

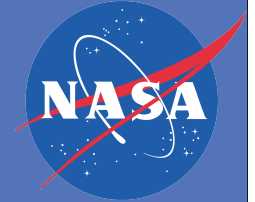


# Anomaly Detection in Power Quality at Data Centers

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## ABSTRACT

The goal during my internship at the National Center for Critical Information Processing and Storage (NCCIPS) is to implement an anomaly detection method through the StruxureWare SCADA Power Monitoring system. The benefit of the anomaly detection mechanism is to provide the capability to detect and anticipate equipment degradation by monitoring power quality prior to equipment failure. First, a study is conducted that examines the existing techniques of power quality management. Based on these findings, and the capabilities of the existing SCADA resources, recommendations are presented for implementing effective anomaly detection. Since voltage, current, and total harmonic distortion demonstrate Gaussian distributions, effective set-points are computed using this model, while maintaining a low false positive count.



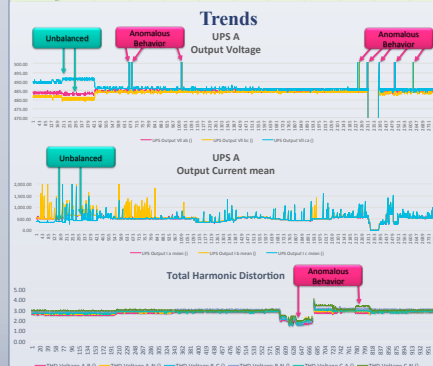
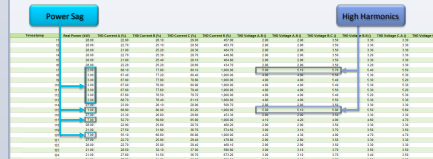
## INTRODUCTION

The aim of this project is to investigate possible anomaly detection tools within the StruxureWare Power Monitoring system. The goal is to try to use tools already built into the system to try and detect anomalies in the power quality. The starting point is the investigation of a previous failure. Our hypothesis is that anomalous behavior in the power quality can be used to detect anomalous load behavior and differentiate it from facility equipment degradation. Initial assumptions are that there were detectable abnormalities in the current, voltage, and/or total harmonic distortion (THD) prior to the failure. Criteria for project completion will be successful early detection of malfunctioning hardware and possible classification of the type of malfunction, whether load side or facility infrastructure.

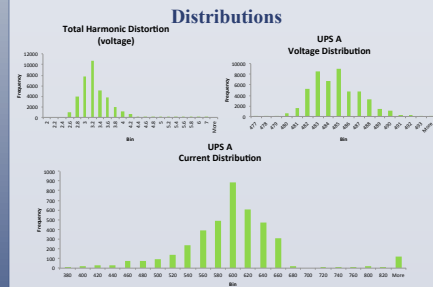
## VIZUALIZING RAW DATA



Power quality problems such as transients, sag/undervoltage, and harmonics exceeding the IEEE standard can be found when examining raw data around the time of known failures.



Plotting trend data from the StruxureWare historian shows outliers present in power quality.



Gaussian distributions indicate choosing proper set-points will be an effective form of catching anomalies in necessary features.

## OBJECTIVES

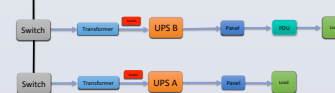
- Perform data analysis to check raw data for anomalous behavior.
- Investigate existing solutions for monitoring power quality with the ION meters and StruxureWare software.
- Calibrate the built-in StruxureWare SCADA Power Monitoring system to detect anomalous behavior in power quality.
- Detection of anomalies should give informative messages regarding what type of anomalies have occurred.
- Use and maintenance of anomaly detection implementations should be simple.



## MATERIALS & METHODS

- Schneider-Electric StruxureWare Power Monitoring Software
- Schneider-Electric PowerLogic SCADA Power Monitoring System
- Gaussian distribution of voltage, current, and total harmonic distortion indicate that an estimation of Gaussian distribution can be formed for these features. The result will indicate the probability of the current value occurring. If the value is extremely unlikely to occur, it is an anomaly and should throw an error.
- Gaussian distribution is given by
 
$$p(x, \mu, \sigma^2) = \frac{1}{\sqrt{2\pi\sigma^2}} e^{-\frac{(x-\mu)^2}{2\sigma^2}}$$
- Choosing the smallest threshold of probability while maintaining low false positives can be chosen by selecting the threshold with the highest  $F11$  score on a large set of test data.
- $F11$  score is given by  $F11 = 2 \cdot \frac{prec \cdot rec}{prec + rec}$  where,  $prec = \frac{tp}{tp + fp}$  and  $rec = \frac{tp}{tp + fn}$

## ONE-LINE DIAGRAM



## RESULTS

- Anomalous instances of voltage found at the input and output of UPS A
- To isolate the anomalies, data from the UPS's source and panels at the UPS's output was analyzed
- Through the historical trend data, voltage anomalies are isolated to UPS A, transformer, and switch
- Waveform capture is possible at UPS A using the StruxureWare Power Monitoring software and built-in circuit monitor meter
- Proper configuration of the circuit monitoring meter on UPS A will log anomalous waveforms and allow the data center to study what is happening during an anomalous event at each individual waveform cycle

## Future Work

- Perform waveform capture on an anomalous event
- Examine the distributions and relationships between other measured features.
- Explore how 'Learning' is done by advanced meters.
- Compare effectiveness of Gaussian anomaly detection against advanced techniques used in newer meters.

## RECOMMENDATIONS

- It is unclear what is causing the anomalous voltage readings in the data stored on the historian. Using the StruxureWare Power Monitoring software and the circuit monitoring meter on UPS A, it is possible to set triggers to perform waveform capture when a certain condition is met. Examination of what occurs in the voltage cycles could reveal why the historian is recording such high voltages at certain intervals.
- Upgraded meters on the electrical panels offer more functionality than the existing meters. Current meters do not offer disturbance detection however meters such as the PM 8000 offer compatibility with current StruxureWare software as well as modules that offer waveform detection, set-point learning, and advanced diagnostics not offered by the current meters.

## LIMITATIONS

Due to the sensitive, critical, and classified information stored at NCCIPS, access to the monitoring software was restricted. Instead, time was scheduled with appropriate staff to access, explore, and configure the system. Unrestricted access limited the ability to freely explore the functionality of the software. Documentation of software was researched to mitigate access restriction.

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