated per Box.

OPQ Box	Location	Events Generated
1021	Marine Science Building	5208
1003	LAVA Lab	3895
1002	POST 2	3736
1022	Ag. Engineering	3119
1007	Frog 2	2953
1006	Frog 1	2376
1025	Kennedy Theater	2192

1005	Parking Structure Ph II	1365
1024	IT Building	1246
1000	POST 1	1061
1001	Hamilton	800
1008	Mile's Office	617
1010	Holmes	396
1023	Law Library	277
1009	Watanabe	148
Total		**29389**

Events 2019-12-10 to 2019-12-17

The following figure shows Events per Box per day.



Conclusion

This past week proved to be a fairly nominal week in terms of PQ observations. Other than the large spikes observed at Box 1008, the rest of the grid remained nominal. We provide more information on our approach for grouping similar Incidents in an attempt to filter out the bigger picture from the large amount of Incidents generated.

Programming

Micro-report on the UHM micro-grid: 12/03 to 12/10

Open Power Quality
Dec 10, 2019 · Unlisted

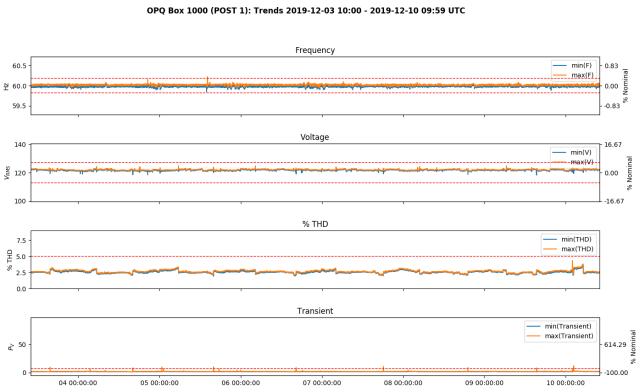
General Summary

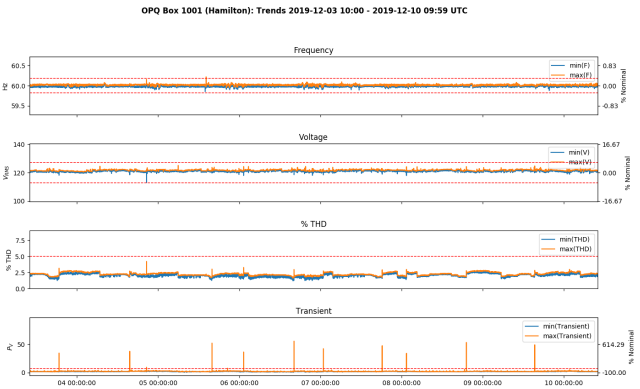
University of Hawaii at Manoa micro-grid report on data from 12–03–2019 10:00 to 12–10–2019 10:00 UTC.

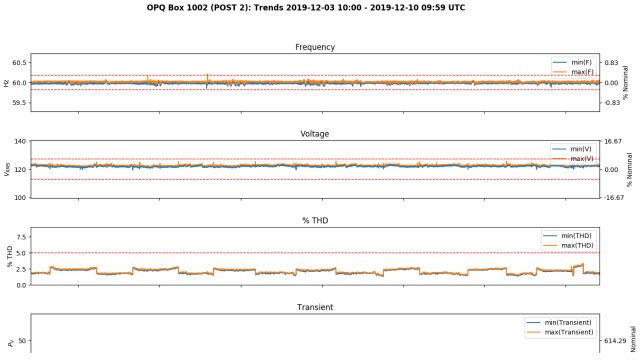
Trends Summary

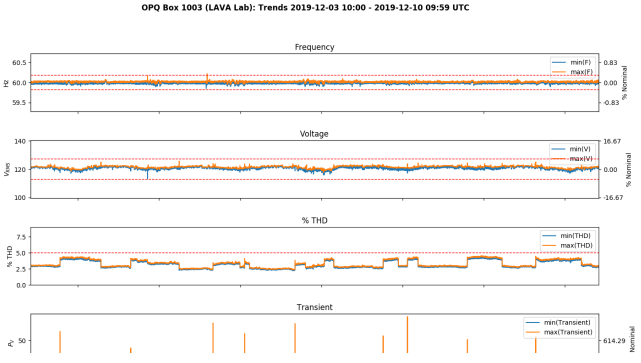
Weekly trends measure the minimum, average, and maximum values for Voltage, Frequency, THD, and transients for each OPQ Box at a rate of 1 Hz.

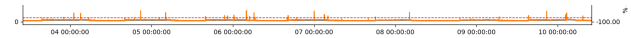
The following figures show Trends for each Box between 2019–12–03 10:00:00 and 2019–12–10 10:00:00.

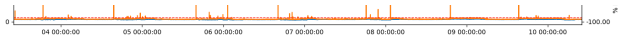




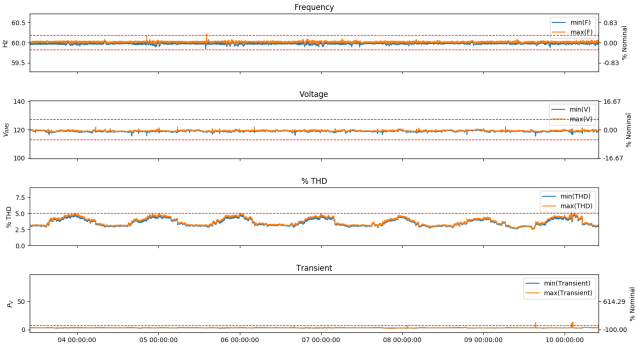




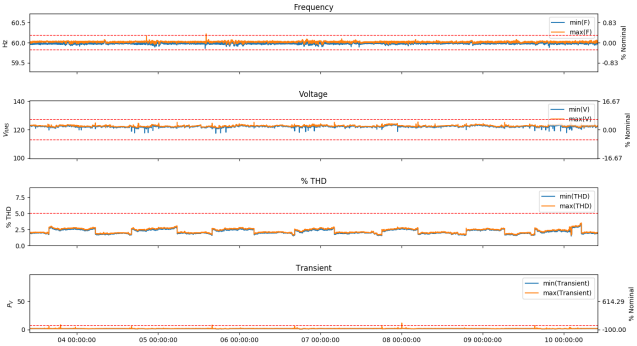




OPQ Box 1005 (Parking Structure Ph II): Trends 2019-12-03 10:00 - 2019-12-10 09:59 UTC

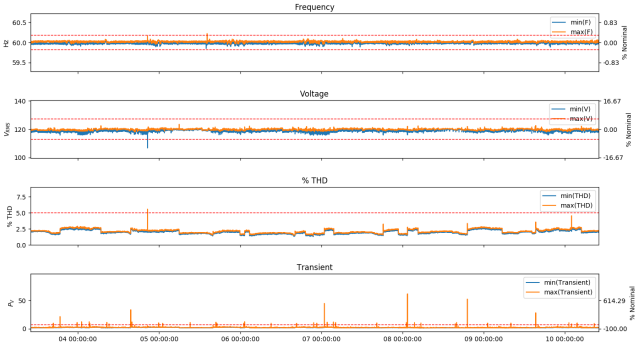


OPQ Box 1006 (Frog 1): Trends 2019-12-03 10:00 - 2019-12-10 09:59 UTC

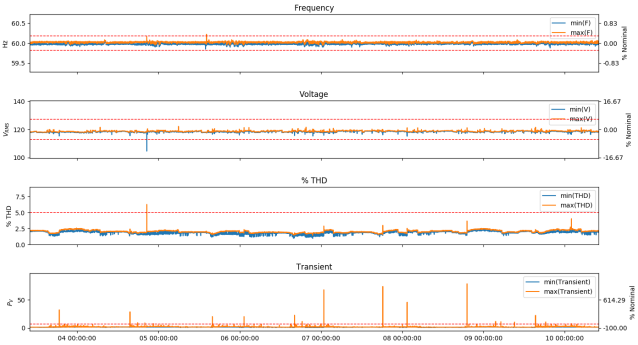


OPQ Box 1007 (Frog 2): Trends 2019-12-03 10:00 - 2019-12-10 09:59 UTC

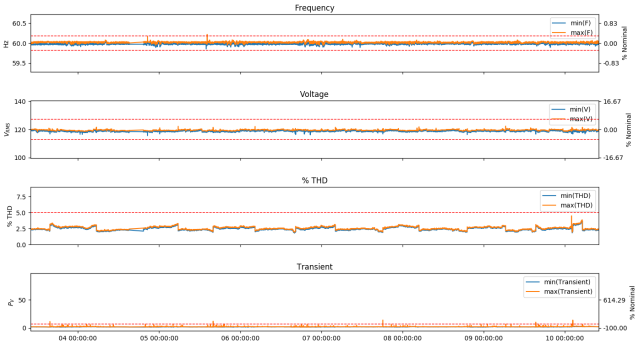
OPQ Box 1008 (Mile's Office): Trends 2019-12-03 10:00 - 2019-12-10 09:59 UTC



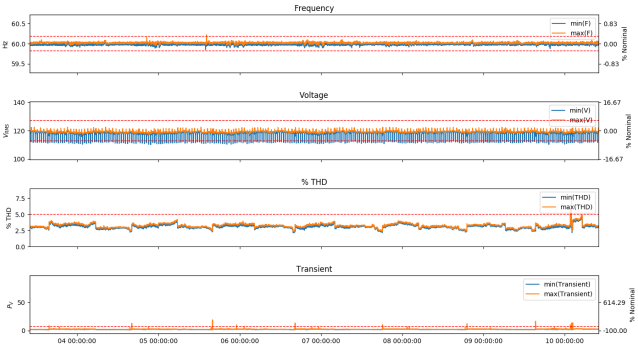
OPQ Box 1009 (Watanabe): Trends 2019-12-03 10:00 - 2019-12-10 09:59 UTC



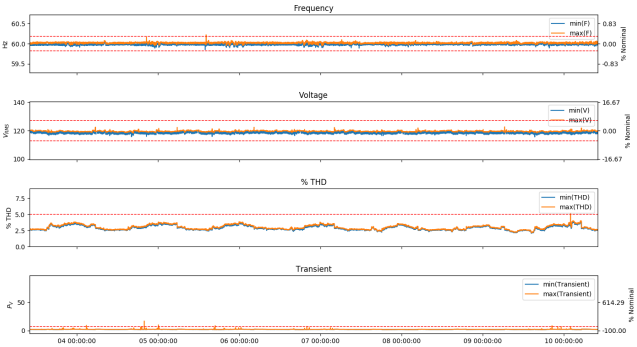
OPQ Box 1010 (Holmes): Trends 2019-12-03 10:00 - 2019-12-10 09:59 UTC



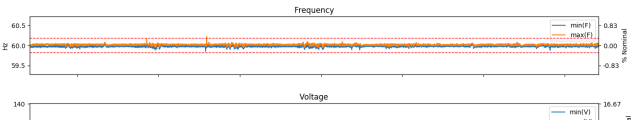
OPQ Box 1021 (Marine Science Building): Trends 2019-12-03 10:00 - 2019-12-10 09:59 UTC



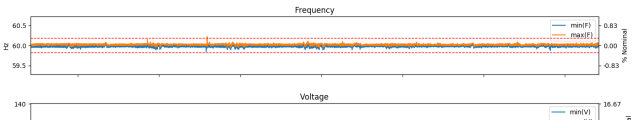
OPQ Box 1022 (Ag. Engineering): Trends 2019-12-03 10:00 - 2019-12-10 09:59 UTC

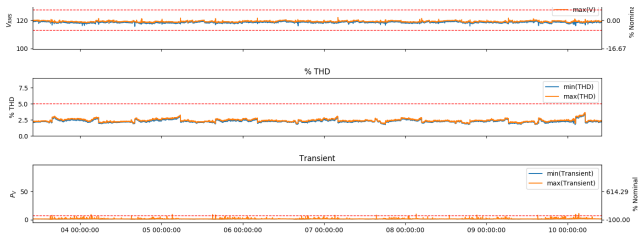


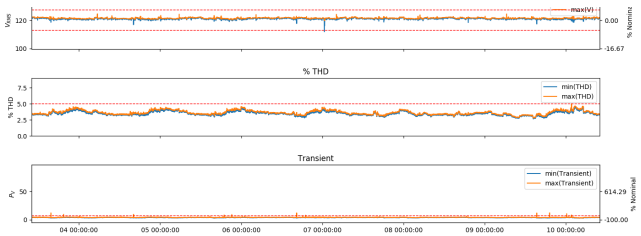
OPQ Box 1023 (Law Library): Trends 2019-12-03 10:00 - 2019-12-10 09:59 UTC



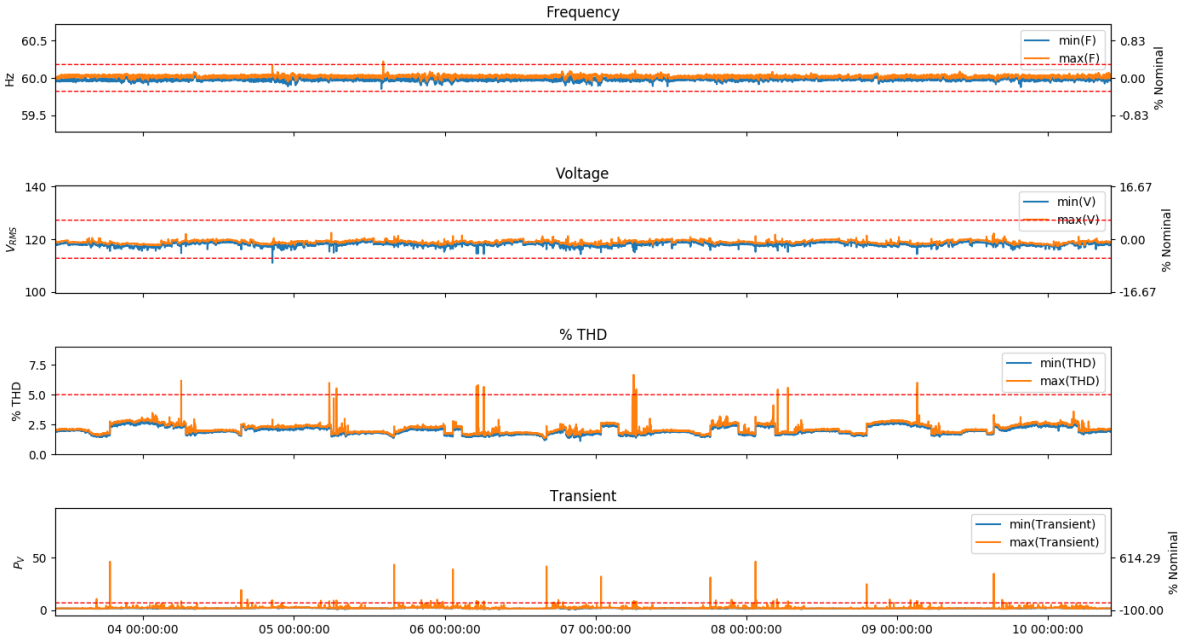
OPQ Box 1024 (IT Building): Trends 2019-12-03 10:00 - 2019-12-10 09:59 UTC







OPQ Box 1025 (Kennedy Theater): Trends 2019-12-03 10:00 - 2019-12-10 09:59 UTC



This past week's data is similar to last week in that PQ remained mostly nominal except for a few instances. We observe a a Voltage sag that was observed in both Mile's office as well as Watanabe. We also observed periodic THD at Kennedy Theater.

Phenomena

Phenomena are an abstract concept for Anthony's PhD dissertation that provide actionable insights and context on top of classified Incidents. In terms of PQ monitoring, Phenomena provide added context on top of PQ Incidents.

This past week Anthony has continued making improvements to Periodic Phenomena and Future Phenomena. Periodic Phenomena is being modified so that it can identify periodic activity on time periods greater than a day. To achieve this, Trends are being used to determine periodicity rather than Measurements. I expect that if the periodic

THD continues at the Theater, we should pick it up as a Pheneoma for next week's report.

Future Phenomena is also being implemented and should make an appearance in next week's report.

Once Future Phenomena is implemented, Anthony will be shifting his focus to separating the interesting Incidents from the non-interesting Incidents. This will be accomplished using Similarity Phenomena to ground collects of similar Incidents together. When that is finished, we will be able to say things like "Box 1021 experienced N related Voltage sags".

Finally, the concept of "nominality" will also be getting some focus in next week's report to help filter out the signal from the noise.

Incidents Summary

Incidents are classified PQ issues that were found in the previously provided Events. Incidents are classified by OPQ Mauka according to various PQ standards. OPQ Mauka provides classifications for Outages, Voltage, Frequency, and THD related issues.

A total of 64353 Incidents were processed.

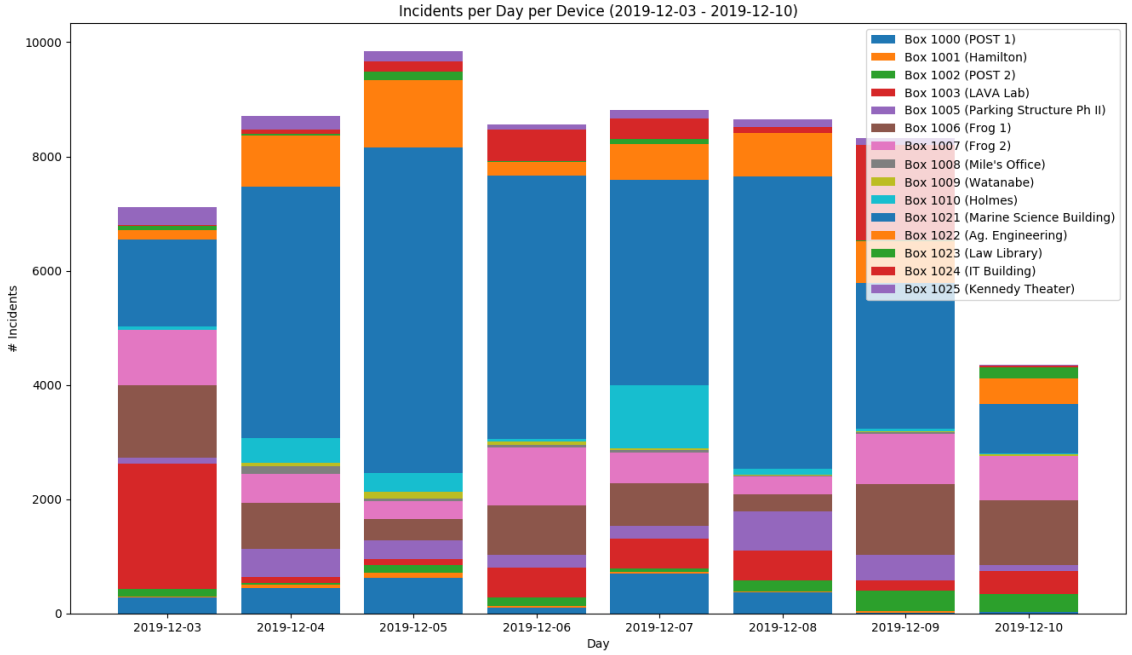
A breakdown of Incidents per Box is provided in the following table.

Box	Cnt	FSag	FSwell	THD	Outage	VSag
1021	28352	3046	25283	23	0	0
1006	6711	5880	827	4	0	0
1007	5304	4512	789	0	3	0
1022	5062	2145	2908	9	0	0
1003	4556	2015	2522	19	0	0
1024	2995	1254	1724	17	0	0
1005	2632	1018	1412	201	1	0
1000	2596	1192	1402	2	0	0
1010	2111	475	1619	12	5	0
1002	1363	371	991	0	1	0

1025	1217	845	305	67	0	0
1023	556	212	339	4	1	0
1008	347	203	123	17	0	4
1009	315	52	235	23	1	4
1001	236	144	71	21	0	0
Total	**64353**	**23364**	**40550**	**419**	**12**	**8**

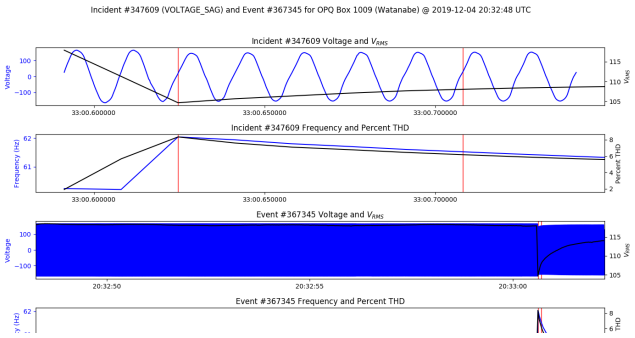
Incidents 2019-12-03 to 2019-12-10

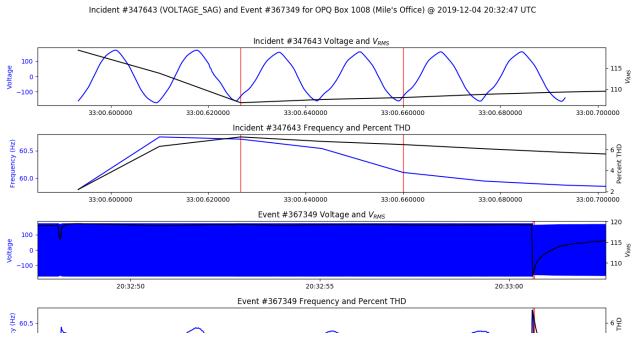
The following figure shows Incidents per Box per day.

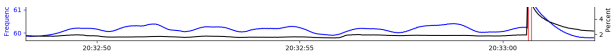


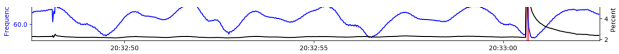
Voltage Sags

The following figures show the major Voltage sags that were observed in the Trend data.



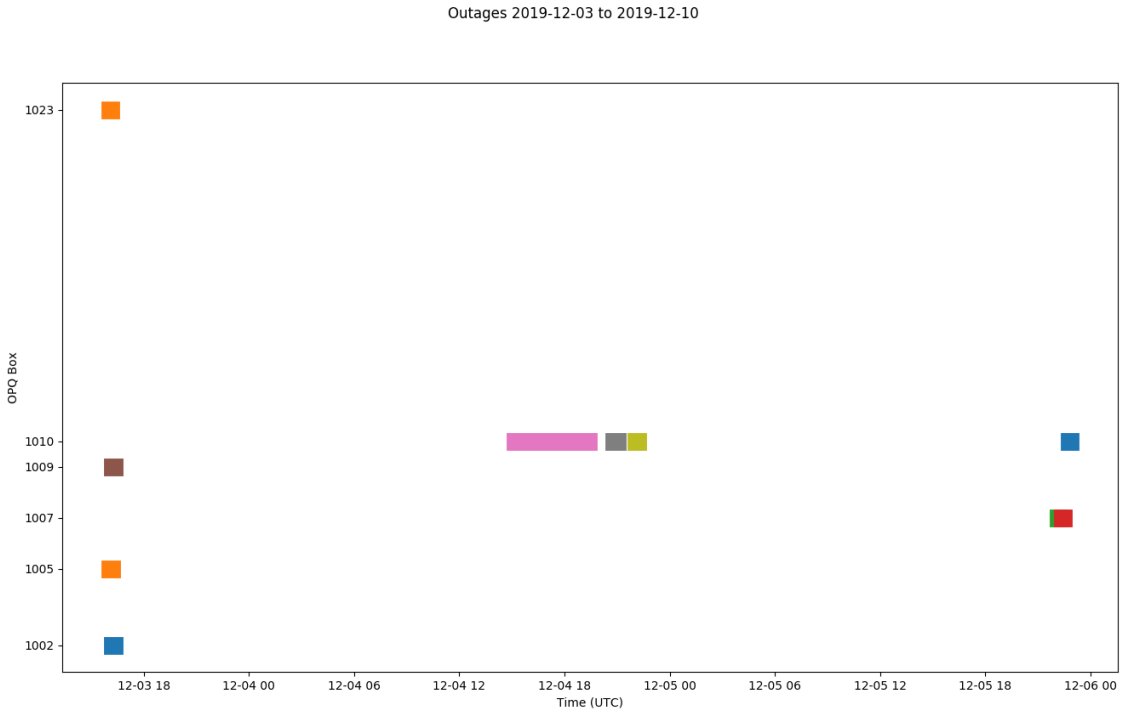






Outages

The Box in Holmes has experienced several data gaps this week as shown in the following figure:



We also note several other outages from Boxes around the same time period which could be indicative of OPQ performance degradation or UHM network degradation.

Events Summary

Events are ranges of PQ data that may (or may not) have PQ issues within them. Events are generated by two methods. The first method uses Voltage, Frequency, and THD thresholds as defined by IEEE. The second method uses the Napali Trigger which was developed by Sergey as part of his dissertation research. The Napali trigger uses statistical methods to determine when Boxes may contain PQ issues. This summary of Events examines the number of times that Boxes were triggered due to possible PQ issues.

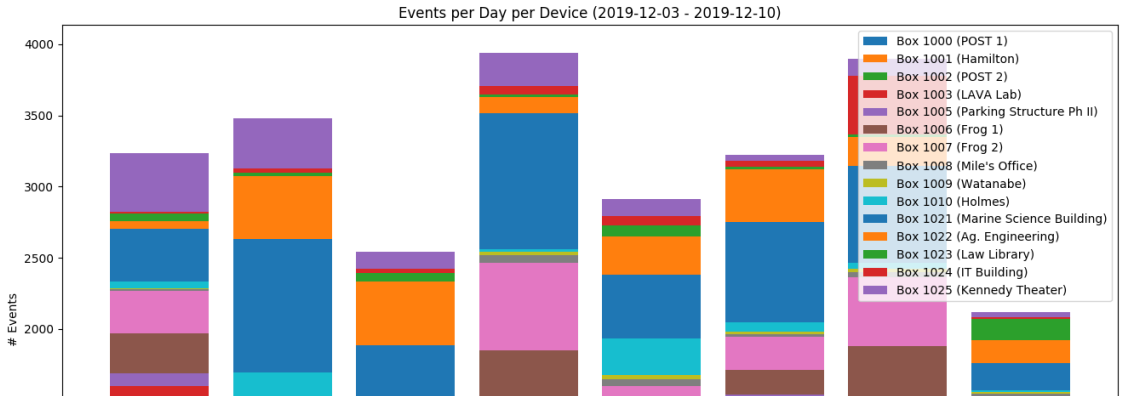
There were a total of 25347 Events processed.

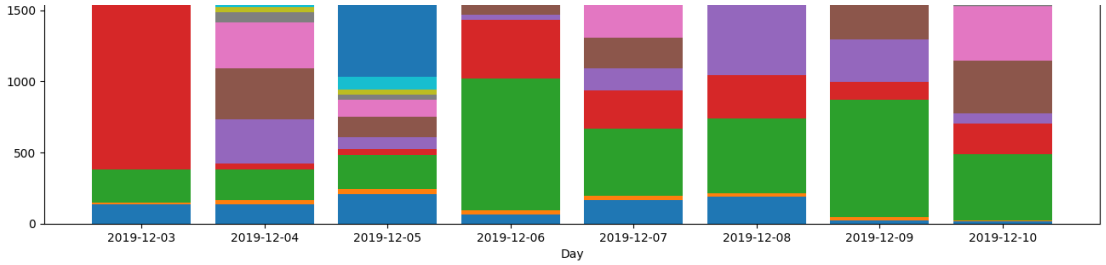
The following table shows Events generated per Box.

OPQ Box	Location	Events Generated
1021	Marine Science Building	5137
1002	POST 2	3892
1007	Frog 2	2734
1003	LAVA Lab	2625
1006	Frog 1	2516
1022	Ag. Engineering	2067
1005	Parking Structure Ph II	1541
1025	Kennedy Theater	1434
1000	POST 1	952
1010	Holmes	711
1024	IT Building	653
1023	Law Library	418
1008	Mile's Office	295
1001	Hamilton	192
1009	Watanabe	180
Total		**25347**

Events 2019-12-03 to 2019-12-10

The following figure shows Events per Box per day.





Analyzing Ground Truth

Makeup of Ground Truth Data

The UHM Office of Energy Management has been kind enough to provide us access to data collected by high quality power meters installed at the mains of selected campus buildings. This data set provides the basis of the ground truth data that we are collecting.

Ground truth data was scraped from a UHM internal server over the same time window of this report. We collected ground truth data for 15 features and upwards of 72 meters per feature. The ground truth data is mostly complete, however, there are a few missing features for some meters.

The provided ground truth data is similar to our Trends in that it provides rolled up summary statistics for features over a window of 60 seconds. The included statistics include the actual, minimum, maximum, average, and standard deviation of the feature measured.

We are collecting the following available features for ground truth: “Frequency”, “Average Voltage THD”, “VAB”, “VAN”, “VBC”, “VBN”, “VCA”, “VCN”, “Voltage CN THD”, “Voltage AN THD”, “Voltage BN THD”, and “Voltage CN THD”.

The Frequency and THD measurements are in units that similar to what OPQ collects (Frequency @ 60Hz and % THD), but the Voltage values are in RMS at 420V where OPQ collects RMS at 120V. This means that the Voltage values can not be compared directly and that we either need to scale the Voltage values or use straight thresholds for determining Events and Incidents.

To complicate things, we do not have a UHM meter colocated with every OPQ Box and several of our Boxes are colocated with multiple UHM meters making the determination of which combination of Box and Meter to compare difficult.

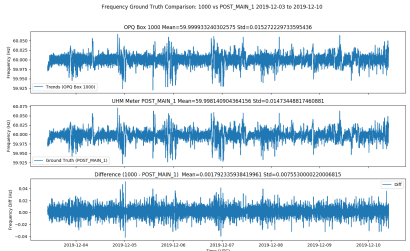
The following deployment document shows the UHM meters that are associated with OPQ Boxes. Fields marked as N/A do not have an accessible colocated ground truth meter.

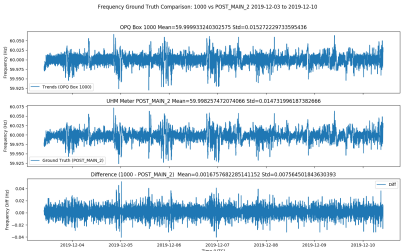
https://docs.google.com/spreadsheets/d/1aHBilgJThelPYck4Z8JnYTgEZyh6tJUjJS07jgYvneA/edit?usp=sharing

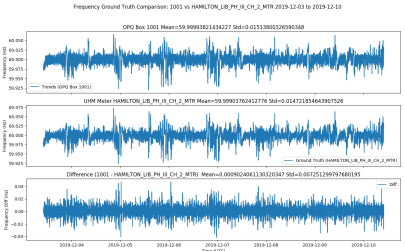
Ground Truth Frequency Evaluation

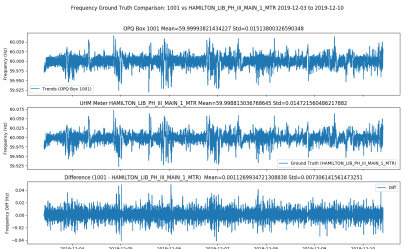
The following figures show Frequency comparisons between OPQ Boxes and UHM ground truth meters. We include all colocated UHM meters if there are multiple per building. Once we determine which meters correlate with our data, we can filter this list.

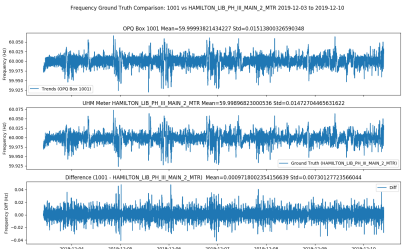
The top panel of each figure is the OPQ Box data, the middle panel is the UHM meter data, and the bottom panel is the difference between the two.

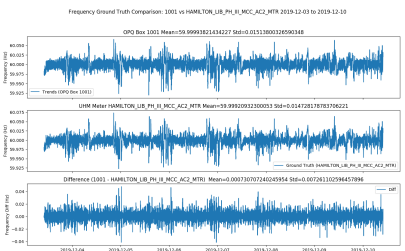


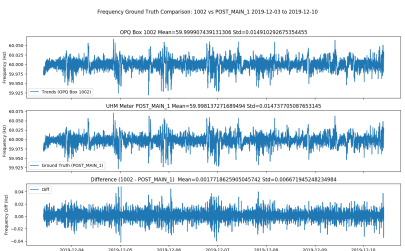


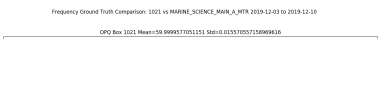


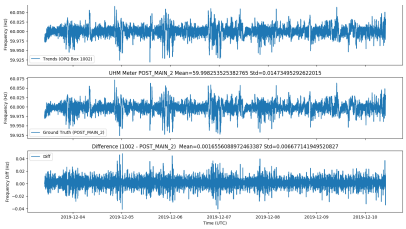


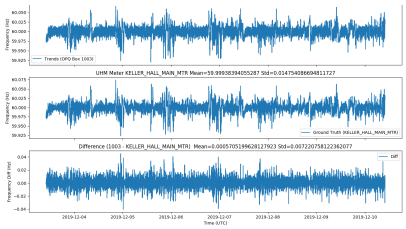


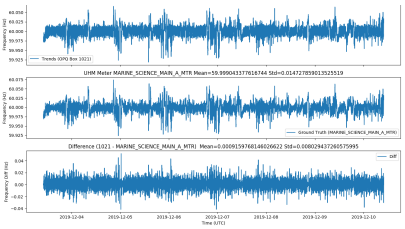


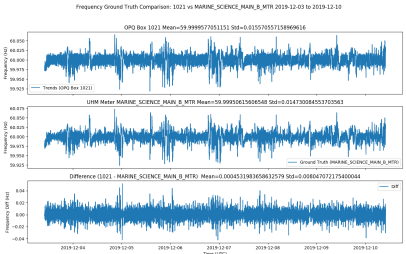


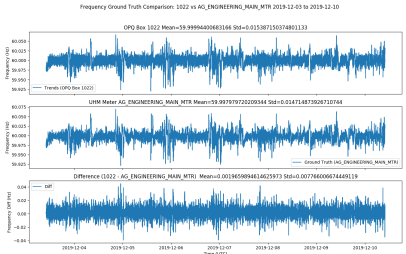


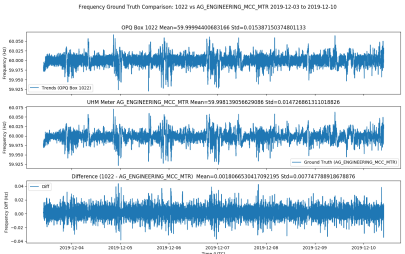


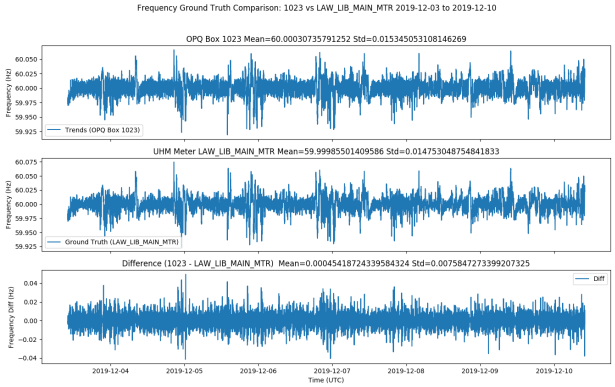


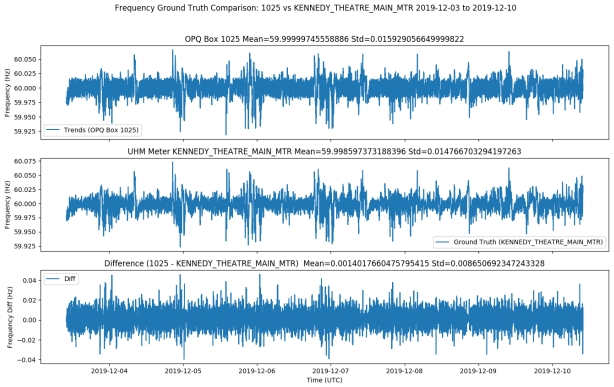








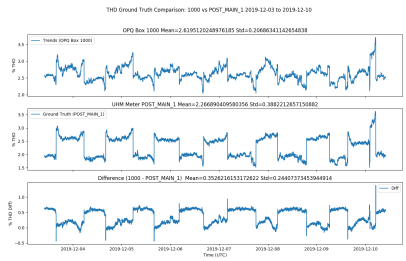


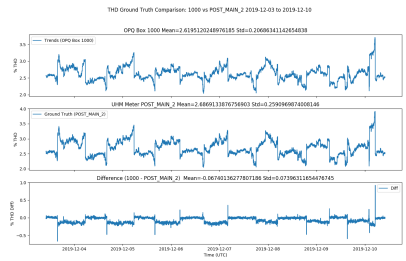


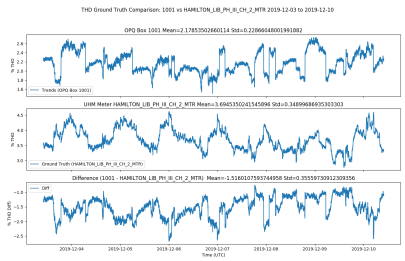
As can be observed, the OPQ Boxes and UHM meters correlate pretty well. We observe mean differences for each sensor close to 1 mHz with max differences up to 4 cHz.

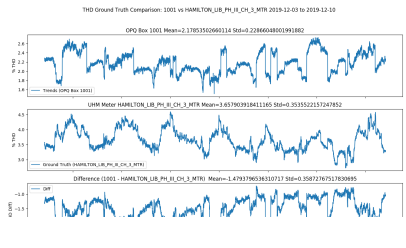
Ground Truth THD Evaluation

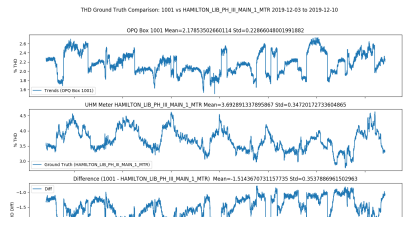
The following figures display THD correlation between OPQ Boxes and UHM ground truth sensors.

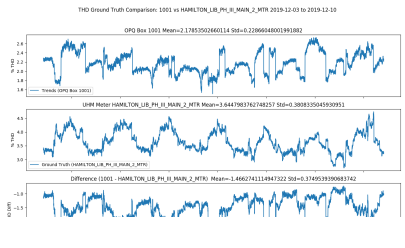


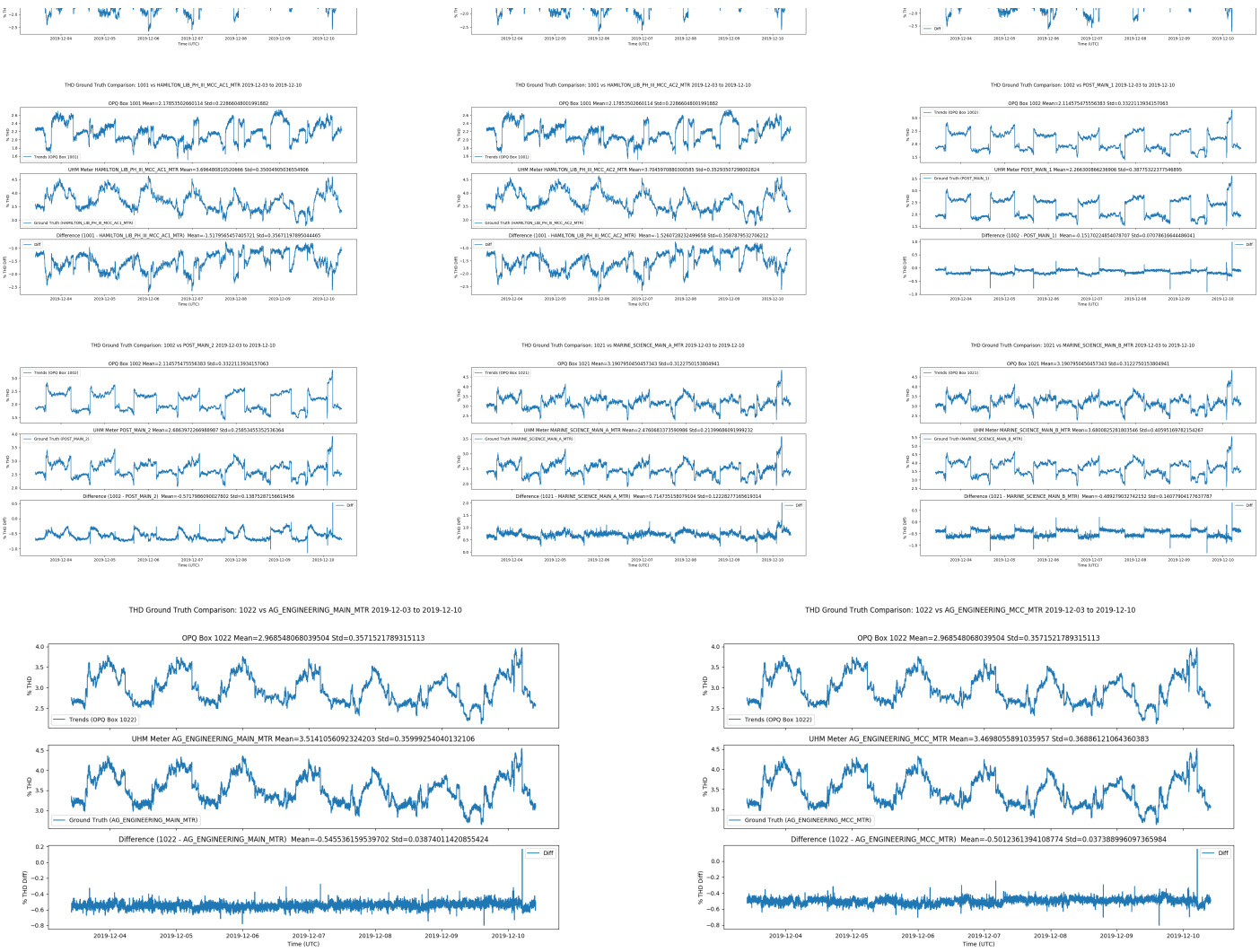












These are a bit more interesting and they could help us determine which OPQ Box is associated with which UHM meter. For instance, the THD for OPQ Box 1000 and 1002 correlate much more closely with the POST_MAIN_2 meter than they do with the POST_MAIN_1 meter.

Of the THDs that correlate well, we see a mean difference of around half a % THD between what OPQ observes and the ground truth. It's quite possible that this difference can be explained by the increased THD from electronics within a building by the time the power gets to an OPQ Box (though this is total speculation).

Ground Truth Voltage, Events, and Incidents Evaluation

Because of the difference in scale between the Voltage measurements from OPQ Boxes and UHM meters, special care must be taken to compare these readings. This is currently being worked out and will be a subject of next week's post.

Events and Incidents also require special care since they can not be compared directly. This is being worked on this week and the results will be presented next week.

Conclusion

This past week we observed fairly nominal trends with an interesting Voltage sag that was observed across multiple Boxes. We started to analyze ground truth data collected from UHM meters and compared it to data collected by OPQ. We continued to discuss improvements of Phenomena.

Unlisted

Data Science

Micro-report on the UHM micro-grid: 11/26 to 12/03

Open Power Quality
Dec 5, 2019 · Unlisted

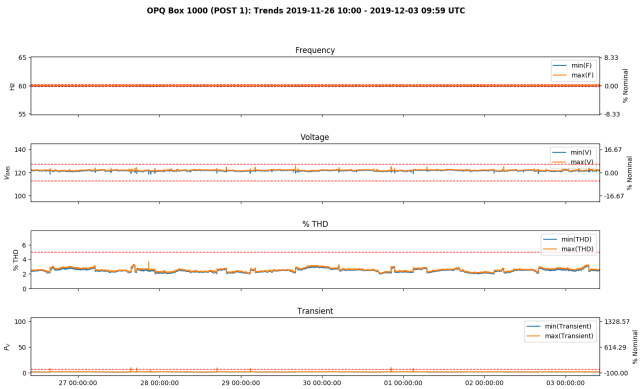
General Summary

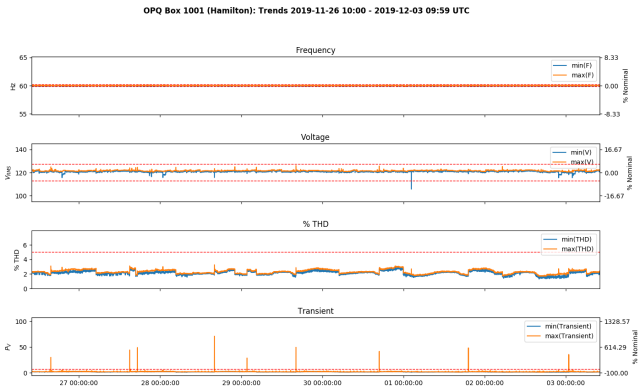
University of Hawaii at Manoa micro-grid report on data from 11–26–2019 10:00 to 12–03–2019 10:00 UTC.

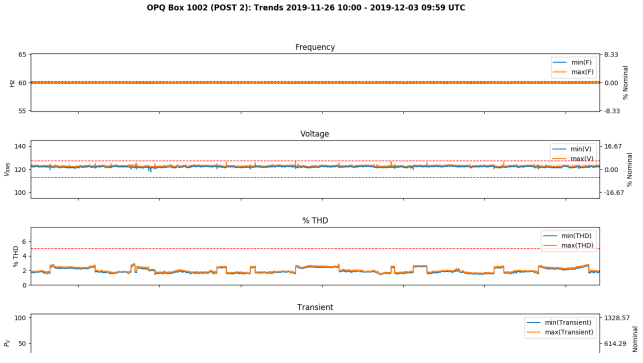
Trends Summary

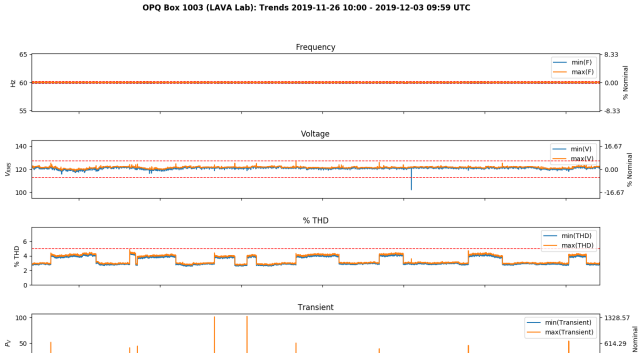
Weekly trends measure the minimum, average, and maximum values for Voltage, Frequency, THD, and transients for each OPQ Box at a rate of 1 Hz.

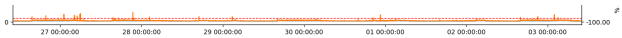
The following figures show Trends for each Box between 2019–11–26 10:00:00 and 2019–12–03 10:00:00.

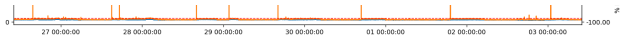




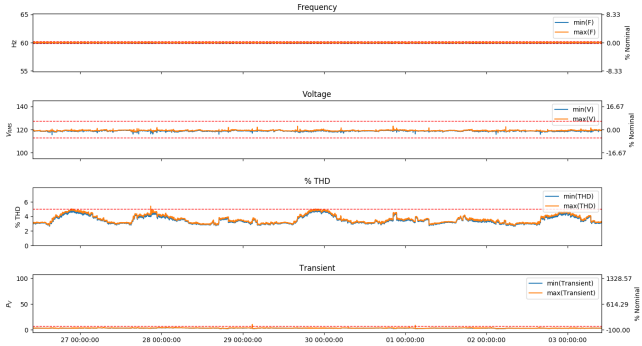




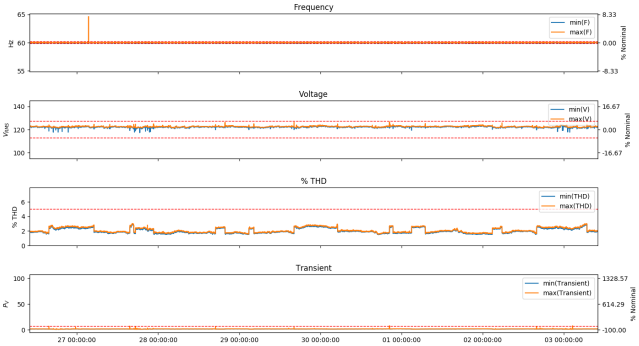




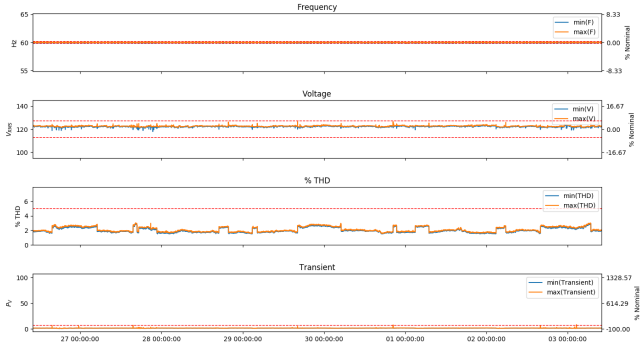
OPQ Box 1005 (Parking Structure Ph II): Trends 2019-11-26 10:00 - 2019-12-03 09:59 UTC



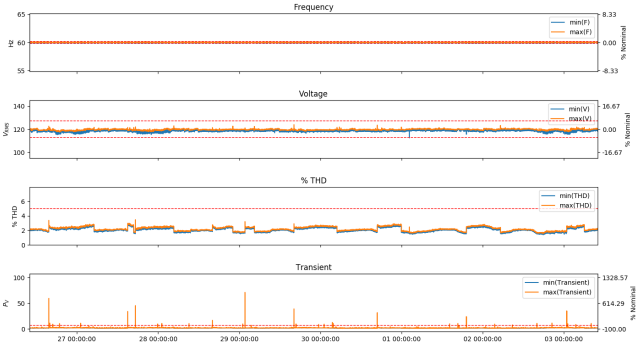
OPQ Box 1006 (Frog 1): Trends 2019-11-26 10:00 - 2019-12-03 09:59 UTC



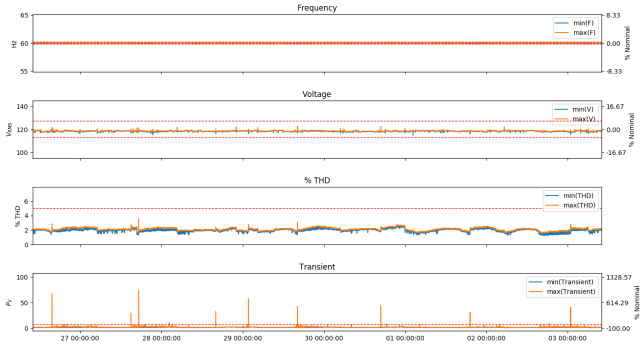
OPQ Box 1007 (Frog 2): Trends 2019-11-26 10:00 - 2019-12-03 09:59 UTC



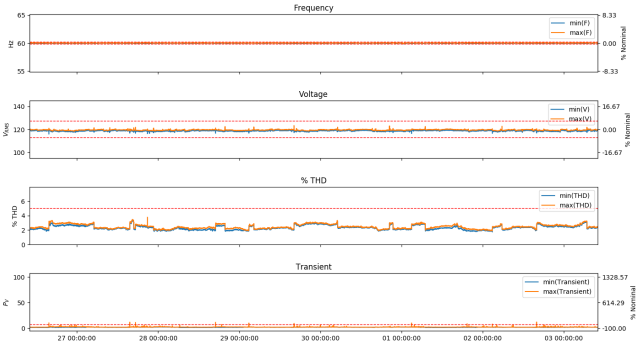
OPQ Box 1008 (Mile's Office): Trends 2019-11-26 10:00 - 2019-12-03 09:59 UTC



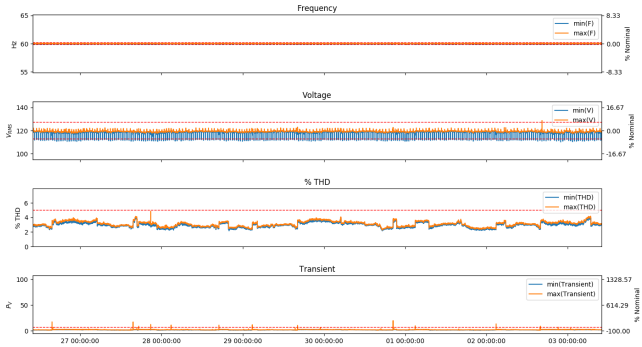
OPQ Box 1009 (Watanabe): Trends 2019-11-26 10:00 - 2019-12-03 09:59 UTC



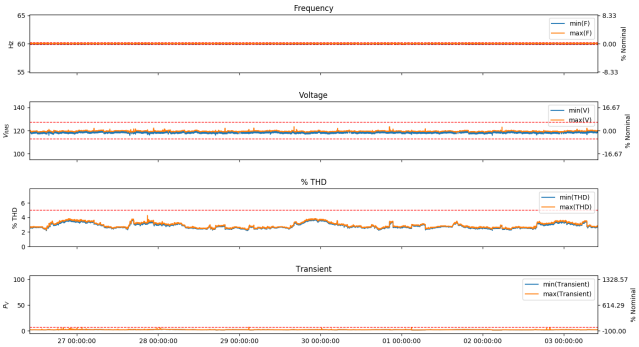
OPQ Box 1010 (Holmes): Trends 2019-11-26 10:00 - 2019-12-03 09:59 UTC



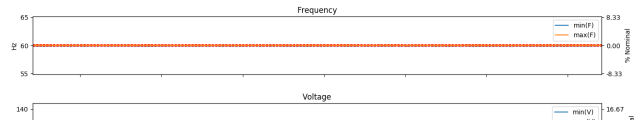
OPQ Box 1021 (Marine Science Building): Trends 2019-11-26 10:00 - 2019-12-03 09:59 UTC



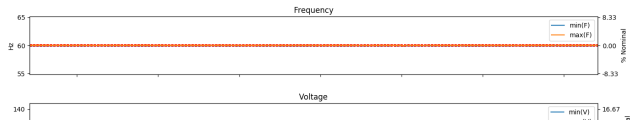
OPQ Box 1022 (Ag. Engineering): Trends 2019-11-26 10:00 - 2019-12-03 09:59 UTC

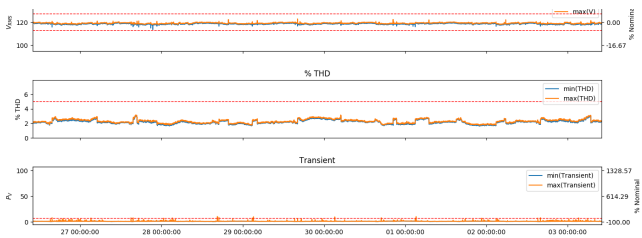


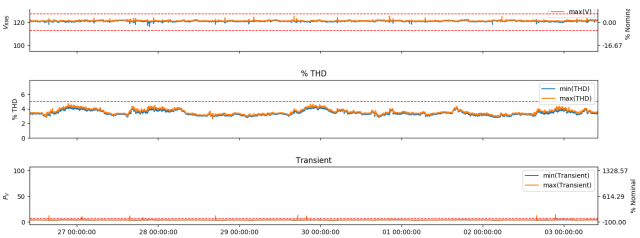
OPQ Box 1023 (Law Library): Trends 2019-11-26 10:00 - 2019-12-03 09:59 UTC



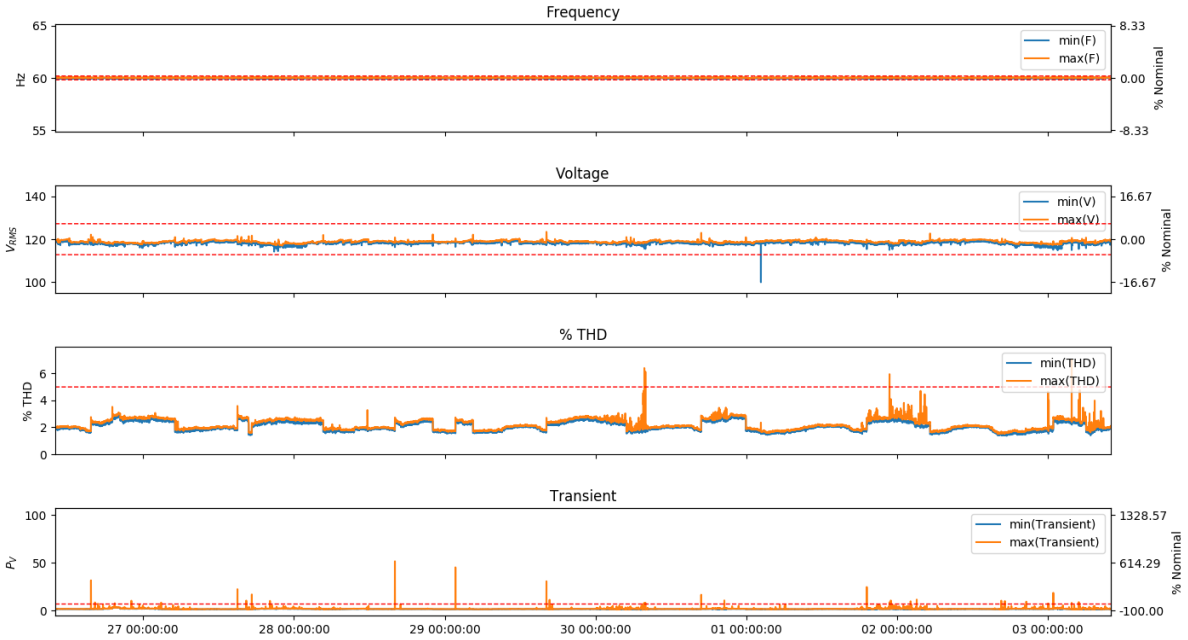
OPQ Box 1024 (IT Building): Trends 2019-11-26 10:00 - 2019-12-03 09:59 UTC







OPQ Box 1025 (Kennedy Theater): Trends 2019-11-26 10:00 - 2019-12-03 09:59 UTC



This past week has been relatively quiet and Trends do not show many grid wide PQ issues. The only discernible grid-wide PQ issue is a Voltage Sag that was observed by Hamilton, Kennedy, and the LAVA Lab early in the morning of the 1 Dec UTC.

Kennedy Theater still displays higher amounts of THD compared to other Boxes.

We also observed a single large Frequency swell in Frog I which was not observed at any other Boxes. This particular swell is of note because of its magnitude.

Phenomena

Phenomena are an abstract concept for Anthony's PhD dissertation that provide actionable insights and context on top of classified Incidents. In terms of PQ monitoring, Phenomena provide added context on top of PQ Incidents.

We are happy to announce that OPQ has produced its first Phenomena! The Periodicity algorithm discussed last week has been implemented in Mauka. As of this writing, the plugin has identified a single periodic Phenomena whose standard deviation falls above the threshold (15 minutes). The meta-data associated with the Phenomena is provided below:

```
{
        "_id" : ObjectId("5de955d9d086f30f0012dd1a"),
        "phenomena_id" : 1,
        "created_ts_ms" : 1575570023000,
        "updated_ts_ms" : 1575570023000,
        "expire_at" : 1638728423,
        "is_active" : true,
        "phenomena_type" : {
                "type" : "periodic",
                "periodic_at" : [
                        "measurements",
                        "trends"
                ],
                "affected_boxes" : [
                        "1021"
                ],
                "periodicity_ms" : 2340444.4444444445,
                "periodicity_ms_std" : 490113.1640552485,
                "last_period_ts_ms" : 1575570120000
        }
}
```

gistfile1.txt hosted with ❤️ by GitHub view raw

. . .

From this, we can gather that Mauka identified a periodic signal with a mean period of 39 minutes and a standard deviation of 8 minutes.

Unfortunately, I am still working out how to convert the periods into times from the original data stream. For this Phenomena, the most recent signal arrival was modified by hand.

One thing that has been tricky is ensuring that multiple Periodic Phenomena don't get created from the same data.

Periodicity is checked once per day using measurements and I am working on adding checks over trends with a time period of a week. We compare the Box Id and period when the plugin identifies something periodic. If a Periodic Phenomena already exists with a similar period, then a new Phenomena is not created. If the periodic data is similar and contains a better standard deviation, the previously created Periodic Phenomena is updated with the more accurate measurements.

I am now working on creating Future Phenomena from this Periodic Phenomena. Given an estimated Period and the last known signal arrival, the Periodic Phenomena should create Future Phenomena that expects the next periodic signals and adjusts DSN parameters to either filter for or filter against those signals. I am hoping to have Future Phenomena implemented by late next week.

Incidents Summary

Incidents are classified PQ issues that were found in the previously provided Events. Incidents are classified by OPQ Mauka according to various PQ standards. OPQ Mauka provides classifications for Outages, Voltage, Frequency, and THD related issues.

A total of 55644 Incidents were processed.

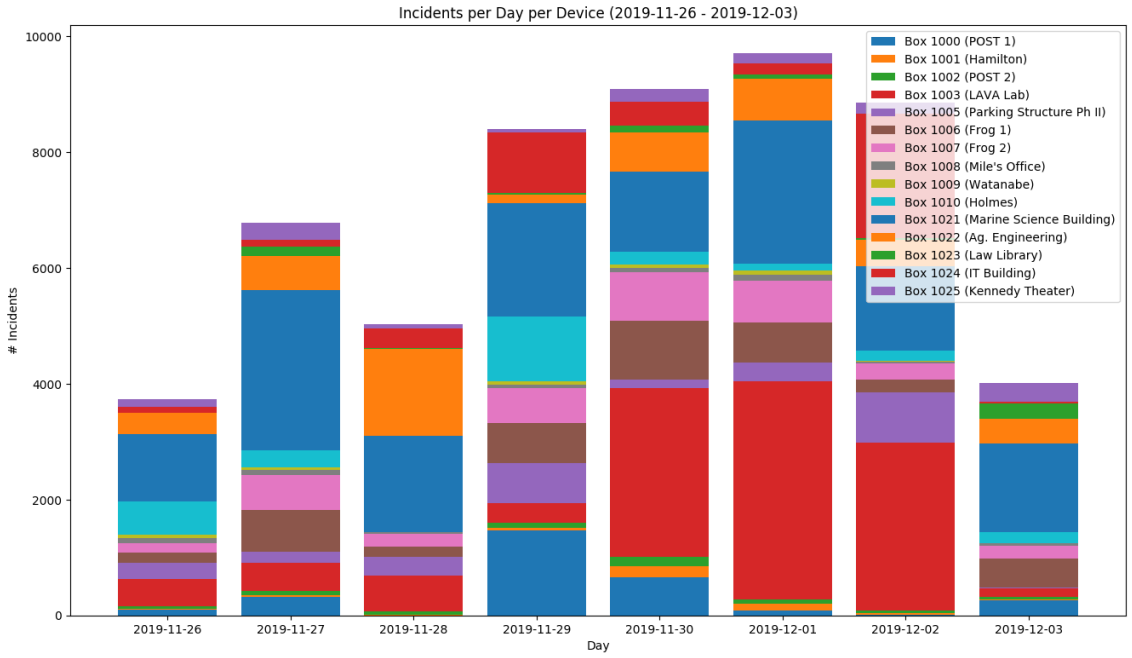
A breakdown of Incidents per Box is provided in the following table.

Box	Cnt	FSag	FSwell	THD	Outage	VSag
1021	14355	2230	12102	23	0	0
1003	11668	3991	7651	23	0	3
1022	4917	1662	3245	10	0	0
1024	4385	2512	1863	9	1	0
1006	4212	3963	248	0	1	0
1007	3646	3397	249	0	0	0
1000	2968	1440	1526	2	0	0
1005	2822	1017	1448	357	0	0
1010	2703	1117	1577	9	0	0

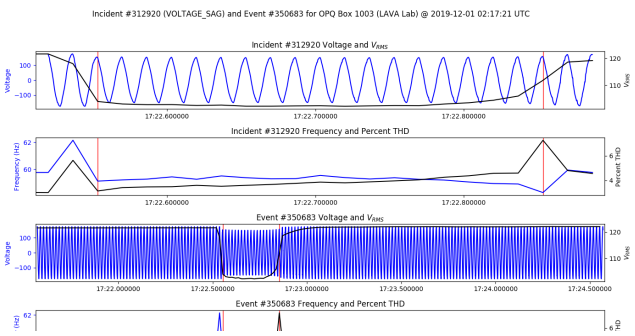
1025	1487	1196	250	39	0	2
1023	669	366	303	0	0	0
1002	576	187	389	0	0	0
1008	520	329	175	16	0	0
1001	405	277	105	20	0	3
1009	311	132	163	16	0	0
Total	**55644**	**23816**	**31294**	**524**	**2**	**8**

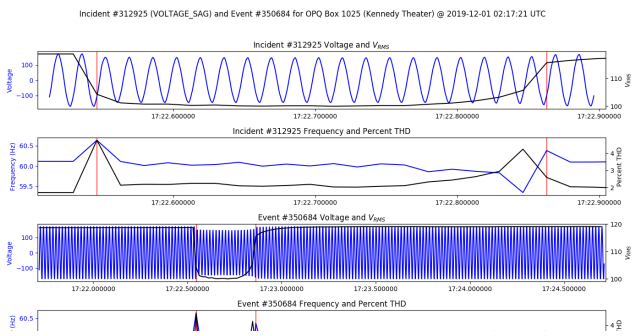
Incidents 2019-11-26 to 2019-12-03

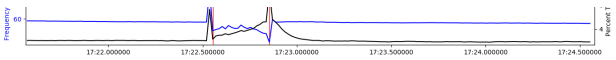
The following figure shows Incidents per Box per day.

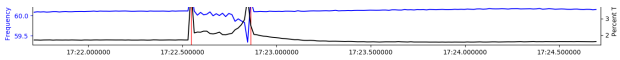


Let's examine the Voltage sag that was picked up nicely as both Kennedy and the LAVA Lab









Events Summary

Events are ranges of PQ data that may (or may not) have PQ issues within them. Events are generated by two methods. The first method uses Voltage, Frequency, and THD thresholds as defined by IEEE. The second method uses the Napali Trigger which was developed by Sergey as part of his dissertation research. The Napali trigger uses statistical methods to determine when Boxes may contain PQ issues. This summary of Events examines the number of times that Boxes were triggered due to possible PQ issues.

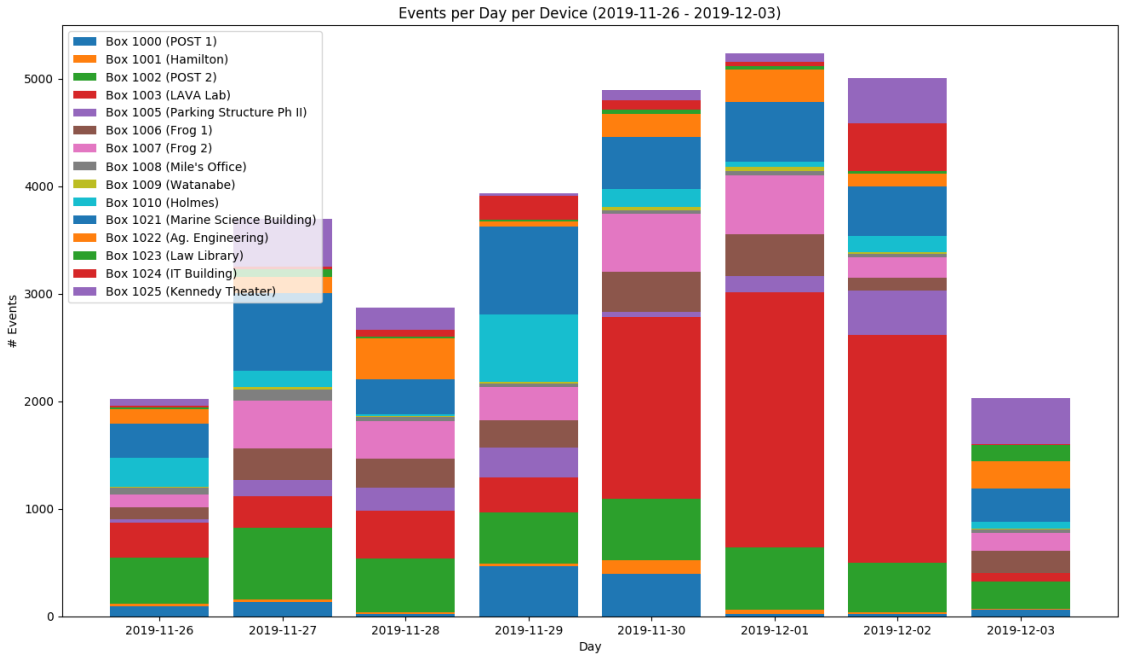
There were a total of 29688 Events processed.

The following table shows Events generated per Box.

OPQ Box	Location	Events Generated
1003	LAVA Lab	7656
1021	Marine Science Building	3999
1002	POST 2	3929
1007	Frog 2	2664
1006	Frog 1	2021
1025	Kennedy Theater	1750
1022	Ag. Engineering	1588
1010	Holmes	1484
1005	Parking Structure Ph II	1281
1000	POST 1	1241
1024	IT Building	916
1008	Mile's Office	364
1023	Law Library	362
1001	Hamilton	270
1009	Watanabe	163
Total		**29688**

Events 2019-11-26 to 2019-12-03

The following figure shows Events per Box per day.



Conclusion

This past weeks data collection provided relatively nominal data throughout the week. We observed a multi-Box Voltage sag as well as a large Frequency swell for a single Box. We discuss the implications of OPQ's first Periodic Phenomena.

Unlisted

Programming

Micro-report on the UHM micro-grid: 11/19 to 11/26

Open Power Quality
Nov 26, 2019 · Unlisted

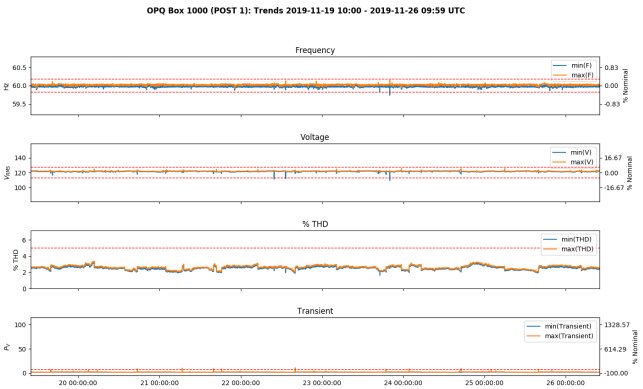
General Summary

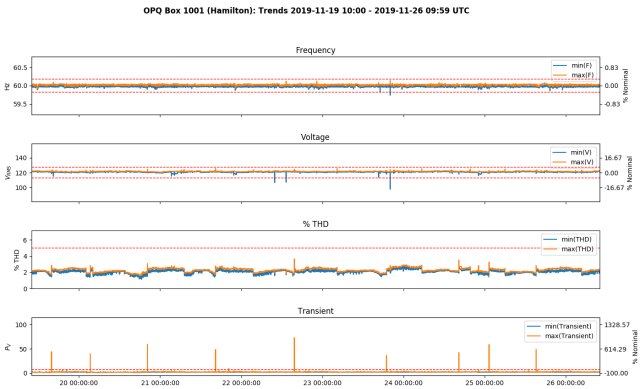
University of Hawaii at Manoa micro-grid report on data from 11–19–2019 10:00 to 11–26–2019 10:00 UTC.

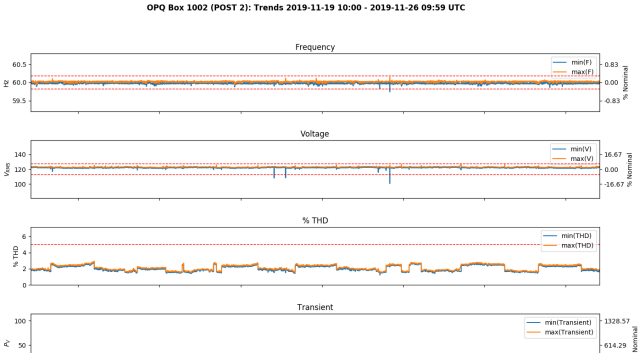
Trends Summary

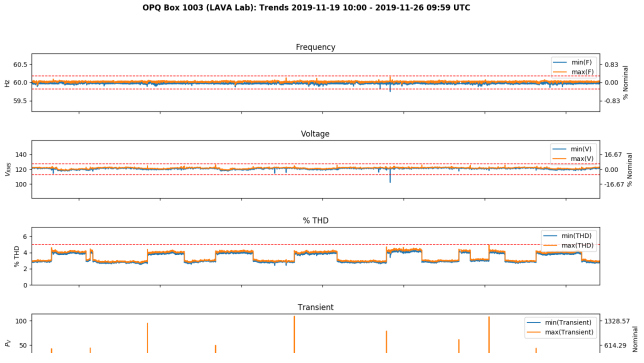
Weekly trends measure the minimum, average, and maximum values for Voltage, Frequency, THD, and transients for each OPQ Box at a rate of 1 Hz.

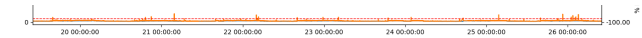
The following figures show Trends for each Box between 2019–11–19 10:00:00 and 2019–11–26 10:00:00.

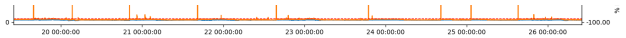




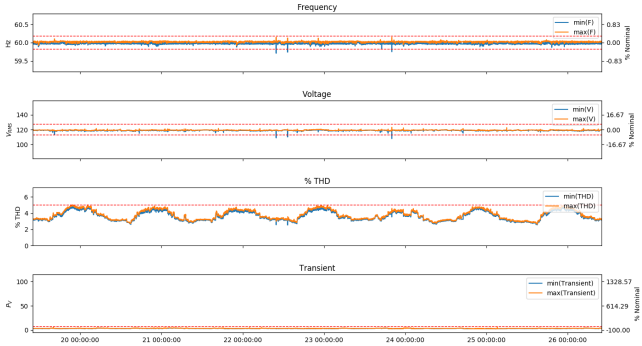




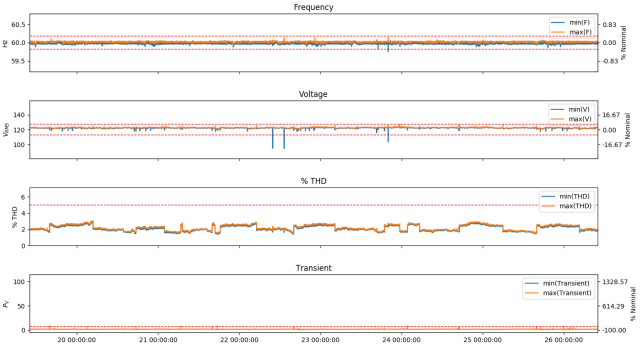




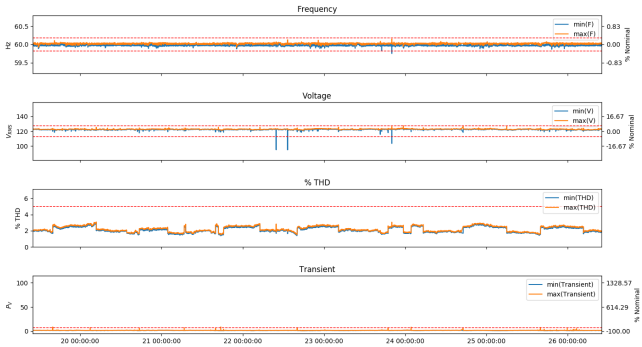
OPQ Box 1005 (Parking Structure Ph II): Trends 2019-11-19 10:00 - 2019-11-26 09:59 UTC



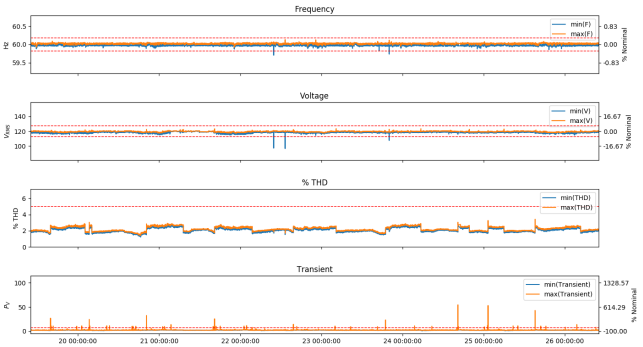
OPQ Box 1006 (Frog 1): Trends 2019-11-19 10:00 - 2019-11-26 09:59 UTC



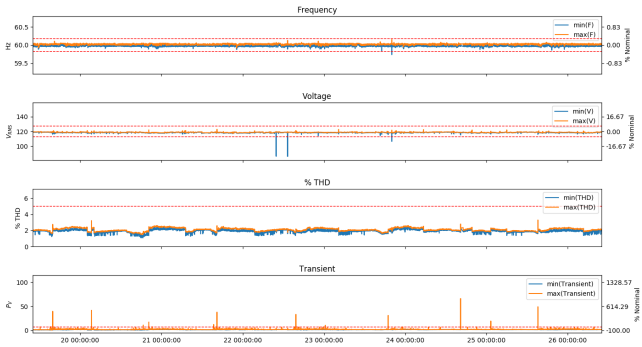
OPQ Box 1007 (Frog 2): Trends 2019-11-19 10:00 - 2019-11-26 09:59 UTC



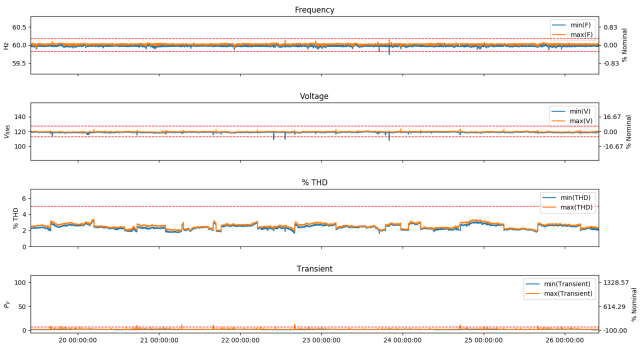
OPQ Box 1008 (Mile's Office): Trends 2019-11-19 10:00 - 2019-11-26 09:59 UTC



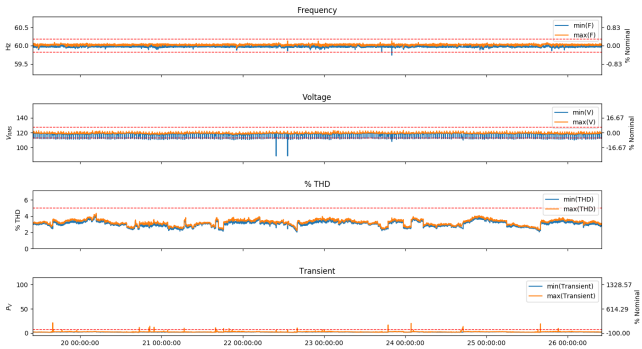
OPQ Box 1009 (Watanabe): Trends 2019-11-19 10:00 - 2019-11-26 09:59 UTC



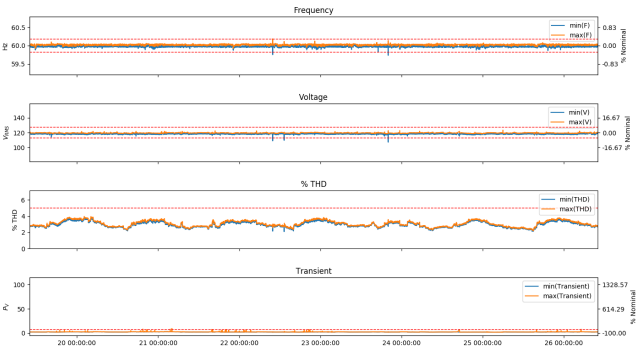
OPQ Box 1010 (Holmes): Trends 2019-11-19 10:00 - 2019-11-26 09:59 UTC



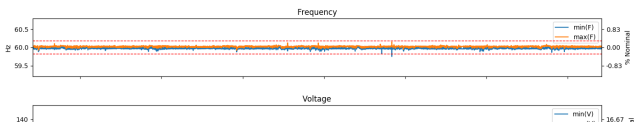
OPQ Box 1021 (Marine Science Building): Trends 2019-11-19 10:00 - 2019-11-26 09:59 UTC



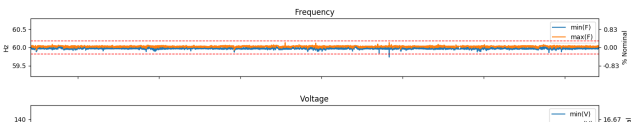
OPQ Box 1022 (Ag. Engineering): Trends 2019-11-19 10:00 - 2019-11-26 09:59 UTC

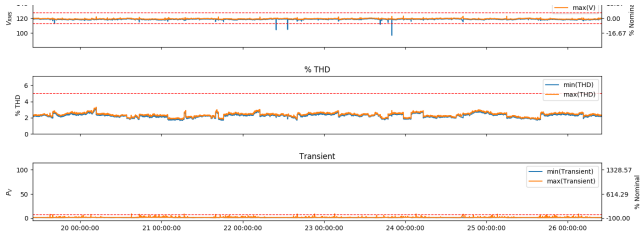


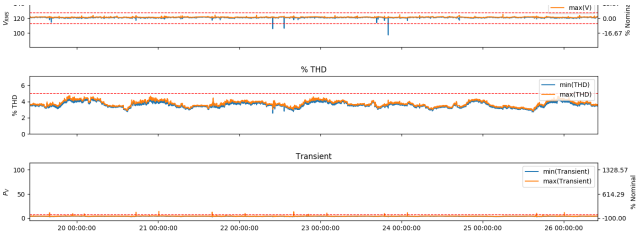
OPQ Box 1023 (Law Library): Trends 2019-11-19 10:00 - 2019-11-26 09:59 UTC



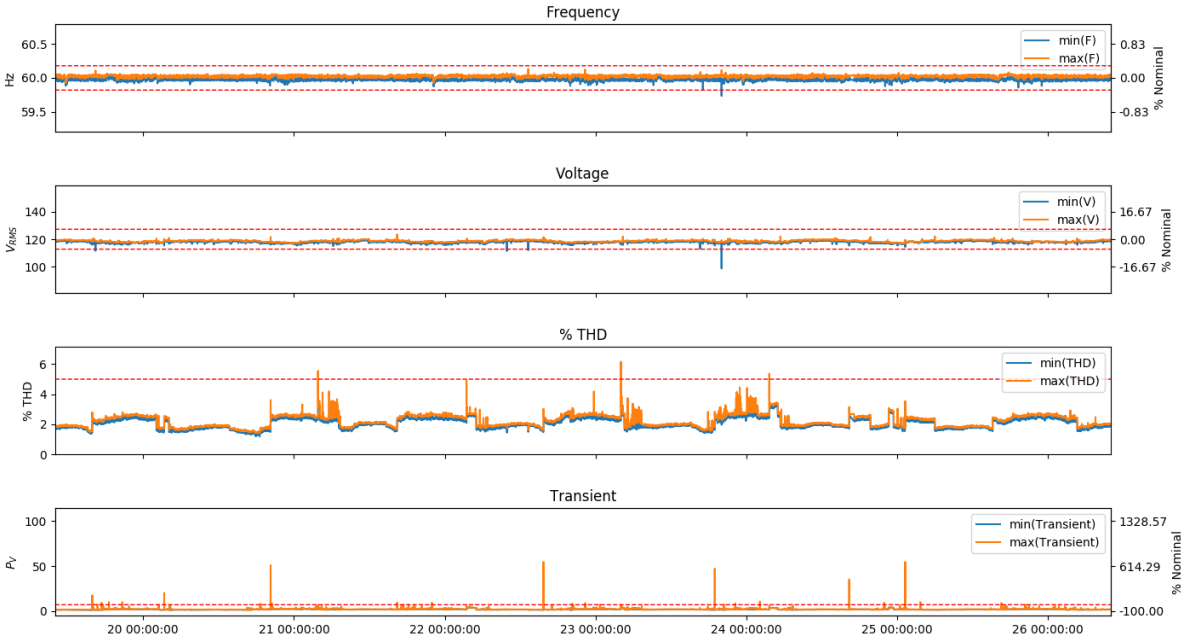
OPQ Box 1024 (IT Building): Trends 2019-11-19 10:00 - 2019-11-26 09:59 UTC







OPQ Box 1025 (Kennedy Theater): Trends 2019-11-19 10:00 - 2019-11-26 09:59 UTC



Trends remained fairly nominal over the past week. We are still observing higher amounts of THD at the Ph II Parking Structure (1005). We also observed a handful of large grid-wide Voltage and Frequency swells.

Phenomena

Phenomena are an abstract concept for Anthony's PhD dissertation that provide actionable insights and context on top of classified Incidents. In terms of PQ monitoring, Phenomena provide added context on top of PQ Incidents.

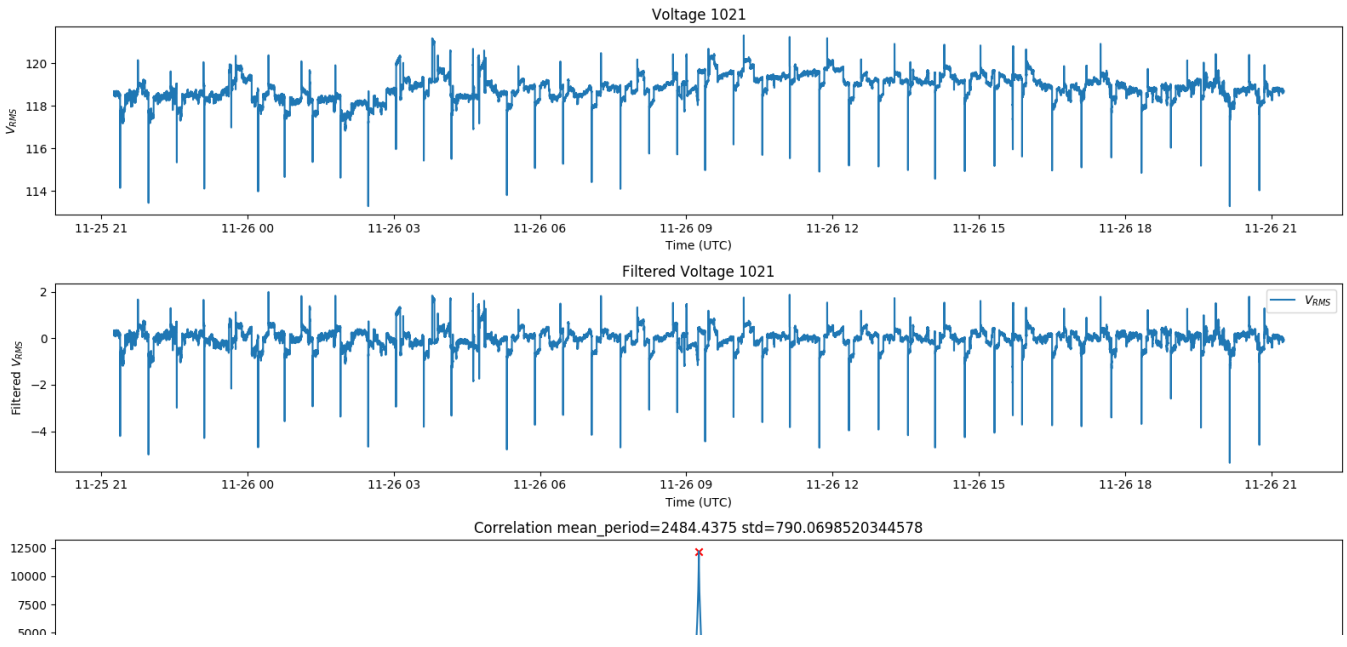
Periodic Phenomena

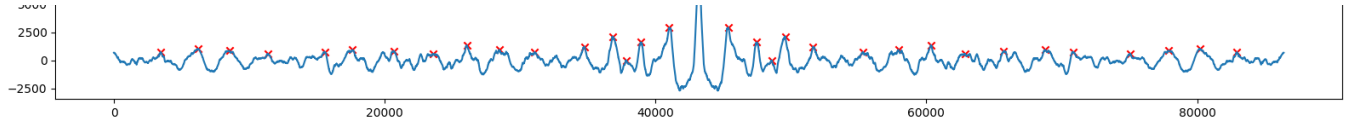
This past week we focused on implementing Periodic Phenomena which are used to identify periodic signals in the data. We chose Box 1021 as a test case because it provides a really nice periodic Voltage sag with a period of around ~34 minutes.

The following steps are performed to identify periodic signals in a data set.

1. Obtain Measurements over selected time period
2. Smooth the signal with a 4th order high-pass Butterworth filter with a window of 1/3600
3. Subtract the mean value from the signal
4. Auto-correlate the signal with itself
5. Find the peaks of the auto-correlation using a configurable prominence
6. Calculate the mean difference and standard deviation of the distance between the peaks (this is the mean period)
7. If there are enough peaks and the standard deviation is low enough, classify this signal as periodic
8. Determine start and stop points of period in original signal
9. Save Phenomena to DB
10. Utilize Phenomena to create Future Phenomena that tune the system

We've currently implemented up to 7 and are finishing the final steps. Here are some preliminary results of automatic period detection on Box 1021.





Similar Phenomena

We have also begun sketching out the details of Similar Phenomena (Phenomena that group similar Incidents together). This Phenomena can help us make sense of the large number of Incidents that we are seeing (both Frequency and THD), by detecting if these Incidents are similar (in type, duration, magnitude, and location).

Once implemented, we will be able to classify sets of Incidents as related Frequency sags,related excessive THD, etc.

Nominality Phenomena

One of the difficulties in defining thresholds for a DSN is that there are multiple ideas of what constitutes “nominal”. For instance, there are IEEE standards for Voltages sags and Swells and industry provided curves that consumer electronic makers test against (Semi F47, ITIC). There there are definitions of nominal provides by the utilities, and further sets of nominal values provides by facilities and institutions. There is another definition of nominal (perhaps the most correct) that states that whatever the steady state of a signal is over time is what is nominal.

Nominality can also be defined globally or locally. For instance, what is nominal for an entire power grid versus what is nominal at an individual location?

Why discuss nominality at all? On one hand, it provides us points in time to look for signals-of-interest. A Voltage sag here, an excessive THD there, but another use of nominality could be to determine if the physical state of an environment is changing over time. That is, is the power grid degrading over the entire grid or at a particular location? Nominality Phenomena are being designed to help answer these questions.

By combining the multiple definitions of nominality, we hope to provide weighted statistics that provide a measure of nominality both at the grid and at individual sensors.

More to come next week.

Incidents Summary

Incidents are classified PQ issues that were found in the previously provided Events. Incidents are classified by OPQ Mauka according to various PQ standards. OPQ Mauka provides classifications for Outages, Voltage, Frequency, and THD related issues.

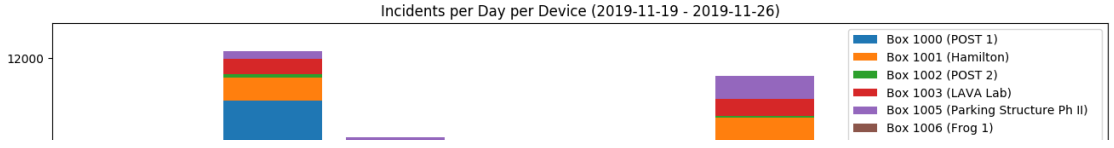
A total of 64497 Incidents were processed.

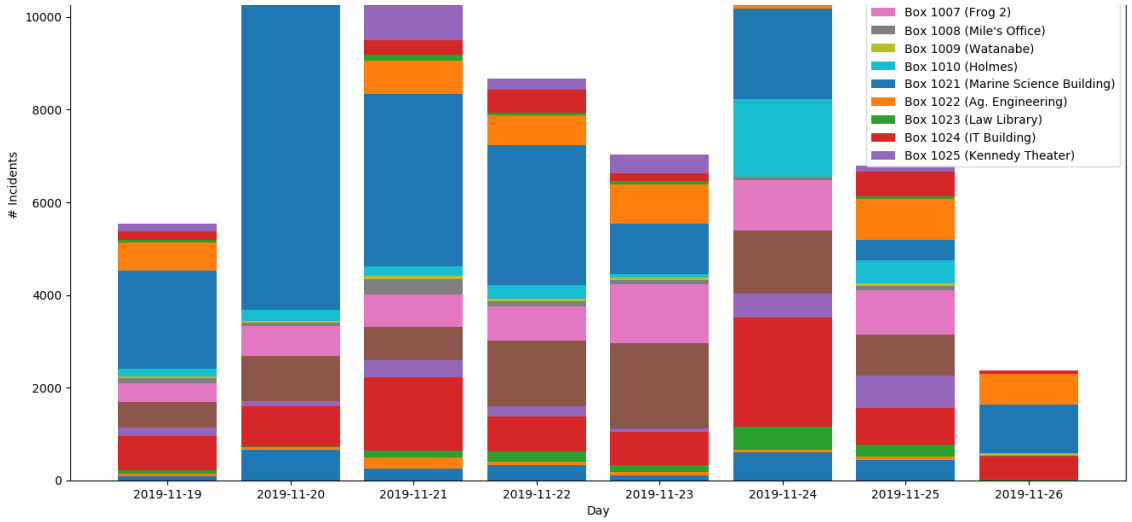
A breakdown of Incidents per Box is provided in the following table.

Box	Cnt	FSag	FSwell	THD	Outage	VSag
1021	20753	3449	17258	39	0	7
1003	8287	3352	4911	21	0	3
1006	7754	6996	735	15	0	8
1007	5819	5125	674	12	1	7
1022	5422	1932	3476	6	0	8
1010	3193	1396	1789	5	0	3
1000	2496	1410	1072	2	0	12
1024	2470	1353	1086	19	0	12
1025	2411	1659	718	28	0	6
1005	2208	1043	1045	117	0	3
1002	1377	749	621	4	0	3
1008	891	590	267	26	0	8
1001	626	566	26	26	0	8
1023	468	398	58	0	0	12
1009	322	182	101	28	0	11
Total	**64497**	**30200**	**33837**	**348**	**1**	**111**

Incidents 2019-11-19 to 2019-11-26

The following figure shows Incidents per Box per day.





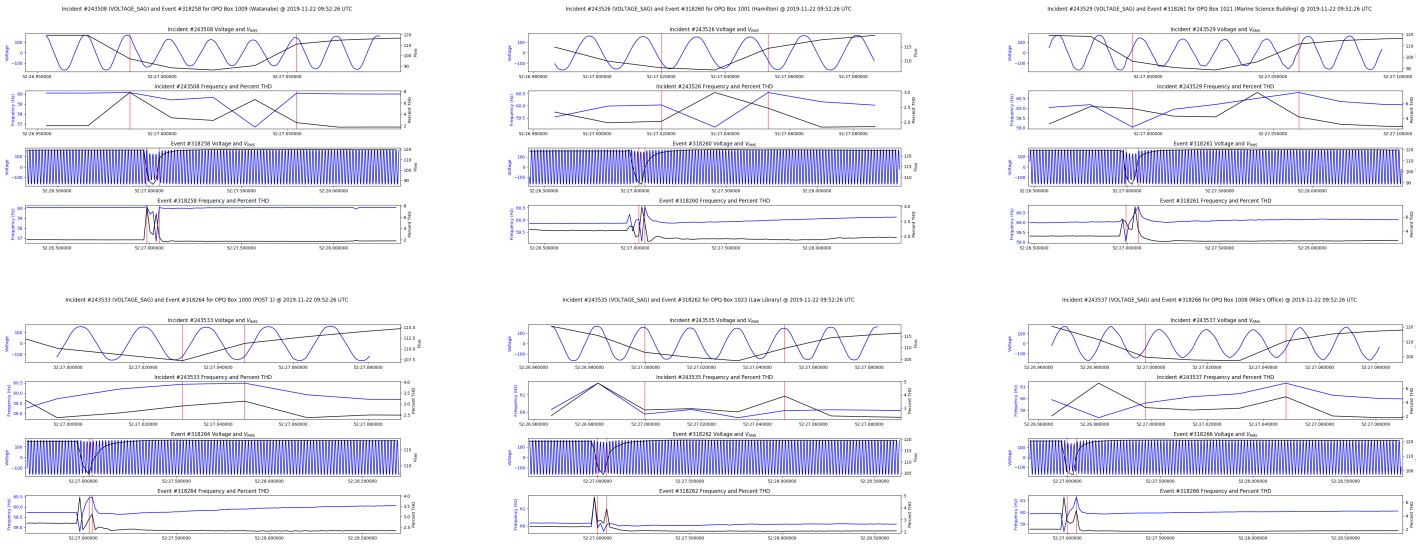
Outages

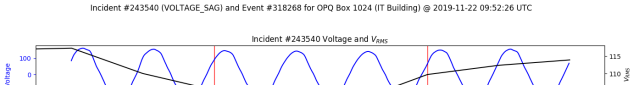
A single spurious outage was encountered at Box 1007. However, post analysis shows that we did indeed collect data for that Box over the outage period so this is a false positive and requires further investigation.

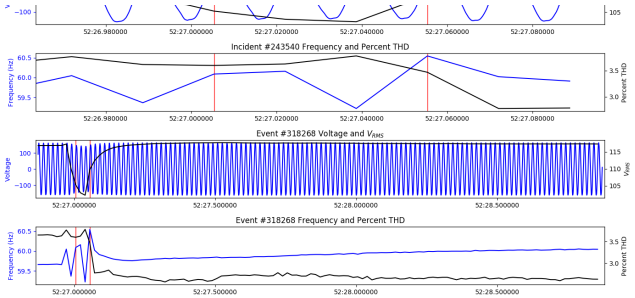
Voltage Sags

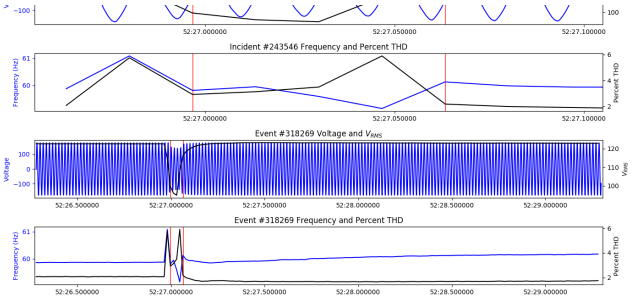
There are several Voltage sags that stick out well in the Trend data. Let's examine those in more detail.

Voltage Sag (11/22 09:52 UTC)

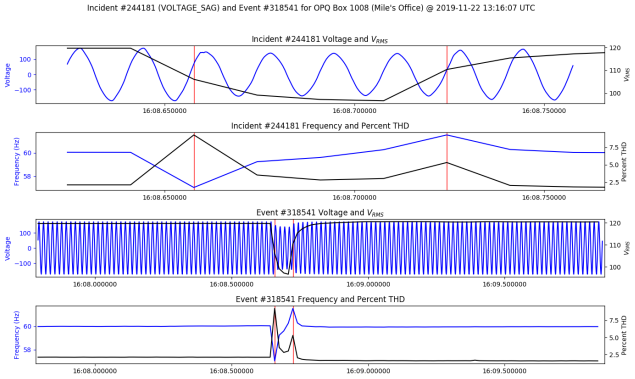


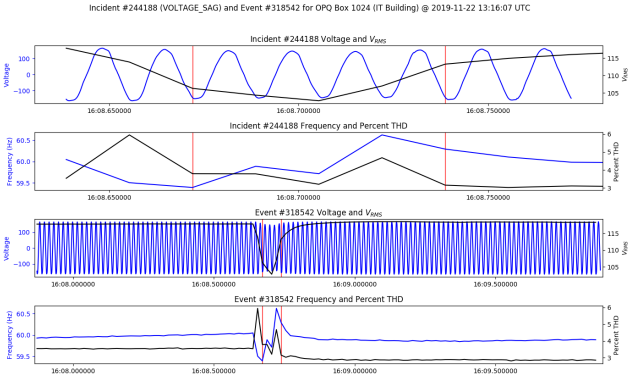




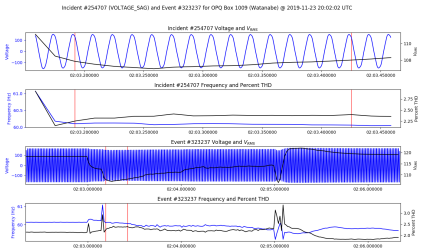


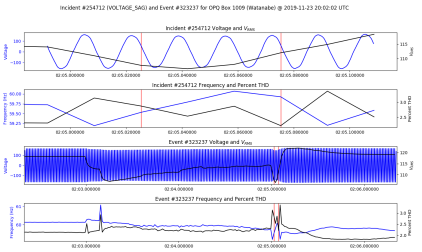
Voltage Sag (11/22 13:16 UTC)

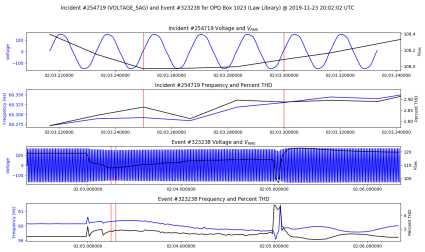


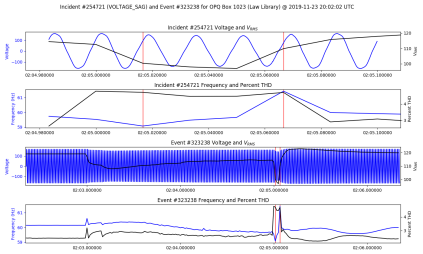


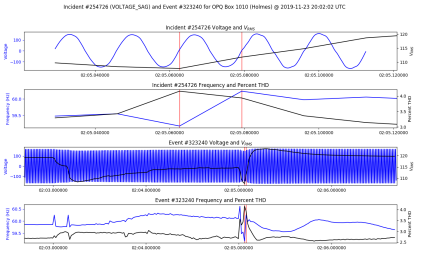
Voltage Sag (11/23 20:02 UTC)

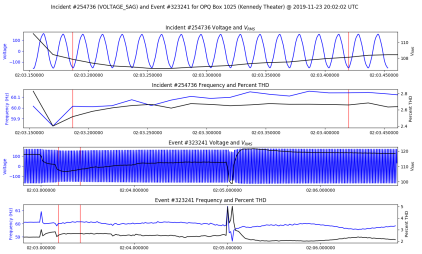


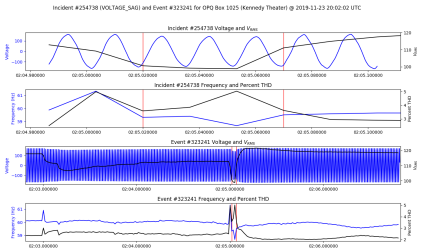


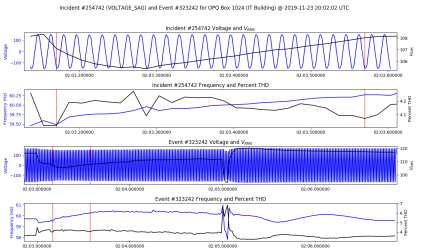


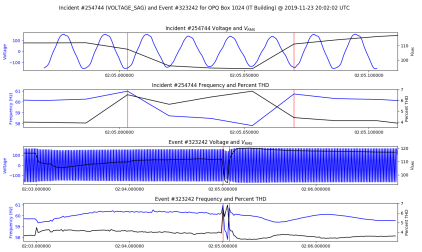


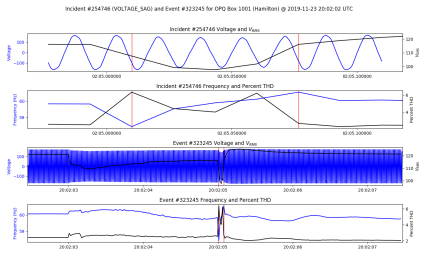


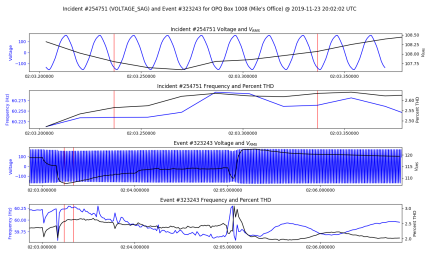


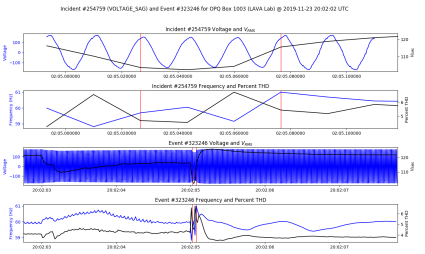


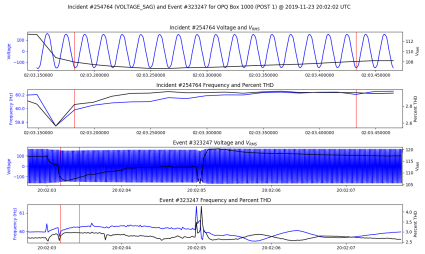


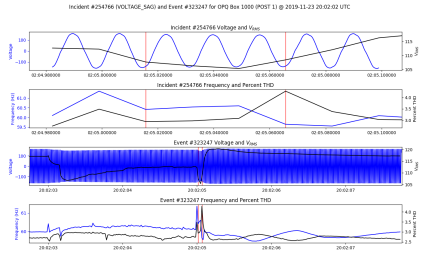


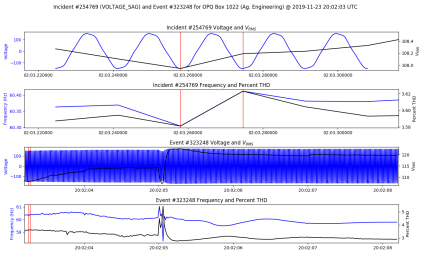


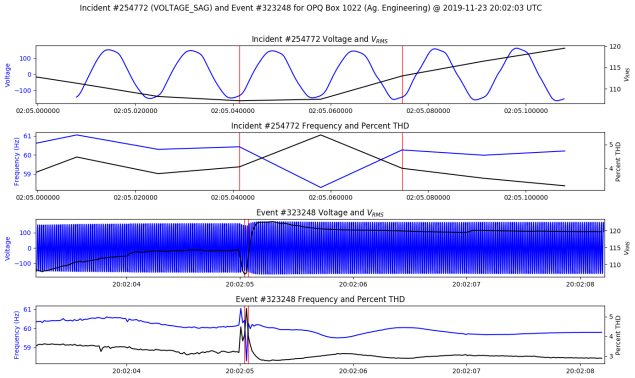


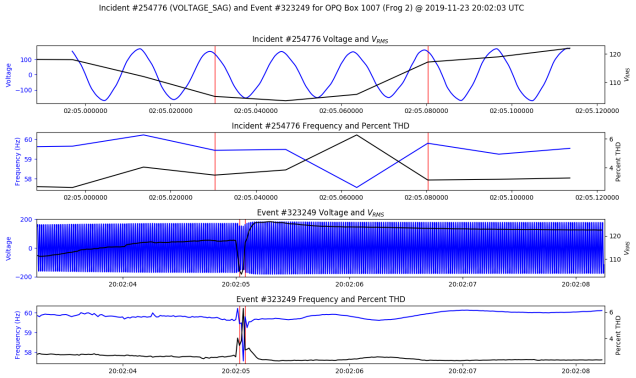












A Note on Incidents

It turns out that we have several Incidents classified from different Events over the same data. This shows that both Serge's and Anthony's triggering plugins are observing signals-of-interest, however it would be prudent to not duplicate work. We need to find a way to reconcile events so that Events over the same data are only generated once from one of our Triggering plugins rather than multiple times from out triggering plugins. These means that many of our Incidents are currently duplicated.

Events Summary

Events are ranges of PQ data that may (or may not) have PQ issues within them. Events are generated by two methods. The first method uses Voltage, Frequency, and THD thresholds as defined by IEEE. The second method uses the Napali Trigger which was developed by Sergey as part of his dissertation research. The Napali trigger uses statistical methods to determine when Boxes may contain PQ issues. This summary of

Events examines the number of times that Boxes were triggered due to possible PQ issues.

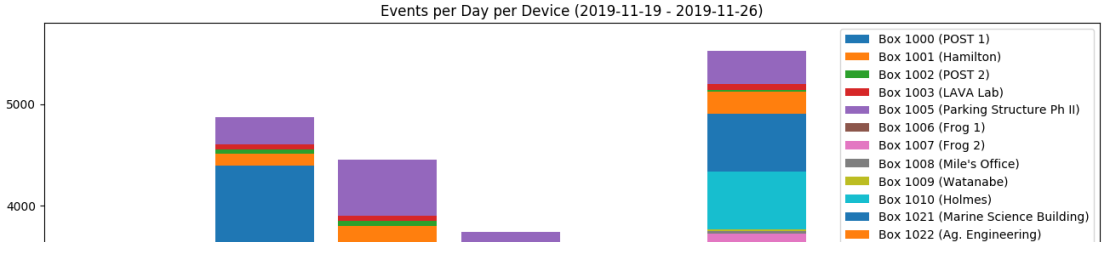
There were a total of 29013 Events processed.

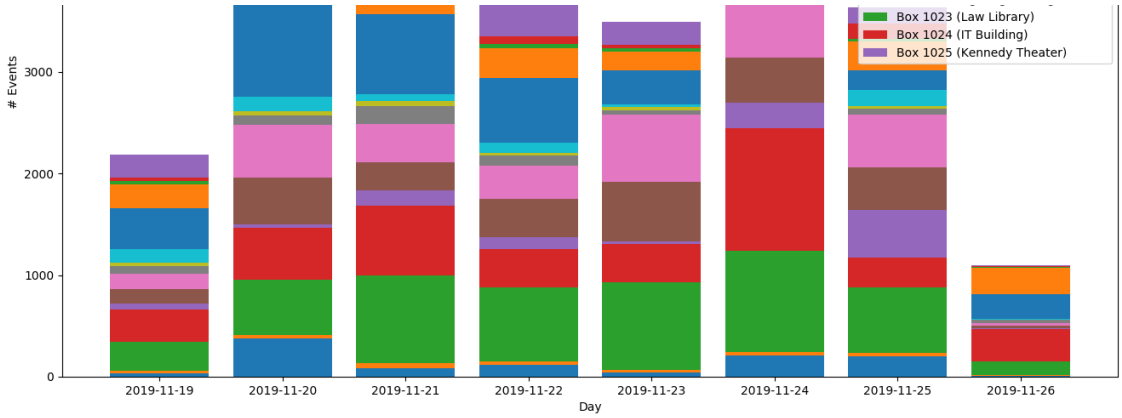
The following table shows Events generated per Box.

OPQ Box	Location	Events Generated
1002	POST 2	5053
1021	Marine Science Building	4808
1003	LAVA Lab	4090
1007	Frog 2	3160
1006	Frog 1	2728
1025	Kennedy Theater	2174
1022	Ag. Engineering	1824
1010	Holmes	1202
1005	Parking Structure Ph II	1116
1000	POST 1	1078
1008	Mile's Office	614
1024	IT Building	468
1023	Law Library	245
1001	Hamilton	235
1009	Watanabe	218
Total		**29013**

Events 2019-11-19 to 2019-11-26

The following figure shows Events per Box per day.





Peculiarities in the UHM Micro-grid

Conclusion

This week's report focused on the new Phenomena being implemented in Mauka and also looked at several interesting grid-wide Voltage sags and Frequency sags.

Unlisted

Data Science

Micro-report on the UHM micro-grid: 11/12 to 11/19

Open Power Quality
Nov 19, 2019 · Unlisted

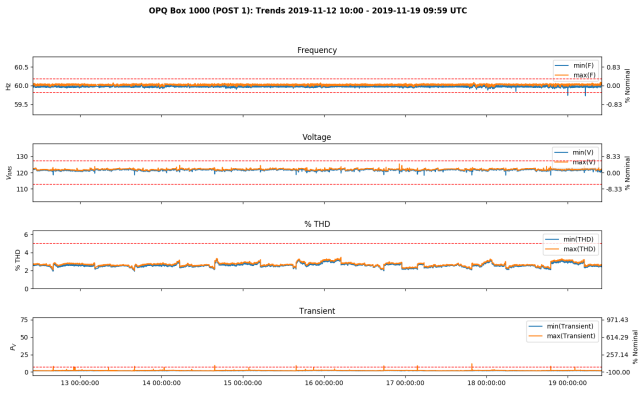
General Summary

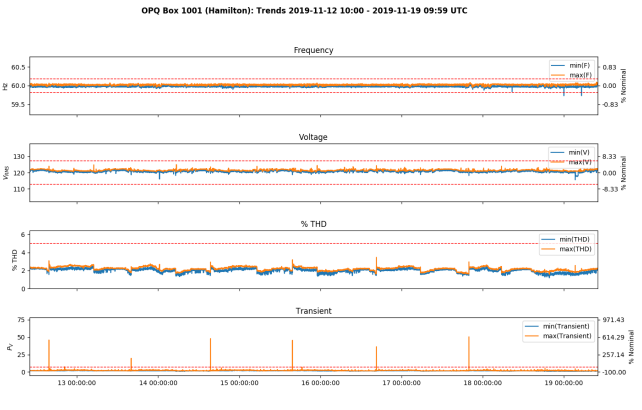
University of Hawaii at Manoa micro-grid report on data from 11–12–2019 10:00 to 11–19–2019 10:00 UTC.

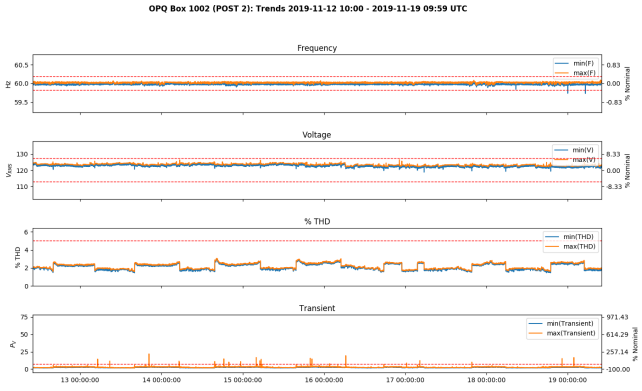
Trends Summary

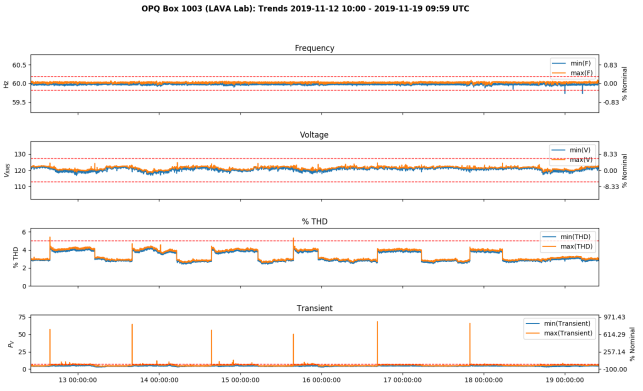
Weekly trends measure the minimum, average, and maximum values for Voltage, Frequency, THD, and transients for each OPQ Box at a rate of 1 Hz.

The following figures show Trends for each Box between 2019–11–12 10:00:00 and 2019–11–19 10:00:00.

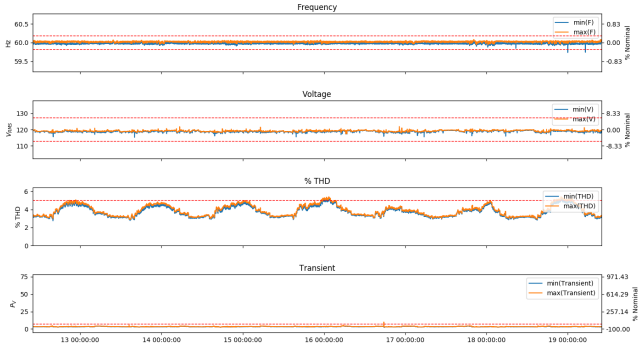




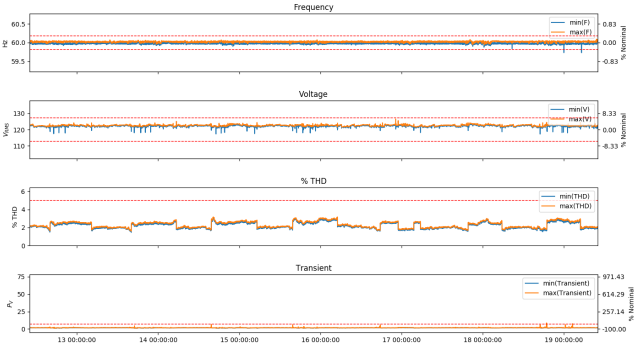




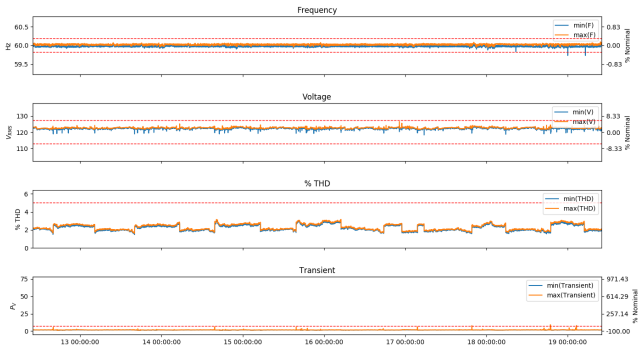
OPQ Box 1005 (Parking Structure Ph II): Trends 2019-11-12 10:00 - 2019-11-19 09:59 UTC



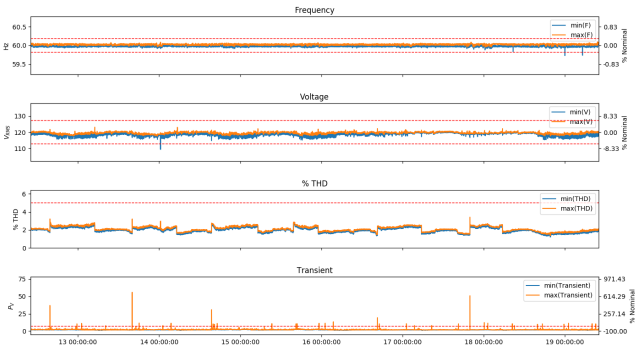
OPQ Box 1006 (Frog 1): Trends 2019-11-12 10:00 - 2019-11-19 09:59 UTC



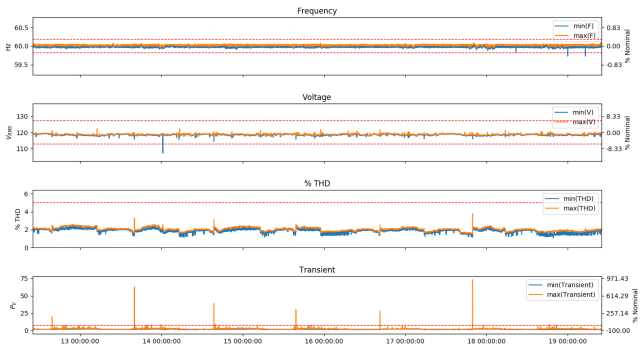
OPQ Box 1007 (Frog 2): Trends 2019-11-12 10:00 - 2019-11-19 09:59 UTC



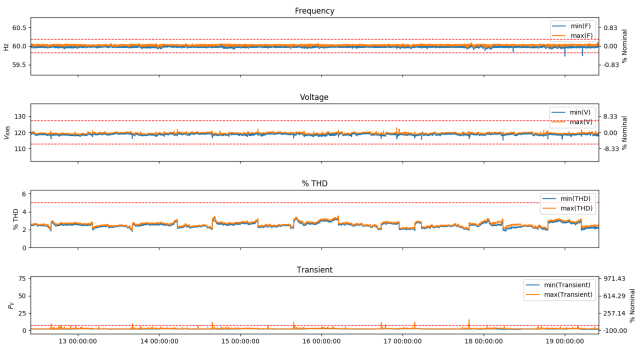
OPQ Box 1008 (Mile's Office): Trends 2019-11-12 10:00 - 2019-11-19 09:59 UTC



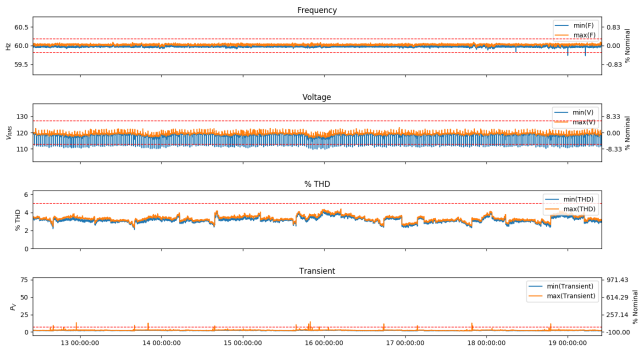
OPQ Box 1009 (Watanabe): Trends 2019-11-12 10:00 - 2019-11-19 09:59 UTC



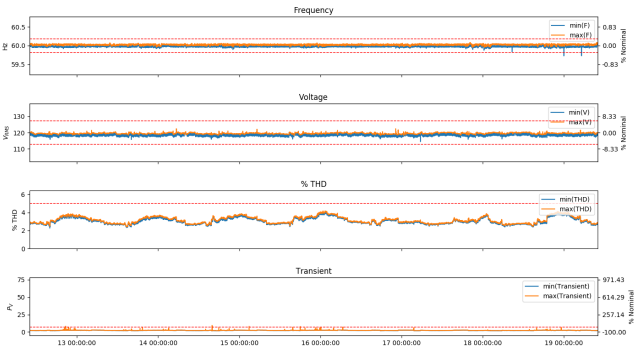
OPQ Box 1010 (Holmes): Trends 2019-11-12 10:00 - 2019-11-19 09:59 UTC



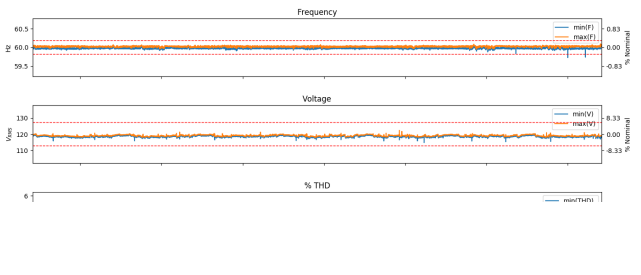
OPQ Box 1021 (Marine Science Building): Trends 2019-11-12 10:00 - 2019-11-19 09:59 UTC



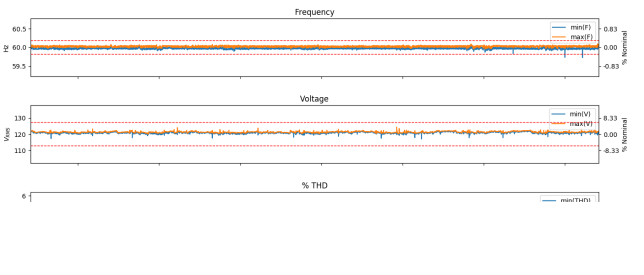
OPQ Box 1022 (Ag. Engineering): Trends 2019-11-12 10:00 - 2019-11-19 09:59 UTC

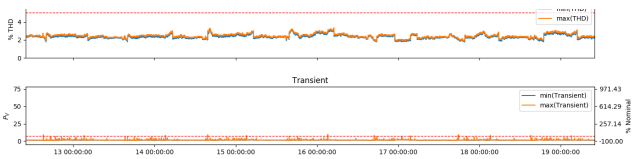


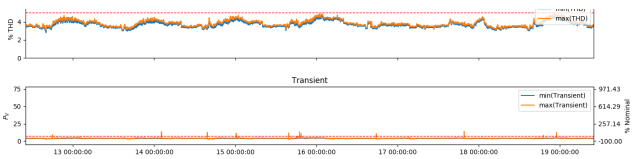
OPQ Box 1023 (Law Library): Trends 2019-11-12 10:00 - 2019-11-19 09:59 UTC



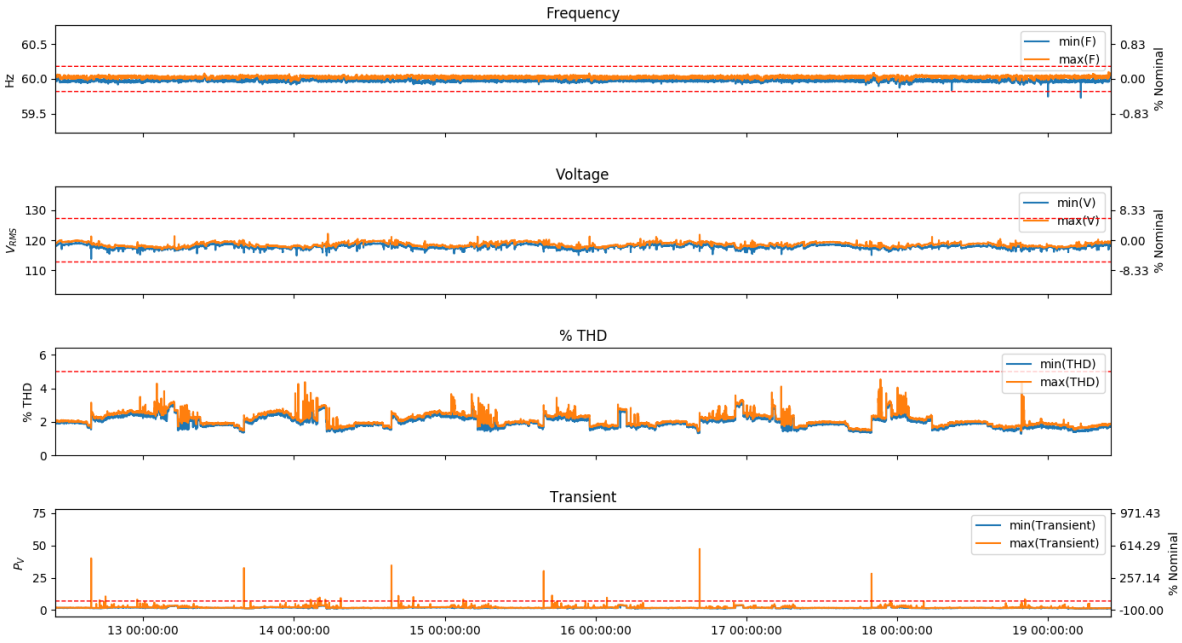
OPQ Box 1024 (IT Building): Trends 2019-11-12 10:00 - 2019-11-19 09:59 UTC







OPQ Box 1025 (Kennedy Theater): Trends 2019-11-12 10:00 - 2019-11-19 09:59 UTC



The main focus of trend data for this past week is two frequency sags that were observed by the entire network towards the end of the week, higher than usual amounts of THD observed by Box 1005 in the parking structure, and a Voltage sag from Box 1009 in Watanabe.

Otherwise, the grid remained relatively stable this past week.

Phenomena

Phenomena are an abstract concept for Anthony's PhD dissertation that provide actionable insights and context on top of classified Incidents. In terms of PQ monitoring, Phenomena provide added context on top of PQ Incidents.

We are currently implementing Cyclic Phenomena that can detect Cyclic signals within the network. These signals include Trends, Events, and Incidents.

To motivate this discussion, consider the cyclic Voltage sags observed on Box 1021. These Sags are intriguing, but we currently only observe them in Trend data because they are not large enough in magnitude nor long enough in duration to be currently classified as an Event or Incident.

If these sags were identified as a Cyclic Phenomena, then Future Phenomena could be created from them to predict future Voltage sags! The Future Phenomena has the ability to either tune the network for or against these cyclic signals either enabling more fine grained detection or ignoring the signals altogether.

If Future Phenomena were to tune for this signal, then it would be possible for this system to collect high-fidelity data from this signal even if it doesn't meet the default thresholds.

Incidents

Incidents are classified PQ issues that were found in the previously provided Events. Incidents are classified by OPQ Mauka according to various PQ standards. OPQ Mauka provides classifications for Outages, Voltage, Frequency, and THD related issues.

A total of 85195 Incidents were processed.

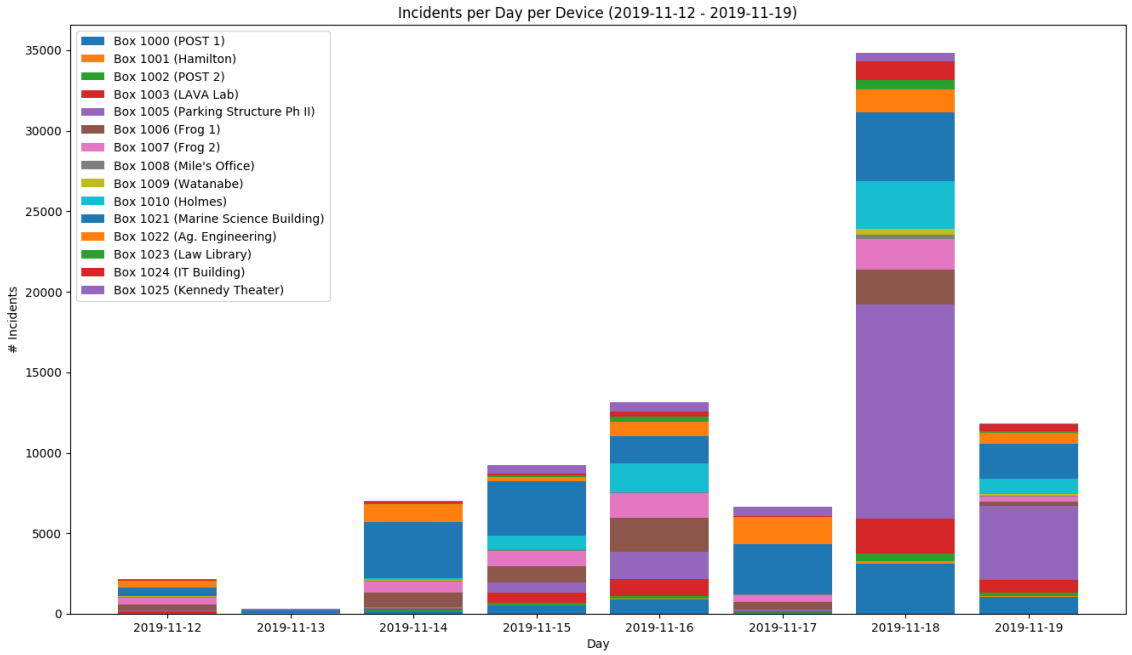
A breakdown of Incidents per Box is provided in the following table.

Box	Cnt	FSag	FSwell	Outage	THD	VSag
1005	20489	874	1183	0	18432	0
1021	18800	2655	16120	6	19	0
1006	7325	6183	1142	0	0	0
1010	6648	1902	4739	0	7	0
1022	6454	2158	4294	0	2	0
1007	6163	5123	1039	1	0	0
1000	5802	2859	2940	2	1	0
1003	4809	1862	2939	0	8	0
1025	2547	1951	582	0	14	0
1024	2140	1079	1055	0	6	0
1002	1280	570	710	0	0	0

1023	1227	684	543	0	0	0
1008	738	508	220	0	10	0
1009	534	203	315	0	12	4
1001	239	227	2	0	10	0
Total	**85195**	**28838**	**37823**	**9**	**18521**	**4**

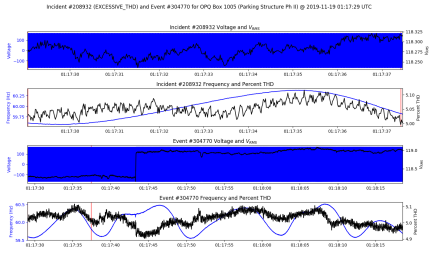
Incidents 2019-11-12 to 2019-11-19

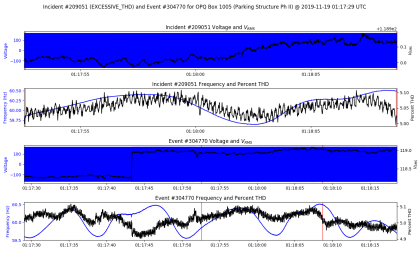
The following figure shows Incidents per Box per day.

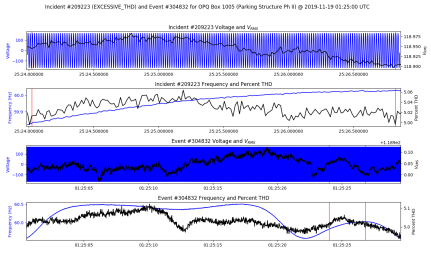


THD Incidents

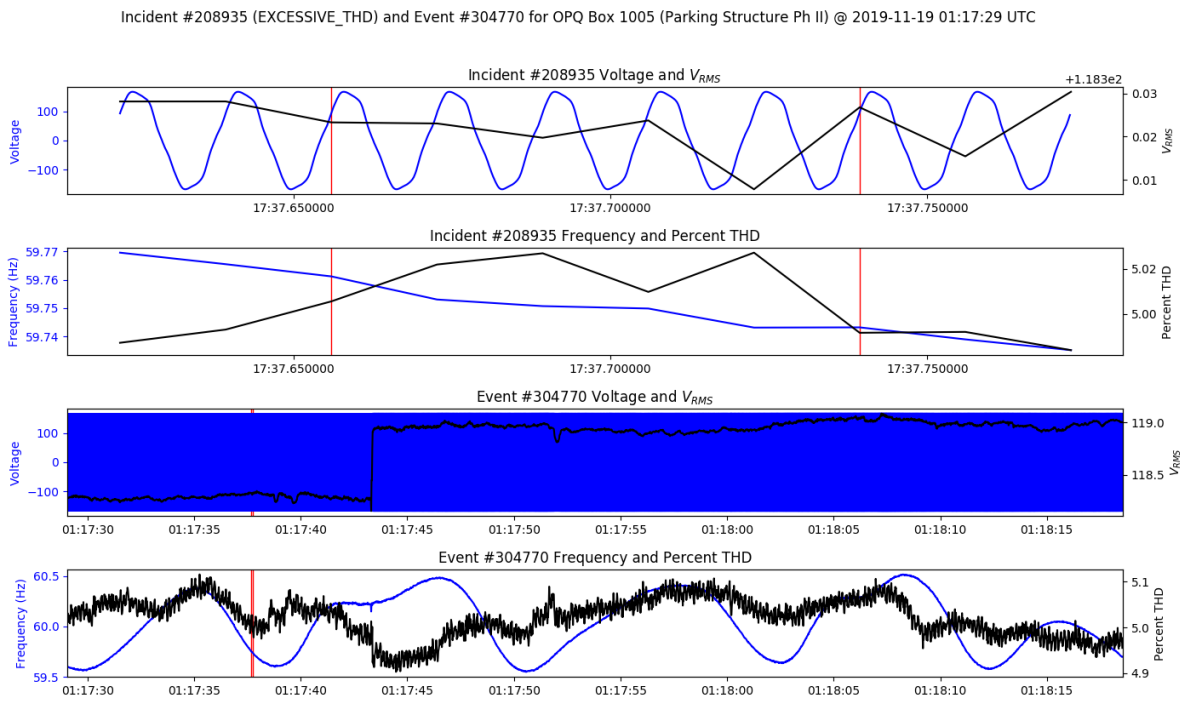
We observed a high amount of excessive THD at Box 1005 (Parking Structure). This is also evident when looking at the trends. The Waveforms of all sampled THD incidents display the same distortion. Below are some examples.





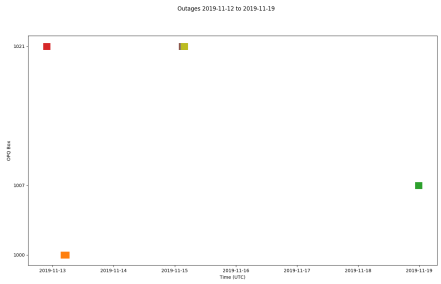


As we can see from the above longer THD Incidents, THD of this device is fluctuation at right around 5%.



This shorter Incident shows the main cause of the THD. We can see squaring of the waveform which is producing the THD.

Outage Incidents



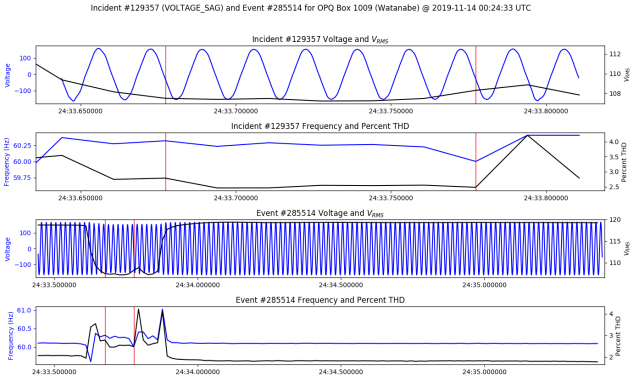
OPQ Box	Location	Incident #	Outage Start	Outage End	Duration (s)
1000	POST 1	129338	11-13 04:34:17	11-13 05:18:34	2656.591
1021	Marine Science Building	138128	11-15 02:50:42	11-15 03:00:43	600.997
1007	Frog 2	199477	11-18 23:40:39	11-18 23:43:40	180.572
1021	Marine Science Building	128352	11-12 21:41:55	11-12 21:44:23	148.046
1021	Marine Science Building	138141	11-15 03:21:42	11-15 03:23:43	120.881
1021	Marine Science Building	138143	11-15 03:26:42	11-15 03:28:43	120.863
1021	Marine Science Building	138149	11-15 03:43:42	11-15 03:44:43	60.824
1021	Marine Science Building	137924	11-15 01:53:42	11-15 01:54:42	60.219
1000	POST 1	129337	11-13 04:14:17	11-13 04:15:17	60.058

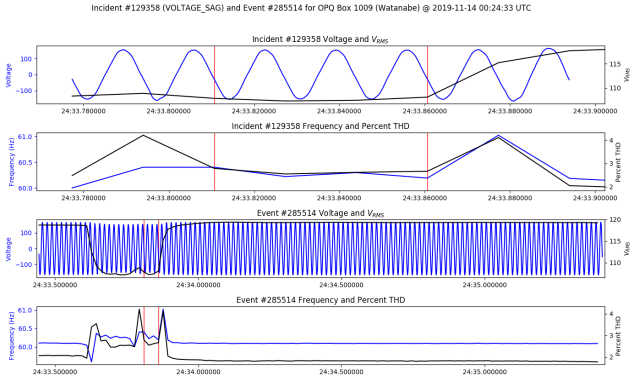
Outages 2019-11-12 to 2019-11-19

We can see that data from MSB has been spotty. We also see outages for the Box in our office, but as far as we know this Box has not lost power, but experienced a sever gap in measurements. Could these outages be network related? We likely need more metrics to find out.

Voltage Sags

Watanabe experienced several short Voltage sags near each other from the same Event, but these did not generate any ITIC or SemiF47 violations.





Frequency Incidents

Last week we predicted that the amount of Frequency fluctuations would decrease due to more stringent Frequency thresholds. The opposite is true and the amount of Frequency Incidents has increased! This is mainly due to a large amount of Frequency swells observed on Box 1005. This can be explained by the waveform distortion that also triggered all of the THD Incidents for this location.

We also observed a larger number of Frequency sags from the Frog buildings as compare to last week. We will continue to dull the Frequency thresholds until we can get to a point where the number of Frequency variations become meaningful.

Events Summary

Events are ranges of PQ data that may (or may not) have PQ issues within them. Events are generated by two methods. The first method uses Voltage, Frequency, and THD thresholds as defined by IEEE. The second method uses the Napali Trigger which was developed by Sergey as part of his dissertation research. The Napali trigger uses statistical methods to determine when Boxes may contain PQ issues. This summary of Events examines the number of times that Boxes were triggered due to possible PQ issues.

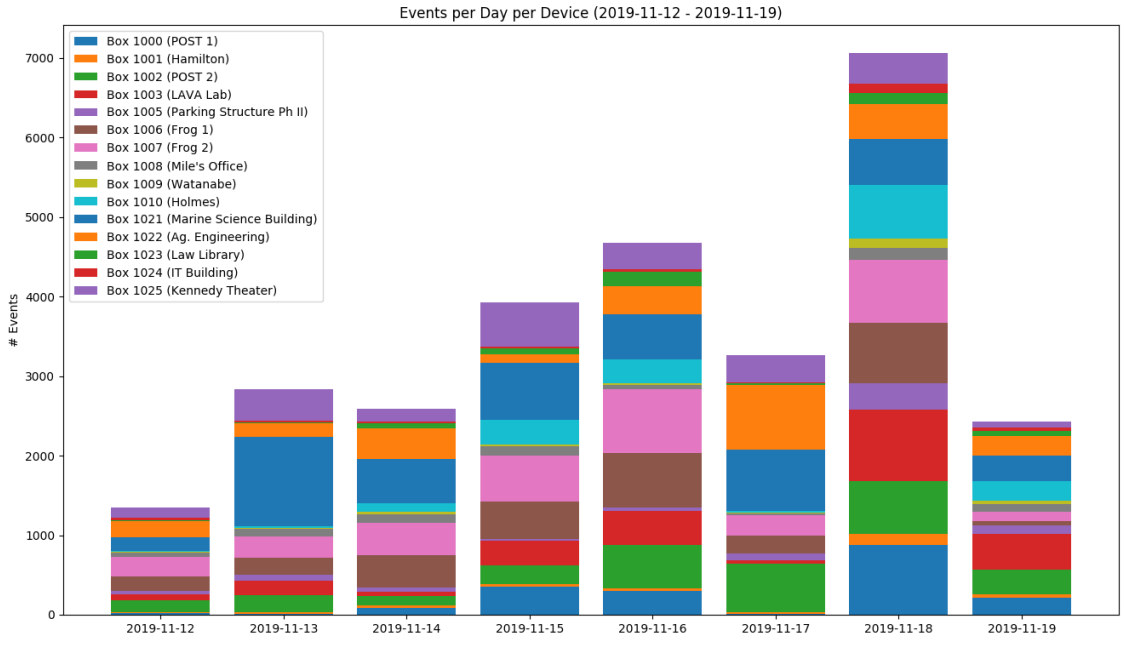
There were a total of 28142 Events processed.

The following table shows Events generated per Box.

OPQ Box	Location	Events Generated
1021	Marine Science Building	4813
1007	Frog 2	3474
1006	Frog 1	2993
1002	POST 2	2851
1022	Ag. Engineering	2723
1003	LAVA Lab	2460
1025	Kennedy Theater	2373
1000	POST 1	1876
1010	Holmes	1669
1005	Parking Structure Ph II	745
1008	Mile's Office	700
1023	Law Library	571
1001	Hamilton	321
1024	IT Building	300
1009	Watanabe	273
Total		**28142**

Events 2019-11-12 to 2019-11-19

The following figure shows Events per Box per day.

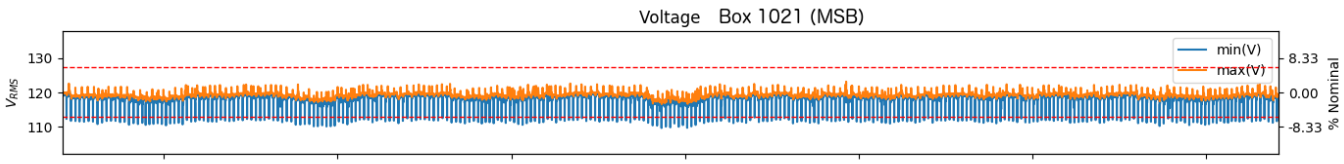


Day

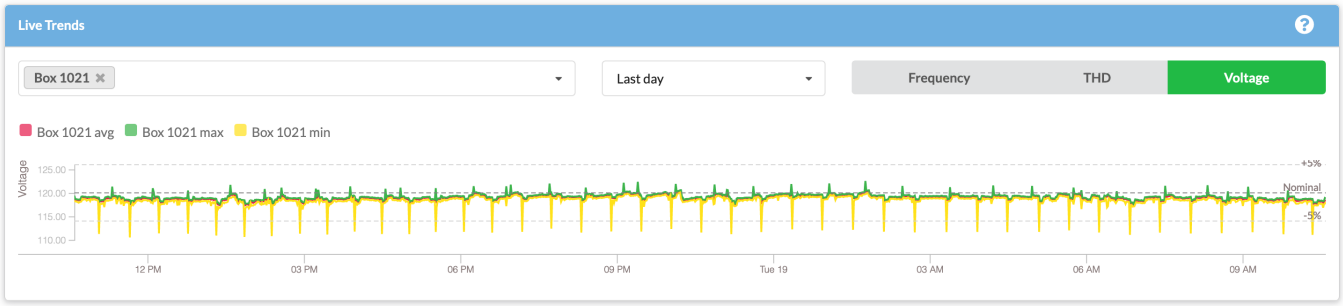
UHM Micro-grid: Making Sense of the Data

Box 1021 (Marine Science Building) Periodic Voltage Sags

Box 1021 has been displaying periodic Voltage sags for some time now. For example, here is Box 1021 over the past week.



We can get a better idea of its periodicity by looking at a day's worth of data from OPQ View.



Looking at the data for one day reveals another interesting feature that is not present in the weekly trends. Not only do we see periodic Voltage sags, but we also see periodic Voltage swells. Our hypothesis is that the Voltage sag is caused by an electrical load switching on and the Voltage swell is caused by that same electrical load switching off. Since we only observe this within MSB, then it is likely caused by an electrical load within MSB.

This is interesting enough that it requires further analysis on the periodicity of the Voltage fluctuations.

We found the peaks of the Voltage sags and swells and used those to compute some statistics on periodicity and the "on cycle" of the electrical load.

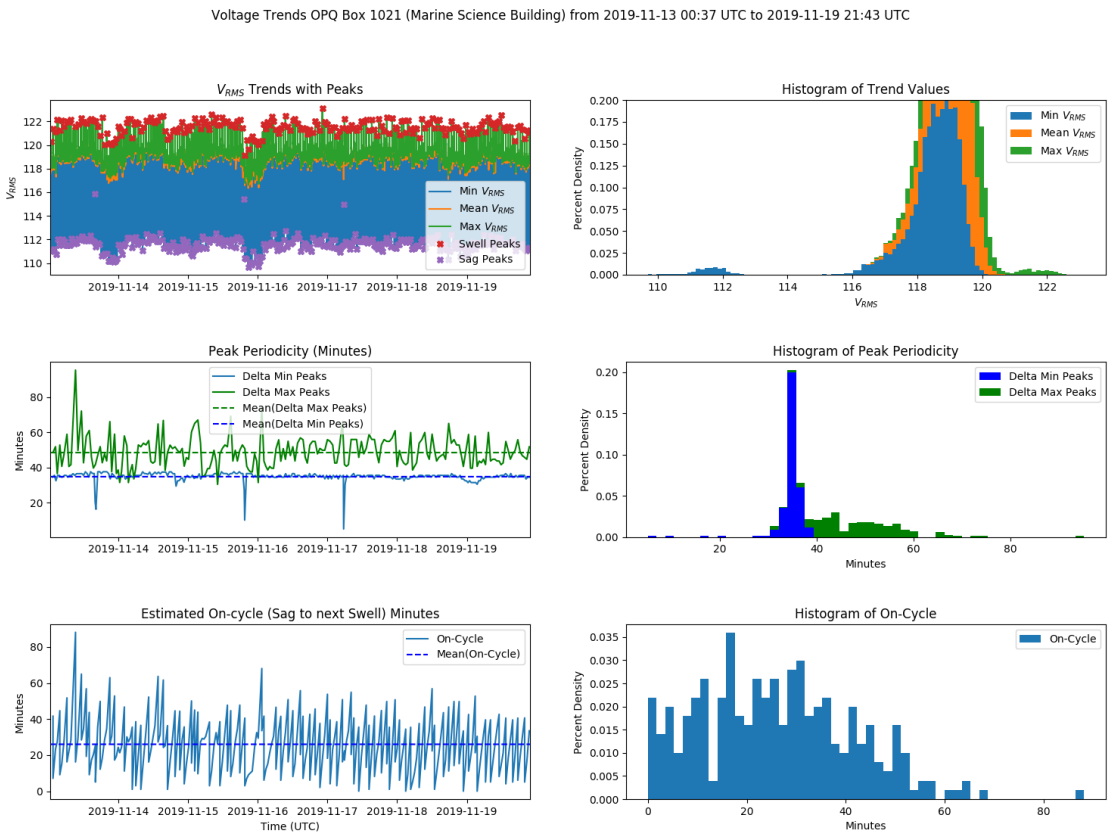
The first row plots Voltage trends over the period of 24 hours and finds the peaks of the minimum and maximum values. Since we are attempting to determine if the Voltage swells are associated with the Voltage sags, we find the peaks of the swells with a minimum length of 30 minutes which should reduce some of the noise in the swells. The second column of the first row shows the distribution of values. We can see the sags on the far left and the swells on the far right.

The second row plots the time difference (in minutes) peaks of the swells and the peaks of the sags. We can see that sags are much more periodic and that swells are less periodic and slightly more noisy.

The third row examines the amount of time from each sag to the next swell. This was performed to determine if an electrical load switching on and off are possible causes of the Voltage fluctuations.

The discrepancy between Sags times and Swell times may be due to the variance of the “on-cycle”.

Can we tell anything about the time of day? Let's look at this data over the course of a week.



It doesn't appear that there are large daily trends taking place, leading us to believe that these Voltage fluctuations may not be related to the time of day.

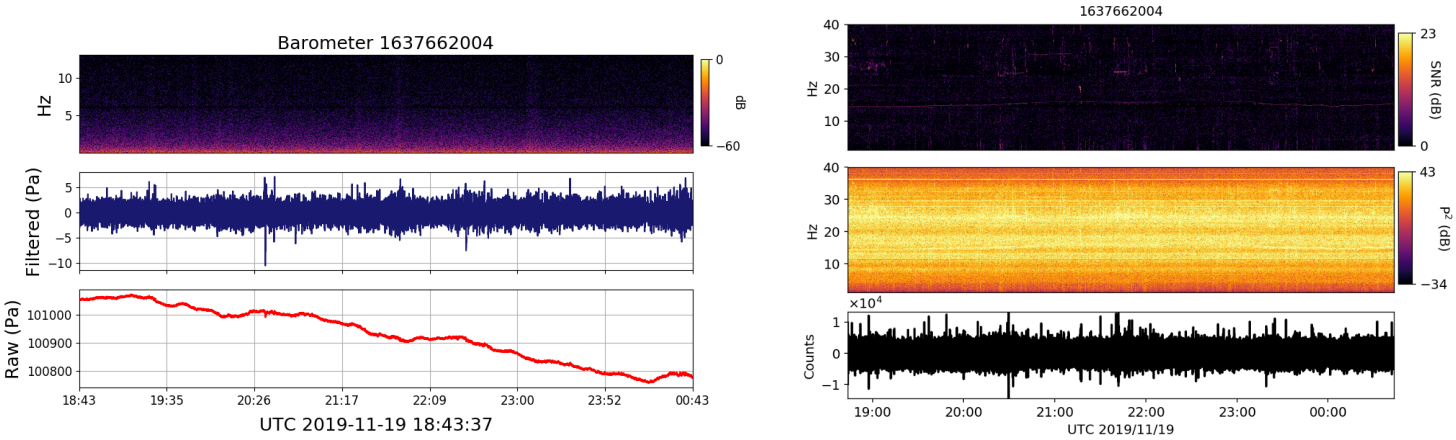
In summary, the data tells us that Voltage sags occur pretty regularly around 34 minutes. The Voltage swells have a larger deviation and the times between sags and swells vary quite a bit. Knowing this, I'm not sure if we can safely say anything about whether the swells are related or a separate signal.

We had originally hypothesized that the cause of these Voltage fluctuations was the cycling of the building's HVAC unit. However, further experiments were not able to verify our theory.

Anthony runs another distributed sensor network that collects Infrasound data (among other things) using cell phones. We installed an Infrasound sensor co-located with Box 1021. We hypothesized that HVAC cycling would create pressure differentials which

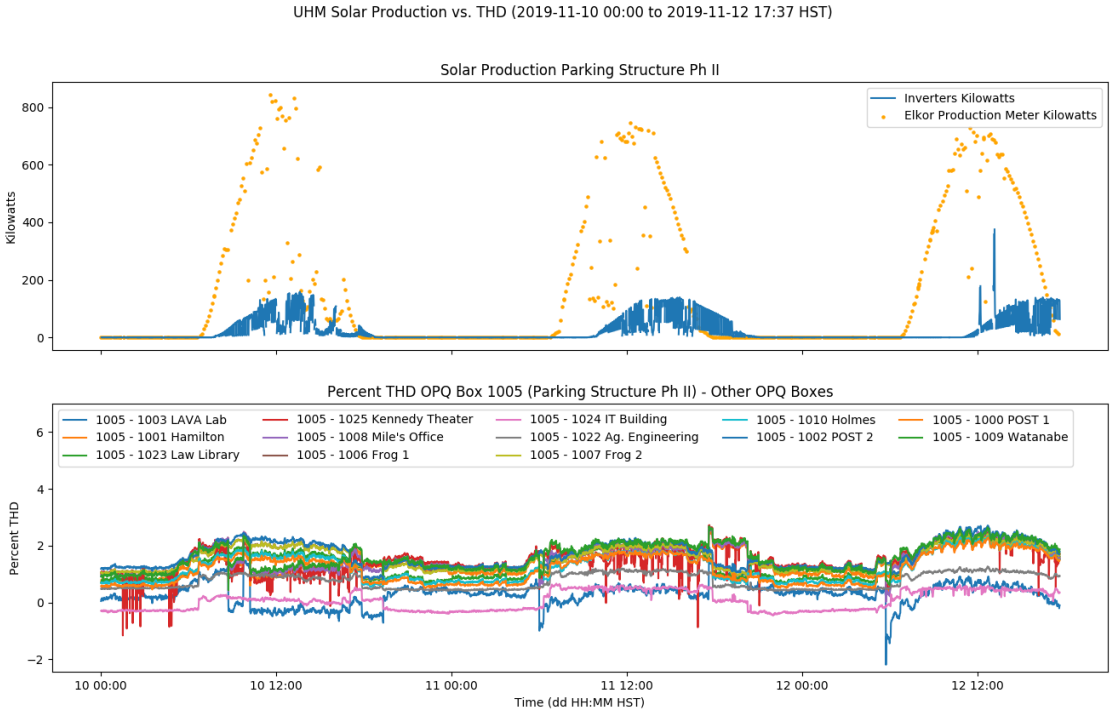
could easily be observed in the Infrasound range (especially using the sensor's barometer).

Here is 6 hours worth of Infrasound data collected from the sensor's microphone and barometer corresponding to unit 1021 in MSB.



As seen above, there are no clear signals at regular intervals of 34 minutes. We can not assume that these Voltage fluctuations are caused by an HVAC unit.

Box 1005 (Parking Structure Ph II) Local THD and Solar Production



Conclusion

This week's report focuses on looking at techniques for comparing solar production vs. THD. We also further examine the Voltage sags at Box 1021 to get better timing bounds on the Voltage sags. We discuss several new algorithms used for Frequency classification.

Unlisted

Data Science

Micro-report on the UHM micro-grid: 11/05 to 11/12

Open Power Quality
Nov 12, 2019 · Unlisted

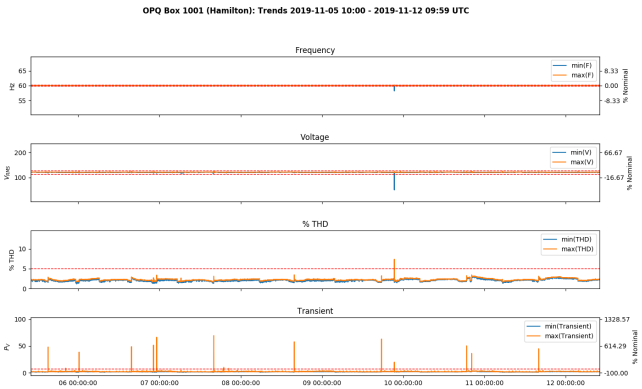
General Summary

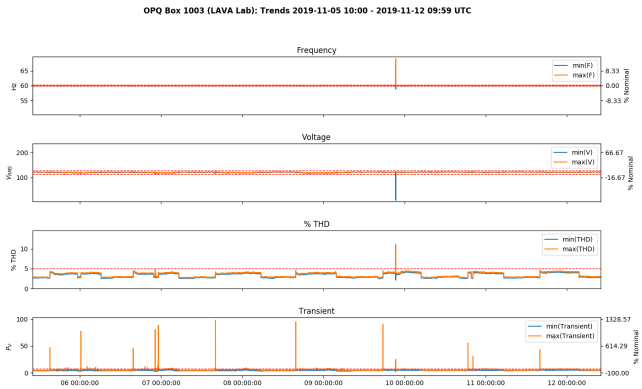
University of Hawaii at Manoa micro-grid report on data from 11–05–2019 10:00 to 11–12–2019 10:00 UTC.

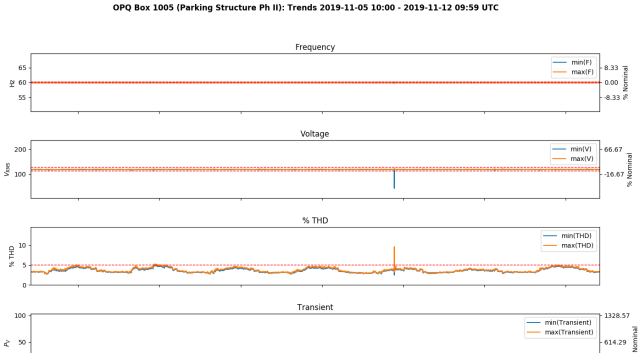
Trends Summary

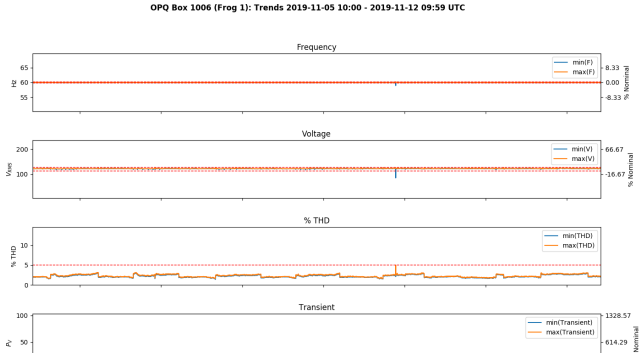
Weekly trends measure the minimum, average, and maximum values for Voltage, Frequency, THD, and transients for each OPQ Box at a rate of 1 Hz.

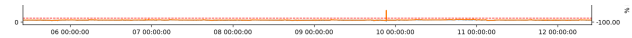
The following figures show Trends for each Box between 2019–10–29 10:00:00 and 2019–11–05 10:00:00.

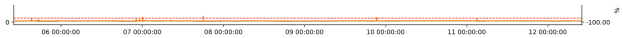




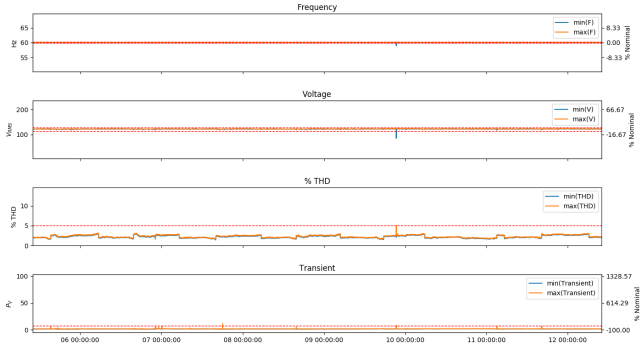




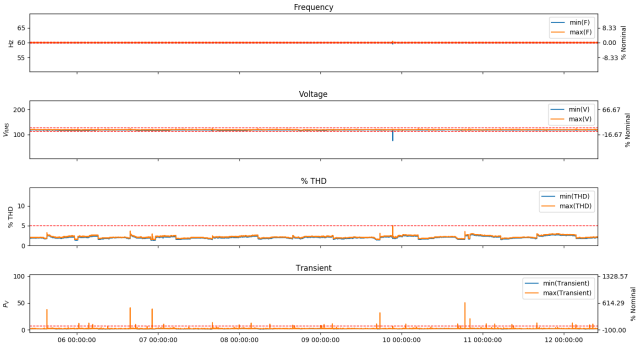




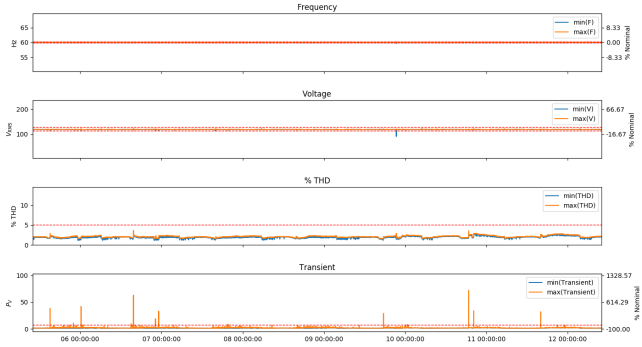
OPQ Box 1007 (Frog 2): Trends 2019-11-05 10:00 - 2019-11-12 09:59 UTC



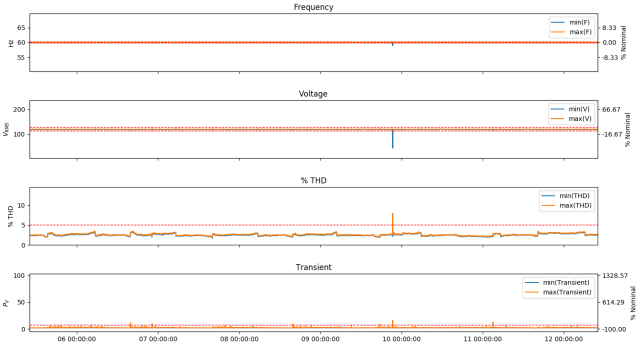
OPQ Box 1008 (Mile's Office): Trends 2019-11-05 10:00 - 2019-11-12 09:59 UTC



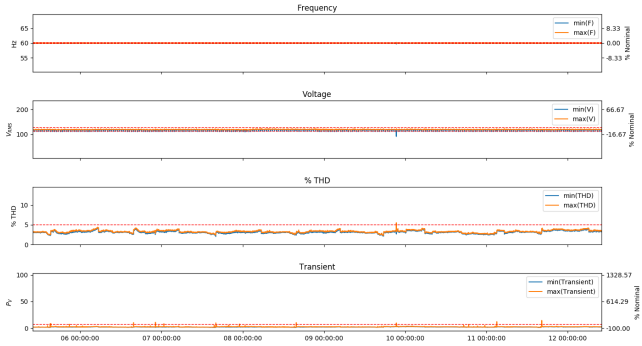
OPQ Box 1009 (Watanabe): Trends 2019-11-05 10:00 - 2019-11-12 09:59 UTC



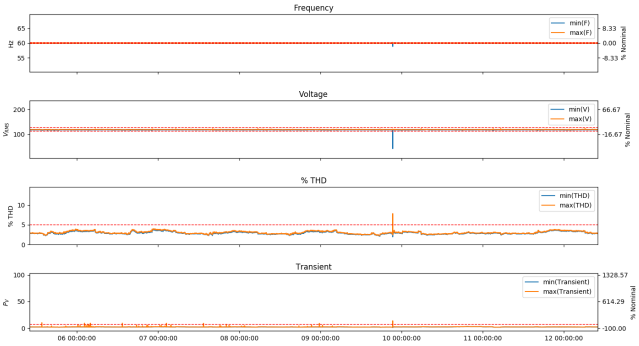
OPQ Box 1010 (Holmes): Trends 2019-11-05 10:00 - 2019-11-12 09:59 UTC



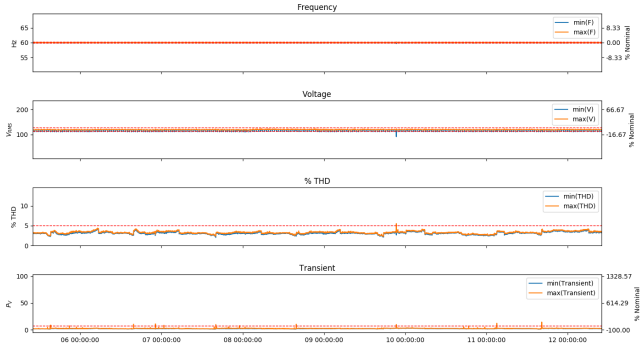
OPQ Box 1021 (Marine Science Building): Trends 2019-11-05 10:00 - 2019-11-12 09:59 UTC



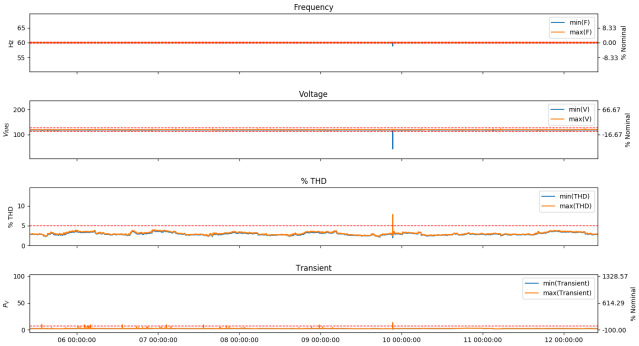
OPQ Box 1022 (Ag. Engineering): Trends 2019-11-05 10:00 - 2019-11-12 09:59 UTC



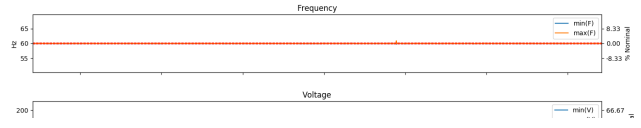
OPQ Box 1021 (Marine Science Building): Trends 2019-11-05 10:00 - 2019-11-12 09:59 UTC



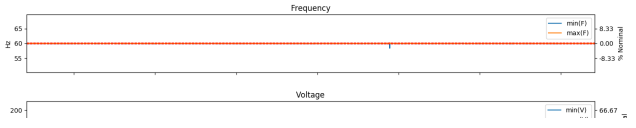
OPQ Box 1022 (Ag. Engineering): Trends 2019-11-05 10:00 - 2019-11-12 09:59 UTC

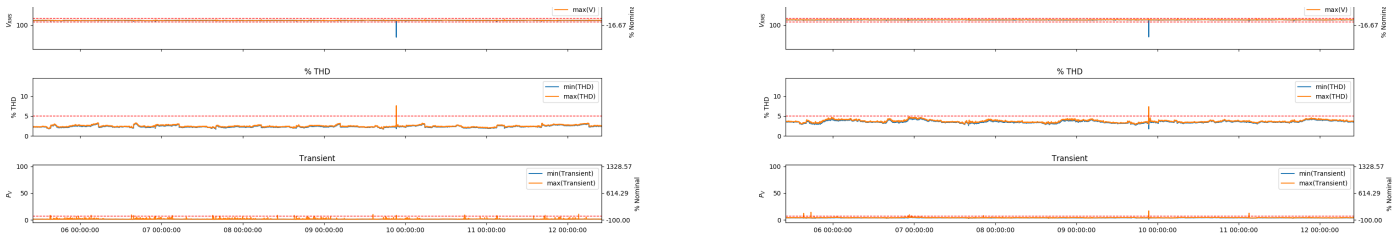


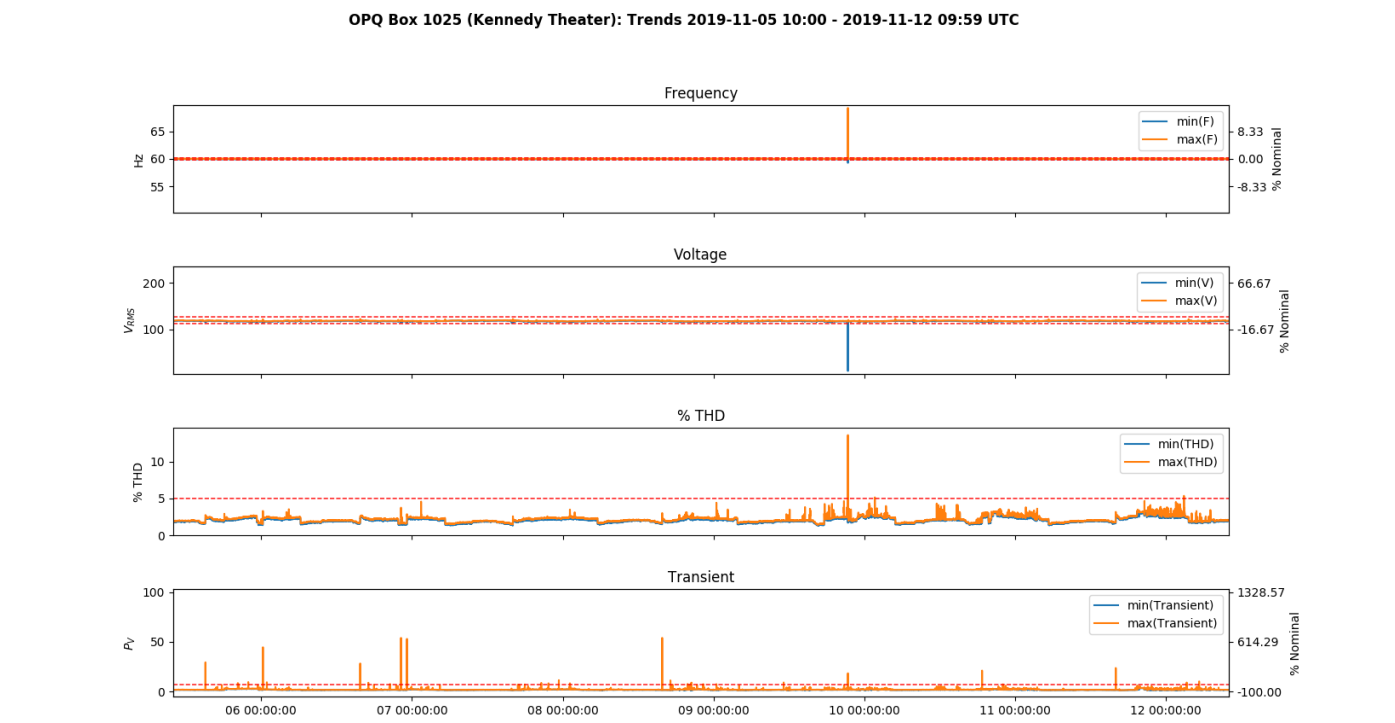
OPQ Box 1023 (Law Library): Trends 2019-11-05 10:00 - 2019-11-12 09:59 UTC



OPQ Box 1024 (IT Building): Trends 2019-11-05 10:00 - 2019-11-12 09:59 UTC







In terms of summarizing Trends, trends for this past week display a single interesting PQ event across all Boxes that took place on Saturday, Nov 9 at around 11:21 HST (Nov 9 21:21 UTC). However, due to the magnitude of this signal, the bounds for Frequency and Voltage are difficult to ascertain for the rest of the week.

We are not certain what exactly caused the above power signal, however an e-mail that Anthony received on Saturday night states:

> *A random power outage today took down the network for a significant amount of time since it also killed some UPS'es in the network closets on the 5th floor [POST]. All hardware was back up by 8:00PM.*

This could be related, but without more information, we can not be sure.

Phenomena

Phenomena are an abstract concept for Anthony's PhD dissertation that provide actionable insights and context on top of classified Incidents. In terms of PQ monitoring, Phenomena provide added context on top of PQ Incidents.

This past week, Anthony has began implementing the infrastructure for two types of Phenomena. First, Annotations which provide context on top of classified Incidents. The data model for Annotations has been completed and now all that remains if a way to enter Annotations into the system and plot Annotations on top of Trends, Events, and Incidents within these reports.

The second Phenomena that saw work last week was the Locality Phenomena which uses the location of Boxes relative to each other in order to trigger Boxes that may not have been originally triggered.

For instance, the THD Incident that was recorded only on a single Box could have utilized locality Phenomena to trigger other Boxes "near" Box 1025 and analyzed their data for Incidents as well. Hopefully this will be done by the end of this week and we can start analyzing the results of this Phenomena next week.

Incidents

Incidents are classified PQ issues that were found in the previously provided Events. Incidents are classified by OPQ Mauka according to various PQ standards. OPQ Mauka provides classifications for Outages, Voltage, Frequency, and THD related issues.

A total of 37215 Incidents were processed.

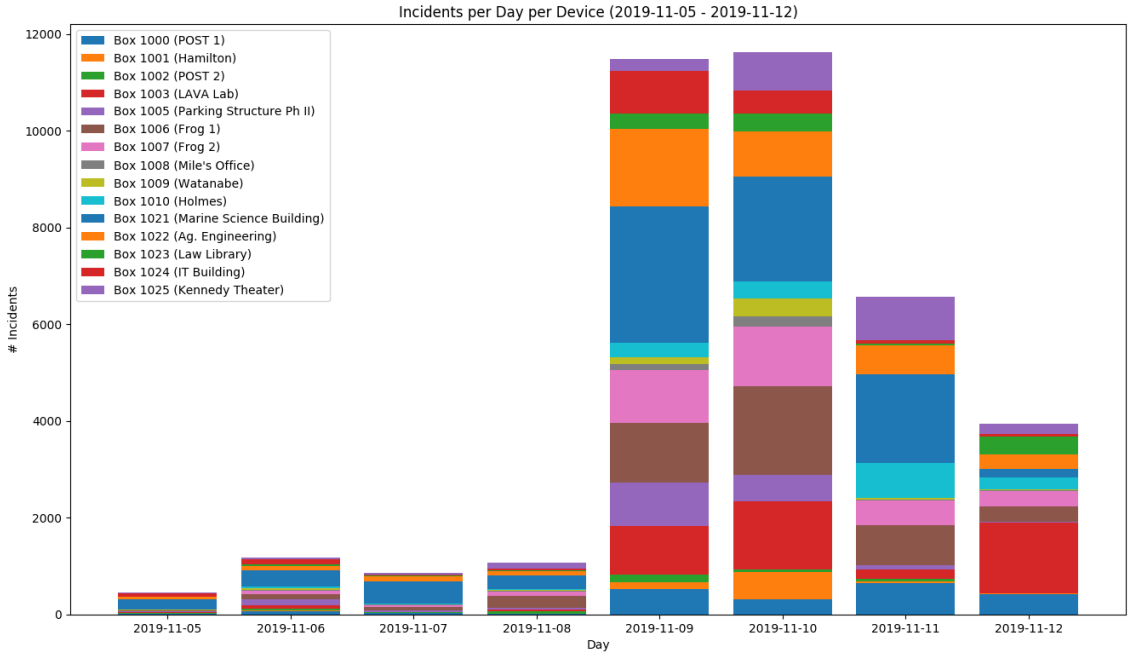
A breakdown of Incidents per Box is provided in the following table.

Box	Cnt	FSwell	FSag	THD	VSag	SemiF47	IticND	VInt
1021	8283	6617	1664	0	2	0	0	0
1006	4652	753	3897	0	2	0	0	0
1003	4209	2472	1723	2	8	0	0	4
1022	3781	2233	1545	0	2	1	0	0
1007	3349	540	2799	6	4	0	0	0
1025	2381	749	1616	4	6	2	2	2
1000	2125	1135	987	0	2	0	1	0

1005	1774	999	765	6	2	0	2	0
1024	1728	775	945	2	4	0	2	0
1010	1712	1064	636	7	4	0	1	0
1023	1165	518	639	5	2	0	1	0
1001	791	179	600	8	4	0	0	0
1009	630	331	297	0	2	0	0	0
1008	482	100	370	8	4	0	0	0
1002	393	163	223	3	4	0	0	0
Total	**37455**	**18628**	**18706**	**51**	**52**	**3**	**9**	**6**

Incidents 2019-11-05 to 2019-11-12

The following figure shows Incidents per Box per day.



ITIC and Semi F47 Incidents

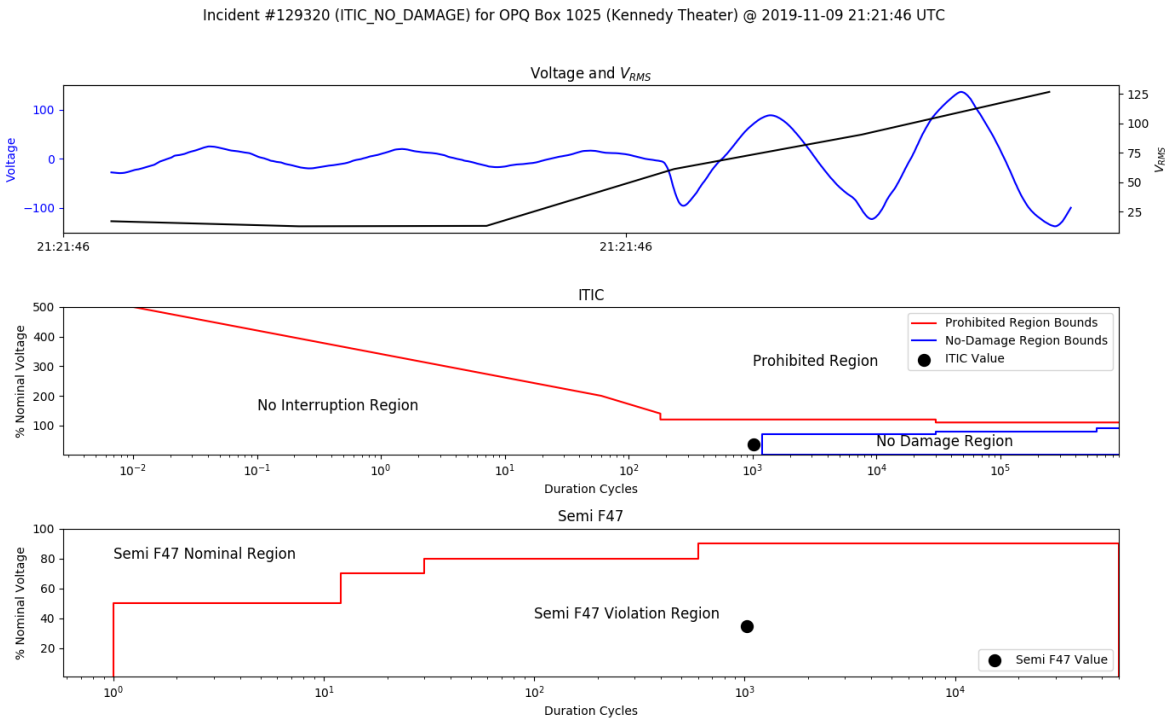
The ITIC and Semi F47 curves are PQ acceptability curves designed to plot frequency swells (ITIC) and frequency sags (ITIC and Semi F47) vs duration of the sag or swell. These curves provide regions that are essentially goal posts for consumer electronics to meet that determine if electronics should continue functioning or be damaged in the presence of Voltage sags and swells of known durations.

ITIC and Semi F47 classifications are provided by Mauka using a Point-in-Polygon algorithm to test if a swell/sag and duration fall within one of the non-nominal regions

of the curves.

The PQ event on the 9th provided us with a few ITIC and Semi F47 Incidents to examine.

Most of the ITIC and Semi-F47 Incidents look incredibly similar. Therefor we will only include one here for examination.



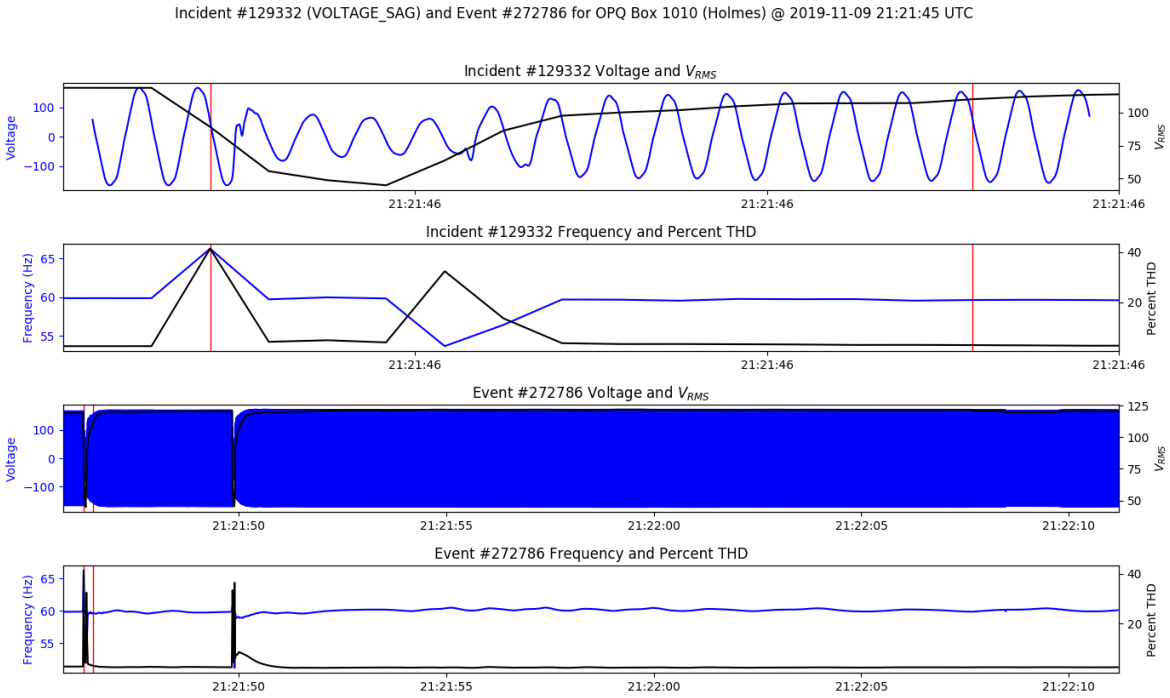
Here, we can see that device 1025 registered both an ITIC NO DAMAGE and a Semi F47 violation during Saturday's PQ event. What's with the plot for ITIC then? The plot calculates the duration of the Incident by looking at the number of cycles in the incident waveform. It appears that the start timestamp of the incident is slightly under represented which is why the plot point for ITIC does not line up exactly within the No Damage Region.

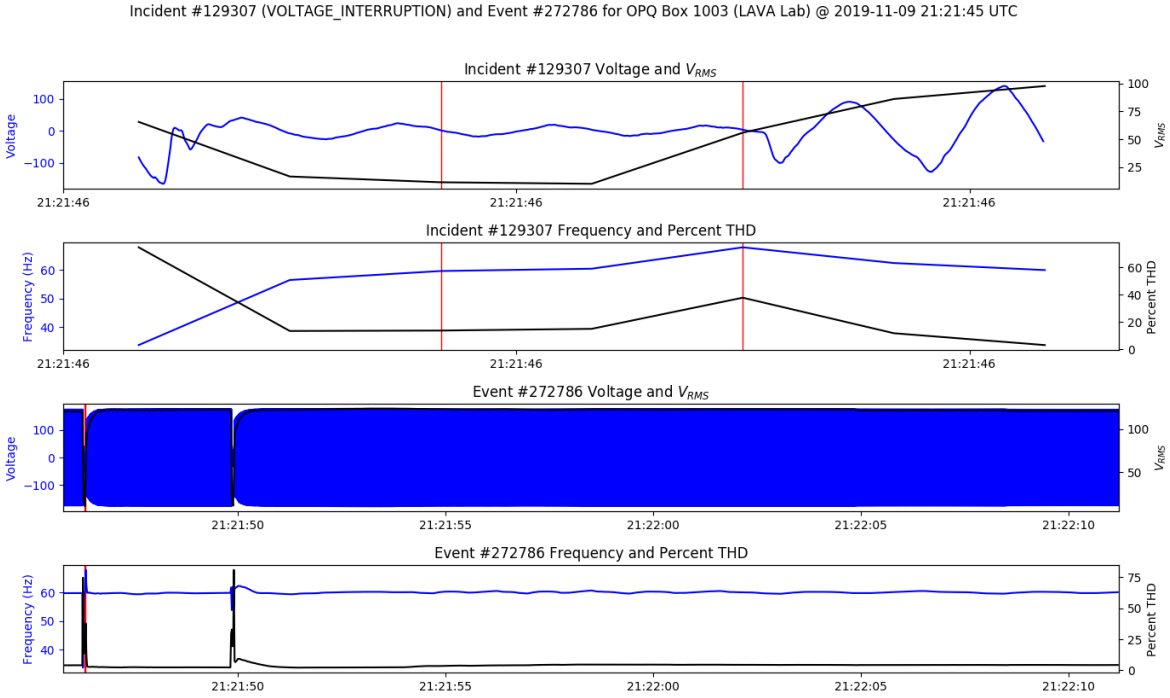
Outage Incident Details

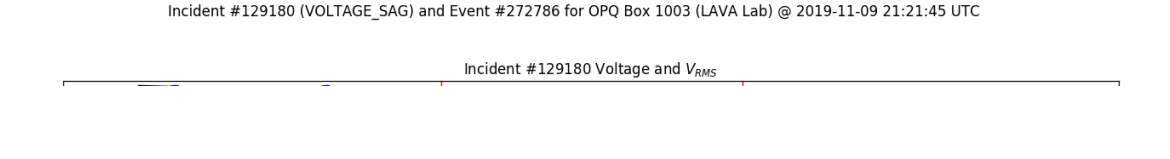
For the first week since we've began these reports, there are no reported outages in the data for the past week. We verified that the Outage plugin was working nominally during this past week's data collection period.

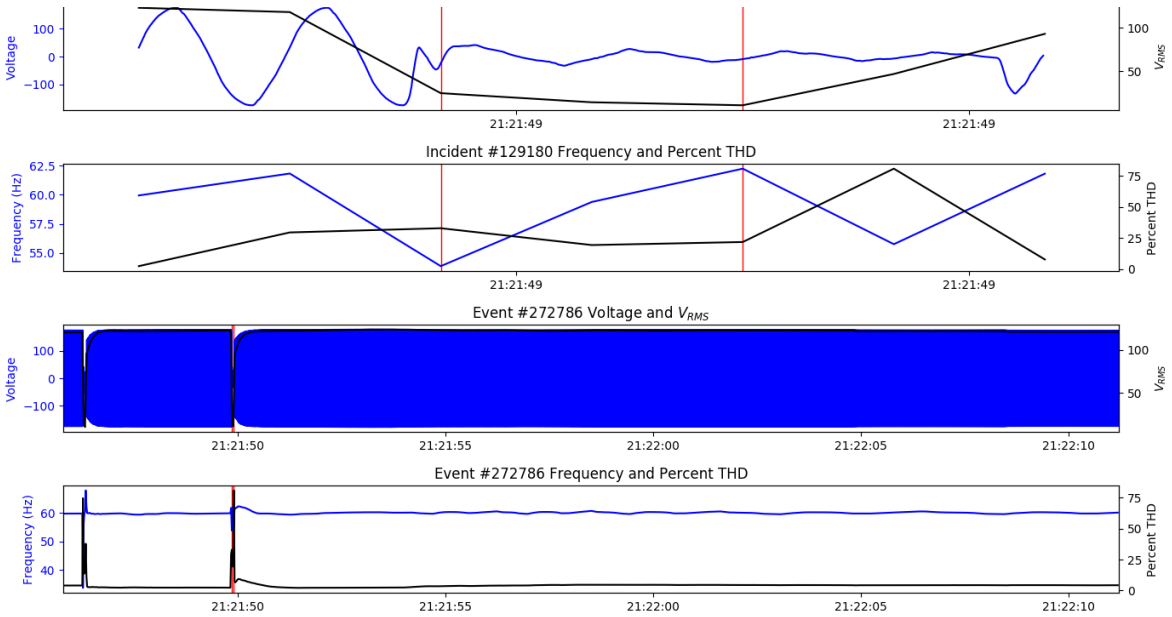
Voltage Sags, Swells, and Interruptions

Saturday's PQ event provided us with a bunch of IEEE 1159 defined Voltage incidents. Let's sample some of the most interesting.









A Deep Dive into Frequency Sags and Swells

Mauka's Frequency Variation Plugin (which classifies Frequency sags and swells) was overhauled late last week to improve its frequency classification ability.

We tried several approaches that did not pan out. We tried using the DFT directly, but this did not provide high enough resolution per cycle as 12kHz sample rate. We tried using auto-correlation and then calculating the frequency by calculating the distance between the peaks of the auto-correlation. Although this approach fairs better than the FFT, it still only provides a resolution of .3 Hz which is too large for the frequency deviations we are trying to identify. We settled on using a Sine wave curve fitting approach.

This approach uses a linear least squares (LLS) optimization function to fit a "best guess" sine wave on top of the collected power waveform segmented per cycle.

This approach was previously used in Mauka's Frequency plugin and was implemented by a previous student. We identified and addressed several issues in the previous implementation.

- The best guesses for the Sine's amplitude, frequency, offset, and phase were static and hard set. This means that frequencies only a few 10's of a percent away from 60Hz would cause the LLS algorithm to fail to converge. Further, pretty much any

waveform that deviated from a standard 60 Hz 120V sine would cause the algorithm to fail to converge.

- The data was filtered and sub-sampled a little too aggressively. This minimized the resolution available to accurately calculate frequency.

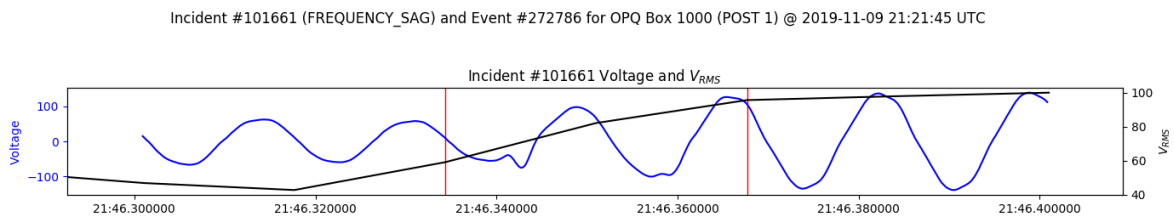
These flaws were addressed in the following ways.

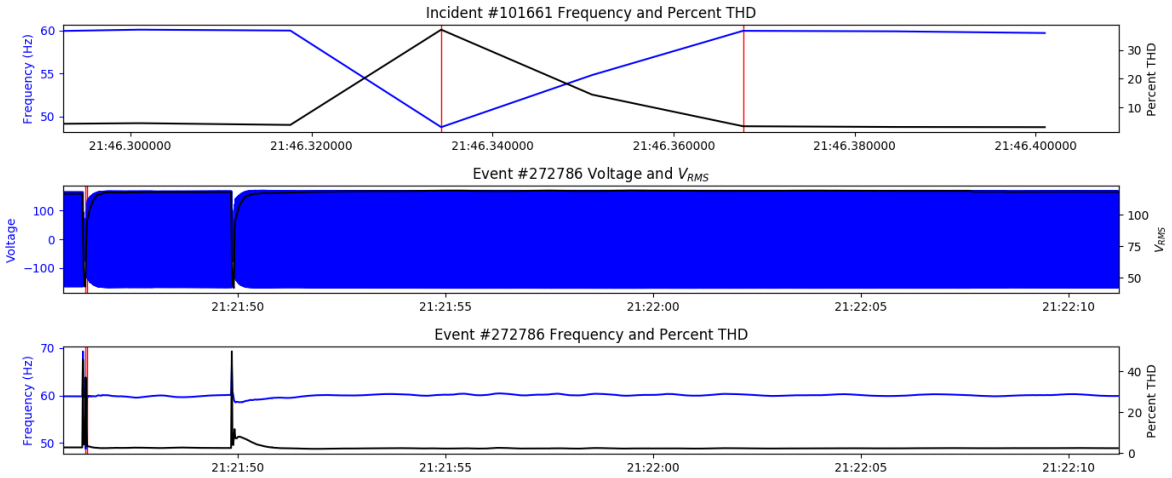
- The “best guess” parameters for the initial sine fitting are calculated from the data. The initial Frequency is estimated from the FFT which is “close enough” to the real frequency to use for an initial guess. The amplitude guess is calculated from the mean of the peak data for the cycle. The offset guess is calculated by taking the mean of the entire data set. The phase is not estimated, but likely could be if the data could be rephrased as a matrix problem.

- When LLS is ran, what is returned are the parameters used that best fitted the actual data. Since we’re fitting a curve per cycle, we use the previous cycle’s parameters to to feed into the next cycle’s curve fitting algorithm. This ensure that continuous data is always provided decent best guesses helping the curve fitting algorithm to converge quickly, and more importantly, accurately. One downside to this approach is that large instantaneous voltage sags or frequency fluctuations may fail to converge on occasion.

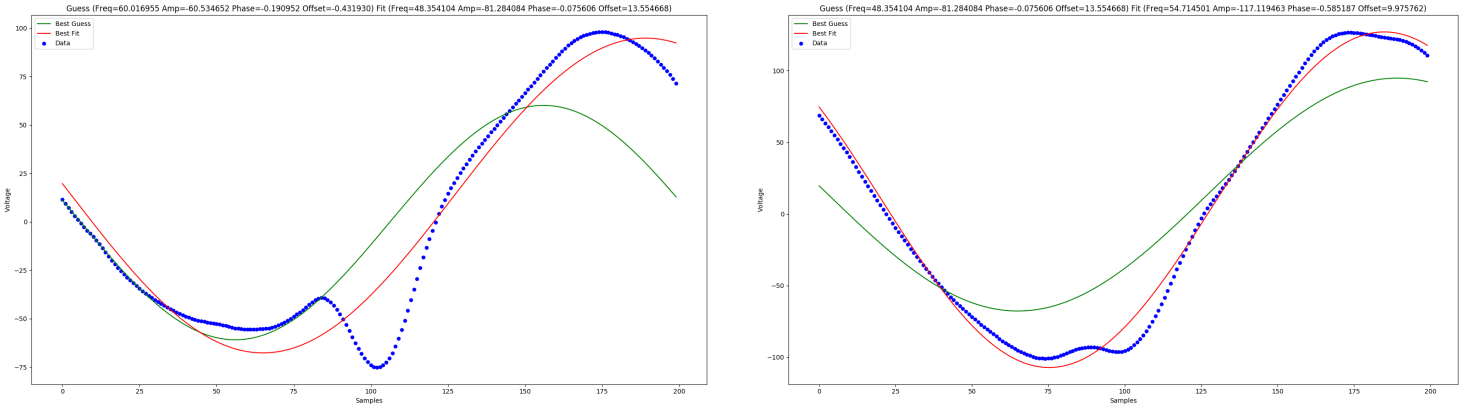
We *do* actually see lots of variations in frequencies on the UH microgrid (hence the large number of Frequency sags and swells). We’ve modified the thresholds of frequency sags and swells to only identify sags and swells that are +/- .25 Hz from nominal and that are also longer than 2 cycles in duration. We will be able to see in next week’s report if this helps reduce the number of Frequency incidents to ones that are more severe/actionable.

For instance, here are some of the largest Frequency Incidents that we classified during Saturday’s power signal event.

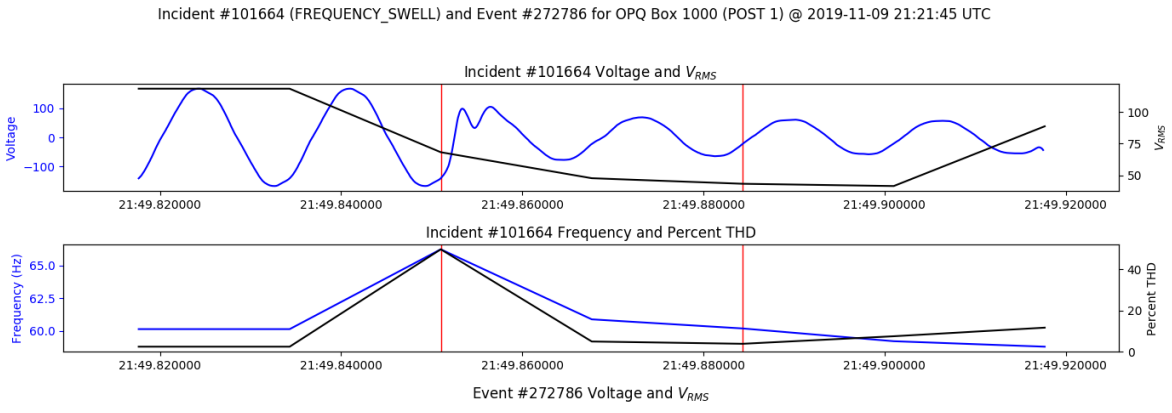


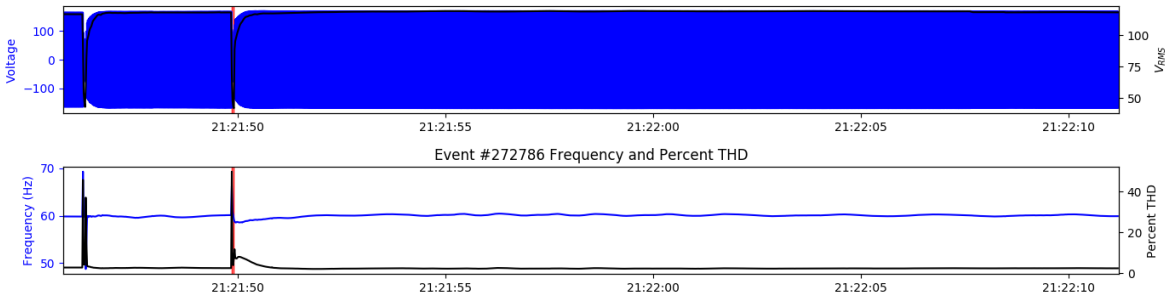


Here, we can see a large Frequency sag that was identified during the first part of the power disturbance.



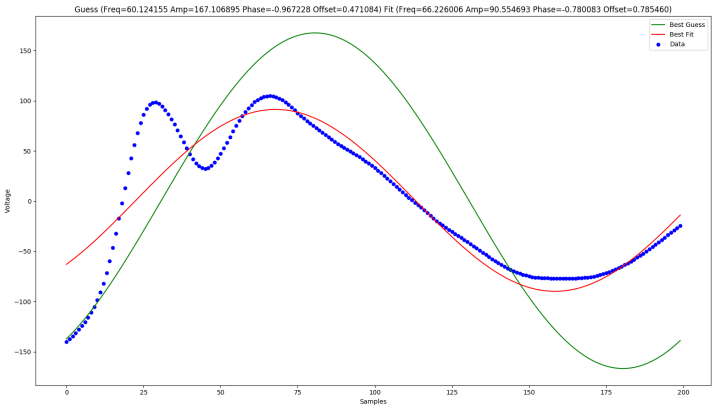
How well does the new FFT algorithm fit the data for this Incident sag? The above figures display the result of Mauka's frequency curve fitting algorithm. The blue points represent the actual data. The green series represents the initial best guess for a curve fit, and the red series represents the best fit using LLS regression.

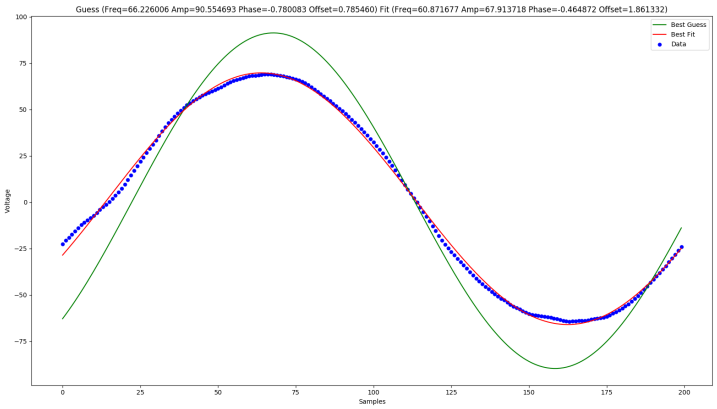




Here, we can see a large Frequency swell that was identified during the second part of the power disturbance.

So how well does the Frequency fit? It's generally pretty good considering the amount of noise in the signal. The large transient in the first Incident cycle does add some error to the Frequency. If anything, the frequency is under-estimated for the first cycle and should be slightly higher than the reported value. Here are the fits for the two cycles of the swell.



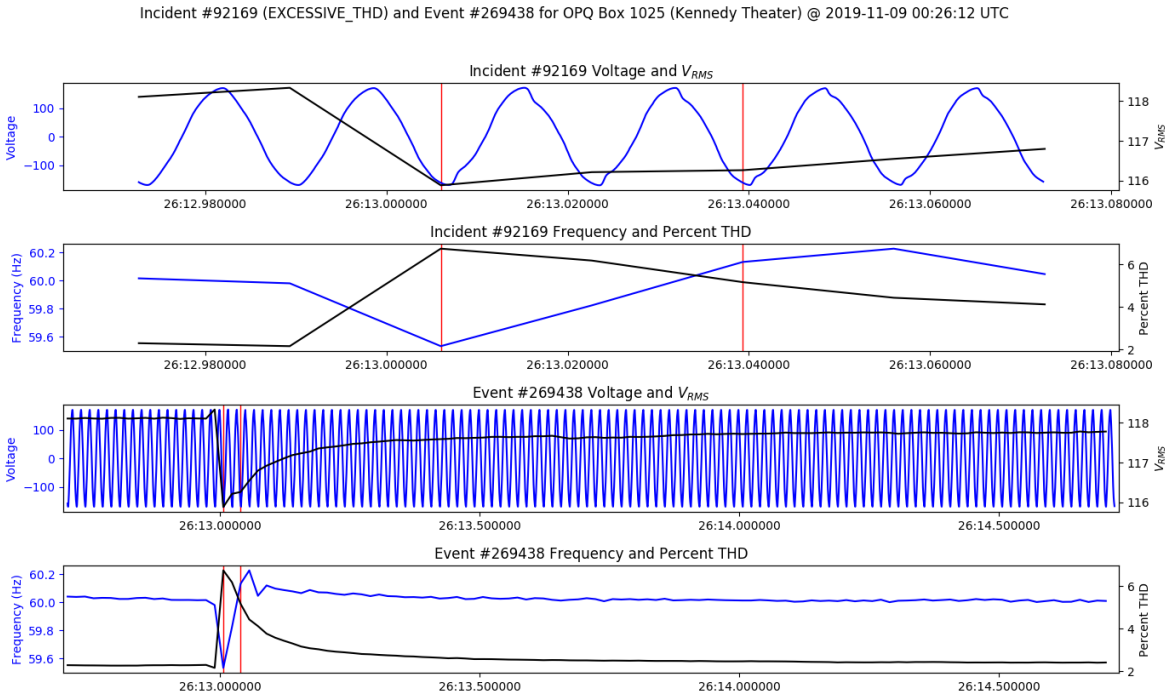


Mauka allows us to calculate Frequency at a higher fidelity than what is calculated on the Boxes. This is due to having more computing resources on Mauka than we have on the Boxes. Since Mauka only calculates Frequency from Events, the processing resources are saved for waveform data that may have something in it instead of computing the Frequency of mostly nominal data.

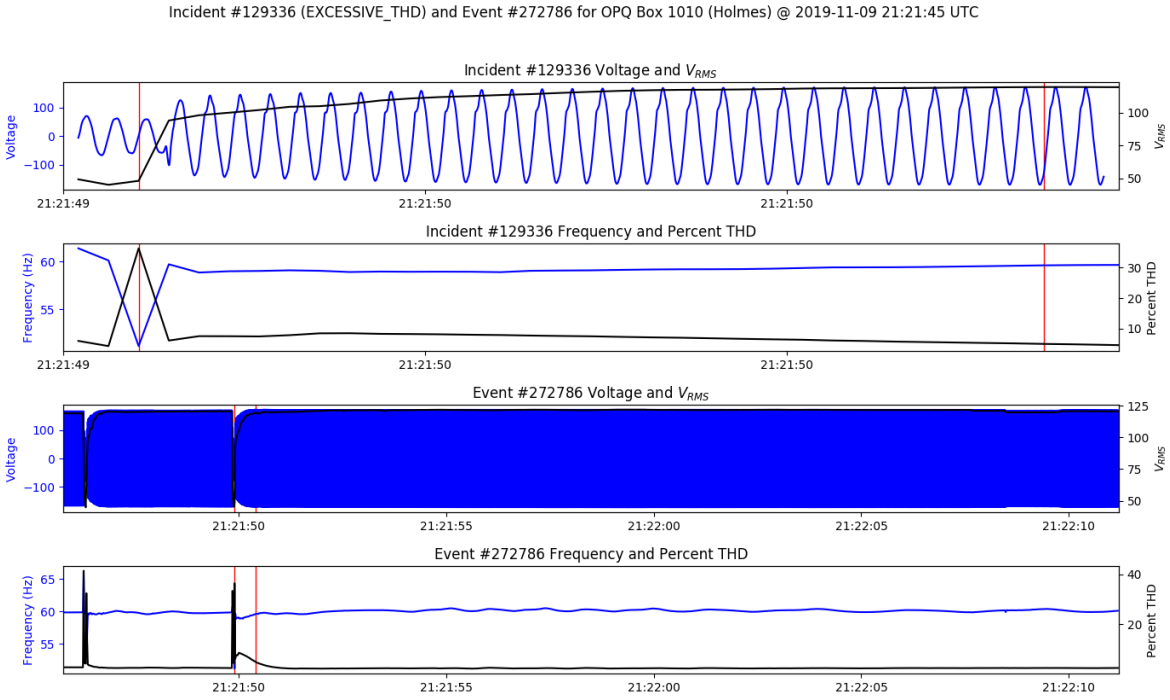
THD Incident Details

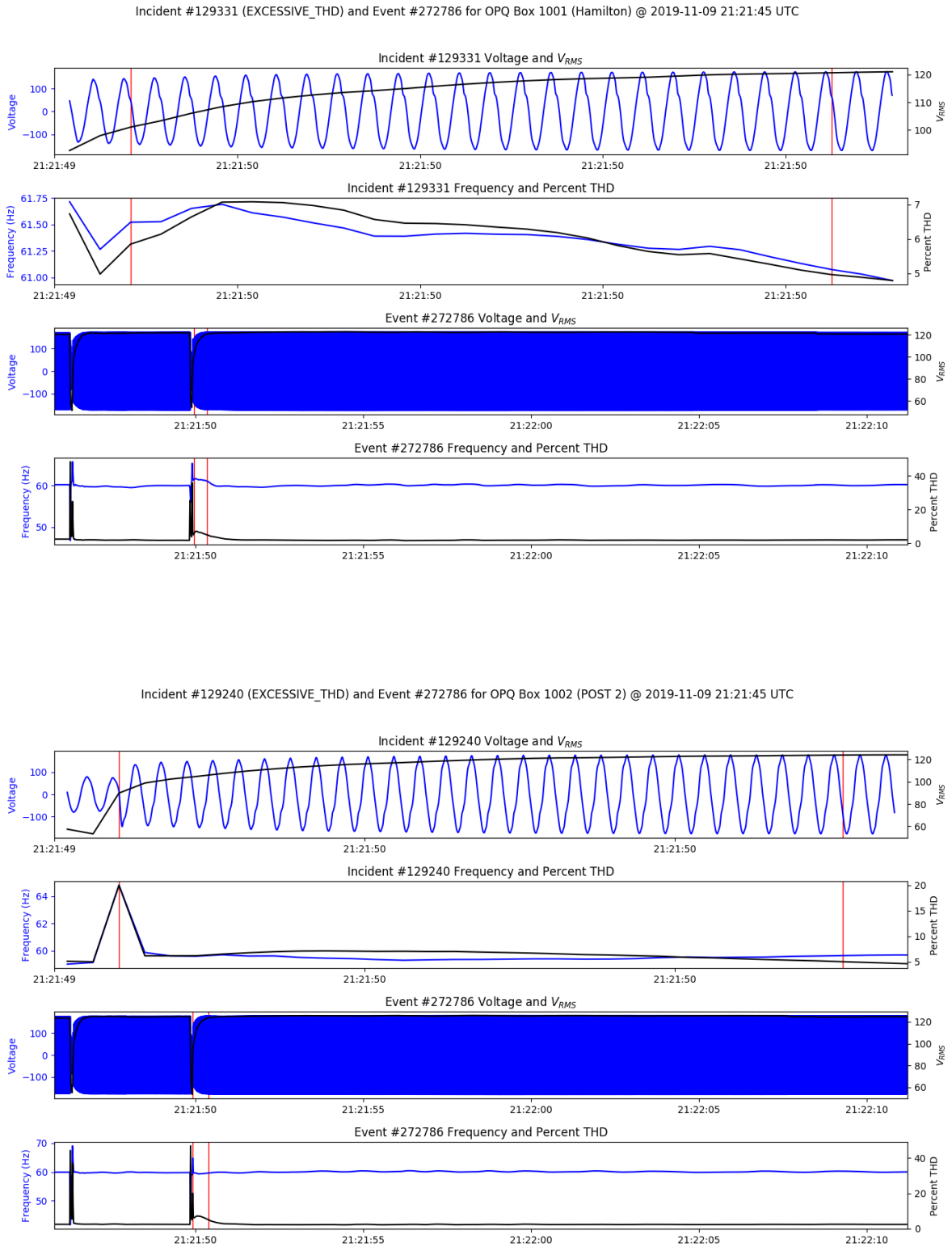
THD classification was updated in the previous week to make use of the same THD algorithm that is used for OPQ Boxes with one significant difference. The THD

calculations in Mauka calculate THD per cycle while the THD calculations on the Box calculate THD per 6 cycles.



The following THD incidents are all sampled from Saturday's PQ event.





The above figure is a new figure that was created this past week for displaying detailed information for Mauka classified Incidents. The first two rows show the details of the classified Incident while the second two rows display the data for the Event that the Incident was generated from. Calibrated voltage, Vrms, Frequency, and THD are all

calculated from the original waveform using high fidelity per-cycle algorithms. The bounds of the classified Incident are provided by the vertical red lines.

Addendum on Incident Classification

When this report was originally written (Monday Nov 11), Mauka had failed to classify many Incidents on Saturday's PQ event. This was caused by several reasons.

- In certain circumstances, data from events failed to be converted into feature streams in the MakaiEventPlugin. This could take place if the frequency values failed to be extracted due to the curve fitting algorithm not converging. This happens rarely in practice, but it did happen for two of the Boxes on Saturday's event. When this happens, the entire Event was discarded and none of the data was analyzed. This has been addressed by ensuring that if any of the feature extractions fail, the rest of the data still gets processed.
- A race condition was identified where if multiple incidents were classified near each other temporally, they would be assigned an incident id that was already assigned to another incident in another plugin. This new incident would then fail to be saved to the database due to a duplicate index error. Events such as those observed on Saturday have the capacity to produce many Incidents. Only a small subset of those Incidents were actually saved due to this race condition. How many Incidents have we missed in the past due to this race condition? This was addressed by adding a new Incident id provider to Mauka which provides atomic thread-safe access to the next available Incident id nullifying this race condition and ensuring that all identified Incidents get stored to the database.

Mauka's plugin architecture makes it possible to easily re-run past events through the analysis pipeline. All that is required is to insert a type safe Event Id message into Mauka's pub/sub communications channel using an external ZMQ client. Then, Mauka's MakaiEventPlugin receives the event id and processes the data as if it were received from Makai itself. No changes are required to accomplish this on a running Mauka instance. This was done for Saturday's PQ event to allow Mauka to re-classify Incidents that it missed the first time.

Now that the issues with Incident classification are nearly ironed out, we intend to focus most of our development energy on implementing the final bits of Mauka, the Phenomena.

Events Summary

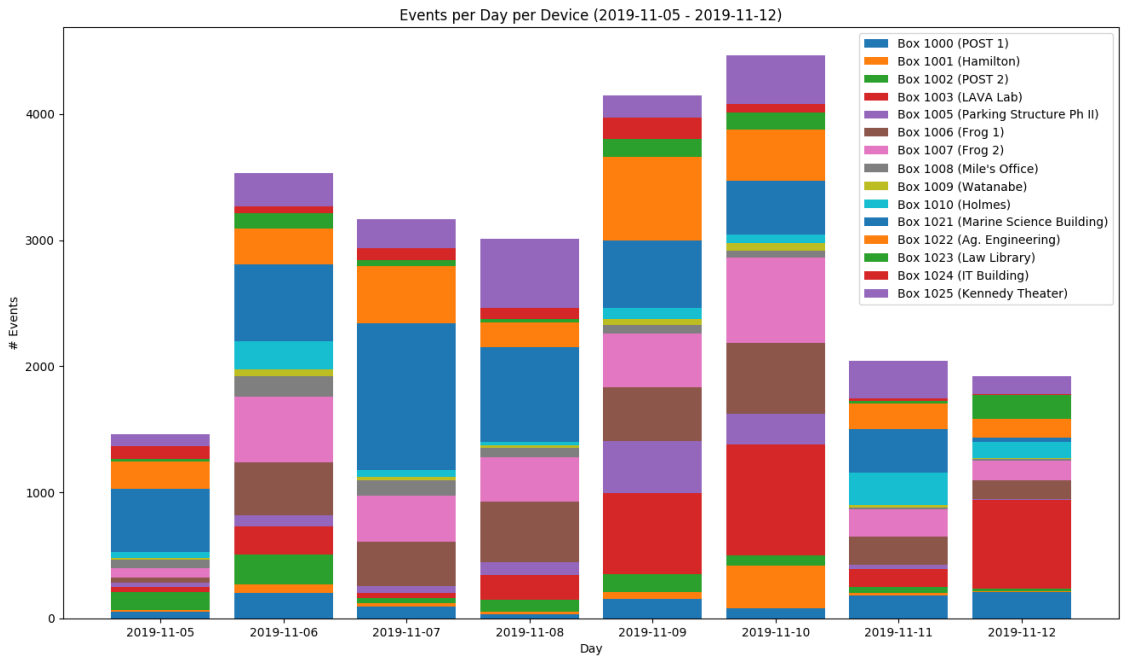
Events are ranges of PQ data that may (or may not) have PQ issues within them. Events are generated by two methods. The first method uses Voltage, Frequency, and THD thresholds as defined by IEEE. The second method uses the Napali Trigger which was developed by Sergey as part of his dissertation research. The Napali trigger uses statistical methods to determine when Boxes may contain PQ issues. This summary of Events examines the number of times that Boxes were triggered due to possible PQ issues.

There were a total of 23750 Events processed.

The following figure shows Events per Box per day.

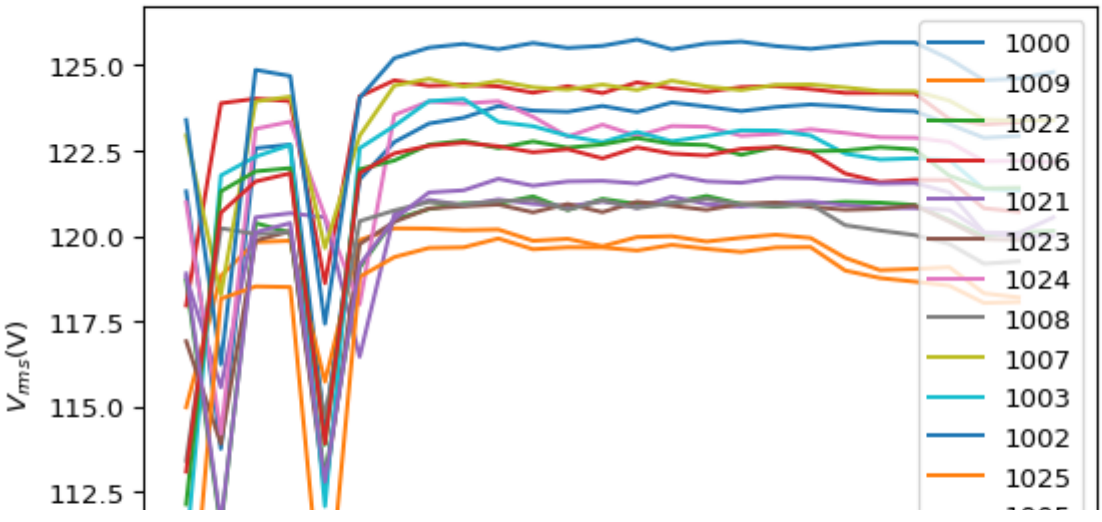
OPQ Box	Location	Events Generated
1021	Marine Science Building	4361
1003	LAVA Lab	2870
1007	Frog 2	2790
1006	Frog 1	2649
1022	Ag. Engineering	2579
1025	Kennedy Theater	2147
1000	POST 1	1012
1005	Parking Structure Ph II	982
1010	Holmes	898
1002	POST 2	795
1023	Law Library	704
1024	IT Building	589
1008	Mile's Office	564
1001	Hamilton	556
1009	Watanabe	254
Total		**23750**

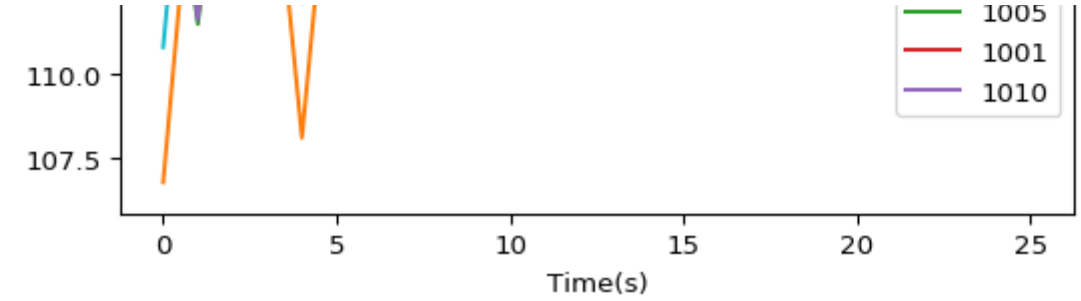
The following figure shows Events per Box per day.

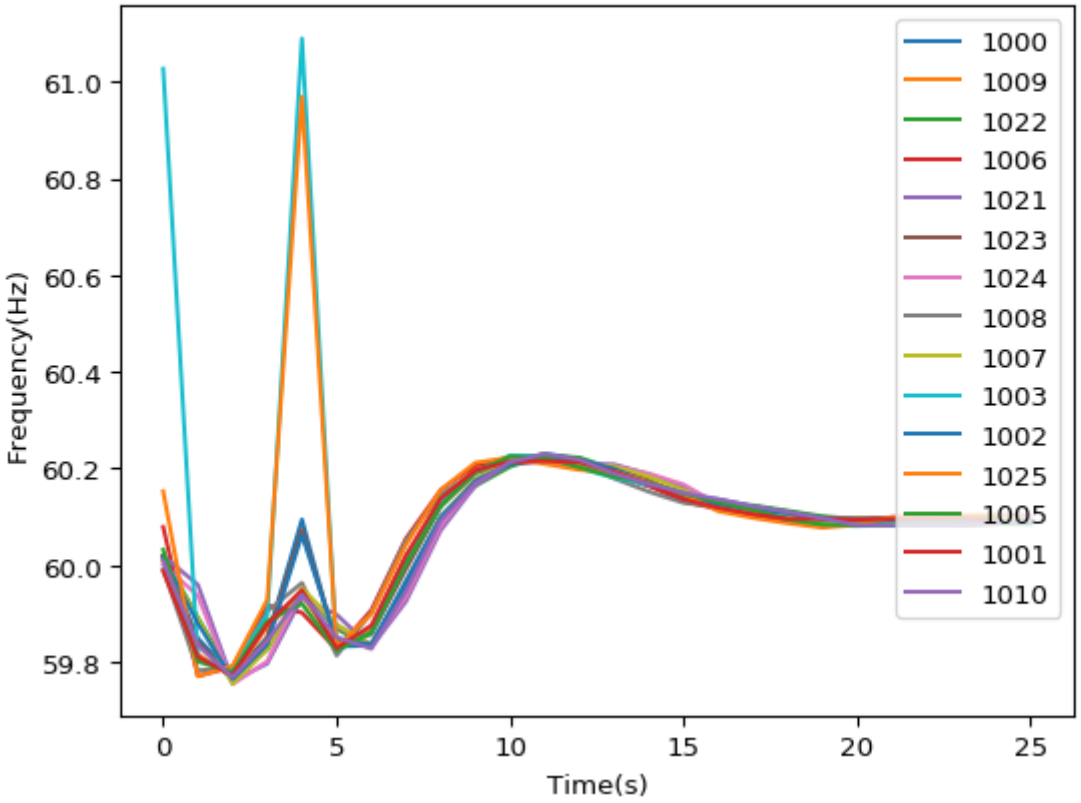


Makai Events.

The star event of this week was event 272786. This event was initiated by two voltage sags, followed by a large frequency instability:





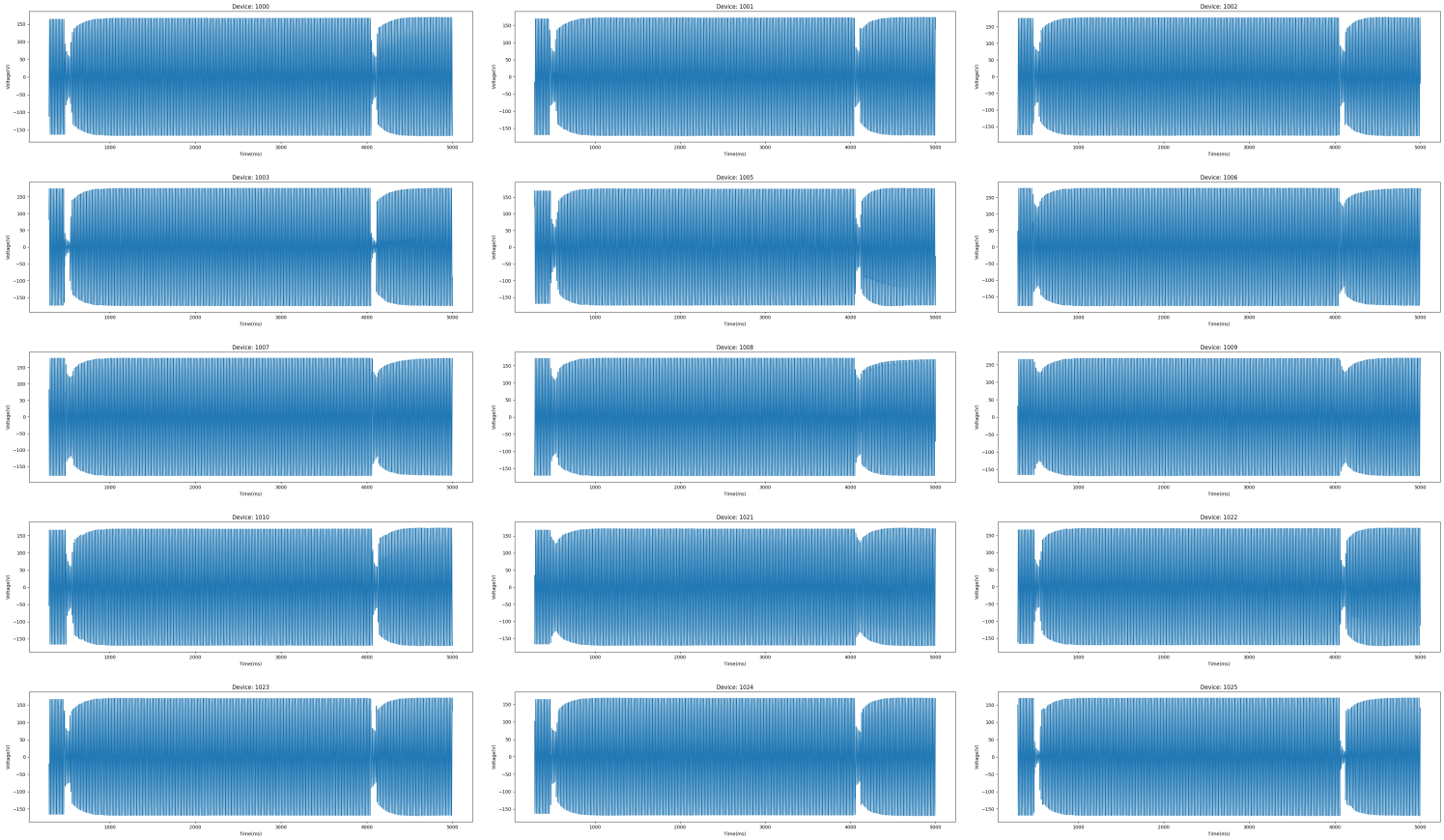


Every device on UH campus observed this event, which leads us to believe that the disturbance epicenter occurred near the main UH feedline. Heco has no public reports consistent with our observation, which leads us to believe that the anomaly was not caused by a power outage.

Particularly interesting is the frequency measurements as reported by the OPQ devices. Algorithms on the OPQ devices are selected specifically to minimize the CPU utilization. After all, the CPU powering the OPQ box is quite slow, and is not able to keep up with the data rate using sophisticated frequency extraction, such as curve fitting. Instead, fundamental frequency is extracted using a bank of low pass filters followed by zero

crossing extrapolation. Nonetheless, OPQ devices were able to produce reasonable frequency measurements, even during severe waveform distortion.

Here are the waveforms observed for each device:



Conclusion

In conclusion, this week showed a relatively nominal power reading across the board. Improvements in the THD and Frequency plugins have allowed us to get better looks of some of the classified Incidents on the grid. We also realized that some of the current plugins may still need some tuning as we expected to see more Voltage and THD Incidents than we did.

Unlisted

Data Science

Micro-report on the UHM micro-grid: 10/29 to 11/05

Open Power Quality
Nov 6, 2019 · Unlisted

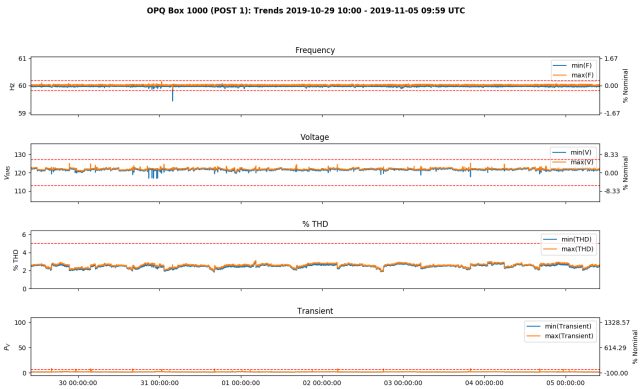
General Summary

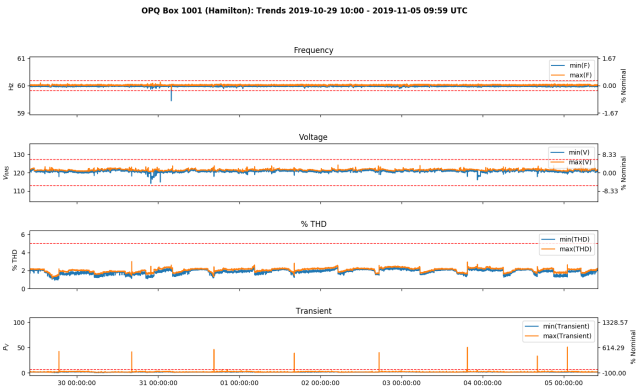
University of Hawaii at Manoa micro-grid report on data from 10–29–2019 10:00 to 11–05–2019 10:00 UTC.

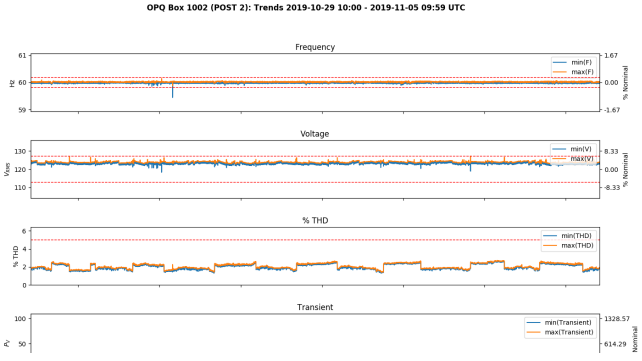
Trends Summary

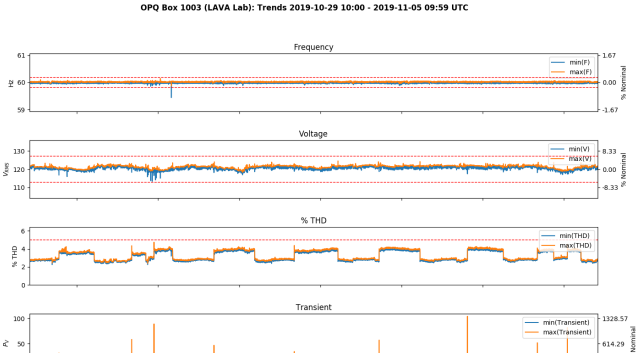
Weekly trends measure the minimum, average, and maximum values for Voltage, Frequency, THD, and transients for each OPQ Box at a rate of 1 Hz.

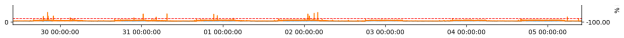
The following figures show Trends for each Box between 2019–10–29 10:00:00 and 2019–11–05 10:00:00.

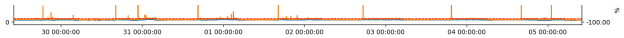




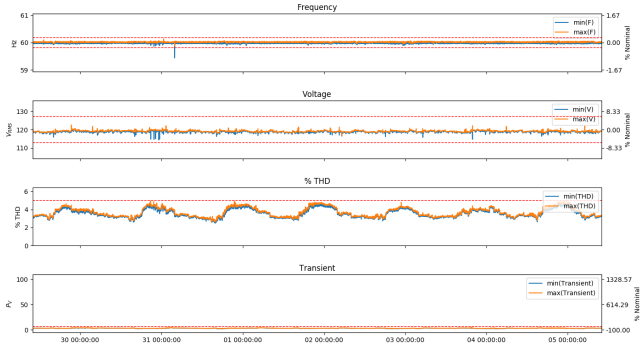




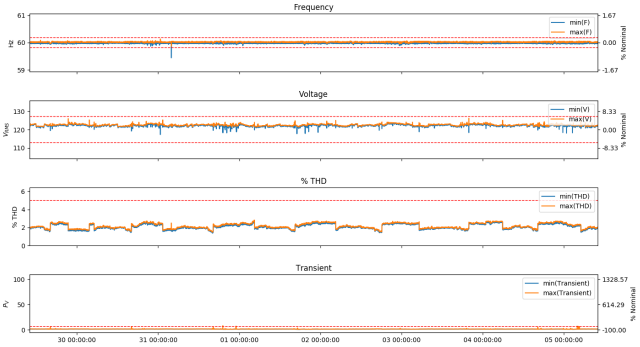




OPQ Box 1005 (Parking Structure Ph II): Trends 2019-10-29 10:00 - 2019-11-05 09:59 UTC

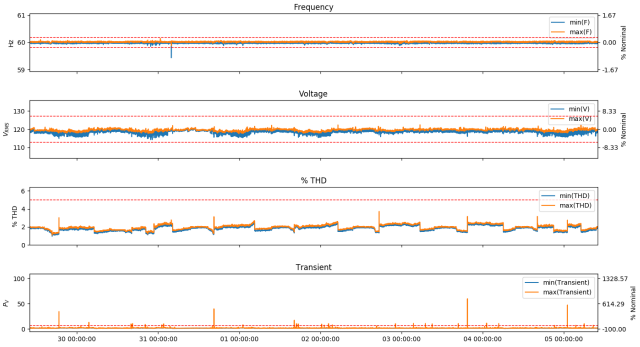


OPQ Box 1006 (Frog 1): Trends 2019-10-29 10:00 - 2019-11-05 09:59 UTC

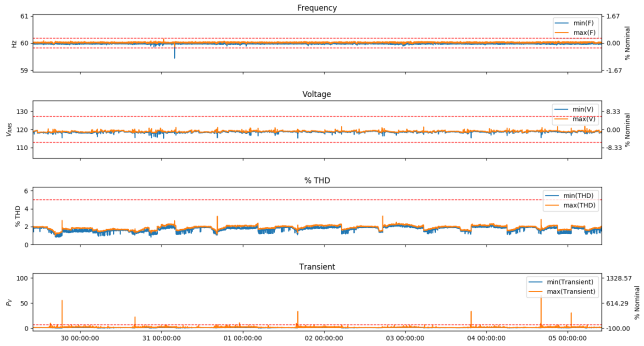


OPQ Box 1007 (Frog 2): Trends 2019-10-29 10:00 - 2019-11-05 09:59 UTC

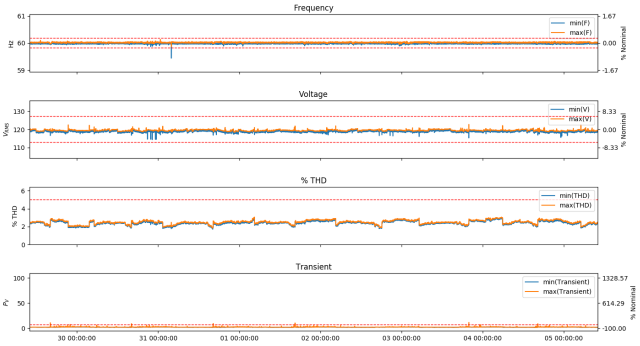
OPQ Box 1008 (Mile's Office): Trends 2019-10-29 10:00 - 2019-11-05 09:59 UTC



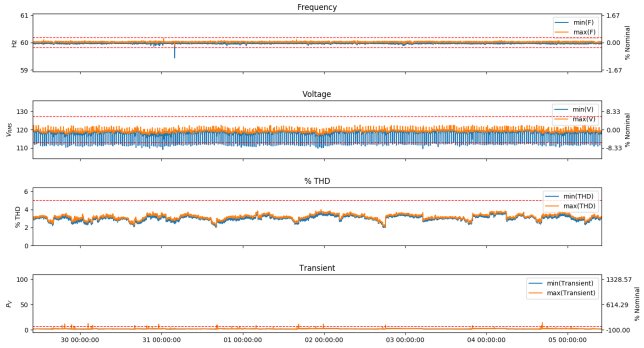
OPQ Box 1009 (Watanabe): Trends 2019-10-29 10:00 - 2019-11-05 09:59 UTC



OPQ Box 1010 (Holmes): Trends 2019-10-29 10:00 - 2019-11-05 09:59 UTC

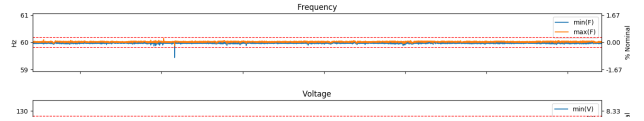


OPQ Box 1021 (Marine Science Building): Trends 2019-10-29 10:00 - 2019-11-05 09:59 UTC

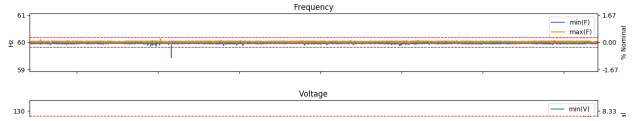


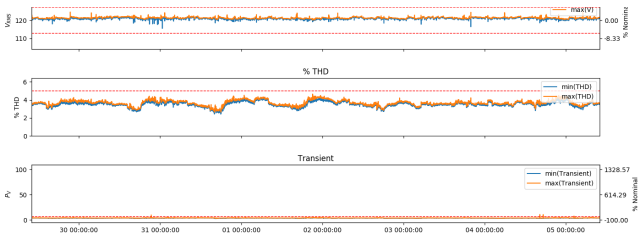
OPQ Box 1022 (Ag. Engineering): Trends 2019-10-29 10:00 - 2019-11-05 09:59 UTC

OPQ Box 1023 (Law Library): Trends 2019-10-29 10:00 - 2019-11-05 09:59 UTC

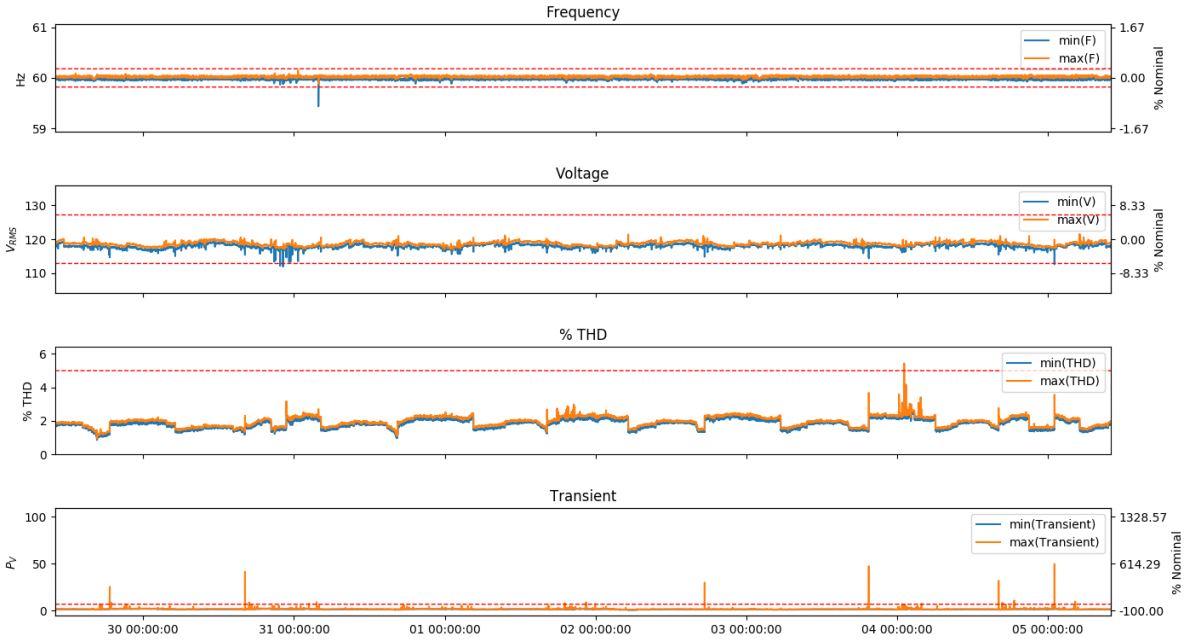


OPQ Box 1024 (IT Building): Trends 2019-10-29 10:00 - 2019-11-05 09:59 UTC





OPQ Box 1025 (Kennedy Theater): Trends 2019-10-29 10:00 - 2019-11-05 09:59 UTC



In terms of summarizing Trends, this past week has been the most stable we've seen the UH micro-grid since the start of these reports. The main points of interest are as follows:

- Regular Voltage sags in MSB
- A single Frequency sag that was observed across all Boxes
- A large spike of THD at Kennedy Theater

Compared to the previous week's report, the grid metrics are much closer to nominal. Specifically, we did not encounter any large Voltage sags or swells. Further, the high amount of THD displayed at Kennedy Theater in last week's report has all but disappeared in this week's report.

Phenomena

Phenomena are an abstract concept for Anthony's PhD dissertation that provide actionable insights and context on top of classified Incidents. In terms of PQ monitoring, Phenomena provide added context on top of PQ Incidents.

Phenomena include *Annotation Phenomena* which provide context for classified PQ Incidents. These include things such as "Campus Power Outage", "Thunderstorm on a particular date", or "HVAC unit cycling".

Cyclic Phenomena identify repetitive behavior relating to PQ on the grid.

Predictive Phenomena use forecasting models to predict future Incidents from past Incidents.

Locality Phenomena utilize a model of the grid topology in an attempt to localize the source of PQ Incidents.

Finally, Phenomena are used to adaptively tune the underlying DSN in an attempt to increase signal-to-noise allowing DSN resources to be focused on identifying actionable PQ issues while discarding noise.

This week's report does not contain any identified Phenomena. This is due to a distinct lack of Phenomena algorithms in the current code base. This is being rapidly addressed.

If Phenomena were properly implemented, we would have expected to see the following Phenomena for this week's report:

- Similarity Phenomena that identified that the grid-wide Frequency sag was similar (and observed) across all Boxes.
- Cyclic Phenomena that identifies the regular Voltage sags in MSB (and would possibly tune the Voltage algorithms to pick these up as they are currently "under threshold" for IEEE 1159 defined Voltage sags).
- Annotation Phenomena that would "label" the regular Voltage sags in MSB.
- Predictive Phenomena that would predict future Voltage sags in MSB. This one should be low handing fruit since the Voltage sags in MSB are so regular.

The past few weeks (including the current week) has been focused on improving Mauka's Incident detection algorithms.

Moving forward, Anthony's focus is shifting to implementing Phenomena in Mauka. Cyclic Phenomena are being designed utilizing the FFT to determine the Frequency of PQ signals-of-interest.

Annotations are also currently being designed. At the moment, the data model is being completed. An interface should be designed in View for adding and editing Annotations, but in the short-term, we will be adding and editing Annotations through a command line interface.

Once Cyclic and Annotation Phenomena are implemented, Anthony will switch his focus to similarity, predictive, and locality Phenomena. At the current rate, Anthony hopes to implement one to two Phenomena per week.

Incidents

Incidents are classified PQ issues that were found in the previously provided Events. Incidents are classified by OPQ Mauka according to various PQ standards. OPQ Mauka provides classifications for Outages, Voltage, Frequency, and THD related issues.

A total of 7985 Incidents were processed.

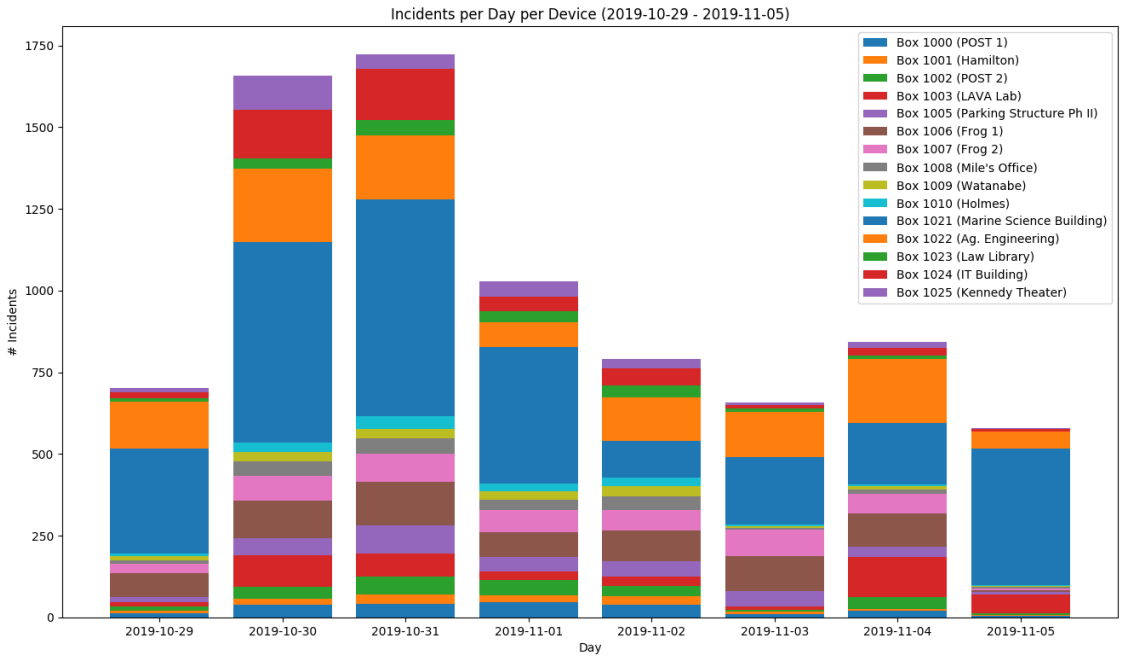
A breakdown of Incidents per Box is provided in the following table.

OPQ Box	Location	Incidents	F Sag	F Swell	Outage
1021	Marine Science Building	2938	1137	1801	0
1022	Ag. Engineering	1154	503	651	0
1006	Frog 1	704	374	330	0
1024	IT Building	463	256	207	0
1007	Frog 2	461	280	172	9
1003	LAVA Lab	430	230	199	1
1005	Parking Structure Ph II	325	183	142	0
1025	Kennedy Theater	268	169	99	0
1002	POST 2	231	110	121	0
1000	POST 1	218	130	87	1
1008	Mile's Office	199	120	79	0
1023	Law Library	178	120	58	0
1010	Holmes	143	94	49	0

1010	Holmes	145	94	49	0
1009	Watanabe	140	98	42	0
1001	Hamilton	112	81	31	0
Total		**7964**	**3885**	**4068**	**11**

Incidents 2019-10-29 to 2019-11-05

The following figure shows Incidents per Box per day.

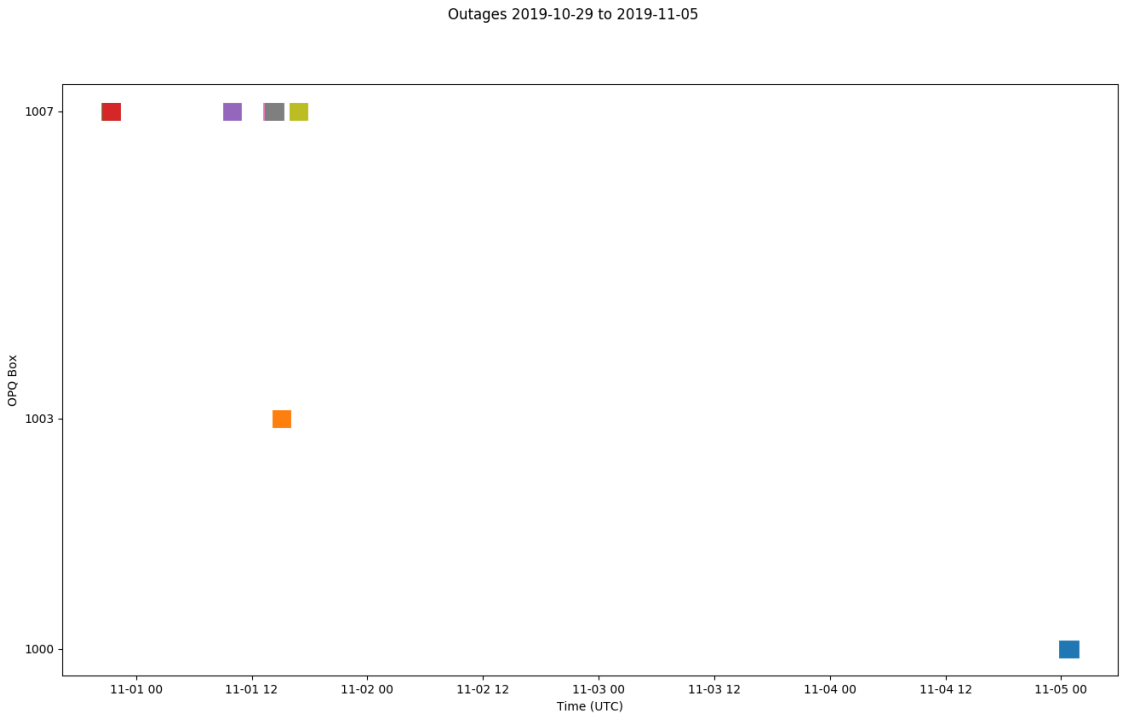


Outage Incident Details

We continue to identify outages from OPQ Boxes using the approach of looking at gaps in measurements. The following table shows observed Outage Incidents

OPQ Box	Location	Incident #	Outage Start	Outage End	Duration (s)
1000	POST 1	87880	11-05 00:39:51	11-05 00:53:52	840.794
1007	Frog 2	84089	10-31 21:23:47	10-31 21:29:48	360.95
1003	LAVA Lab	84948	11-01 15:02:12	11-01 15:08:12	360.366
1007	Frog 2	84852	11-01 09:56:09	11-01 10:02:09	360.252
1007	Frog 2	84928	11-01 14:17:11	11-01 14:23:11	360.1
1007	Frog 2	85431	11-02 00:32:16	11-02 00:36:16	240.272
1007	Frog 2	84926	11-01 14:04:11	11-01 14:08:11	240.153
1007	Frog 2	85418	11-02 00:12:16	11-02 00:15:16	180.384
1007	Frog 2	84916	11-01 12:18:11	11-01 12:20:11	120.658
1007	Frog 2	85001	11-01 16:49:13	11-01 16:51:13	120.531
1007	Frog 2	84078	10-31 21:18:47	10-31 21:20:47	120.142

Let's look at these Outage Incidents vs Time.



Of note, we can see that Frog 2 experienced a large amount of outages early in the report period. It may be worth reaching out to the building coordinator to determine if there were any power issues in Frog 2.

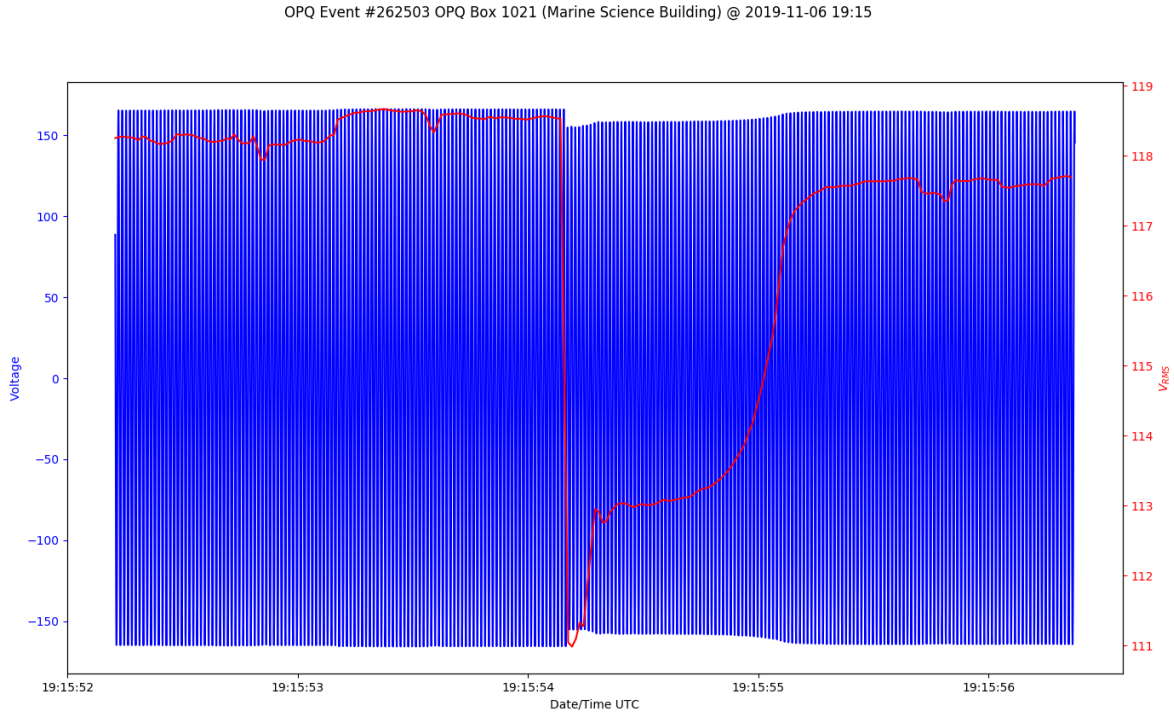
We see a single outage in the Lava lab which we can not explain.

Finally, we see a 15 minute outage from the Box in POST that was a result of the Box being unplugged and plugged back in during testing and development.

Where are the Voltage Incidents?

After revamping the IEEE 1159 Voltage plugin, we were hoping to see more Voltage Incidents this past week.

Voltage Incidents are currently strictly classified using IEEE 1159 parameters. In general, only MSB observed Voltages sags this week. Let's look at those in a bit more detail. As an example, let's look at Event #262503 which displays one of these Voltage sags nicely.



The first part of the sag drops to about 111V (or .925 pu) for about ~5 cycles.

The second part of the sag tends to drop to about ~113V (or ~.94 pu) for a duration of ~1 second.

Interestingly, IEEE 1159 only classifies sags between 0.1 and 0.9 pu. If the sags were slightly larger (more saggy is the scientific term I believe), then these would be classified as IEEE 1159 Momentary Sags, however the sags are just under the threshold for Incident classification.

+/- 6% was chosen as a threshold for plotting Voltage sags and swells in trends as this is the *general* classification for voltage sags and swells which is why we see MSB falling outside of threshold, but not within threshold for IEEE 1159. This is still useful however!

OPQ uses two types of triggering to find signals-of-interest. The first is a threshold trigger that was implemented as part of Anthony's PhD research. This trigger triggers on Voltage, Frequency, and THD minimum and maximum thresholds. This trigger can identify signals from individual Boxes. The second trigger, Napali, was implemented as part of Sergey's PhD research and triggers ensembles of Boxes. Why is this distinction important?

Mauka is able to identify Incidents for individual Boxes when signals originated from one location rather than grid wide. Because of this, Anthony's trigger did (and continues) to create events from the Voltage sags encountered from MSB. Even though these Voltage sags are not classified as IEEE 1159 incidents, the events lead to the creation of Frequency incidents due to the instability of the waveform. These Incidents would not have been originally classified using the Napali Trigger because they originated from a single source rather than grid wide.

Although each trigger provides different research questions and results, working together they allow us to see individual and grid wide PQ signals of interest. With only one or the other, we would only get half of the story.

Where are the THD Incidents?

There was at least one THD swell at Kennedy Theater. Where is the classified Incident? We are focusing on updating and testing the THD classification this week. We will revisit this discussion in next week's report.

Events Summary

Events are ranges of PQ data that may (or may not) have PQ issues within them. Events are generated by two methods. The first method uses Voltage, Frequency, and THD thresholds as defined by IEEE. The second method uses the Napali Trigger which was developed by Sergey as part of his dissertation research. The Napali trigger uses statistical methods to determine when Boxes may contain PQ issues. This summary of Events examines the number of times that Boxes were triggered due to possible PQ issues.

There were a total of 22553 Events processed.

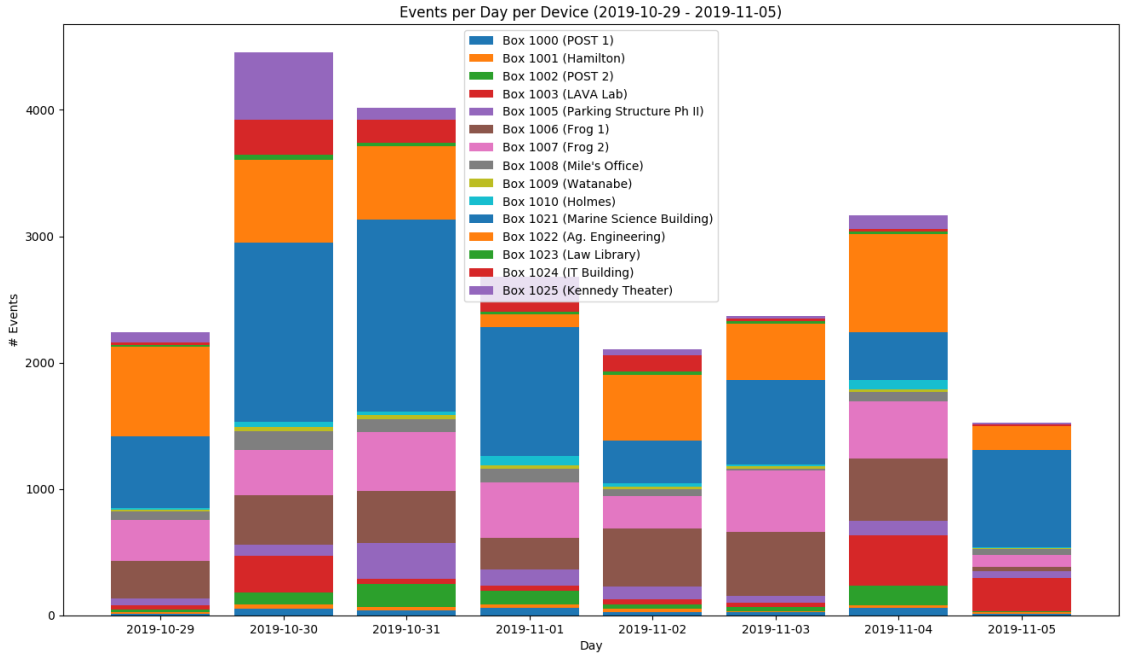
The following table shows Events generated per Box.

OPQ Box	Location	Events Generated
1021	Marine Science Building	6669
1022	Ag. Engineering	3960
1007	Frog 2	2876

1006	Frog 1	2842
1003	LAVA Lab	1138
1025	Kennedy Theater	1086
1005	Parking Structure Ph II	878
1024	IT Building	744
1002	POST 2	638
1008	Mile's Office	609
1010	Holmes	282
1000	POST 1	281
1001	Hamilton	187
1023	Law Library	184
1009	Watanabe	179
Total		**22553**

Events 2019-10-29 to 2019-11-05

The following figure shows Events per Box per day.

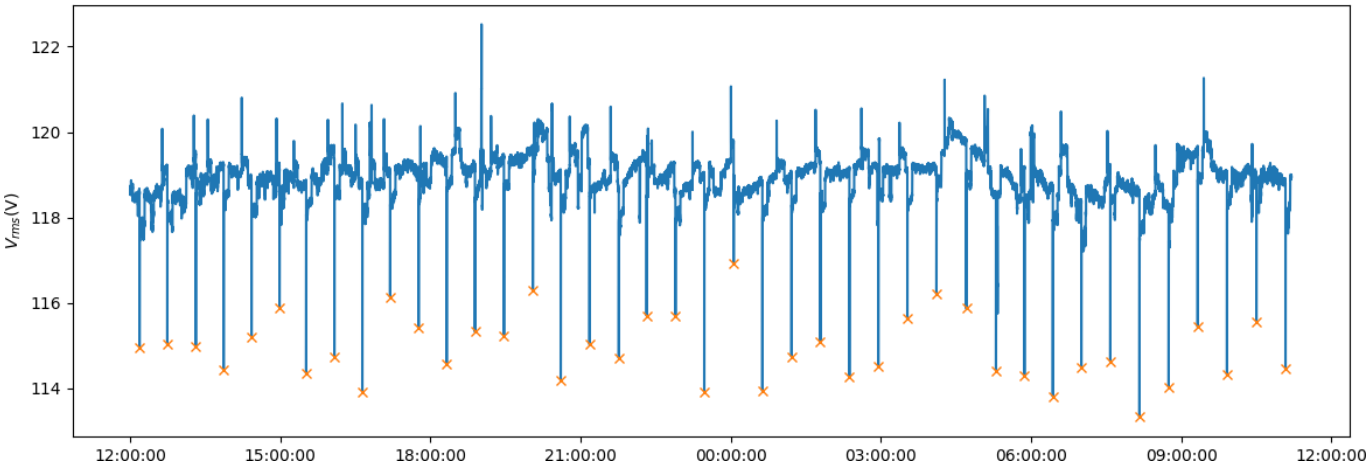


Emerging Peculiarities in the UH power Grid:

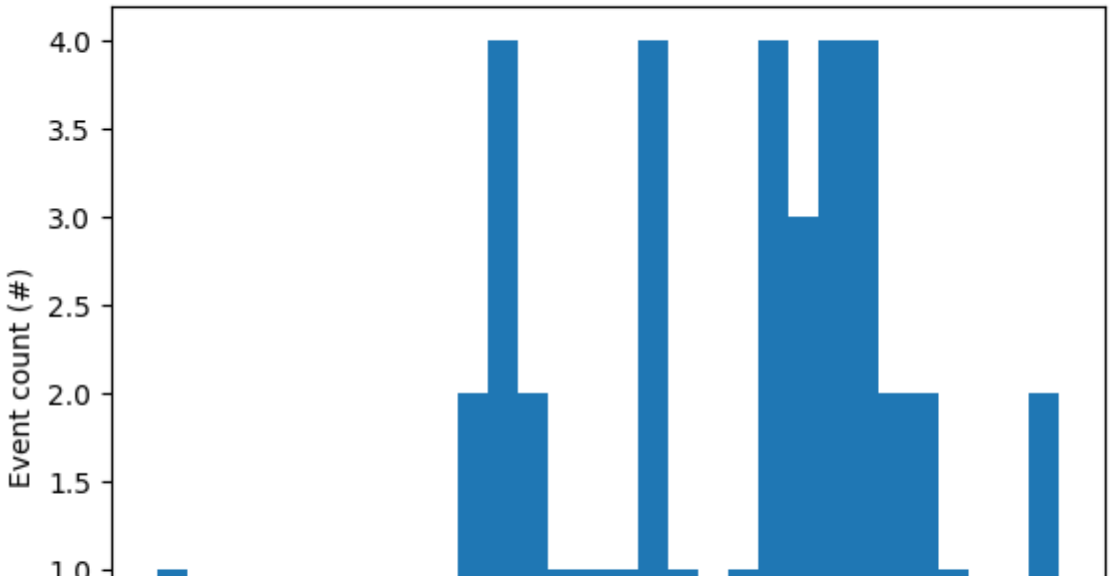
There are a few peculiar and systematic disturbances observed by the OPQ network across the UH power grid. Majority of these disturbances are localized to a specific building and not the grid as a whole. These events are largely ignored by Napali since they originate at a single location and are not observed by neighboring devices. Nonetheless, in 2000 years power quality archeologists may find these events useful.

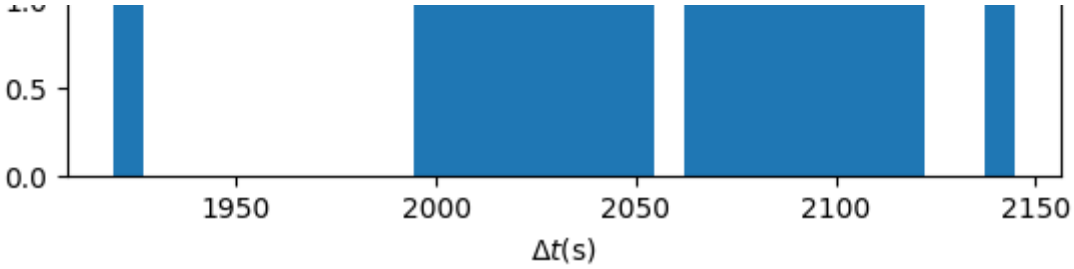
Device 1021 (Marine Science Building)

This device exhibits a periodic voltage drop which is not temporally correlated to any other device on campus.



These voltage sags are very regularly spaced as shown at the histogram depicting the time difference between them:

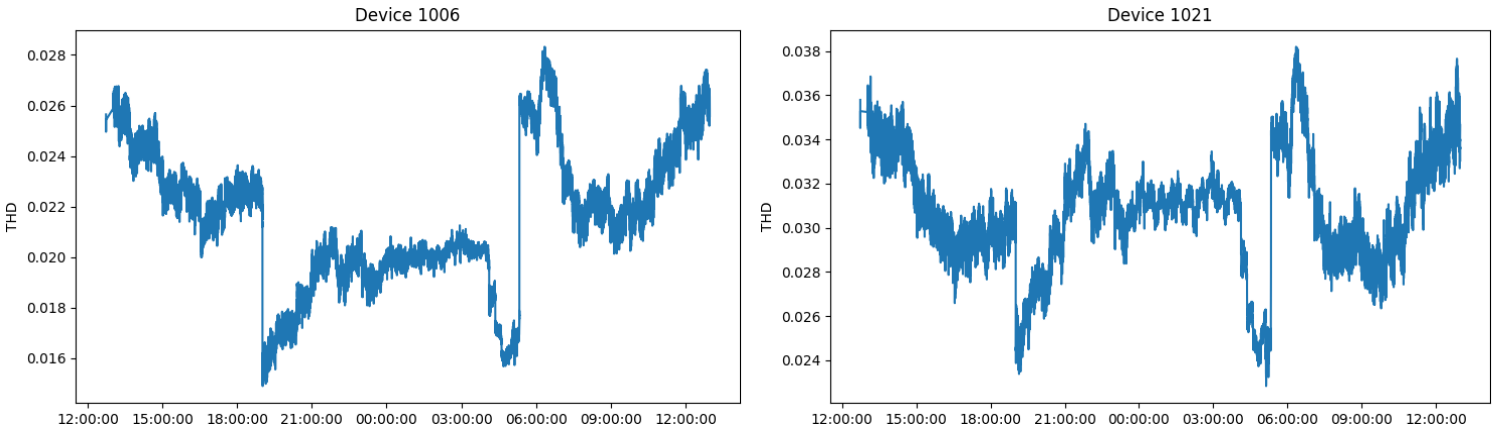




It seems something at the Marine Science Building is programmed to turn on every ~2000s, and this something is quite stout in its power draw. To our untrained eyes this seems like an AC unit. Once we get some free bandwidth, we will deploy a temperature logger in the building, in order to correlate these sags with temperature changes.

THD correlation:

Before we can talk about the next two devices, we must first lay out some background regarding total harmonic distortion. Consider THD across two devices:



If we look at the difference in the THD between result is quite small. Besides the fact that THD at the Device 1021 location is 0.8% worse then that of location of Device 1006, the systematic variation in the plot below is insignificant. (Apart from an apparent correlation to the solar day, more on that later.)

To us such a small difference across devices shows that the majority of THD is originating from the outside of the building the device is located in, and as far as the THD is concerned the building is “healthy”.

Device 1003 (Keller Hall):

Now keeping in mind the THD correlation described above, consider the THD observed by device 1003 located in Keller Hall:

Just looking at the trendline, it is clear that it does not correlate well with the rest of the devices. Now lets look at the difference between this device and device 1021:

It is unclear why device 1003 is observing such strange behavior. At one point Keller Hall was the center for the IT infrastructure of the University. Perhaps some reactive power compensation hardware is left over from days yore when the UH internet backbone terminated there. We will examine the waveform at Keller Hall more closely, but for the moment, device 1003 data remains a mystery.

Device 1005 (Parking Structure):

Similar to previous cases, lets examine the THD reported by this device:

Since we have been comparing all of our device against device 1021, lets once again subtract the THD reading between 1021 and 1005:

Now this is quite interesting! Something is contributing over 1% THD over our 1021 baseline. This something is likely the 1MW solar installation located at the roof of the parking structure:

Solar Installation on the roof of the parking structure.

Just for fun let's compare the projected production numbers for a ground based solar array against the low pass filtered THD difference:

Interestingly enough, November 5th was a rather cloudy day, while the 4th was quite sunny. Data shows that the THD peak on the 4th was 0.1% lower then that record on the 5th. This pattern does not seem to be reflected on Vrms or Transient measurements, however, small daily oscillations in THD are also present in the difference between Devices 1006 and 1021 just nowhere near as pronounced. We intend to go one step further, and correlate the THD with the actual production numbers as generated by the solar installation as soon as we get our hands on them.

The mechanism for this disturbance is quite simple. Solar panels produce a DC voltage. In order to backfeed power to a grid, this DC voltage is converted to AC with help of AC-DC inverters. These inverters are active devices, which lock on to the phase and the frequency of the power grid in order to provide maximum efficiency of power production. If the inverters don't get the frequency or phase quite right, the resulting voltage waveform will exhibit excessive harmonic behavior.

Low pass filtered data shows very clear oscillations in THD while the panels are on. Could this be the inverters drifting with respect to the power grid fundamental frequency and phase?

Ignoring local disturbances:

Napali triggering framework was created in order to filter out local disturbances and only record events which impact the entire grid. As such, all of the local peculiarities described in the section above are ignored by Napali. While interesting in their own right, they provide nothing when it comes to ascertaining the state of the UH power grid as a whole. The fact that Napali ignores voltage sags recorded by device 1021, while including device 1021 in data collected for gridwide events is a testament to its ability to ignore local noise and deliver only actionable grid-global events.

Conclusion

This week's report looks at a fairly nominal week of PQ data. We investigated Voltages sags in MSB and looked more closely at THD. We also changed the layout of the report to be more in line with a top-down approach focusing on different parts of our DSN and how it relates to our PhD dissertations.

Micro-report on the UHM micro-grid: 10/22 to 10/29

Open Power Quality
Oct 29, 2019 · Unlisted

General Summary

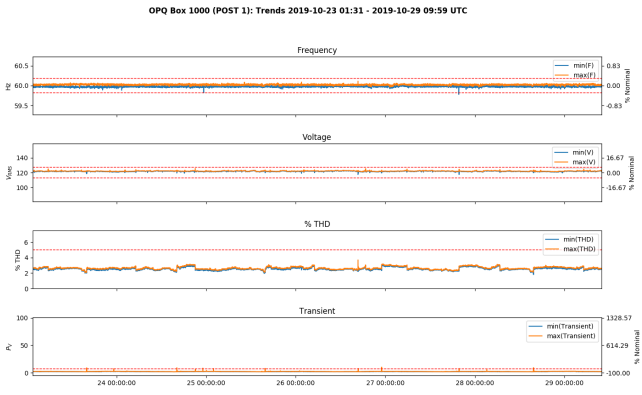
University of Hawaii at Manoa micro-grid report on data from 10–22–2019 10:00 to 10–29–2019 10:00 UTC.

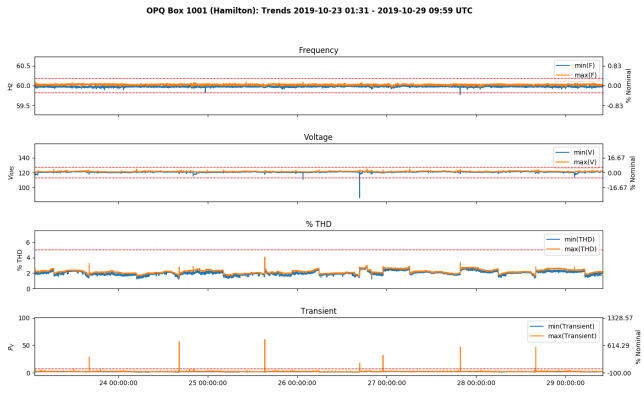
PQ over the past week exhibited a large Voltage sag Event, several Voltage sag Incidents, and some interesting THD trends.

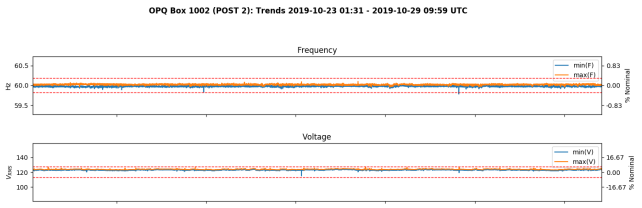
Trends Summary

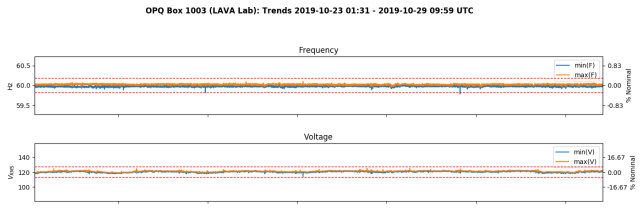
Weekly trends measure the minimum, average, and maximum values for Voltage, Frequency, THD, and transients for each OPQ Box at a rate of 1 Hz.

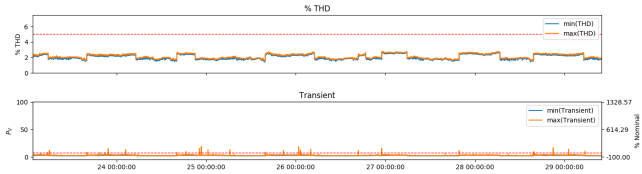
The following figures show Trends for each Box between 2019–10–22 10:00:00 and 2019–10–29 10:00:00.

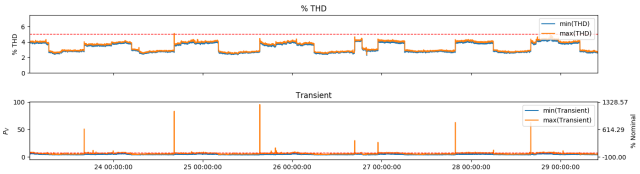




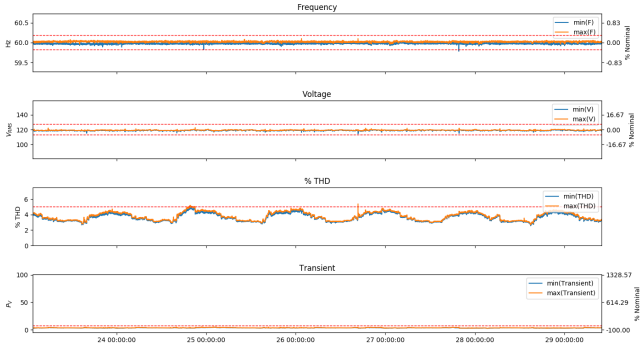




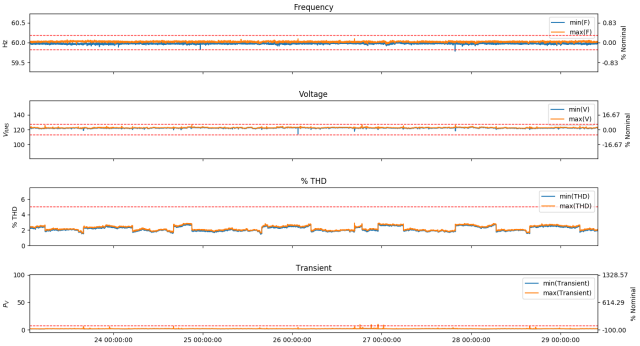




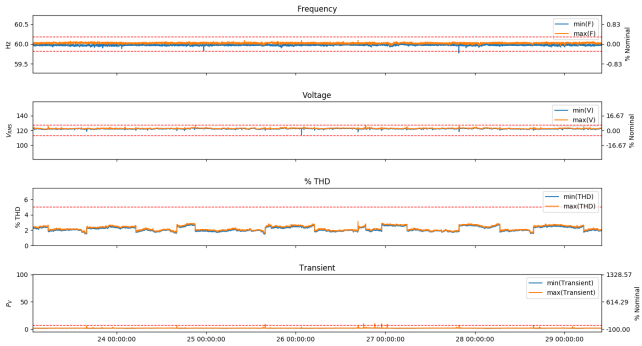
OPQ Box 1005 (Parking Structure Ph II): Trends 2019-10-23 01:31 - 2019-10-29 09:59 UTC



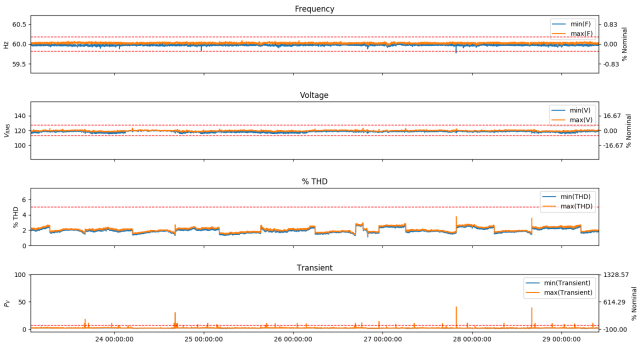
OPQ Box 1006 (Frog 1): Trends 2019-10-23 01:31 - 2019-10-29 09:59 UTC



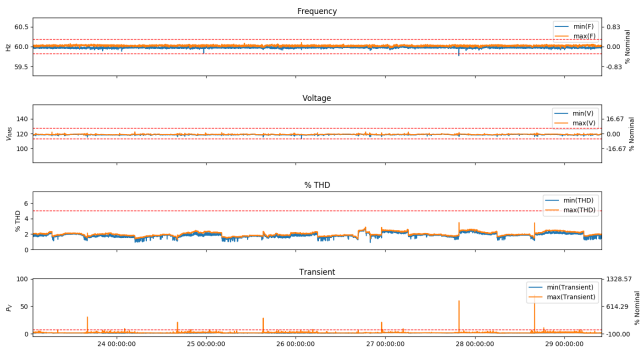
OPQ Box 1007 (Frog 2): Trends 2019-10-23 01:31 - 2019-10-29 09:59 UTC



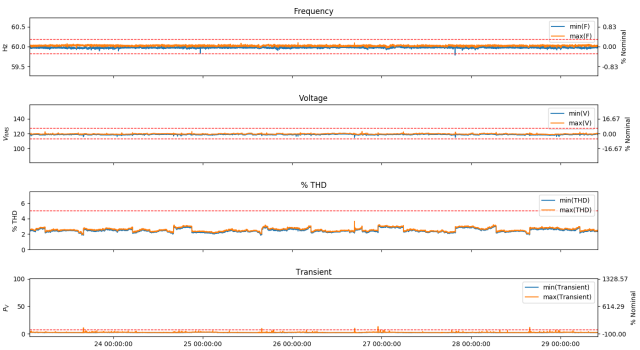
OPQ Box 1008 (Mile's Office): Trends 2019-10-23 01:31 - 2019-10-29 09:59 UTC



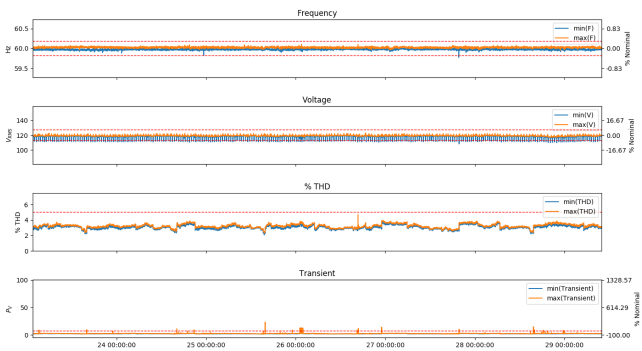
OPQ Box 1009 (Watanabe): Trends 2019-10-23 01:31 - 2019-10-29 09:59 UTC



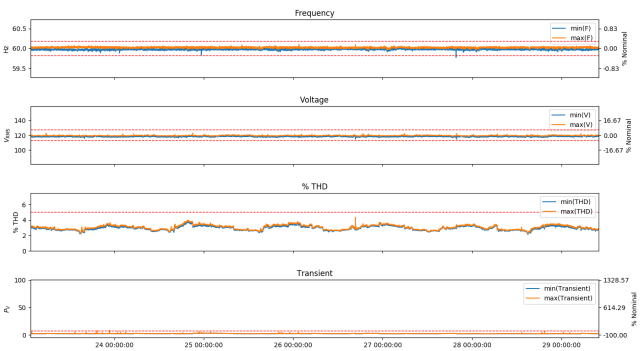
OPQ Box 1010 (Holmes): Trends 2019-10-23 01:31 - 2019-10-29 09:59 UTC

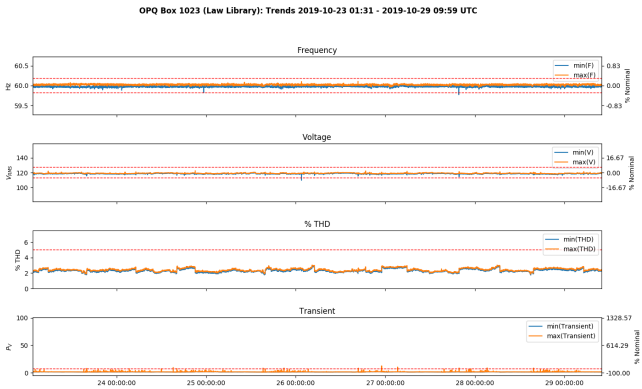


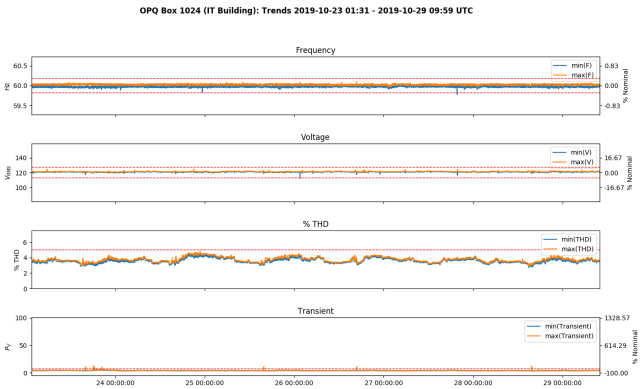
OPQ Box 1021 (Marine Science Building): Trends 2019-10-23 01:31 - 2019-10-29 09:59 UTC

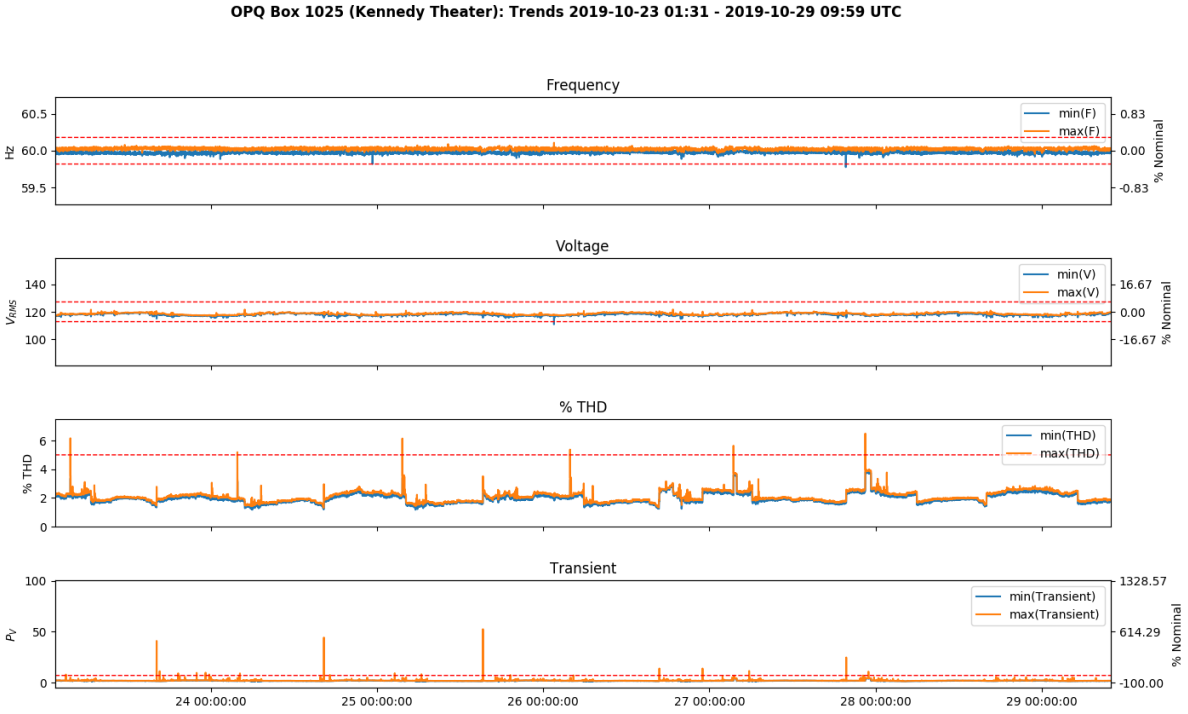


OPQ Box 1022 (Ag. Engineering): Trends 2019-10-23 01:31 - 2019-10-29 09:59 UTC









For the most part, trend data remains nominal for the past week. However, there are some interesting things to look at.

First, a decently sized Voltage sag is apparent in Hamilton library. This Voltage sag can be observed on the other Boxes as well (but the sag does not fall outside of nominal).

Second, we can observe several large Frequency events. These are discussed in greater detail in the Events section.

Third, we observe large levels of THD that appear cyclic in nature on Box 1025 at Kennedy Theater.

Events Summary

Events are ranges of PQ data that may (or may not) have PQ issues within them. Events are generated by two methods. The first method uses Voltage, Frequency, and THD thresholds as defined by IEEE. The second method uses the Napali Trigger which was developed by Sergey as part of his dissertation research. The Napali trigger uses statistical methods to determine when Boxes may contain PQ issues. This summary of Events examines the number of times that Boxes were triggered due to possible PQ issues.

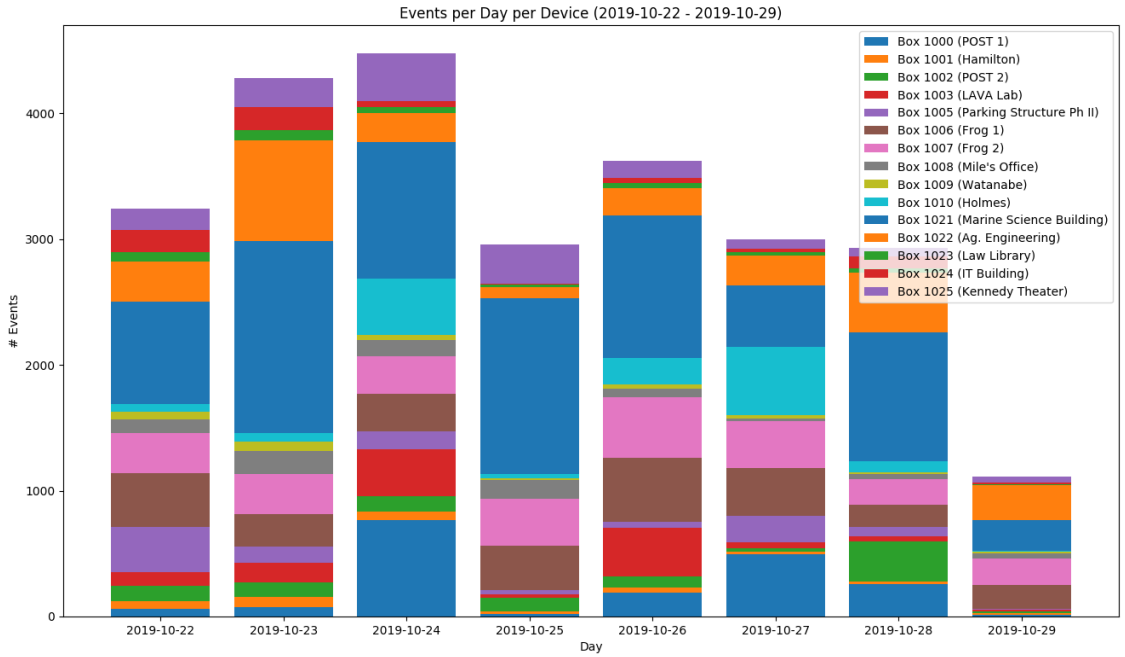
There were a total of 25626 Events processed.

The following table shows Events generated per Box.

OPQ Box	Location	Events Generated
1021	Marine Science Building	7689
1022	Ag. Engineering	2654
1006	Frog 1	2595
1007	Frog 2	2577
1000	POST 1	1879
1010	Holmes	1475
1025	Kennedy Theater	1419
1003	LAVA Lab	1147
1005	Parking Structure Ph II	998
1002	POST 2	927
1008	Mile's Office	735
1024	IT Building	596
1023	Law Library	337
1001	Hamilton	320
1009	Watanabe	278
Total		**25626**

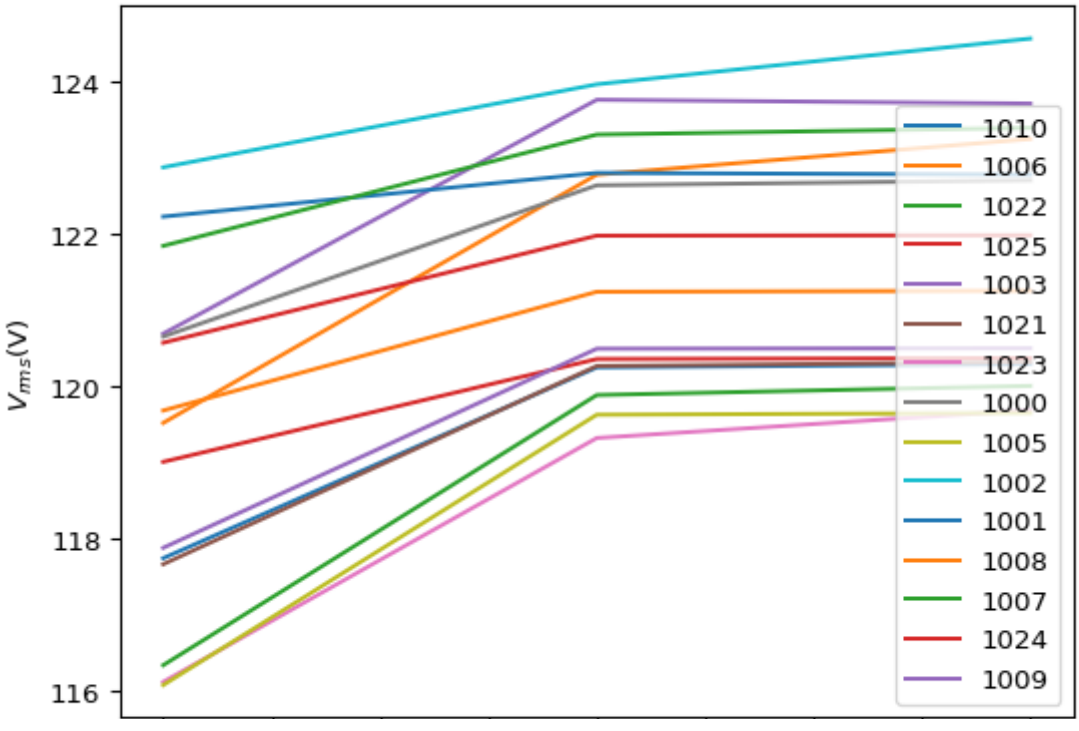
Events 2019-10-22 to 2019-10-29

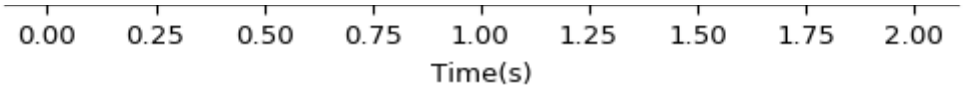
The following figure shows Events per Box per day.



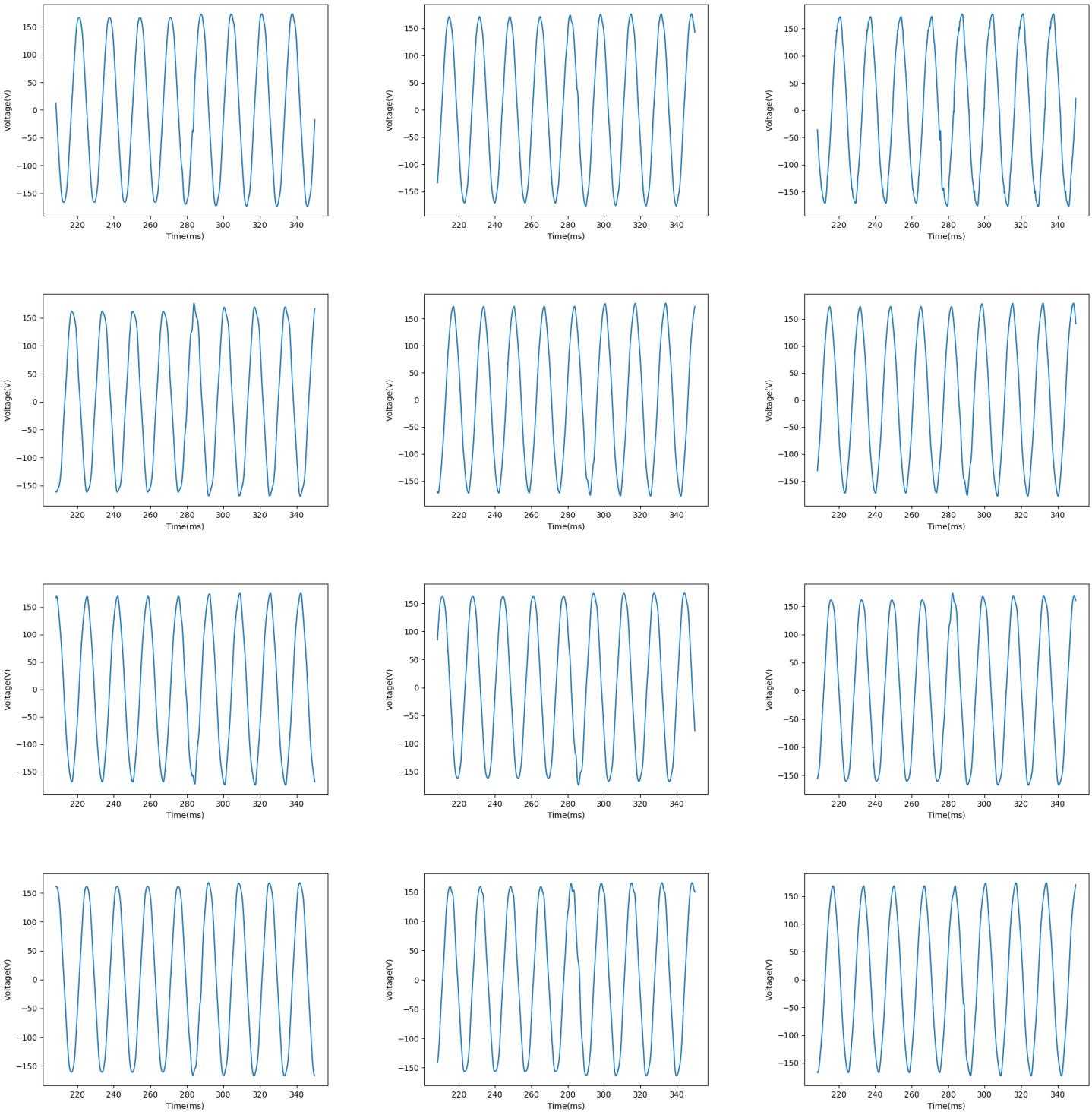
Events of Interest:

While it has been a relatively quiet week at the UH microgrid, it was not without some incidents. Particularly, Oct 26 6–7am OPQ Makai detected a number of voltage sags and associated transients. The most severe of these was event 228742:

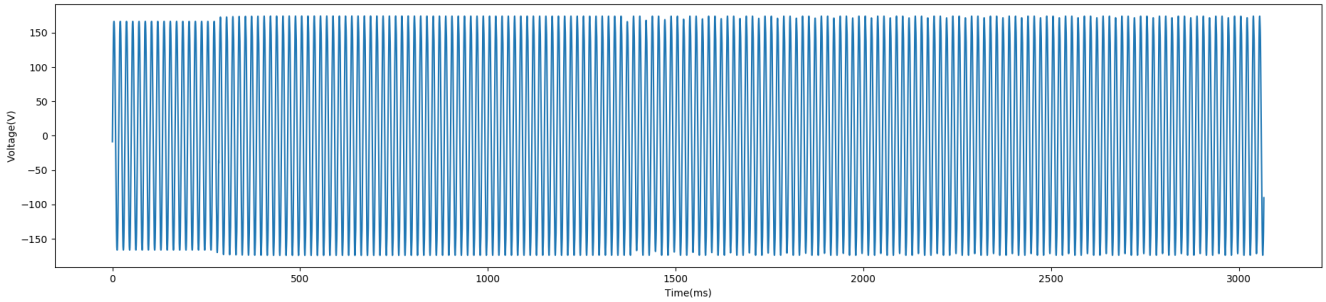




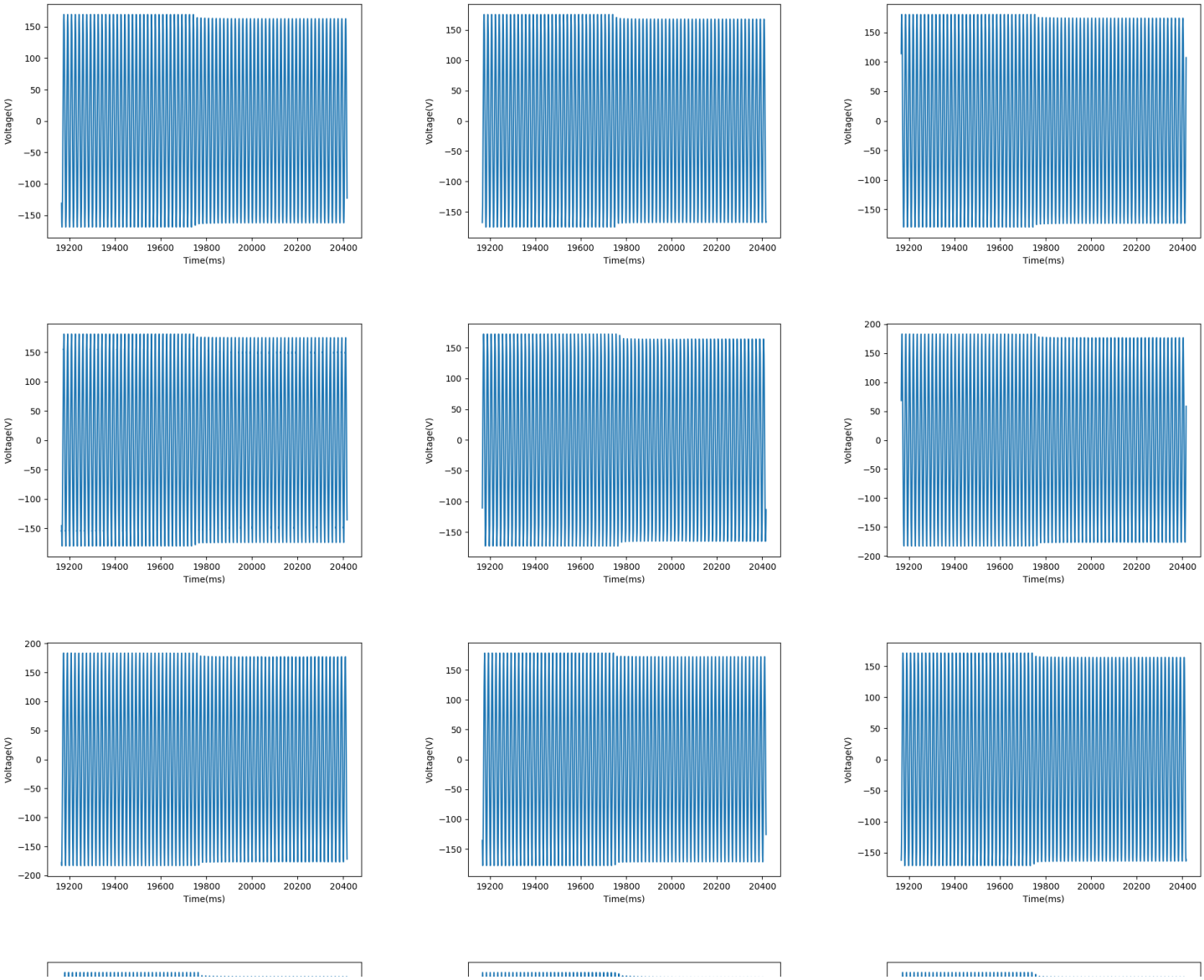
This event was coupled with a large number of transients corresponding to the time of voltage stabilization:

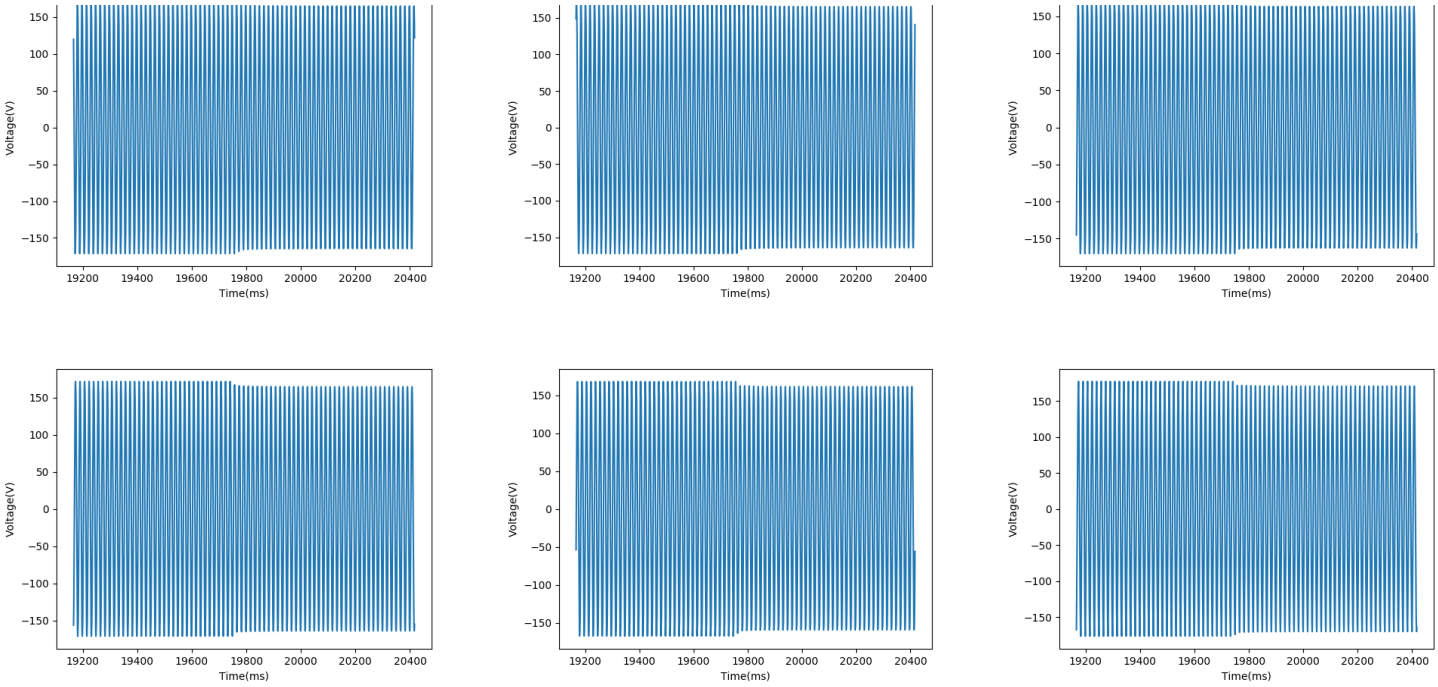


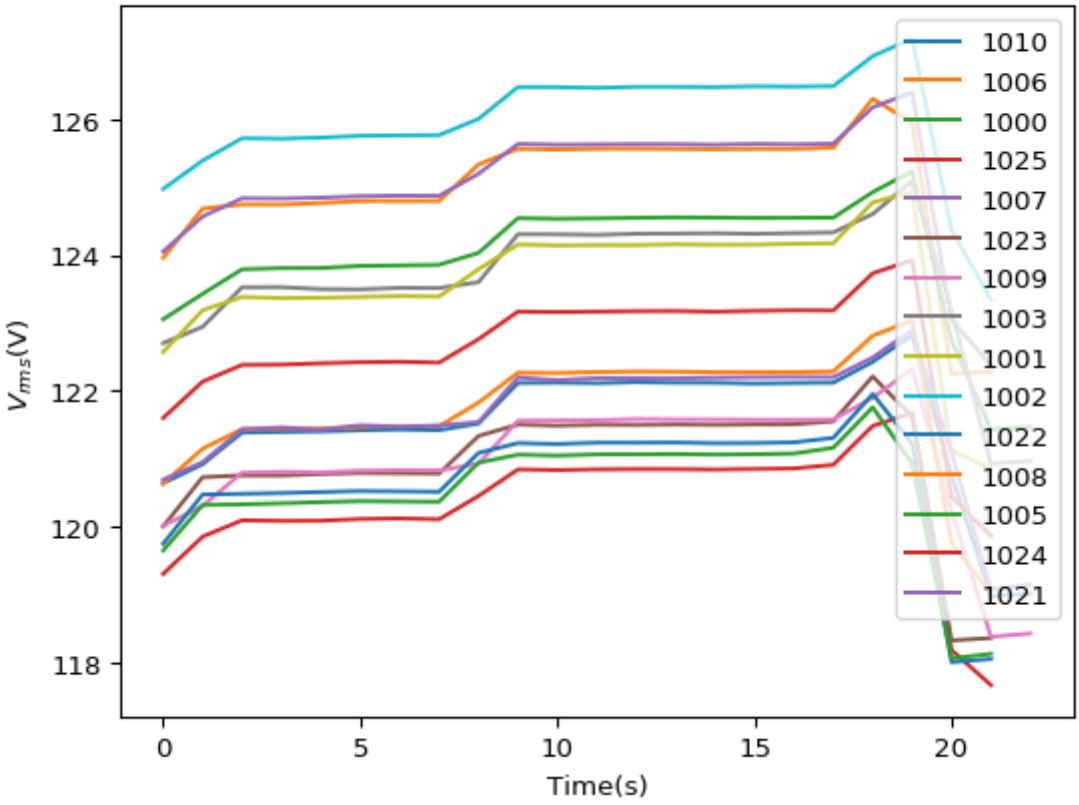
Particularly interesting was data collected from device 1001 located in Kennedy theater, which shows a harmonic amplitude modulation @30Hz:



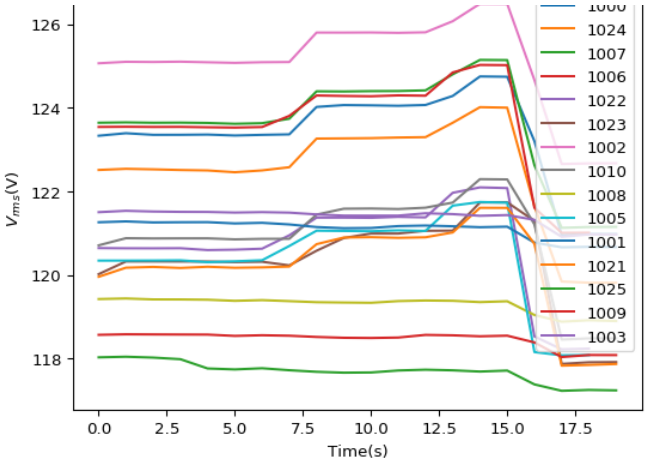
This event was followed by event 229138 which was another voltage sag, this time without a transient:

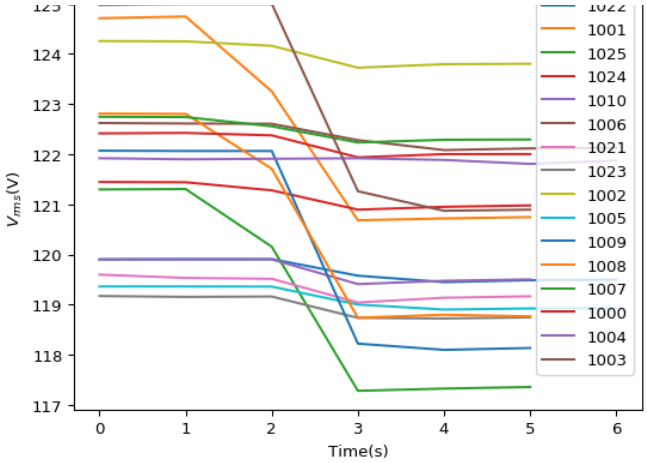




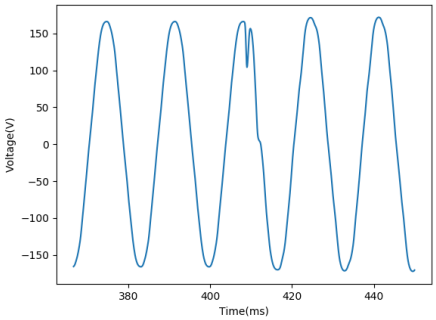


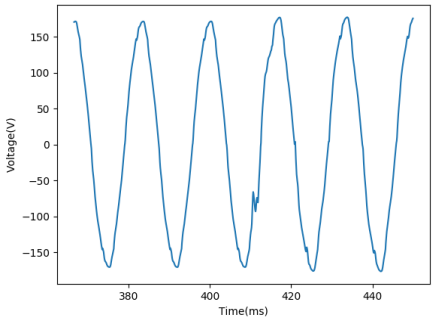
Similar gridwide sags were observed in events 23144, 23177:

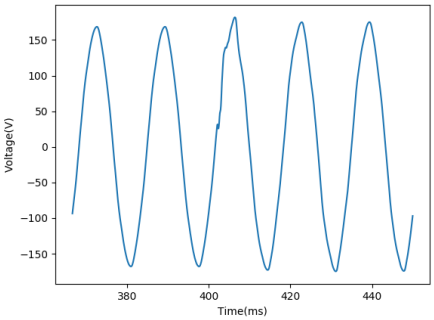


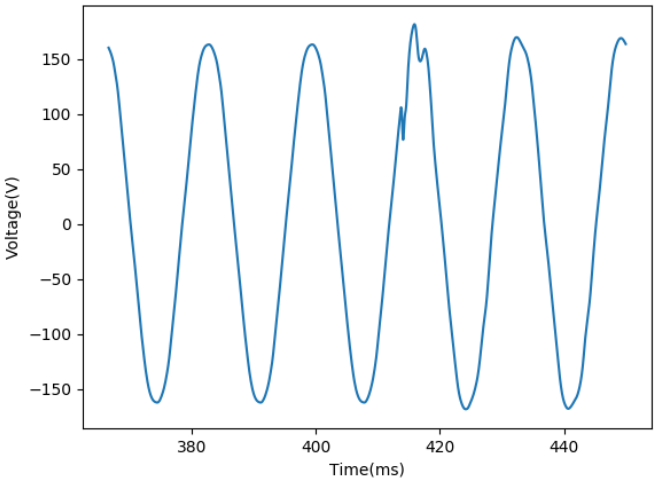


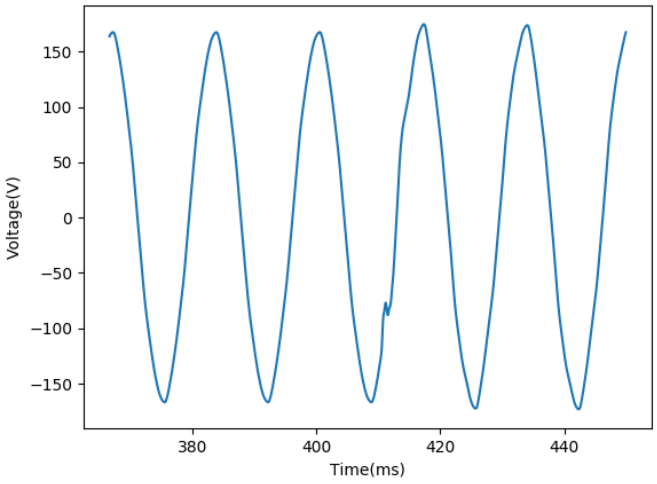
The transients returned in event 229958:











By 7am on Oct 26 the power grid returned to nominal operation.

Incidents Summary

Incidents are classified PQ issues that were found in the previously provided Events. Incidents are classified by OPQ Mauka according to various PQ standards. OPQ Mauka

provides classifications for Outages, Voltage, Frequency, and THD related issues.

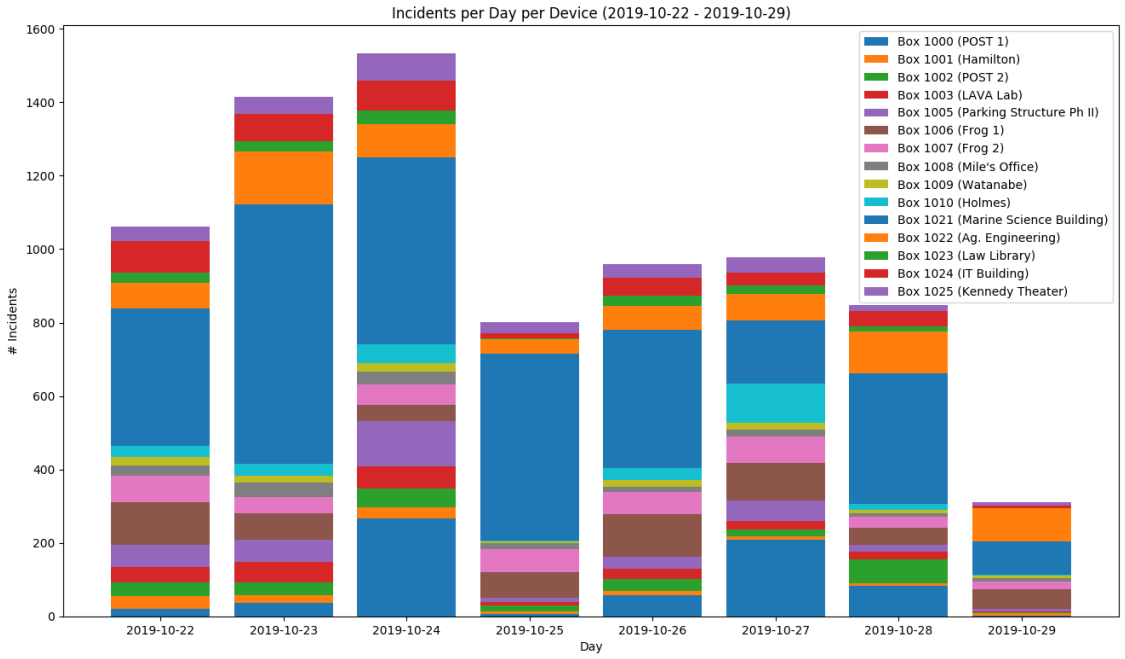
A total of 7909 Incidents were processed.

A breakdown of Incidents per Box is provided in the following table.

OPQ Box	Location	Incidents	F Sag	F Swell	Outage	V Sag
1021	Marine Science Building	3095	1291	1800	1	3
1000	POST 1	687	277	408	2	0
1022	Ag. Engineering	683	289	394	0	0
1006	Frog 1	618	332	286	0	0
1007	Frog 2	421	232	185	4	0
1024	IT Building	385	213	172	0	0
1005	Parking Structure Ph II	372	202	170	0	0
1025	Kennedy Theater	296	152	143	1	0
1010	Holmes	274	135	137	2	0
1002	POST 2	256	119	137	0	0
1003	LAVA Lab	241	110	130	1	0
1008	Mile's Office	168	89	76	3	0
1023	Law Library	166	81	85	0	0
1001	Hamilton	127	79	47	1	0
1009	Watanabe	120	62	57	1	0
Total		**7909**	**3663**	**4227**	**16**	**3**

Incidents 2019-10-22 to 2019-10-29

The following figure shows Incidents per Box per day.



Outage Incidents

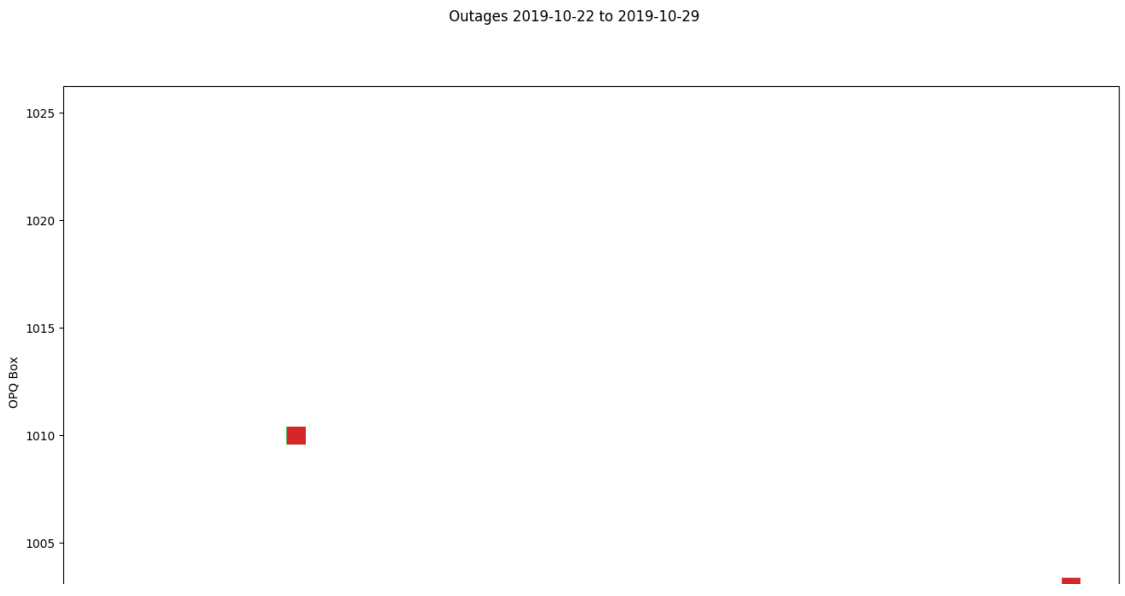
The Outage classification has been rewritten to identify Outages directly from collected Measurements rather than relying on OPQ Health.

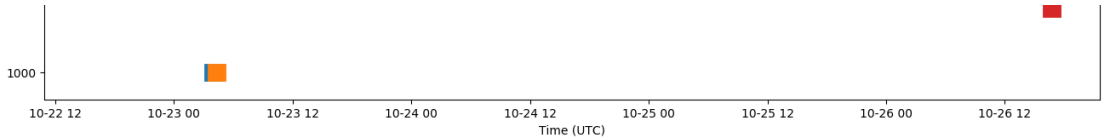
Mauka identified 16 Outages since the Outage plugin has been updated. These outages are summarized in the following table.

OPQ Box	Location	Incident #	Outage Start	Outage End	Duration (s)
1000	POST 1	73305	10-23 03:56:49	10-23 04:03:10	380.806
1010	Holmes	73446	10-23 10:17:21	10-23 10:23:21	360.052
1000	POST 1	73319	10-23 04:18:49	10-23 04:23:00	250.742
1010	Holmes	73447	10-23 10:25:21	10-23 10:28:21	180.035
1003	LAVA Lab	77503	10-26 16:43:14	10-26 16:44:42	88.429
1007	Frog 2	71883	10-22 17:13:25	10-22 17:14:30	64.946
1007	Frog 2	76732	10-25 22:12:03	10-25 22:13:03	60.186
1025	Kennedy Theater	77500	10-26 16:43:14	10-26 16:43:49	35.83
1009	Watanabe	77501	10-26 16:43:14	10-26 16:43:47	33.492
1001	Hamilton	77502	10-26 16:43:14	10-26 16:43:44	30.885
1008	Mile's Office	77504	10-26 16:43:14	10-26 16:43:44	30.768
1008	Mile's Office	71884	10-22 17:17:01	10-22 17:17:23	21.607
1008	Mile's Office	71814	10-22 15:44:55	10-22 15:45:17	21.429
1021	Marine Science Building	74540	10-24 04:43:25	10-24 04:43:26	0.963
1007	Frog 2	76754	10-25 22:44:04	10-25 22:44:04	0.562
1007	Frog 2	74048	10-23 20:15:23	10-23 20:15:23	0.068

Outages 2019-10-26 to 2019-10-26

In an attempt to better visualize the outages, we attempted to plot them as a function of time vs OPQ Box.





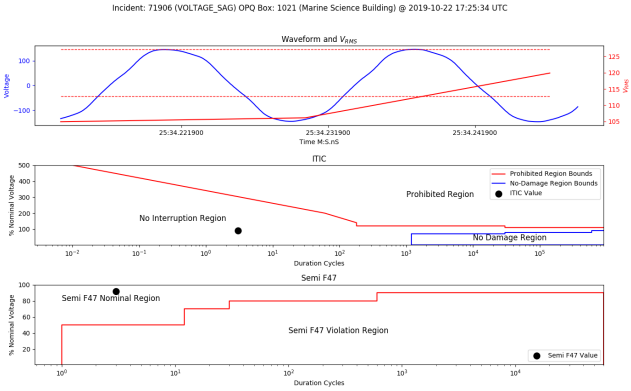
We can see that only the largest of the outages are visible using this representation. Outages less around 1 minute or less are not visible. We are working to address this.

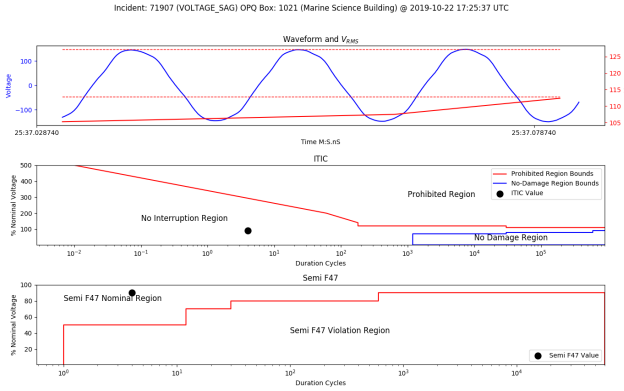
One thing that should be discussed is the fact that looking at Measurements is the best metric we currently have for identifying outages. One issue with this approach however is that network issues, slow MongoDB writes, or other causes of measurement gaps could also look like outages and cause False Positives.

It may be possible to introduce some more metrics to the Box that would send the Box start time. Then, when a Box shuts off and restarts due to an outage, we can use that value to determine if gaps in measurements are actual outages or “something else”.

Voltage Sag Incidents

OPQ Mauka classified 3 Voltage sag Incidents from MSB. For some reason, 2 of the incidents appear to be identical in both time and data. Therefore, Mauka collected 2 unique Voltage sag Incidents which are displayed below.





One thing we noticed is that the captured Incidents appear to only catch the tail end of the sags. This will be investigated and, if needed, a buffer can be added to Incident ranges or perhaps copied from the Event that generated the Incident to show the full cycle of nominal->Incident->nominal.

Conclusion

In terms of identifying issues with Incident analysis, this past week's focus has been on improving Voltage related Incidents including Voltage segmentation, ITIC, and Semi F47. Even though Mauka identified several Voltage sags, we still intend to overhaul the IEEE 1159 plugin this week.

We also improved the Outage classification algorithm by looking at Measurements directly instead of relying on OPQ Health.

The focus for next week is making improvements on the THD and Frequency Incident classification plugins.

Unlisted

Data Science

Micro-report on the UHM micro-grid: 2019–10–15 10:00 to 2019–10–22 10:00

Open Power Quality
Oct 22, 2019 · Unlisted

General Summary

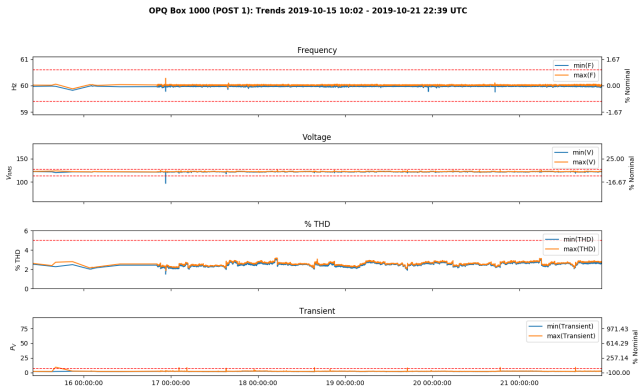
The past weeks data remains close to nominal, however, there is one large Voltage sag that was observed across the entire entire network on 10/16.

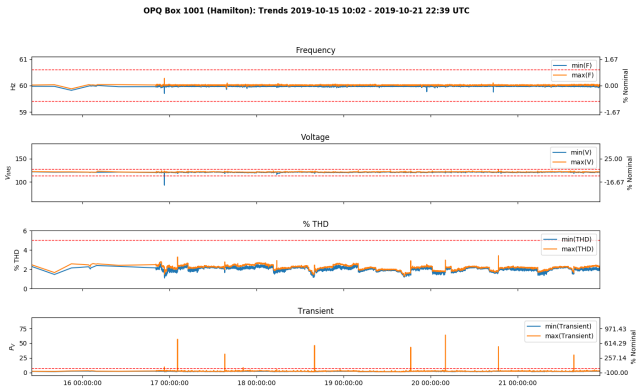
We also start examining a subset of the Incidents generated, namely, the Voltage Interruptions and the Outage incidents.

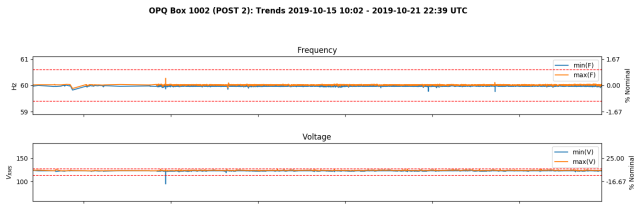
Trends Summary

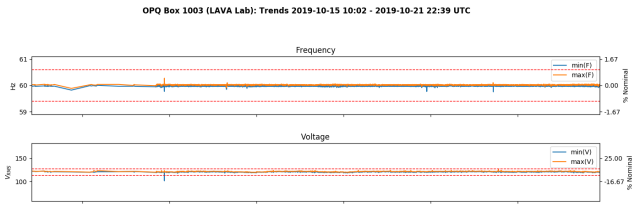
Weekly trends measure the minimum, average, and maximum values for Voltage, Frequency, THD, and transients for each OPQ Box at a rate of 1 Hz.

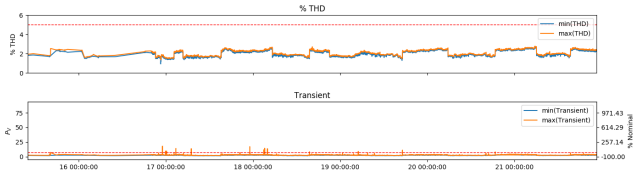
The following figures show Trends for each Box between 2019–10–15 10:00:00 and 2019–10–22 10:00:00.

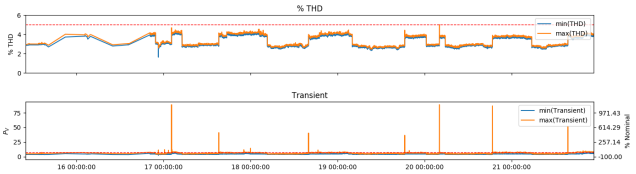




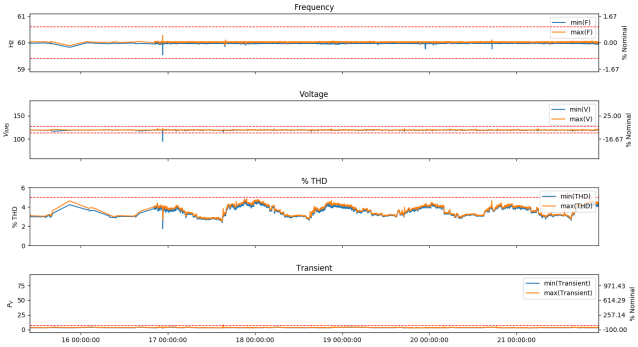




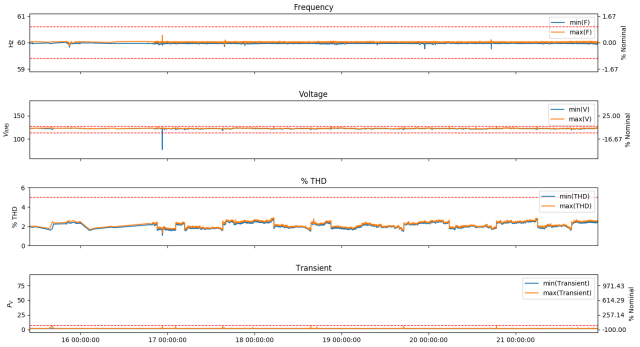




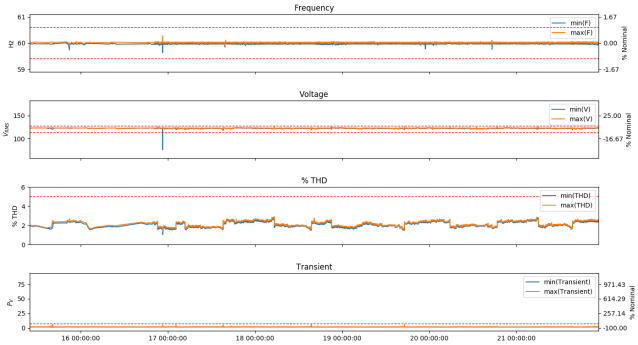
OPQ Box 1005 (Parking Structure Ph II): Trends 2019-10-15 10:02 - 2019-10-21 22:39 UTC



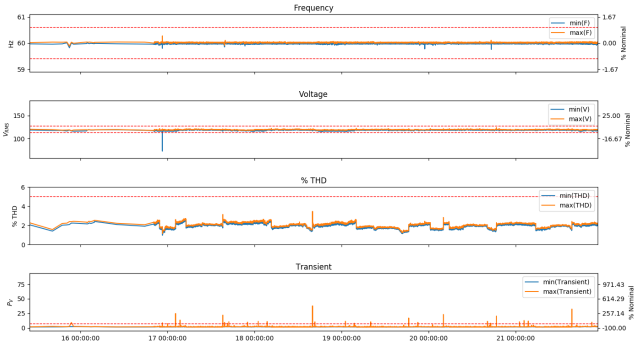
OPQ Box 1006 (Frog 1): Trends 2019-10-15 10:02 - 2019-10-21 22:39 UTC



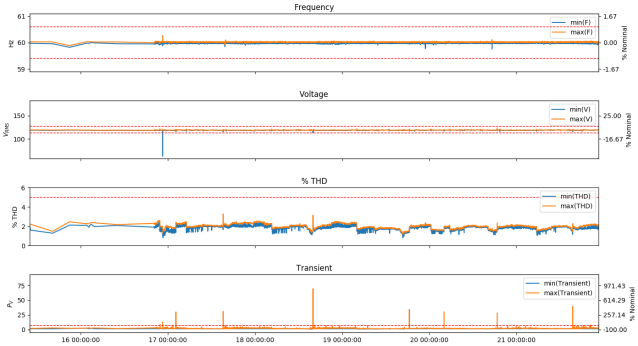
OPQ Box 1007 (Frog 2): Trends 2019-10-15 10:02 - 2019-10-21 22:39 UTC



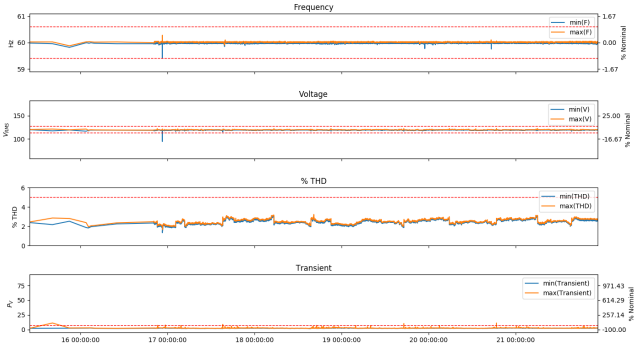
OPQ Box 1008 (Mile's Office): Trends 2019-10-15 10:02 - 2019-10-21 22:39 UTC



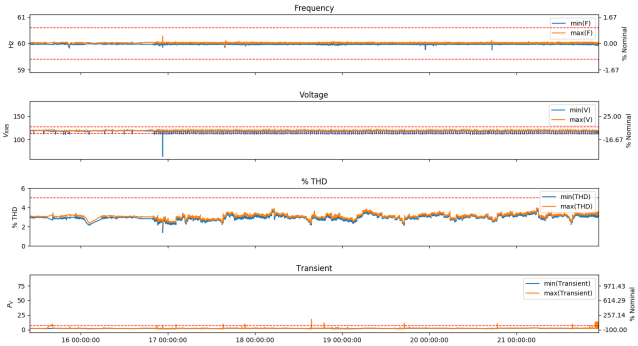
OPQ Box 1009 (Watanabe): Trends 2019-10-15 10:02 - 2019-10-21 22:39 UTC



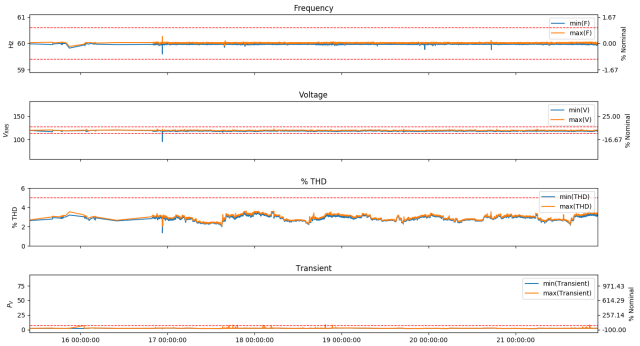
OPQ Box 1010 (Holmes): Trends 2019-10-15 10:02 - 2019-10-21 22:39 UTC

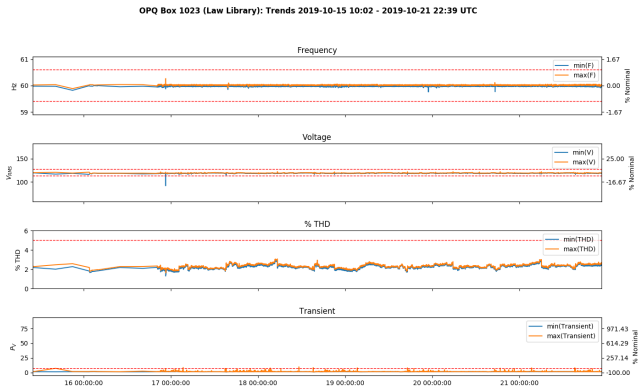


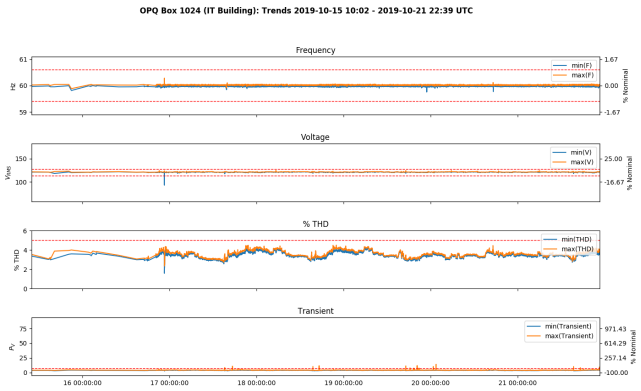
OPQ Box 1021 (Marine Science Building): Trends 2019-10-15 10:02 - 2019-10-21 22:39 UTC

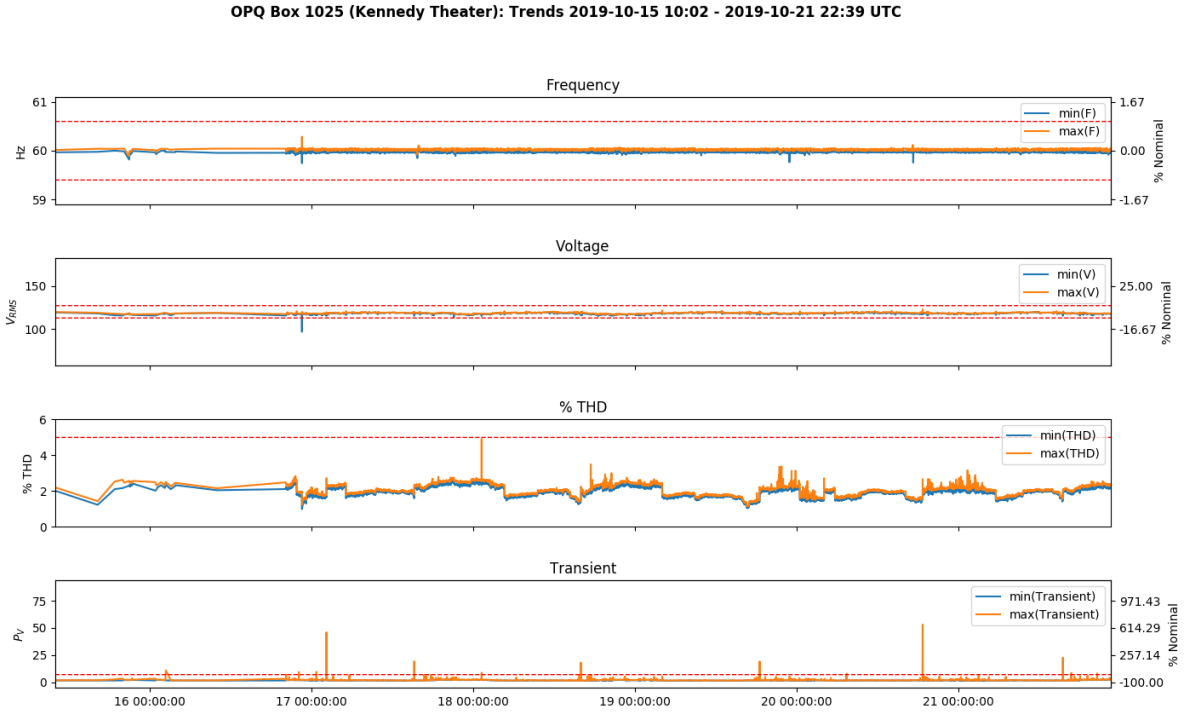


OPQ Box 1022 (Ag. Engineering): Trends 2019-10-15 10:11 - 2019-10-21 22:39 UTC









A large Voltage sag is observed across the network on 10/16 and shows up well in the trends. We can also observe cycles in the THD trends likely shows the power factor correction hardware kicking on and off.

Events Summary

Events are ranges of PQ data that may (or may not) have PQ issues within them. Events are generated by two methods. The first method uses Voltage, Frequency, and THD thresholds as defined by IEEE. The second method uses the Napali Trigger which was developed by Sergey as part of his dissertation research. The Napali trigger uses statistical methods to determine when Boxes may contain PQ issues. This summary of

Events examines the number of times that Boxes were triggered due to possible PQ issues.

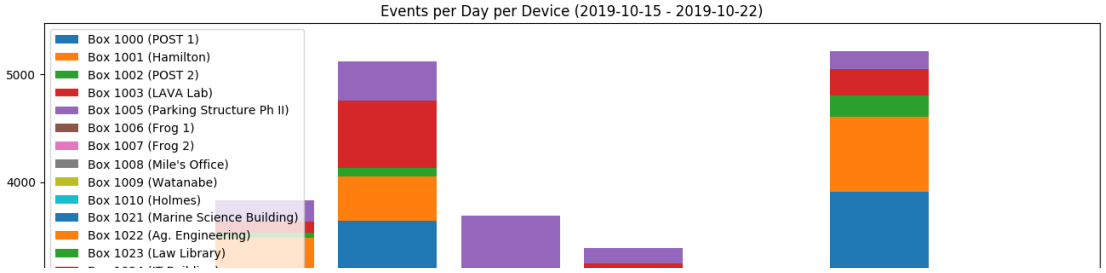
There were a total of 28837 Events processed.

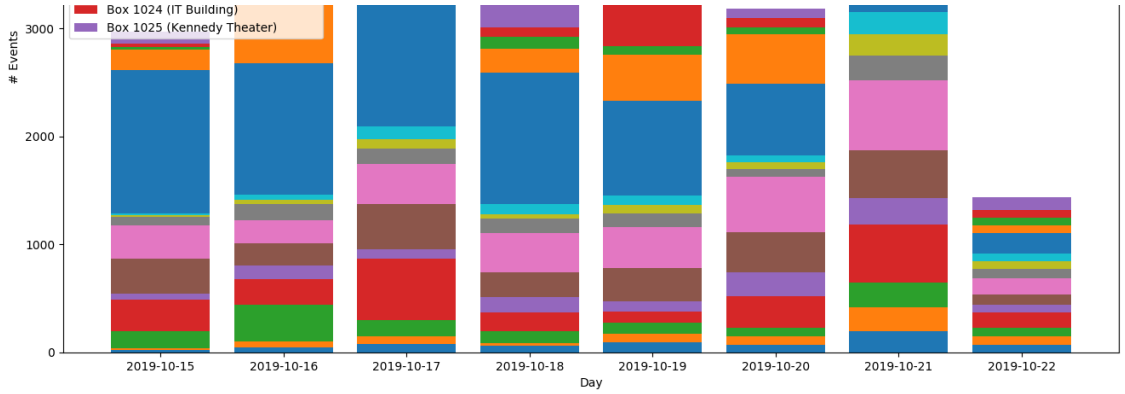
The following table shows Events generated per Box.

OPQ Box	Location	Events Generated
1021	Marine Science Building	7804
1022	Ag. Engineering	3266
1007	Frog 2	2957
1006	Frog 1	2383
1003	LAVA Lab	2354
1025	Kennedy Theater	1863
1024	IT Building	1669
1002	POST 2	1232
1005	Parking Structure Ph II	1037
1008	Mile's Office	1017
1010	Holmes	709
1023	Law Library	674
1000	POST 1	656
1001	Hamilton	629
1009	Watanabe	587
Total		**28837**

Events 2019-10-15 to 2019-10-22

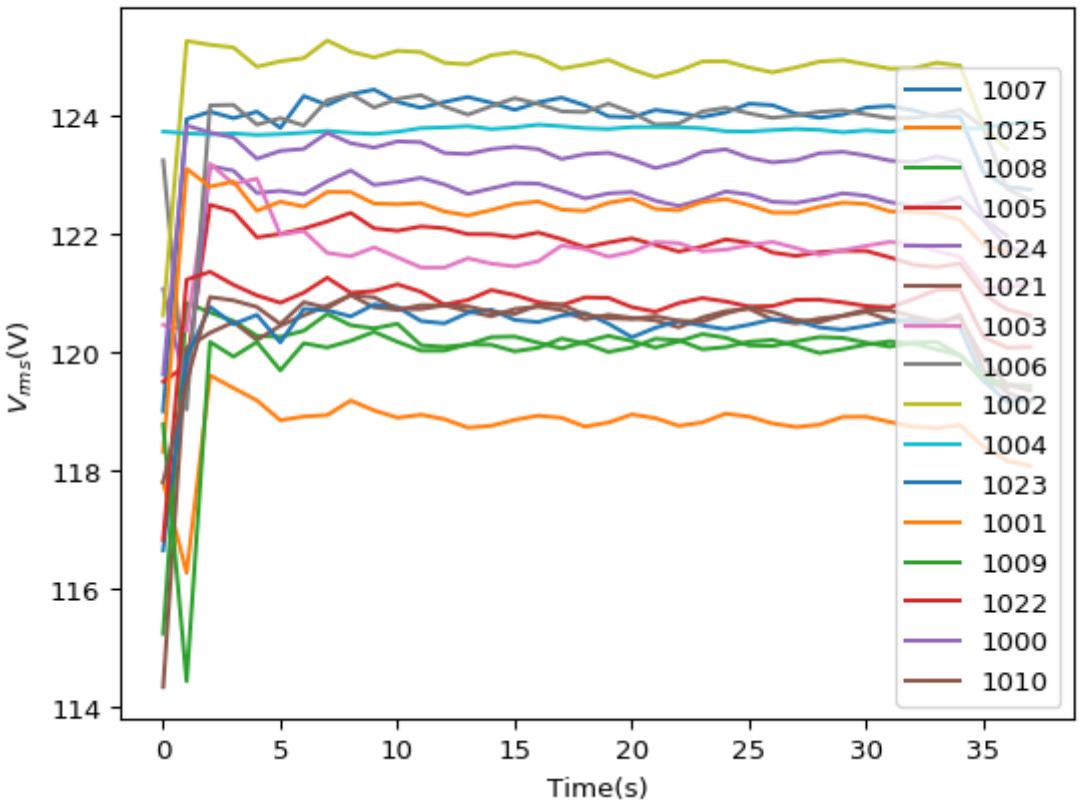
The following figure shows Events per Box per day.



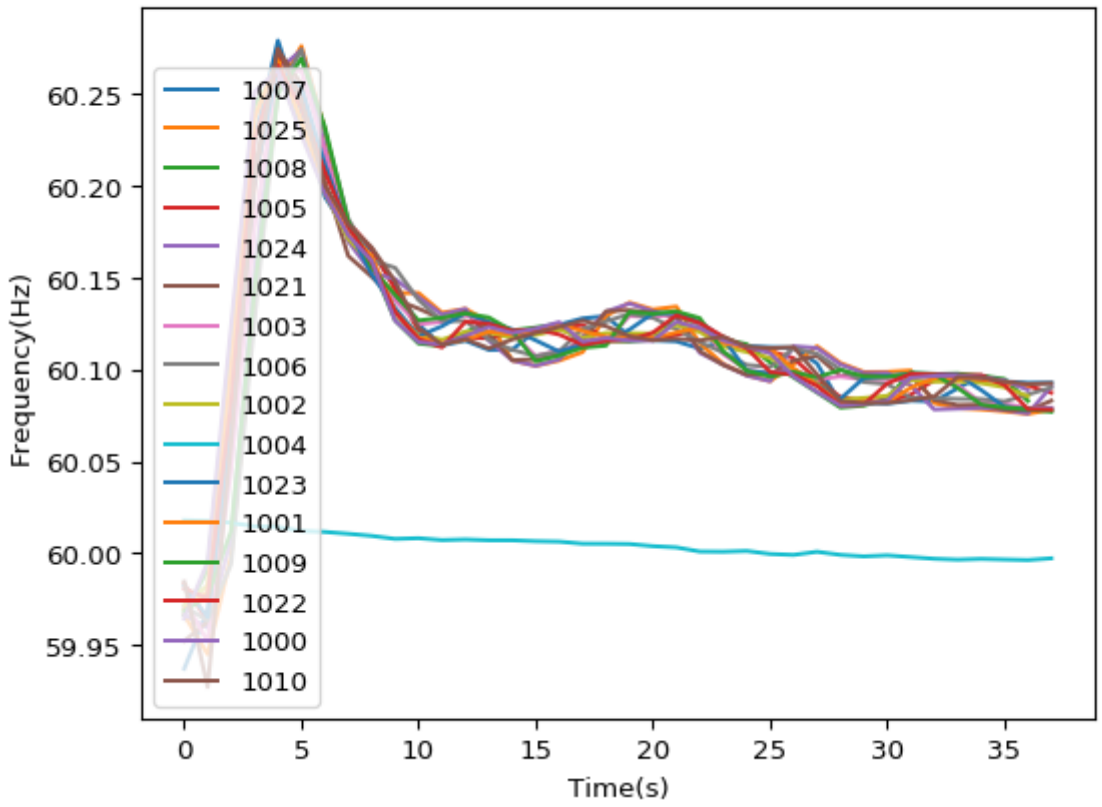


Events of Interest:

It's been a quiet week for the OPQ network. While numerous events have been recorded, the vast majority constitute local disturbances which do not contribute to the overall power grid state. The major recorded disturbance was event 191293 recorded on 2019/10/16 at 12:37:28. This event started out as a significant voltage sag recorded by the entire OPQ Network:



After a few cycles of a voltage sag, the offending portion of the Oahu power grid must have been closed off via a recloseser, which resulted in a major power overproduction as a portion of consumers were cut off. This in turn manifested as a major frequency swell:



35 seconds into the incident, HECO was able to stabilize production to match consumption, bringing the fundamental frequency to with in nominal +/- 0.1Hz.

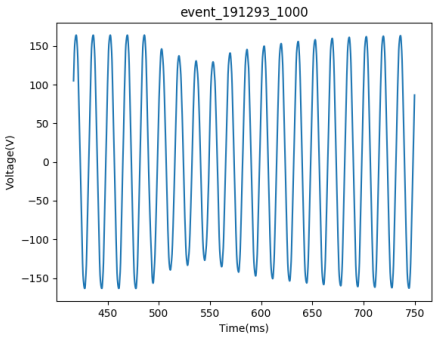
The incident was likely related to the 700 HECO customers losing power in Makiki, Oahu:

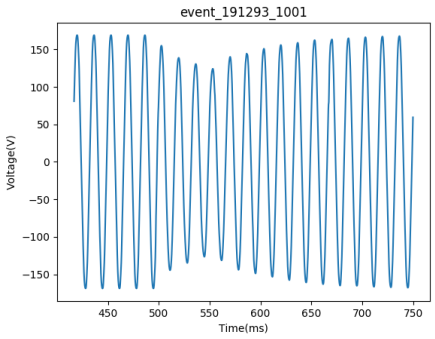
Hawaiian Electric
@HwnElectric

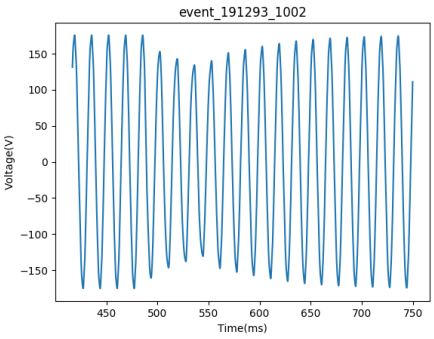
150p: ~710 customers without power in the Makiki area. 1st responder en route. Mahalo for your patience. #oahuoutage

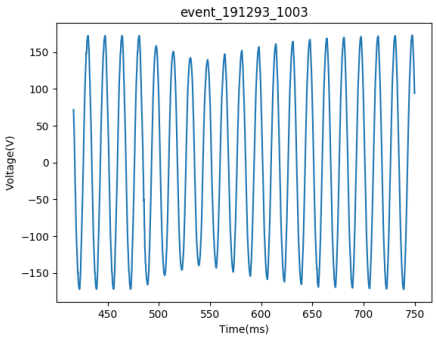
3 2:00 PM - Oct 16, 2019

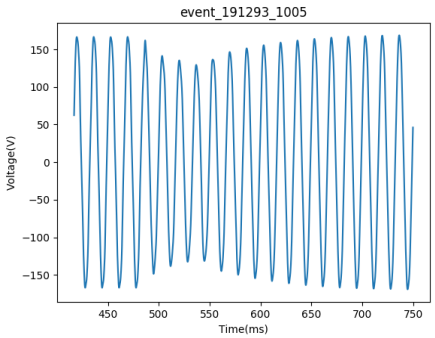
Bellow is the raw data collected during the voltage sag by the OPQ network:

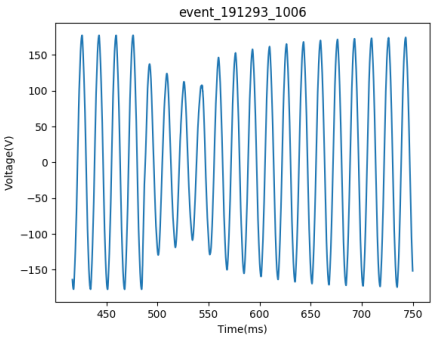


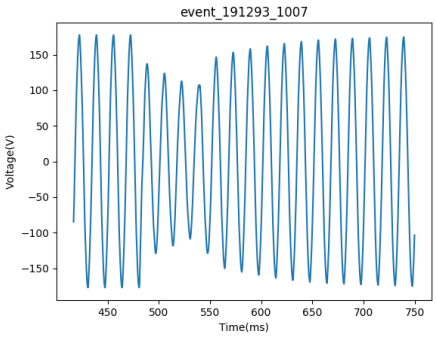


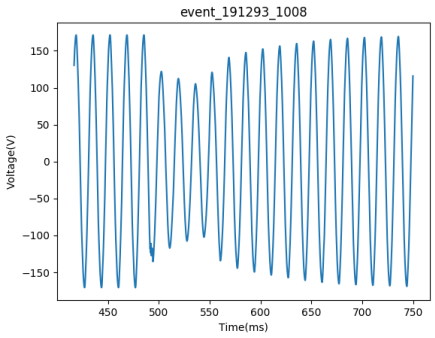


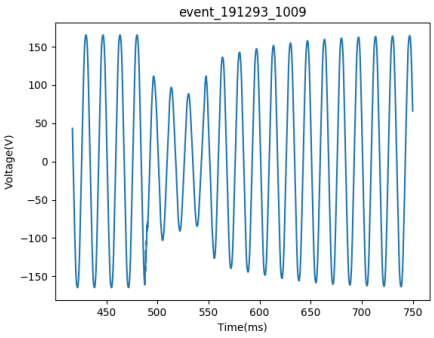


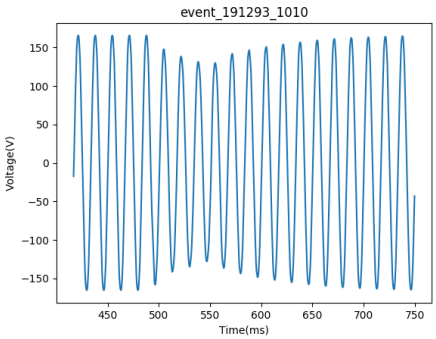


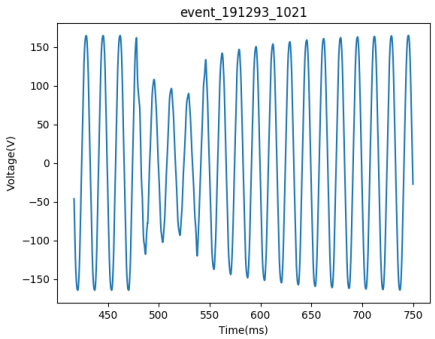


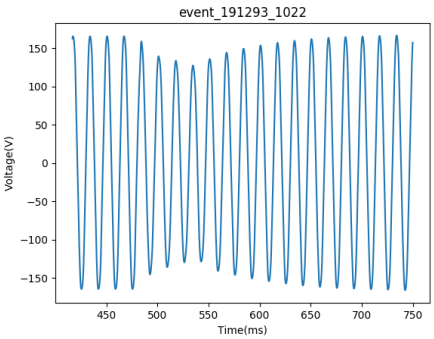


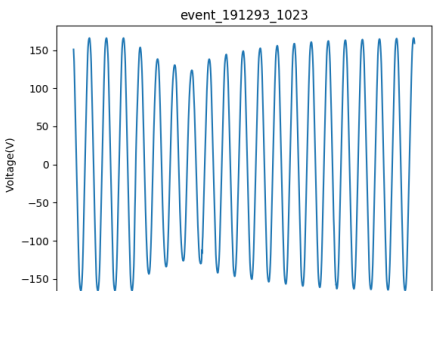


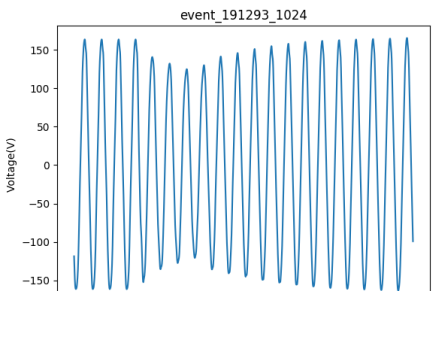


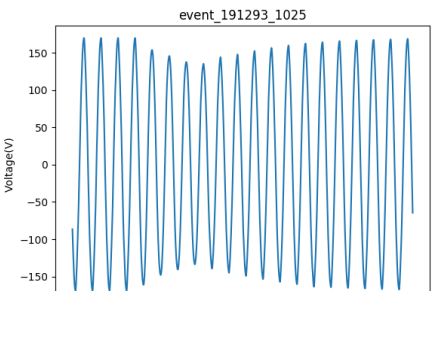


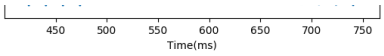


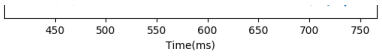


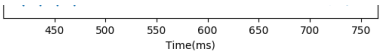




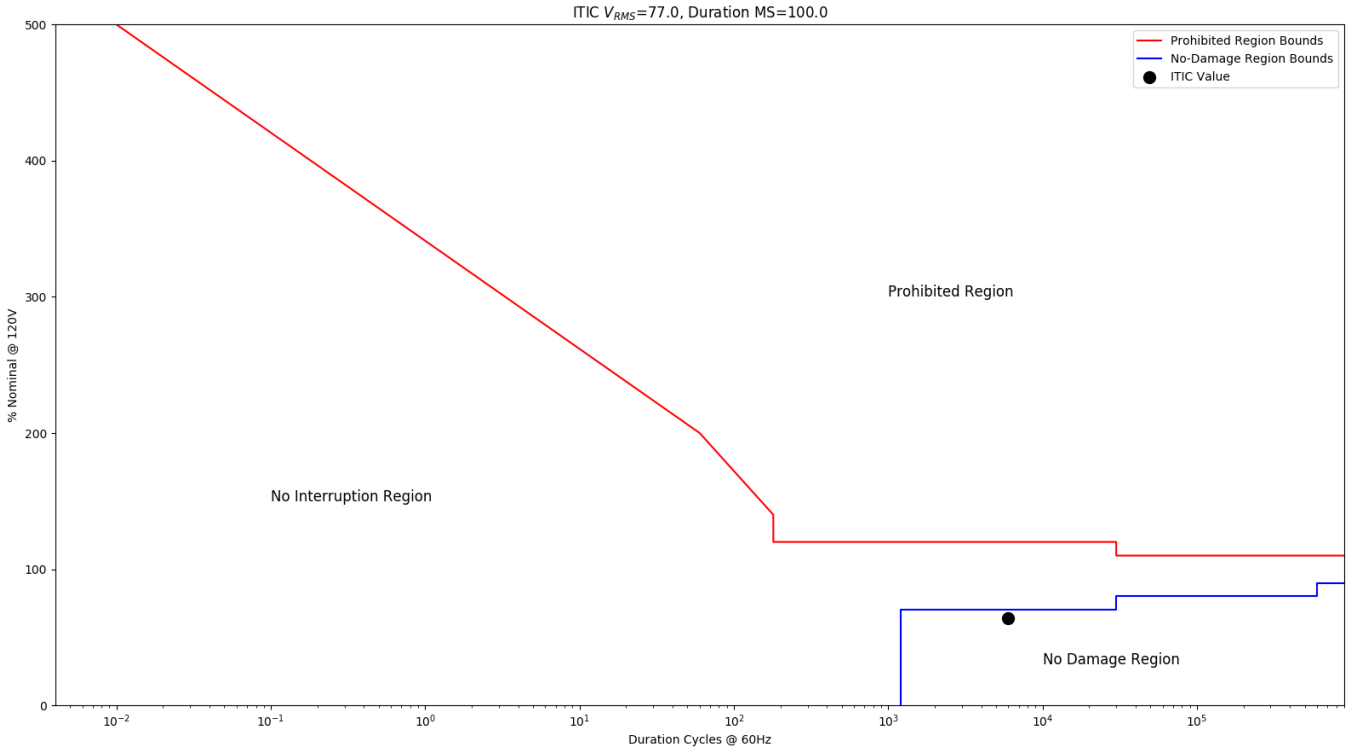








An ITIC plot of this sag is provided below:



Incidents Summary

Incidents are classified PQ issues that were found in the previously provided Events. Incidents are classified by OPQ Mauka according to various PQ standards. OPQ Mauka provides classifications for Outages, Voltage, Frequency, and THD related issues.

A total of 12212 Incidents were processed.

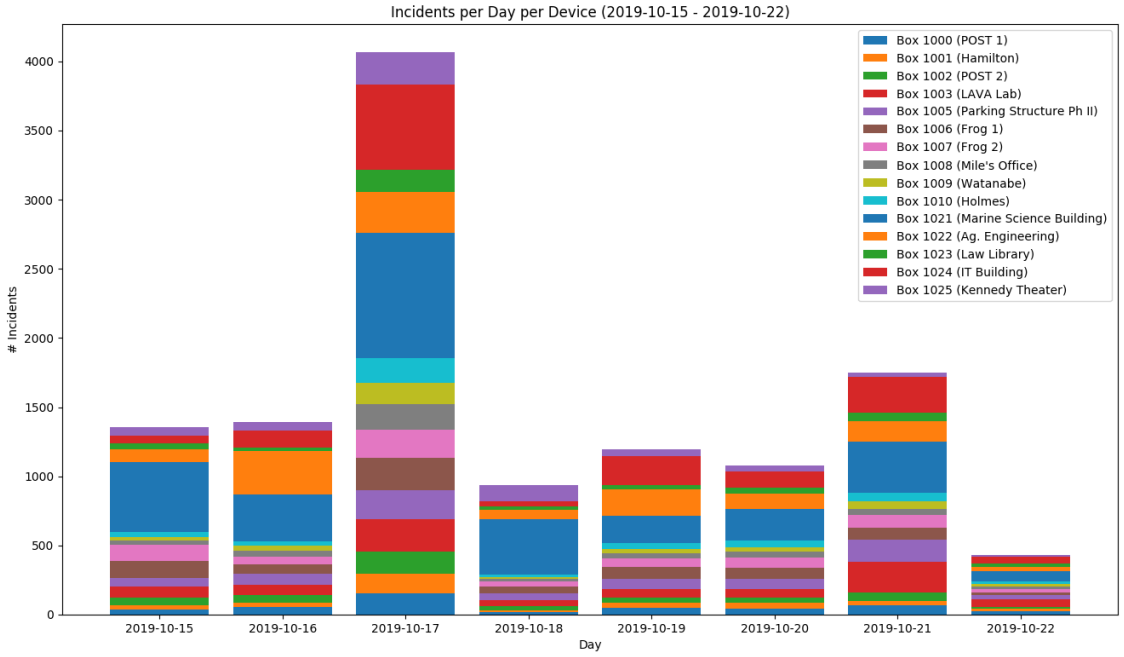
A breakdown of Incidents per Box is provided in the following table.

OPQ Box	Location	Incidents	F Swell	F Sag	Outage	F Int
1021	Marine Science Building	3016	1581	1435	0	0
1024	IT Building	1458	644	814	0	0
1022	Ag. Engineering	1256	633	623	0	0
1003	LAVA Lab	834	399	434	1	0
1005	Parking Structure Ph II	750	316	434	0	0
1006	Frog 1	730	243	481	6	0
1007	Frog 2	675	231	437	7	0
1025	Kennedy Theater	621	242	379	0	0

1000	POST 1	456	186	269	1	0
1002	POST 2	454	180	274	0	0
1010	Holmes	426	152	271	3	0
1023	Law Library	419	145	274	0	0
1008	Mile's Office	418	139	276	0	3
1009	Watanabe	366	134	232	0	0
1001	Hamilton	333	98	235	0	0
Total		**12212**	**5323**	**6868**	**18**	**3**

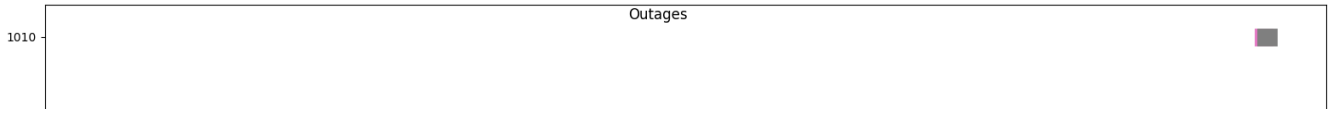
Incidents 2019-10-15 to 2019-10-22

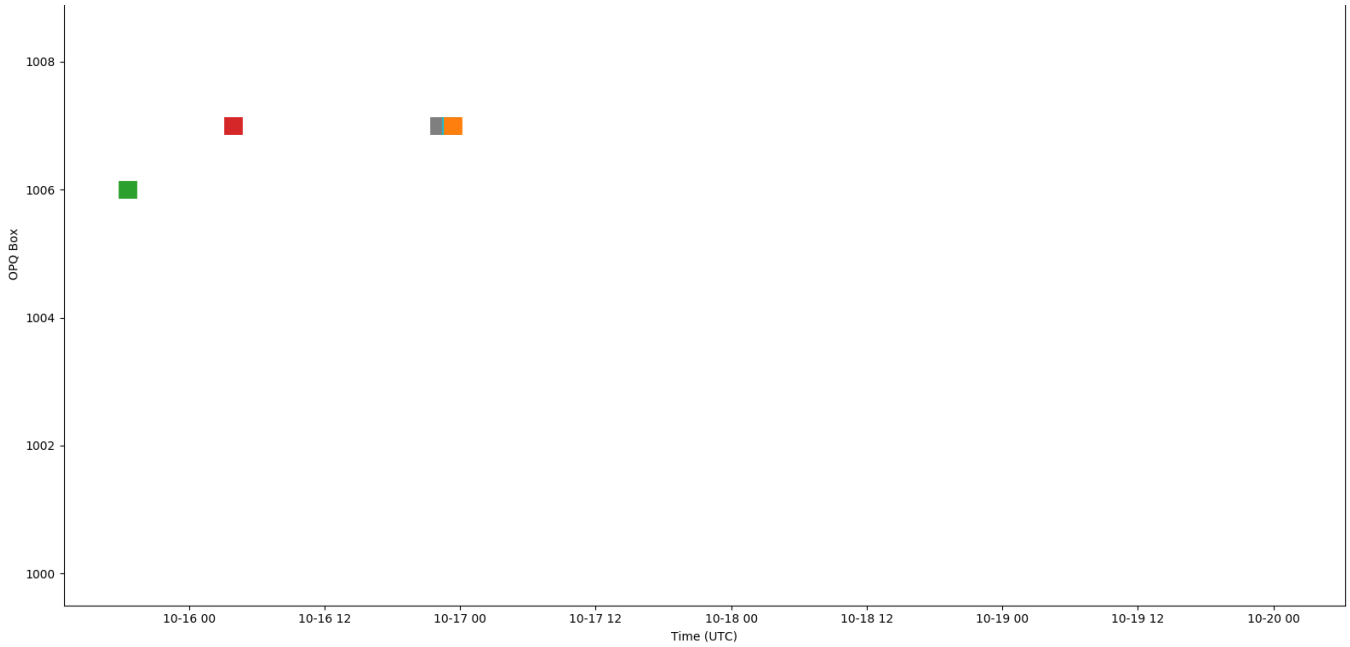
The following figure shows Incidents per Box per day.



We examined in more detail the frequency interruptions observed by Box 1008. Each of the 3 frequency interruptions were about 1 cycle in length which is incredibly small. They were classified with max frequency deviations of around -2 Hz each over the duration of a cycle. Due to the length of these incidents, it's likely that these incidents are false positives.

Next, we examined the outage incidents. Below is a table listing the outages that we observed.





Outages are identified by making use of a service called OPQ Health. OPQ Health is responsible for checking the up/down status of not only our software services, but also whether OPQ Boxes are up or down during a specified time range. Health inserts documents into the database providing the status of each OPQ Box.

The outage plugin checks the database for Health status documents. The outages that we observed do not have any associated records in the Health database collection. This tells us that the outage check is working as intended, but that doesn't mean that the OPQ Health service is working as intended.

Digging deeper, I realized I could look up associated measurements and trends for the outage range to see if we collected data for a particular Box during a supposed outage. If we have data, then the outage is a likely a false positive. Since trends are produced once a minute, it's possible that an outage range may not contain trend(s). Therefore, measurements are a better metric to use to verify outages since they are produced once a second.

While doing this, I realized that the Outage plugin has a bug where it doesn't update the TTL of measurements and trends when an Outage incident is created. The act of updating the TTL means that any measurements and trends associated with the outage will live as long as the outage incident (default 1 year). This bug has been fixed and any future outages will have the associated measurements and trends. I also ensured that all other Incident plugins update the TTLs correctly, and they do.

This isn't a complete loss though. We may not have measurements (which expire after an hour), but we should have trends going back 7 days (Oct 15). This means that we can check the trends for any outage that occurred after Oct 15.

Of the 18 outage Incidents, 3 of the Incidents (from Box 1007) contain trend data over the duration of the outage. This tells us that there are at least 3 false positives in the Outage Incidents.

It should be noted that as of Oct 21, the Trend data TTL has been increased to 2 weeks. This will allow us to analyze the previous week's trends without worrying if the data will disappear.

Conclusion

We still see a high number of frequency incidents this week even after slightly adjusting some of the parameters for the frequency plugin. It's clear that the frequency incidents still need some tuning.

The Frequency interruptions appear to be false positives due to the length of the Incidents. We will work to tune frequency incidents to ignore ones with such small windows.

The fact that we are receiving outage incidents that are likely false positives tells me there may be an issue with the way that we classify outages. The lack of health documents in the database points to OPQ Health as the issue. This will be examined and discussed.

I'm still surprised by the absence of any Voltage related Incidents. Perhaps this shouldn't be too surprising since the trends show mostly nominal data. However, we should still have observed at least one Voltage sag Incident and a few ITIC Incidents. I suspect there is an issue with the segmentation of VRMS values being fed into the Voltage analysis. This is something that I intend to investigate for next week.

Micro-report on the UHM micro-grid: Week 1 (Oct 7–14, 2019)

Open Power Quality
Oct 18, 2019 · Unlisted

Synopsis

This is the first weekly report on the Open Power Quality's (OPQ) UHM micro-grid power quality (PQ) sensor network deployment. The deployment has 15 PQ sensors (called OPQ Boxes) stationed at strategic locations throughout the UHM campus.

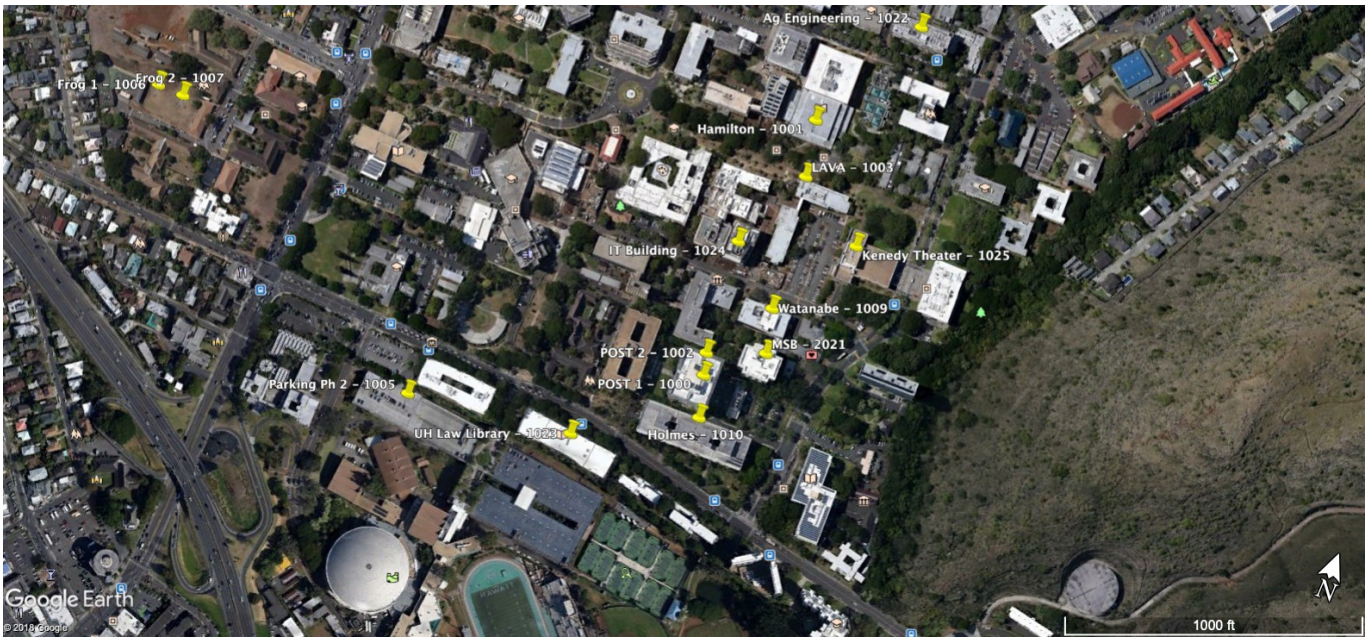
The sensors send data to a cloud-based backend running on infrastructure at the University of Hawaii. A live view of our system is available as is our open source hardware and software.

These reports will focus on high level PQ trends as well as investigate individual PQ Events and Incidents. We also hope to use these analyses to reveal insights into our tech stack.

These reports are produced by the following members of the Open Power Quality team: Philip Johnson, Anthony Christe and Sergey Negrashov.

Deployment

To begin, the following map and table illustrate where the 15 OPQ Boxes are deployed on the University of Hawaii campus.



OPQ Box	Location
1000	POST 1
1001	Hamilton
1002	POST 2
1003	LAVA Lab
1005	Parking Structure Ph II
1006	Frog 1
1007	Frog 2
1008	Mile's Office
1009	Watanabe
1010	Holmes
1021	Marine Science Building
1022	Ag. Engineering

1023	Law Library
1024	IT Building
1025	Kennedy Theater

OPQ Deployment 2019

General Summary

October 7–14 contained two occurrences of particular interest:

1. A significant frequency sag on Oct 8th visible across the entire OPQ network.
2. A large thunderstorm which passed through the island of Oahu on the morning of Oct 11th.

Trend Data (Oct 7–14)

OPQ "Trend" data measures the minimum, average, and maximum values for Voltage, Frequency, THD, and transients for each OPQ Box at a rate of 1 Hz (once per second).

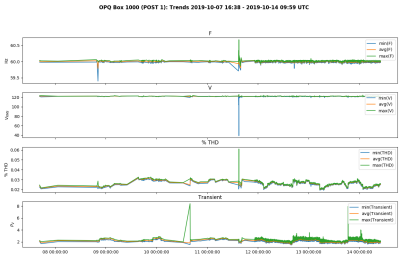
Each trend chart below has the same X and Y axis scaling so you can easily compare different boxes by visual inspection. In addition, the chart contains horizontal lines indicating "nominal" values. In general, deviations in values within the nominal range are not problematic.

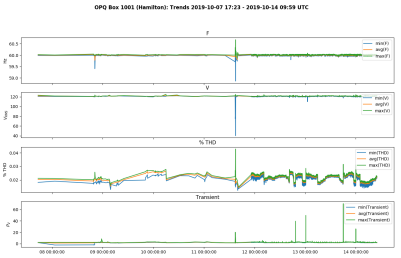
As noted above, there were two interesting occurrences this week. First on October 8, there was a frequency sag collected on all boxes. We do not know what caused this sag, but it was (within? outside?) nominal value.

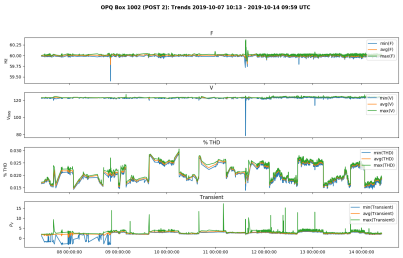
Second, the thunderstorm on October 11 caused deviations in Frequency, Voltage and THD.

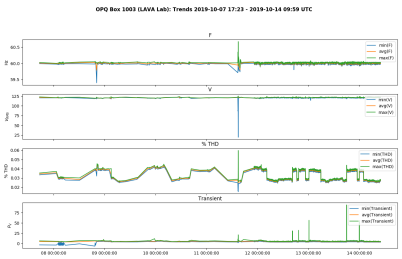
We also observe cyclic daily trends in THD and transients that we suspect may be related to the cycling of intermittent renewables (such as those from PV), but more research is needed to annotate these trends with confidence.

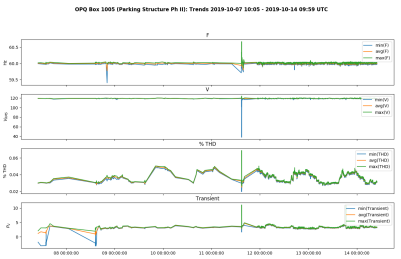
The following figures show Trends for each Box between October 7, 2019 and October 14, 2019.

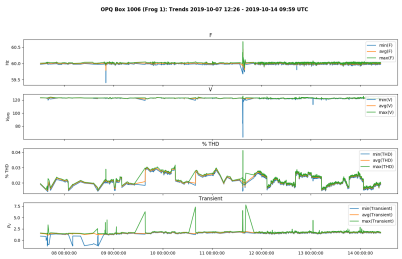


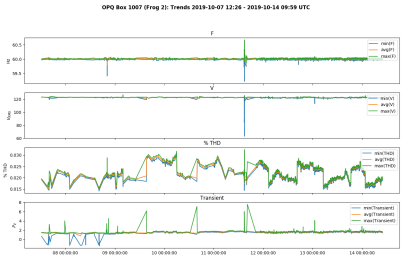


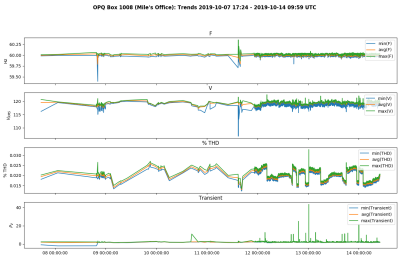


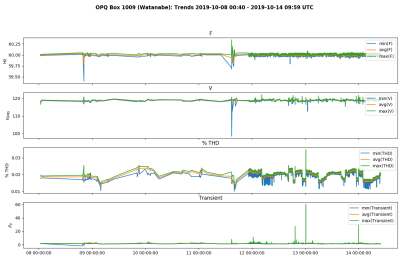


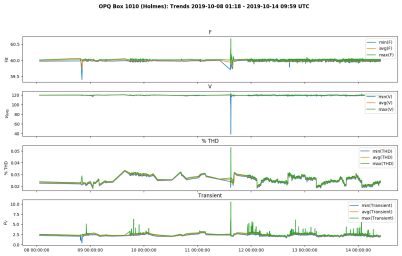


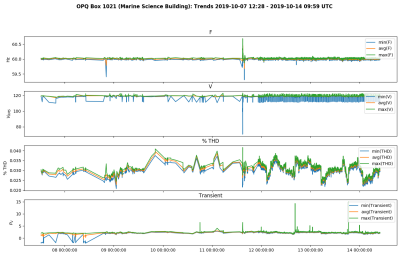


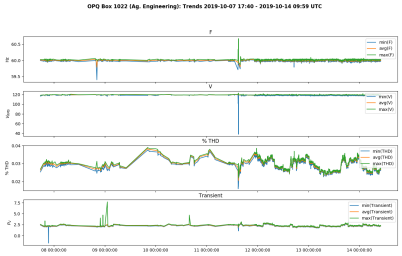


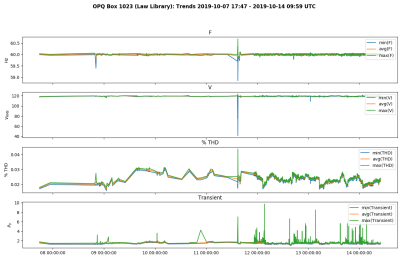


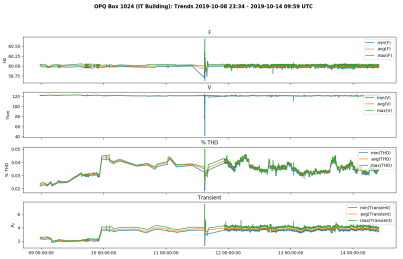


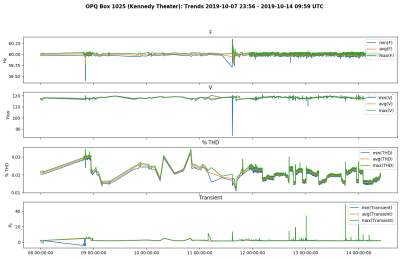












Event Data (Oct 7 -14)

Events are intervals in time in which the system has collected high fidelity (waveform) data in order to assess whether or not there are power quality issues, and if so, what might have caused them.

Event data is generated by two methods. The first method uses Voltage, Frequency, and THD thresholds as defined by IEEE. The second method uses the Napali Trigger which was developed by Sergey as part of his dissertation research. The Napali trigger uses statistical methods to determine when Boxes may contain PQ issues.

From October 7–14, there were a total of 32,754 Events collected across the 15 boxes, broken down as follows:

OPQ Box	Location	Events Generated
1021	Marine Science Building	4384
1002	POST 2	4198
1007	Frog 2	3487
1006	Frog 1	3148
1022	Ag. Engineering	3066
1025	Kennedy Theater	2199
1000	POST 1	2168
1003	LAVA Lab	2071
1010	Holmes	1883
1005	Parking Structure Ph II	1693
1024	IT Building	1126
1023	Law Library	1073
1008	Mile's Office	916
1001	Hamilton	682
1009	Watanabe	660
Total		**32754**

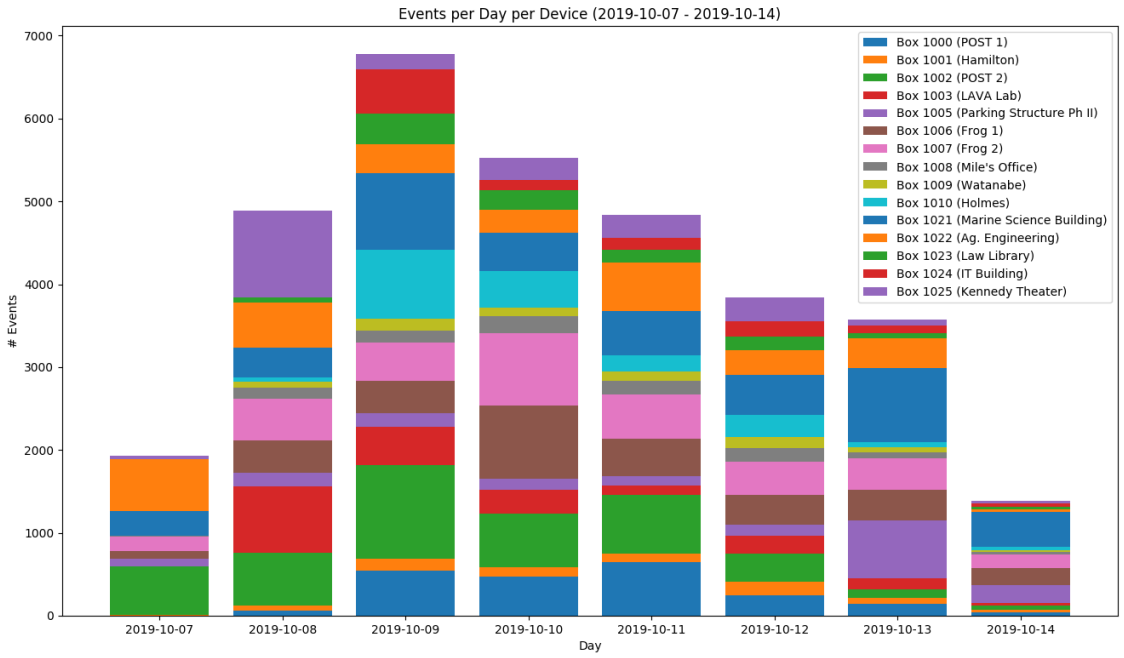
Events 2019-10-07 to 2019-10-14

The large number of Events doesn't necessarily indicate significant PQ issues, but it does indicate that there was a great deal of variation in Voltage, Frequency, THD, and transient trend data.

A large number of Events also creates a higher chance of generating classified PQ Incidents. It's not currently clear to us why some Boxes produce large numbers of Events

while others do not. We hypothesize that the Boxes that produce large amounts of Events have their metrics sitting right on top of the thresholds that are used for triggering.

The following figure shows Events per Box per day.



We'll note that there are less events on the 11th (day of the storm) than there are for other days which is somewhat unexpected. This could be caused by the Events for that day having larger trigger windows. In future, we intend to examine the distribution of Event window sizes and how they correlate to Incident creation.

Incidents Data (Oct 7–14)

Incidents are classified PQ issues that were found in the previously provided Events. Incidents are classified by OPQ Mauka according to various PQ standards. OPQ Mauka provides classifications for Outages, Voltage, Frequency, and THD related issues.

During Oct 7–14, a total of 14,382 Incidents were generated, or just under 50% of the number of Events.

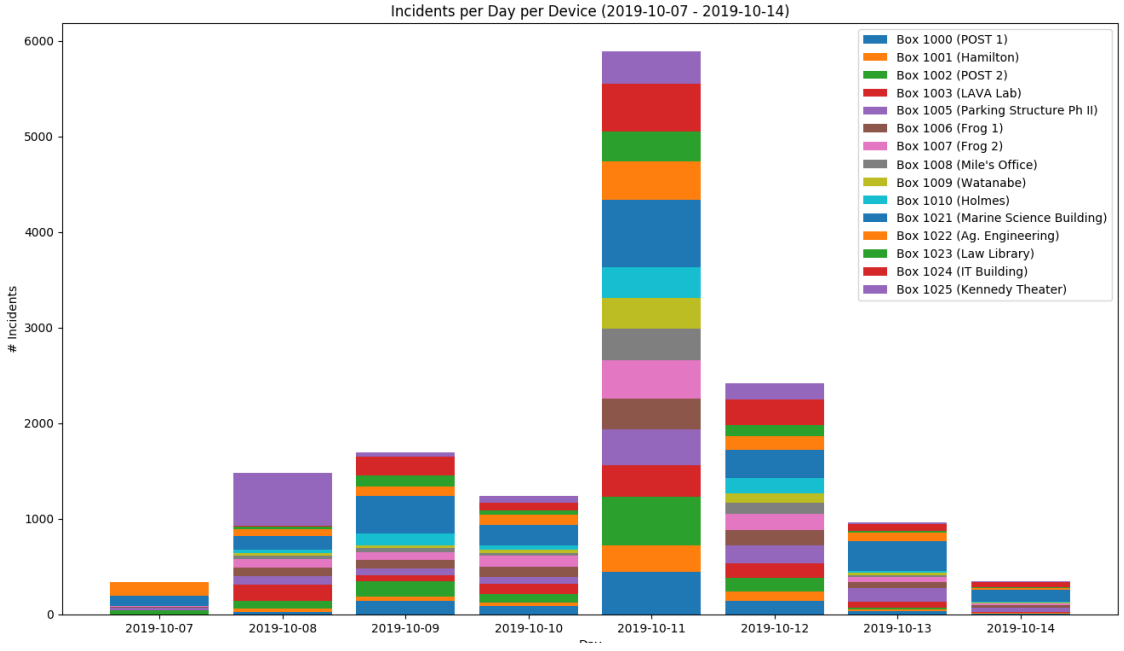
A breakdown of Incidents per Box is provided in the following table.

OPQ Box	Location	Incidents	F Swell	F Sag	Outage	F Int
1021	Marine Science Building	2293	1368	917	8	0
1025	Kennedy Theater	1208	640	568	0	0
1024	IT Building	1176	648	526	2	0
1022	Ag. Engineering	1079	601	478	0	0
1002	POST 2	1062	710	351	0	1
1005	Parking Structure Ph II	1000	559	434	7	0
1007	Frog 2	943	430	510	1	2
1000	POST 1	894	509	384	1	0
1003	LAVA Lab	888	442	432	12	2
1006	Frog 1	872	382	488	0	2
1010	Holmes	700	347	314	39	0
1023	Law Library	646	378	261	5	2
1008	Mile's Office	573	297	276	0	0
1009	Watanabe	541	294	247	0	0
1001	Hamilton	507	263	242	0	2
Total		**14382**	**7868**	**6428**	**75**	**11**

Incidents 2019-10-07 to 2019-10-14

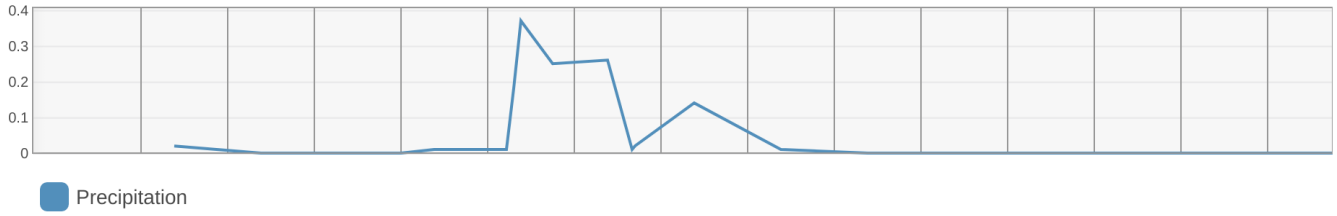
Most of the Incidents are either Frequency sags or Frequency swells. Although there are many Incidents, most of them are for very small amounts of time, such as those caused by transients. It's not clear that these are useful. It may make sense to parameterize the Frequency classifications to be a little less sensitive.

The following figure shows Incidents per Box per day. Clearly, the thunderstorm was responsible for the majority of Incidents, as would be expected.

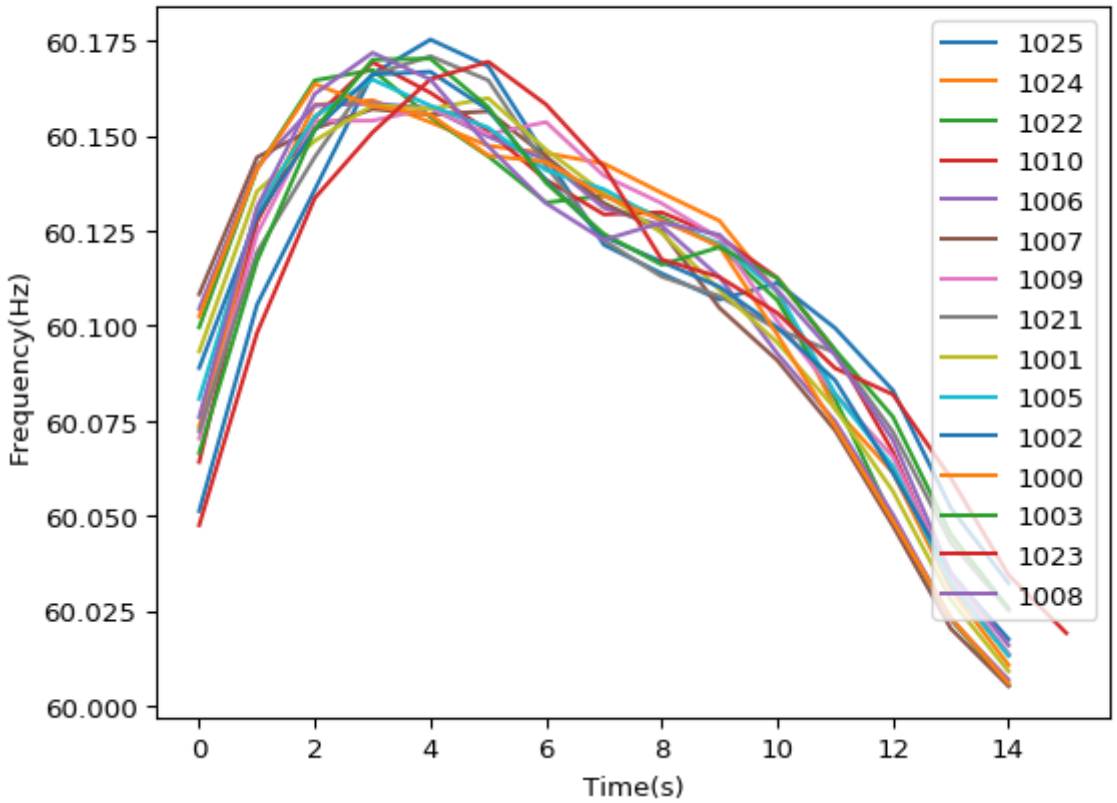


Storm of Oct 11th

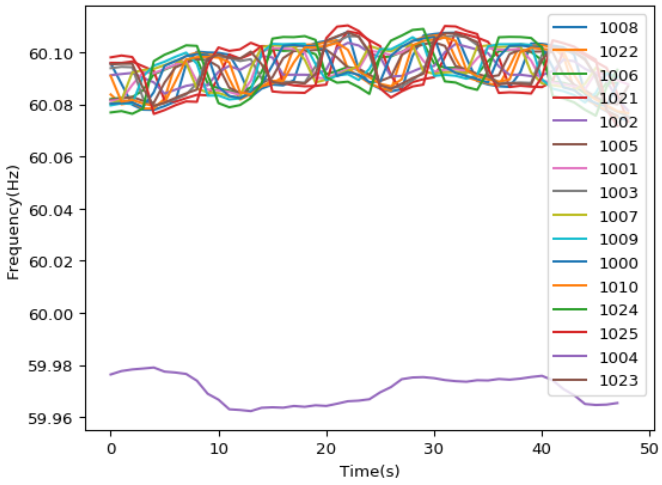
A large rain storm passed through the island of Oahu the night of Oct 11th. Below is the precipitation in inches per hour recorded by a rain gauge at the Daniel K. Inouye International Airport.

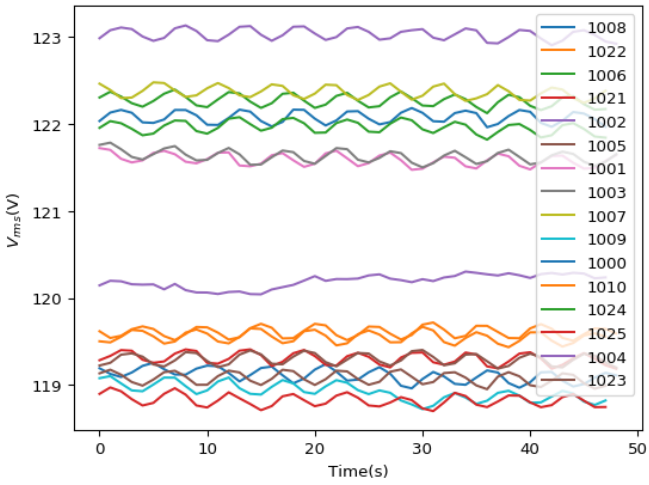


As the storm passed over Oahu, it had an impact on the power grid. Throughout the night we observed numerous frequency fluctuations such as event #171998 (https://ics02.colo.hawaii.edu/#/inspector/event/171998).



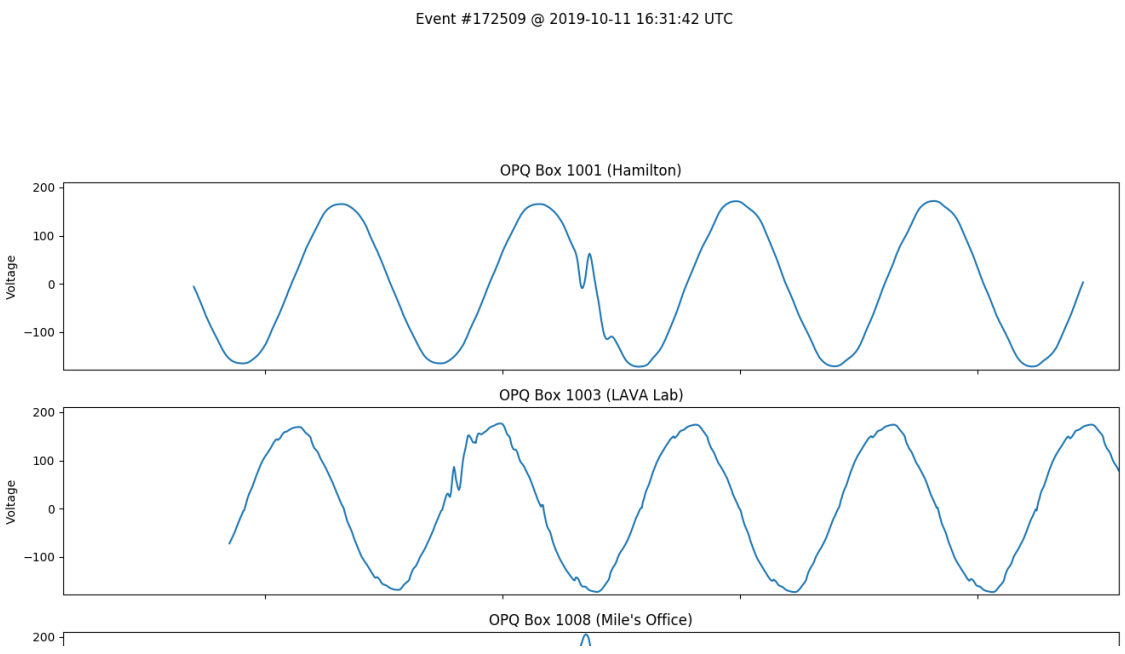
Furthermore, the OPQ network recorded numerous frequency and voltage flicker events, such as event #171218 (https://ics02.colo.hawaii.edu/#/inspector/event/172218) on October 11 at 6:01am:

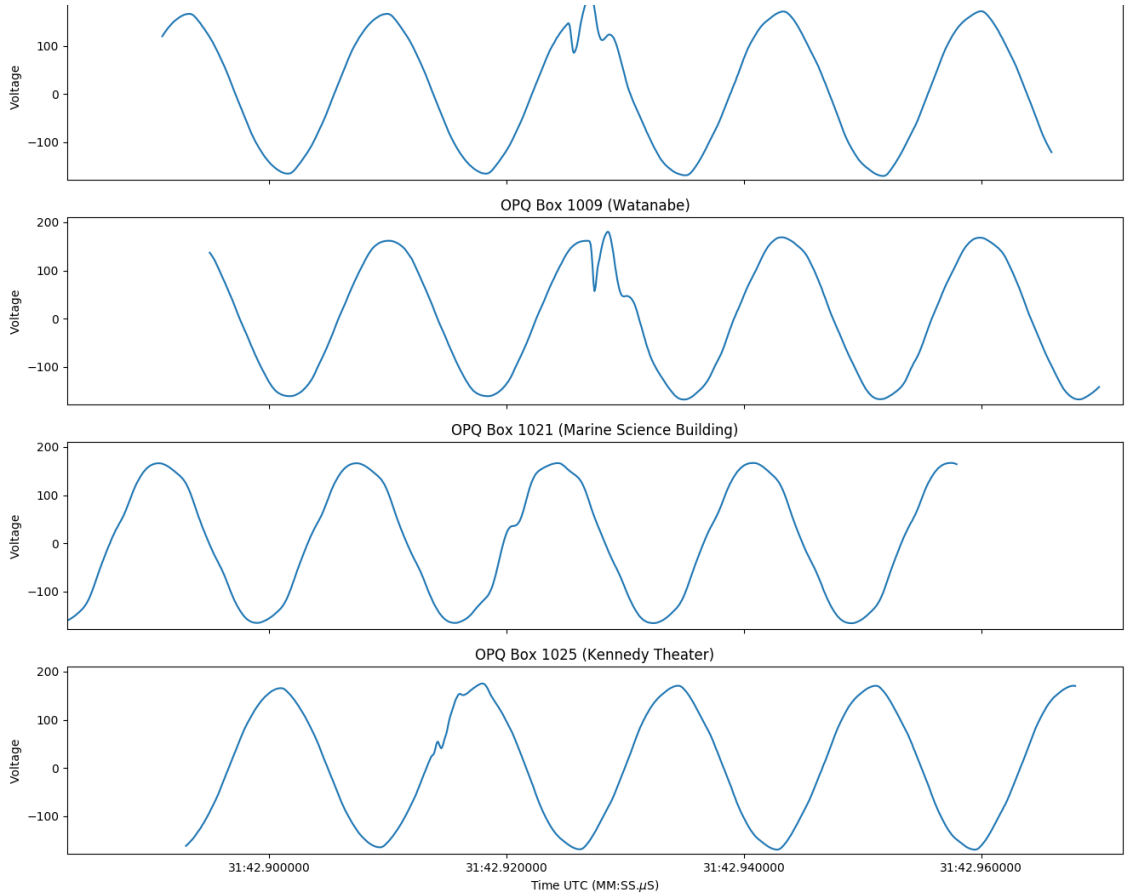




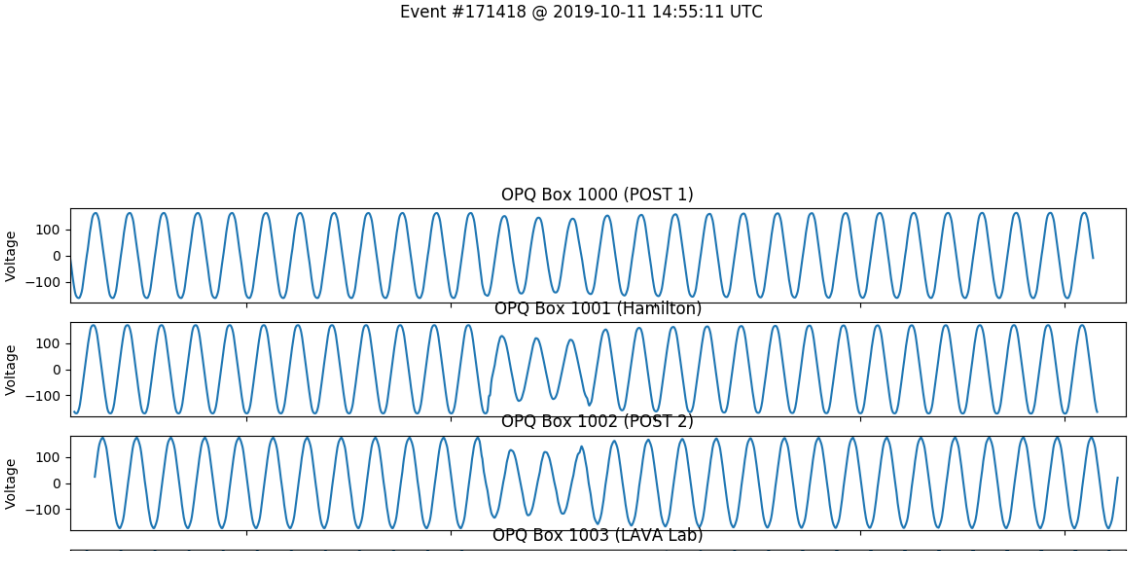
Notice, the device 1004 (next to last listed) is located in Nashville Tennessee, and is included as a reference.

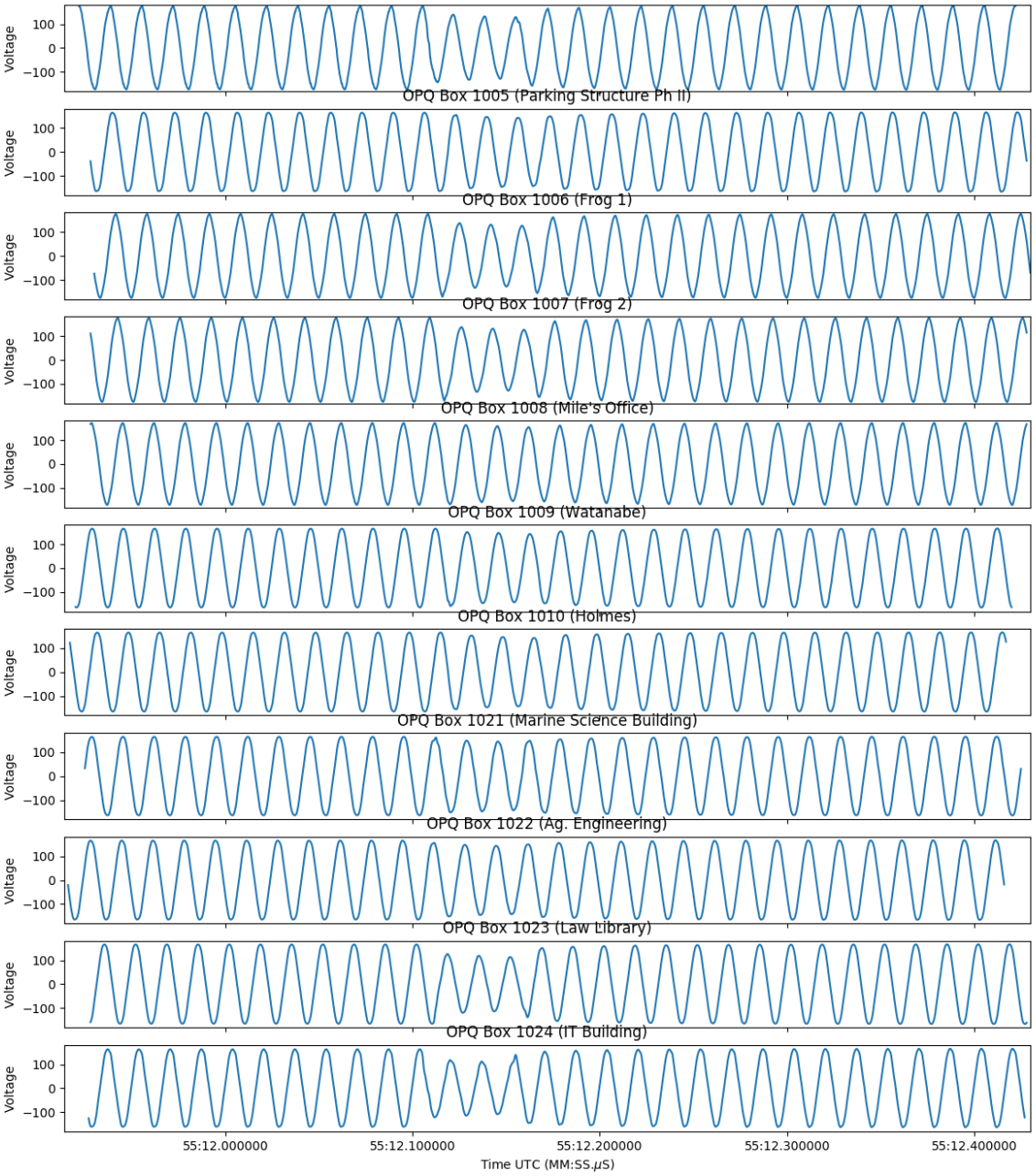
Numerous transients were recorded propagating through the grid. For example, Event #172509 (https://ics02.colo.hawaii.edu/#/inspector/event/172509) occurred on October 11 at 6:31am. Here are the waveforms for six boxes that recorded transients associated with this event.



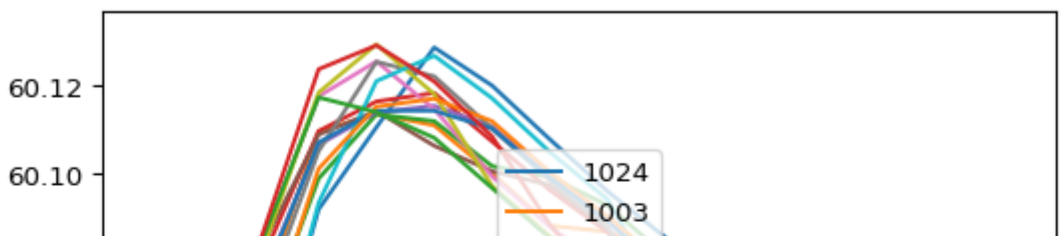


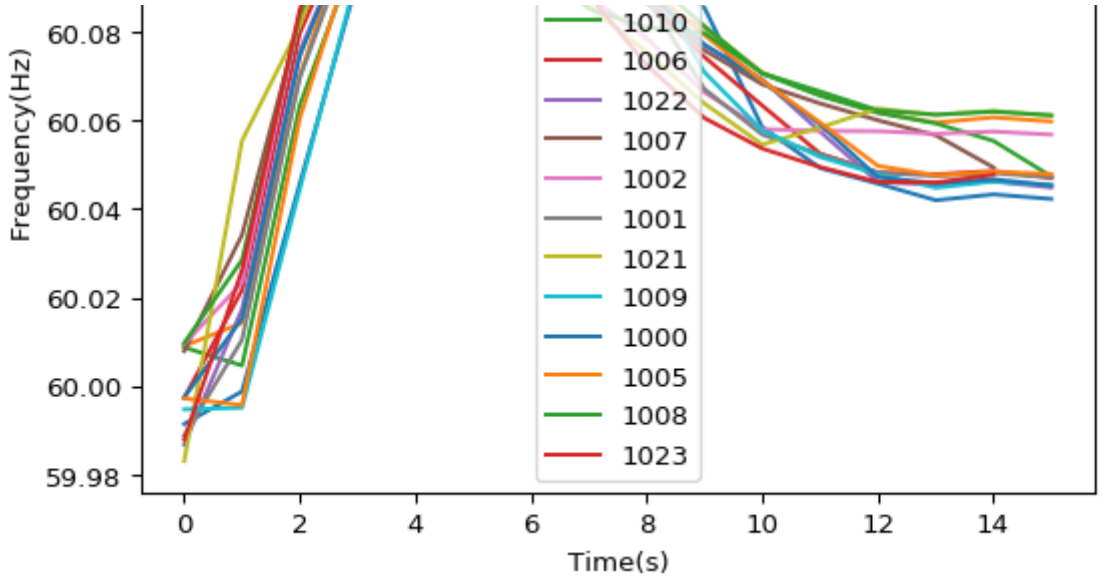
Finally, a large number of momentary sags were recorded throughout the storm. The most severe of these was event #171418 (https://ics02.colo.hawaii.edu/#/inspector/event/171418) on October 11 at 4:55am. Here is the waveform data for 14 out of 15 boxes:





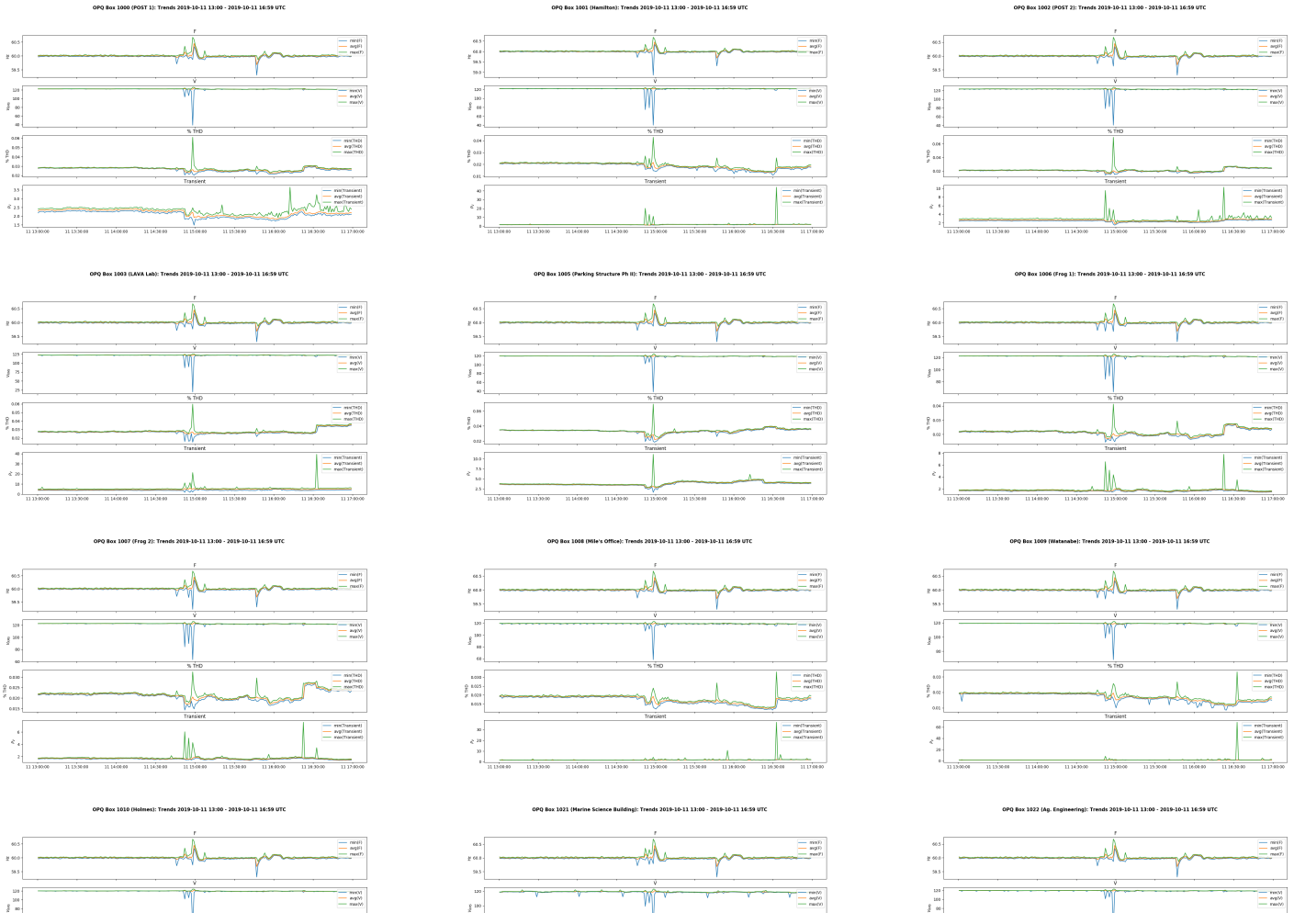
This event was followed by a significant frequency spike.

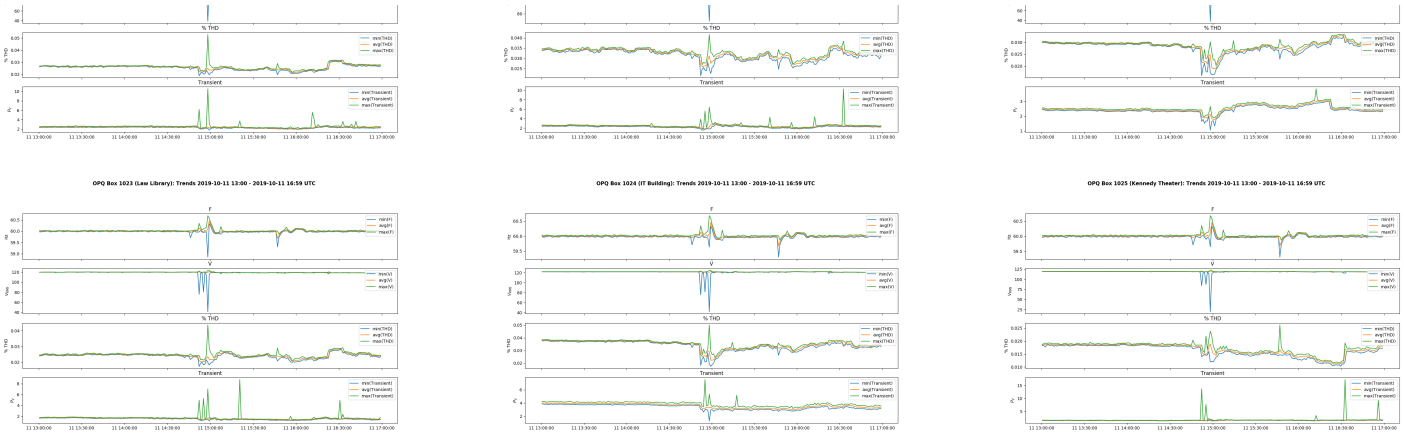




Storm Trends

Finally, let's examine the Trends for all Boxes over the duration of the storm. These trends are from Oct 11 13:00 UTC to Oct 11 17:00 UTC with the UH power outage centered in the middle at around 15:00 UTC.





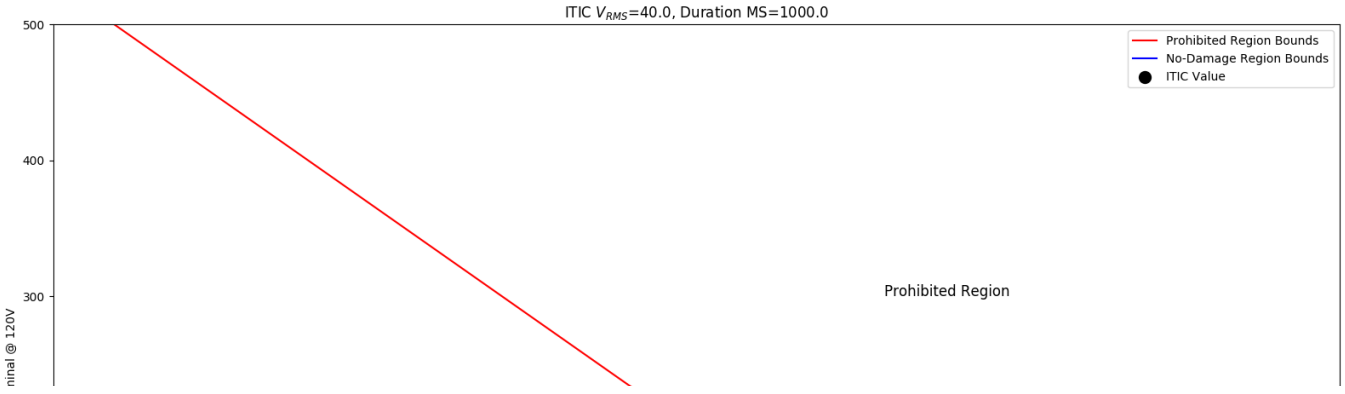
The trends clearly show how the PQ was affected for all sensors on the UHM micro-grid. We see an initial large Frequency swell on all Boxes followed by a separate Frequency sag about 45 minutes later. The network also experiences a several large Voltage drops. We also observed that the THD remains somewhat unstable after the first initial storm event.

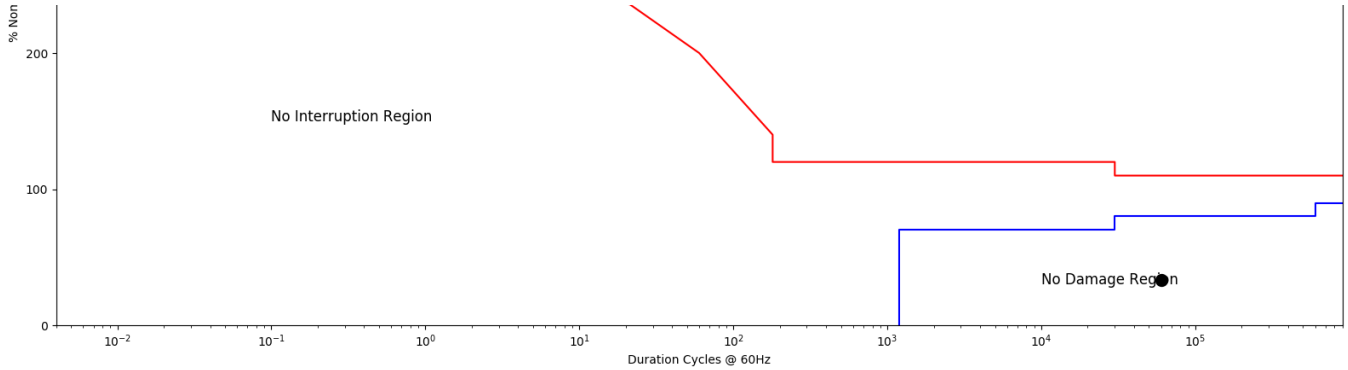
Conclusion

As this is our first weekly analysis of OPQ data, our conclusions are quite tentative.

In terms of PQ standards, Frequency fluctuations of half a Hz are certainly outside the nominal range and thus might indicate something significant.

The Voltage sag during the storm is also quite significant. It falls way outside of the thresholds for standard Voltage (+/- 6% of 120V) with a maximum sustained sag of about 80V from nominal. With voltages this low, electronic equipment might not operate correctly. The Voltage sag observed during the storm, according to the ITIC standards, was not sufficient to harm electronic equipment. The following graphic shows where this voltage sag occurred in the ITIC curve:





We were told that there was a power outage during the storm. We can see several outage Incidents during this time period that were likely generated due to the outage. However, our data does not make the outages clear, which we need to fix. The next step is to look at the building level power monitor data to determine when (or if) there were outages, and investigate why they are not apparent in our system.

With such a large abundance of Events and Incidents, we may need to investigate modifying our thresholds to collect less noisy data. We believe that the number of Events can remain large (since only Incidents provide any real classification), but may need to investigate modifying the thresholds for Incidents. Although the Incidents do appear genuine, they are often so small that they may not be interesting for PQ understanding. We need to investigate how we can either filter “insignificant Incidents” or provide a better measure of significant Incidents.

Unlisted

Data Science