



# T&D POWER QUALITY ANALYSIS

Using Revenue Grade Advanced Metering

## ABSTRACT

Although there are many PQ measurement devices available to a utility to analyze transmission and distribution power quality issues, most PQ meters can only be installed temporarily. Wouldn't it be a lot more convenient and practical to install a device that can be left on site permanently to provide continuous power quality monitoring and logging? You can do it with the right revenue grade billing meter.

Charles Kachel P.E.

## Executive Summary

A lot more scrutiny is being paid to power quality issues these days. Utility customers have become more concerned about the quality of the power the utility is providing, and utilities are much more concerned with the effects certain customer loads (LED lighting, Variable Frequency Drives, Inverters used in Photovoltaic and Wind Turbine Generation, other non-linear devices) may be having on their transmission and/or distribution systems. In addition, there are the typical maintenance issues related to capacitor banks, reclosers, fuses, insulators, conductors, and substations that can consume a lot of utility resources. It is not unusual for a utility to have one or more engineers on staff that spend the majority of their time analyzing anomalies on the transmission and distribution systems they own. Likewise, it is not unusual for utility customers to have facility engineers on staff with specific knowledge and training related to power quality.

With declining utility electric revenues nationwide\* and the effect of global competition on utility customers, the quality of power, both from a utility and a utility customer perspective, has become an extremely important profitability concern. In many cases, the only recourse a utility has to maintain an acceptable margin is to lower costs. By leveraging revenue meters with advanced power quality capability, a utility can ultimately reduce maintenance costs for their transmission/distribution system. This paper will present case studies that demonstrate the benefits of deploying utility revenue meters with advanced power quality capability for commercial/industrial customers.

## Continuous, Permanent, Power Quality Data

Imagine you are a Power Quality engineer at a major electric utility somewhere in the United States where there is a four season climate. One of the company's largest industrial accounts has been struggling with power quality events that have affected their production schedule and profitability. A recent event cost over \$100k in damage to machinery and machine tools, and the customer is asking a lot of questions. What option do you have to try to collect data that can be used to analyze the problem and arrive at the root cause?

You have some portable, advanced PQ analyzers at your disposal, so you decide to install one at the customer's location. At this particular location, the incoming lines terminate at a customer-owned outdoor substation with steel structure, where metering instrument transformers are mounted on the structure, and a socket based utility billing meter is mounted in an outdoor meter socket enclosure. The power quality analyzer connections would be made inside the meter socket enclosure; however, the device will have to be mounted to the steel structure to keep it off the ground. Historically, the customer has experienced damaging PQ events very intermittently, making a temporary PQ analyzer installation a less than ideal situation. You can't keep the analyzer there permanently, and within six months winter will begin. Even though the PQ analyzer can be installed outdoors using a weatherproof case, its operating temperature range may not be able to handle cold winter weather.

You decide to install the PQ analyzer for 6 months (June 1 – November 30) with a connection to the cellular router that is also connected to the utility meter. By the 30<sup>th</sup> of November you are ready to remove the analyzer, but there have been no customer complaints about voltage anomalies. Data downloads over the installed period reveal some voltage dips of 3%, but that is within the 5% acceptable variation for the distribution system. You decide to remove the PQ analyzer to avoid possible complications from winter temperatures that will certainly fall below the 32 °F lower operating limit.

So now you're a little frustrated. You really need continuous monitoring with a permanently mounted PQ logging device. After giving it some thought, you decide to contact an engineer in the metering group for information on the new advanced meters the company has just started purchasing. The Metering engineer you speak to gives you a rundown on the capabilities of their new billing meter that is just starting to be used for the company's largest electric accounts. He tells you the meter will also measure and record a large variety of power quality conditions and events. You are skeptical about the power quality measurement capability of a meter used for revenue purposes, but you decide to give it a try. The Metering engineer has the new meter installed at the location of the customer in question within several days. It is programmed to send email to a group mailbox whenever a PQ event is recorded that falls outside the limits that you specified, and which the Metering engineer programmed into the meter before it was installed. Whenever an event occurs, all members of the group mailbox will receive notification. You have yourself added to the group mailbox member list. After several

months, an email is sent from the meter installed at the customer's facility. A PQ data download from the meter includes tabular and waveform data. You contact the customer's Facility engineer immediately, to discuss the situation. He is surprised you found out about the PQ event so quickly, but is glad to discuss the recent event. You begin to analyze the PQ data from the meter and over the course of the next several months, enough data is acquired from the meter to recommend some actions to the distribution engineer in the area, and the problem is finally resolved. You meet with the customer to present your analysis and solution, and the customer is completely satisfied.

Even though the situation described above is hypothetical, the same scenario played out many times over my tenure as the Primary Metering engineer at We Energies in Wisconsin. The addition of Electro Industries' Nexus® 1272 meters to our primary rate accounts allowed many problems to be solved using the advanced power quality capabilities of the meter. Although PQ analyzers were used as supplements in some cases, installing a Nexus® 1272 billing meter was adequate for most of the power quality investigations that were performed. Many of these PQ issues were costing We Energies' customers many thousands of dollars and eroding customer confidence. After 5 years of Nexus® 1272 meter deployments to We Energies primary rate accounts, customer satisfaction scores in the annual TQS Research survey moved from the second quartile to the first quartile and eventually reached the top 5 utilities in the country. Obviously it takes more than one improvement to improve customer perceptions, but the scores improved despite almost yearly increases in electric rates. Customer focus and improved response to distribution system problems had something to do with that. The addition of Nexus® 1272 meters for billing and power quality analysis made that possible.

There was also the benefit of using PQ data from Nexus® billing meters for planning various substation conversions and rebuilds. By utilizing PQ data from Nexus® 1272 meters, it was possible to do longer term studies and gather more accurate data for analysis. This allowed better decisions to be made regarding design and construction, which ultimately reduced project costs and improved distribution system performance.

## Case Studies:

Following are two case studies\*\* that demonstrate the value associated with the use of revenue grade meters with advanced power quality measurement and recording capability. The first study describes a project to rebuild a 60-year-old substation at We Energies, where there was a mix of heavy industrial, residential, foundries, sensitive loads (hospitals, data centers), and critical infrastructure loads (water purification and pumping), and various power quality concerns. The second case study details a situation with a major food processing customer in which frequent power quality events were causing the shutdown of variable frequency drives and interrupting production.

### Case 1: A Major Sub-Transmission/Distribution Substation Rebuild

Description: 1950's Era Substation with 26.4 kV Sub-Transmission and 13.2 kV Distribution:

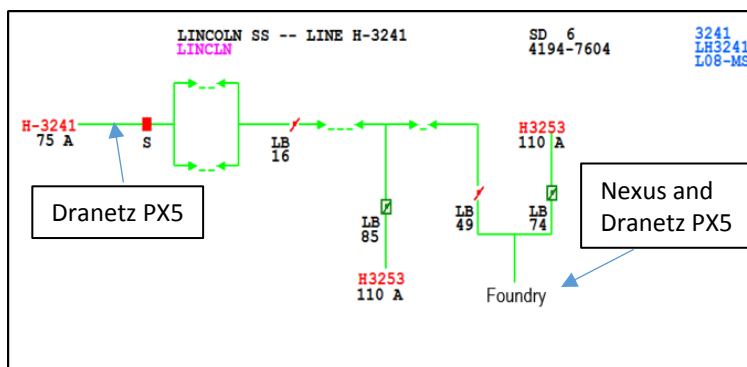
- 60 year-old transformers and oil circuit breakers
- 41kA symmetrical available fault duty at bus (940 MVA)
- Customer Load: Foundries, Heavy Industrial (large motors, high harmonics), Commercial/Sensitive Loads (Hospitals, Data Centers, Newspaper)
- Critical Infrastructure Loads (Water Purification and Pumping)
- Residential
- Continually developing/Growing load area

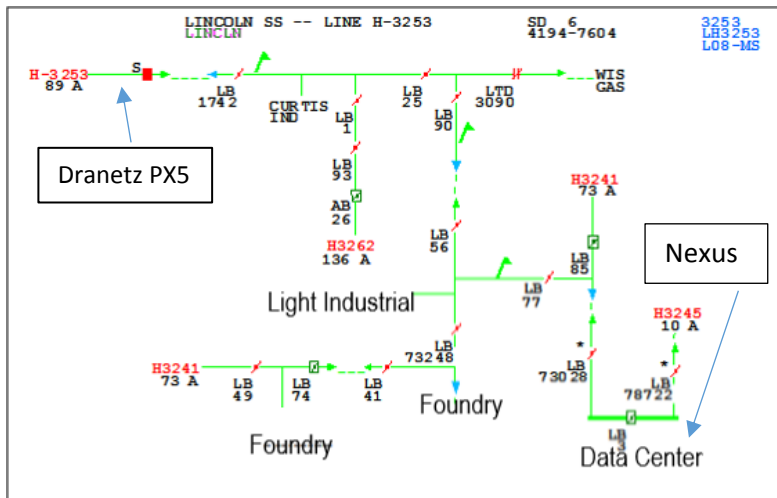
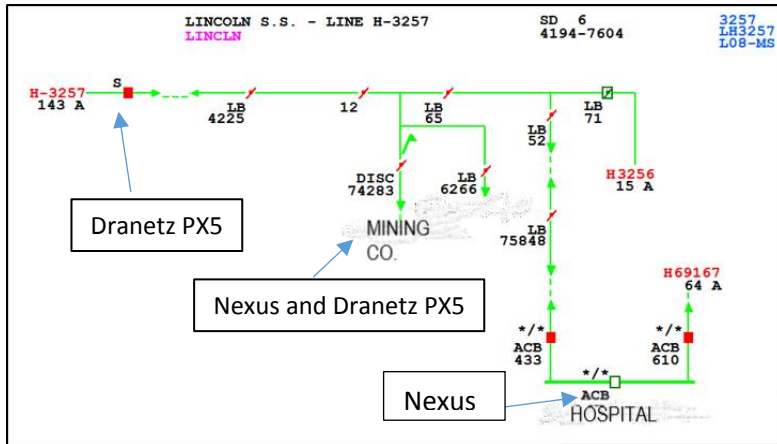
Plan: Need PQ analysis to quantify current state and the impact to key accounts:

- Mining Equipment Mfg. (Large motor testing – impulse testing up to 2000 HP motors)
- Steel Foundry (Large Arc Furnaces – Flicker Source)
- Hospital (Sensitivity)
- Data Center (Sensitivity)

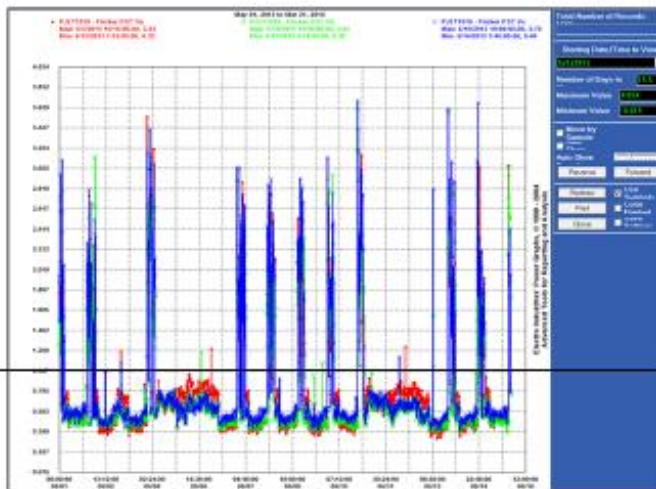
Use PQ measurement/recording devices: Dranetz PX5 portable analyzer, Nexus® 1272 billing meters, installed at key accounts.

**Diagrams of Connection Points and Resulting Nexus® 1272 PQ Data:**



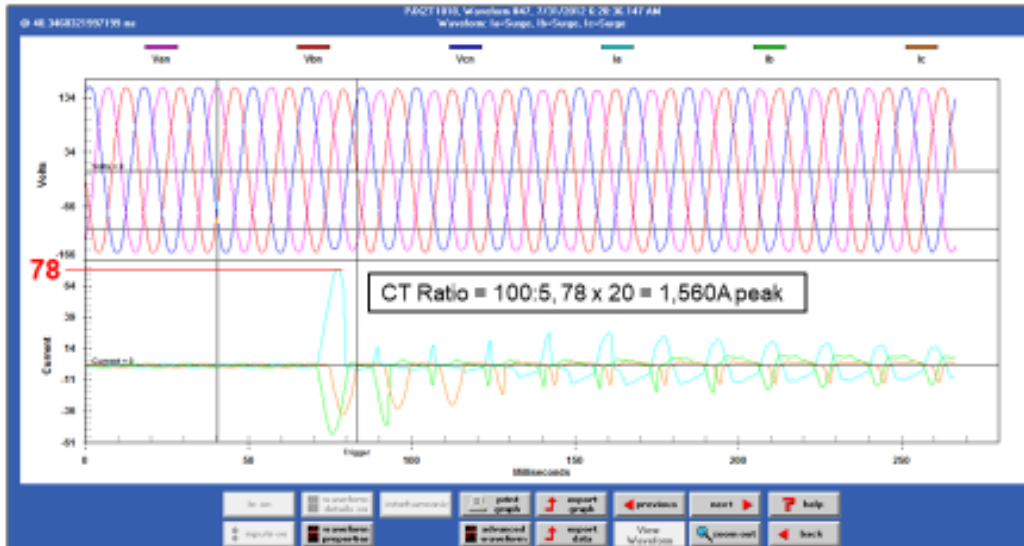


## Major Sub-T/Distribution SS Re-build



Foundry Nexus Meter Flicker Graph

## Major Sub-T/Distribution SS Re-build



Mining Company Nexus Meter Waveform Capture

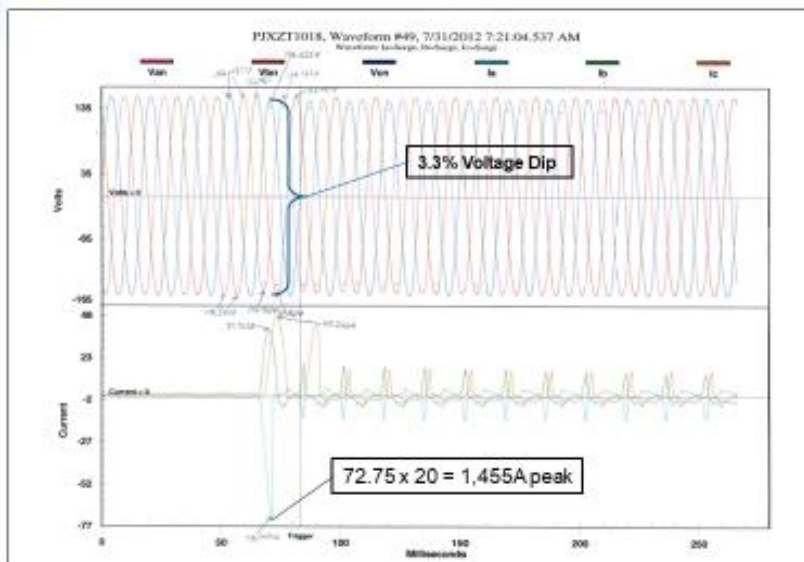
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## Major Sub-T/Distribution SS Re-build



Mining Company Nexus Meter Waveform Capture

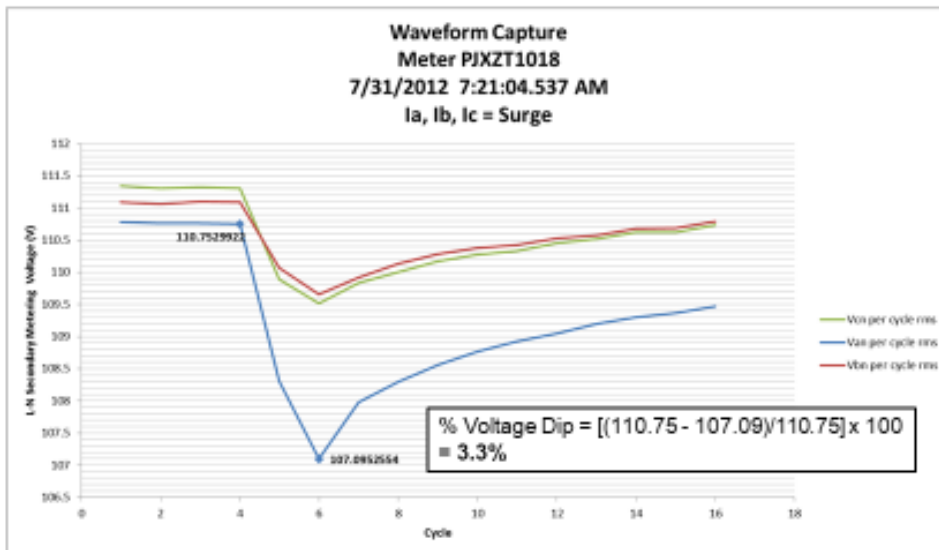
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## Major Sub-T/Distribution SS Re-build



Mining Company MS Excel Data Export Waveform RMS

The results of the PQ data review for the current state indicated it would be best to split the substation into two separate substations. A 13.2 kV distribution substation with 10 kA fault duty would serve the lighter loads, while the 26.4 kV sub-transmission substation with 21 kA fault duty would serve the heavier industrial loads using a “rough bus” and regulated bus. This allowed isolation of the arc furnace and motor test current surges on the higher fault duty sub-transmission substation.

## Case 2: A Customer Power Quality Complaint

**Description:** A large Primary Rate food processing company has been experiencing drop out of their variable frequency drive equipment. This has cost them as much as \$50k per incident due to lost production. A Nexus® 1272 meter had been installed in the recent past to start collecting power quality information due to the ongoing PQ issues.

**Plan:** Begin a systematic review using data from the Nexus® 1272 meter currently installed at the customer site.

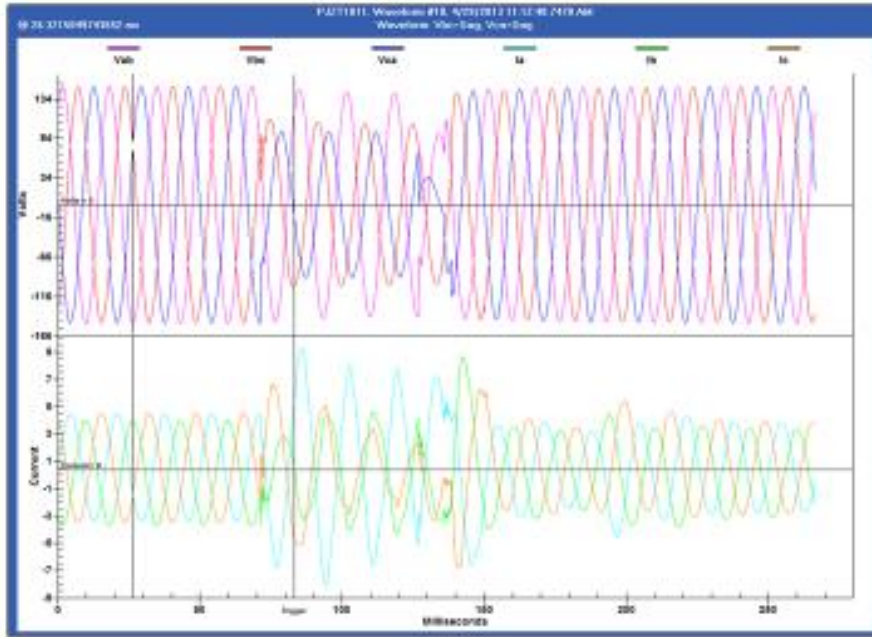
The customer is on a sub-transmission feeder of 26.4 kV. A 3-wire (2 element) Nexus® 1272 meter is installed with 2 VTs and 2 CTs connected in an open Delta configuration and B phase



serving as the neutral. The Nexus® 1272 meter is connected to a cellular router through the Ethernet port, for remote access.

### Waveform Capture of a Voltage Sag $V_{bc}$ and $V_{ca}$

## Customer PQ Complaint



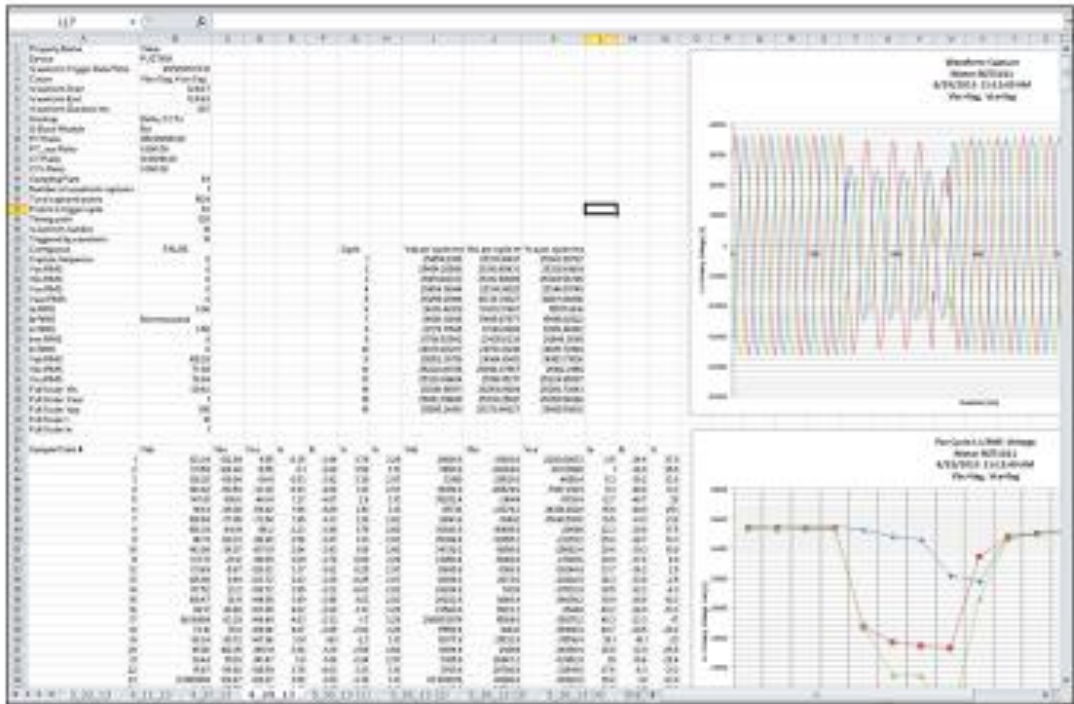
Nexus Meter Waveform Capture

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# Customer PQ Complaint

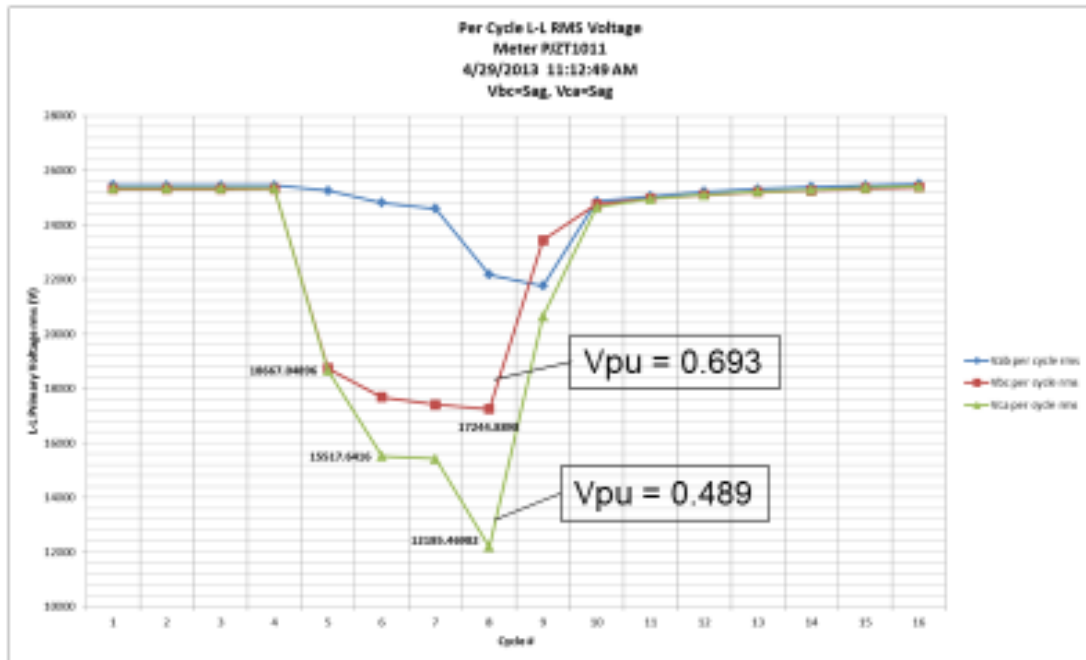


Nexus Meter Waveform Capture Data Exported

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## RMS Plot of the Raw Waveform Data

# Customer PQ Complaint



R.M.S plot created from raw waveform data

The data was shared with the customer and an evaluation of the factory operation revealed some opportunities for changes that would help their equipment ride through voltage sags. Another issue was that the nominal feeder voltage was below 26 kV, which might require more investigation by We Energies.

## Summation

Upgrading to Nexus<sup>®</sup> 1272 revenue meters for Primary Rate accounts and very large Secondary Rate accounts at We Energies has yielded benefits in power quality investigations and substation/distribution system upgrades. The ability to install billing meters with advanced power quality capability on feeders all across the company's service territory has increased the amount of available data and made data acquisition permanent, versus deploying a portable PQ analyzer for a short period of data acquisition. We Energies is also planning on using Nexus<sup>®</sup> 1500+ revenue meters at the Foxconn campus, which is under construction in the Racine, Wisconsin area. In terms of energy consumption, this plant will be the largest customer on the company's system. With that in mind, and taking into account the type of machinery that will

be in use, it is important for We Energies to be able to capture voltage transient information. Harmonic measurement will be important as well. That is why they are choosing the Nexus 1500+ meter as their billing meter, since it is an IEC 61000 Class A transient detection meter that samples the voltage waveform at 50 MHz, or 833K samples/cycle. By upgrading to Nexus® 1272 or 1500+ revenue meters with the most advanced power quality capability in the industry, your utility can become more efficient in maintaining the distribution system, and improve the service level to your largest accounts.

**Sources:**

\*US Energy Information Administration. *Detailed Data US Total*.[www.eia.gov/electricity/data/eia861m](http://www.eia.gov/electricity/data/eia861m)

\*US Energy Information Administration. *Today In Energy*.[www.eia.gov/todayinenergy](http://www.eia.gov/todayinenergy)

\*\*Zagrodnik, Nicholas. *Using Advanced AMI Meter Analytics for Performing Construction Planning and Power Quality Analysis – Case Studies*. Charlotte, North Carolina: EPRI Smart Distribution and Power Quality Conference and Exhibition. July 14-16, 2014