MULTIPLE TONES IN POWER CALIBRATION

Alex Dorchak
Fluke Corporation
6920 Seaway Blvd.
Everett, WA 98206
425 446-6443
halfdome@tc.fluke.com

Warren Wong
Fluke Corporation
6920 Seaway Blvd.
Everett, WA 98206
425 446-6376
warren.wong@fluke.com

Abstract - Increased usage of nonlinear loads such as personal computers, laser printers, and motor controllers is adversely affecting the quality of power distributed within a business facility. Of particular concern are the harmonics introduced on the power line by these loads, causing loss in productivity and potential safety issues. Another issue is the accuracy of revenue meters in the presence of these harmonics. Facilities personnel are purchasing and using sophisticated power quality monitoring equipment to quantify these problems. As with all precision test and measurement equipment, these instruments should be routinely verified and calibrated. International standards are being established to define the test requirements for these devices. This paper gives an overview of the power industry and makes a case for expediting the adoption of these standards to provide adequate traceability of power quality instrumentation and revenue metering.

INTRODUCTION

Over the last several years much has been made of the increasing need for high quality AC line power and of the increasing challenges faced by suppliers in delivering it. Of the many types of events that plague today's power systems, harmonic distortion presents a unique and difficult problem for providers of electric power, customers, and manufacturers of the test tools used to analyze this problem. Inaccurate measurements from this equipment can lead to improper billing, misdiagnosis of problems, and may have other financial and legal ramifications. With an ever-increasing number of these instruments being deployed, and the critical nature of their application, it seems inevitable that this instrumentation would be maintained on a regular calibration cycle with traceability to a national standards institution. Surprisingly, this is not typically the case. This paper explains why this equipment should be calibrated and why a convenient path of traceability must be provided. Finally it discusses where we are today and what may be done in the future to achieve these goals.

POWER QUALITY MONITORING: WHO, WHERE, WHY

Power Quality Monitoring at the Customer's Facility

The one constant in power distribution within a factory, financial institution, or other commercial site is that it is always changing. The addition of non-linear loads like adjustable speed drives (ASD) and ferromagnetic devices (transformers) can dramatically change the harmonic distortion levels within the system. Because of this constant reconfiguration, many businesses are installing permanent power quality monitoring equipment. When a problem does occur, the data can be retrieved for the facilities engineer to evaluate and act upon. Once power quality problems are detected, hand held portable test tools are often utilized to pinpoint the problems.

Power Quality Monitoring by the Utility

An electric utility may monitor power quality for several reasons. Often the utility will assist the customer in pinpointing problems within the customer's facility. This can benefit all parties as correcting power quality events that occur in one customer's facility can protect other customers on that same substation. For instance, if a customer installs a large number of ASDs in his manufacturing facility, third and fifth current harmonics are created on the AC line. These harmonics can affect a second customer on that same feed. If the point of common coupling is in a capacitor bank at the second customer's factory, detecting and determining the source of the problem quickly could save all parties substantial time and money.

The utility may also monitor its grid to gather statistical information about the number, type, and duration of events over their system. This information can be used to isolate problem areas within the system, or for predicting future performance. Notably, a multi-year project was conducted by the Electrical Power Research Institute (EPRI) in conjunction with several utilities across the United States. The Reliability Benchmarking Methodology project (RBM) attempted to gather a statistically valid set of data representing power line quality over the entire United States. Some 300 sites from 24 electric power utilities were monitored. The data was compiled via Internet links and entered into a customized database for analysis.

The first step for the RBM project was to develop a standardized set of Power Quality Indices, or quantifiable measures. These indices provide several key benefits, including a standardized set of terminology and a method to quantify large power quality databases. For harmonic content, 16 indices (or mathematical formulas) were defined; eight were defined for voltage, and likewise, eight were defined for current.

The RBM project produced several key benefits:

- Guidelines for monitoring and simulating distribution system power quality events.
- A distribution system power quality database and statistical analysis program.
- A recommended practice offering solutions to power quality programs.
- Baseline information for utilities considering premium power.

More information on this project can be obtained at the Web site:

www.electrotek.com/projects/dpq/dpq.htm

POWER QUALITY MONITORING AND DEREGULATION (WHO'S TO BLAME)

From turbine to toaster, the electrical system is divided into five key elements that are shown in Figure 1.

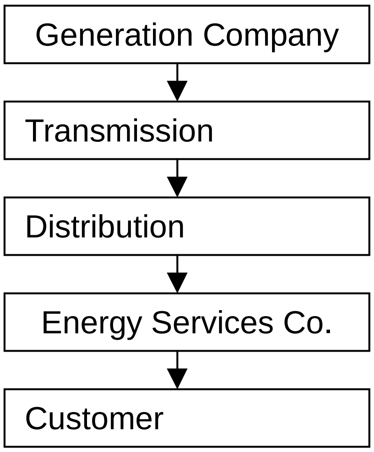

Figure 1. Electrical system before deregulation.

Prior to deregulation, the first four of these are normally controlled by a single or small group of companies. As deregulation continues, several companies may compete at each level [1]. To better appreciate the impact of deregulation, Figure 2 shows the increased complexity of the electric system. A major issue in this scenario is who is responsible for power quality. To win and maintain key customer accounts many utilities may be required to guarantee "premium" power. Examples of this are already appearing. In Detroit one local provider, Detroit Edison, has entered into contracts with each of the "Big Three" automotive manufacturers. In return for a ten year commitment from the automakers, Detroit Edison has agreed to maintain premium power for these users. If power events exceed certain maximum levels set within the contracts, Detroit Edison will pay expensive fines to the auto manufacturers.

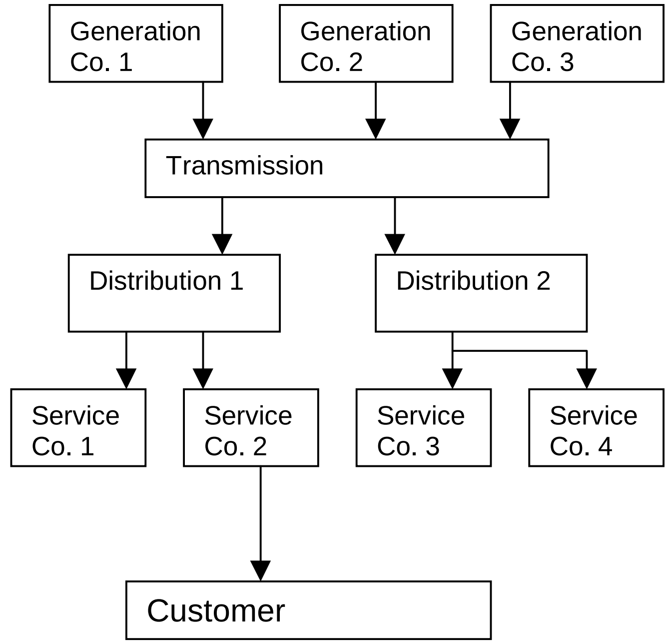

Figure 2. A possible scenario after deregulation.

In the age of deregulation, all parties in the electric system should monitor power quality. It is far less clear what will happen if monitors disagree and none have the proper level of traceability. The result in one California case was perfectly clear. The Claasen Mushrooms, Inc. company experienced serious power quality problems prior to its permanent closure in 1986. That company sued PG&E and was eventually awarded $5.5 million in damages [2].

The fines for power quality problems are not always levied against the utility. Many utilities collect hefty fines from customers that produce large levels of power line distortion.

PQ MONITORING AND REVENUE METERING

Many new revenue meter designs incorporate power quality monitoring capabilities. This functionality may be used by the utilities to monitor the number and severity of events induced on the system by the customer. Many utilities currently have graduated billing schedules for customers who negatively affect the power line quality. But the basic accuracy of some revenue meters, in the presence of high levels of harmonic distortion, has been challenged. Research conducted by the National Research Council of Canada (NRC) and others has shown that some revenue meters read incorrectly when exposed to non-sinusoidal waveforms. This is especially true for older induction meters that were not designed with harmonics in mind. While most revenue meters are on some kind of calibration cycle (at least on a sampled basis), they are not typically tested with non-sinusoidal signals. In their 1992 paper published in the IEEE Transactions on Power Delivery, Dr. P.S. Filipski and P.W. Labaj of the NRC describe an evaluation of four different reactive power meters in the presence of high harmonic distortion. In one case differences of 68% in measured power were observed [3].

With the high cost of energy, testing with actual use waveforms, i.e. non-sinusoids, must be a requirement. How this will be accomplished is less certain. Another paper, co-authored by Dr. Filipski and Dr. R. Arseneau (IEEE Transactions on Power Delivery, July 1995), describes a custom calibration system for harmonic power analyzers [4]. Presently, Fluke and other calibration companies are investigating calibration methods for these analyzers.

WHY CALIBRATE

To effectively troubleshoot and solve harmonic problems within any system, it is imperative that test tools produce a clear and accurate representation of the problem. It seems clear that if data collected with monitoring equipment is used to model a system, predict the future performance of a system, or to negotiate legal issues arising from the performance of a system, that equipment absolutely has to be calibrated traceable to some standard. This is certainly no revelation, as nearly all forms of application critical instrumentation are currently calibrated at regular intervals.

CALIBRATING WITH NON-SINUSOIDS

This paper argues that if these power analysis instruments are used to quantify non-sinusoidal waveforms, they should be calibrated with like waveforms. Often power analyzers are calibrated using simple sine waves. This is probably due to the high cost and unavailability of a traceable multi-tone solution. However, worldwide research indicates that using pure sine waves is inferior to using waveforms with pre-selected harmonic content [3] [5]. Work at the NRC suggests that a standardized set of multi-tone waveforms should be developed, based on real-world data [5] [6].

Figure 3 shows examples of possible voltage and current waveforms, with varying degrees of harmonic content, which can be used to test these analyzers.

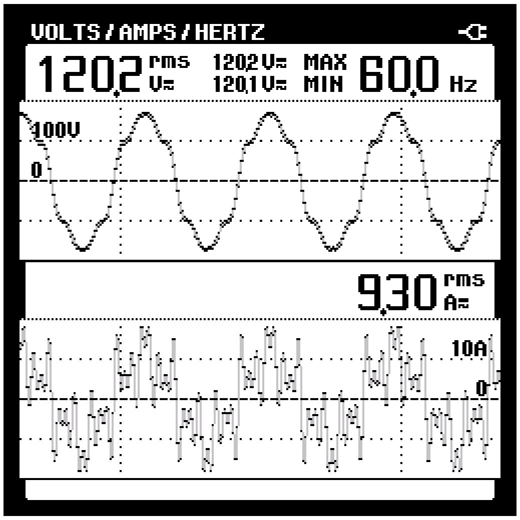

Figure 3. Possible test waveforms which better reflect real-life voltage and current waveforms.

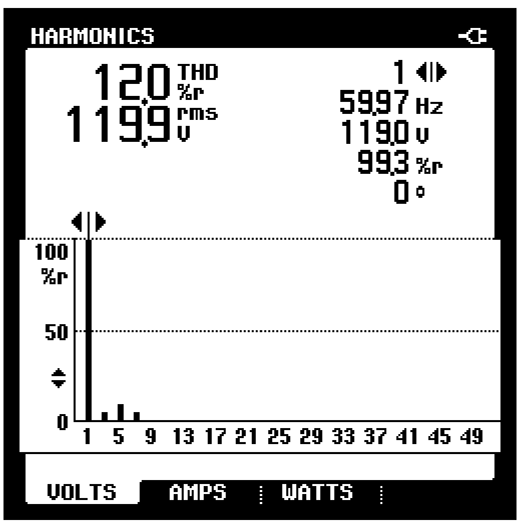

Figure 4. Harmonic content of the voltage waveform in Figure 3.

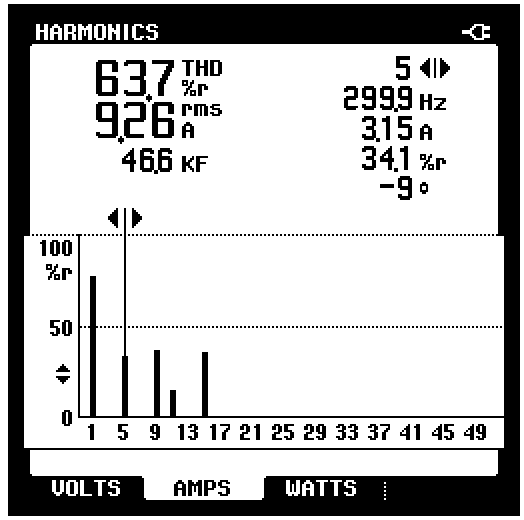

Figure 5. Harmonic content of the current waveform in Figure 3.

Along with identifying a set of “standard” waveforms, the infrastructure to provide traceability back to national standards institutions must be created.

MISSION CRITICAL: ESTABLISHING THE TRACEABILITY PATH

The Lack of Standards

The importance of this problem is recognized worldwide. The National Physical Laboratory (NPL) in the United Kingdom is currently chartered to develop a measurement service for non-periodic waveforms and fluctuating harmonics to support traceability of measurements under IEC-1001 [7]. Dr. Stefan Svensson of the Swedish National Testing and Research institute (SP) is researching methodologies for accurate power measurement of non-sinusoidal waveforms [8]. Similar work is being conducted by the Japan Electrical Testing Laboratory [9], and, as previously mentioned, the NRC in Canada.

A Low Cost Calibration System

As with other electronic instruments, power quality monitors are more likely to be maintained on a regular calibration cycle if the cost and turnaround time can be minimized. The availability of a low cost calibration system can provide that kind of service. As many monitors also measure other power quality events (e.g. sags and swells), these specialized functions along with harmonic-rich waveforms should be incorporated into a calibration system.
At present, there are no readily available calibration systems that meet the real requirements of power quality monitoring equipment. Some calibrators can at least produce accurate non-sinusoidal waveforms as shown in the lower part of Figure 6.

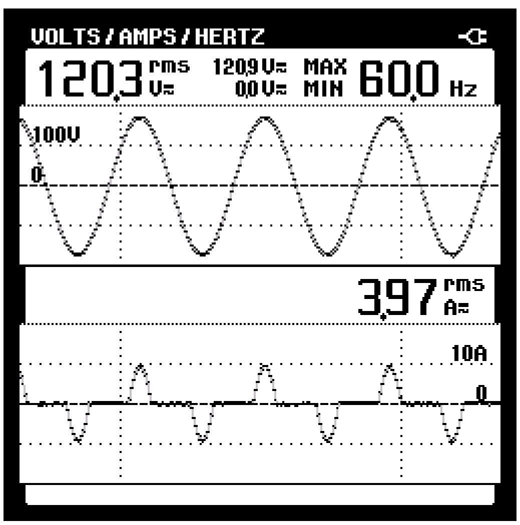

Figure 6. A truncated sinewave output from a commercial calibrator.

What is needed, however, are calibration instruments that can generate a suite of “standardized” waveforms like that in the NRC library. The Fluke corporation is presently researching the feasibility of expanding its multi-product calibrators to include these functions.

CONCLUSIONS

Power quality monitoring is growing worldwide due to an increasing number of nonlinear loads. While regular calibration of the instruments used to monitor and troubleshoot these power quality events is not currently the norm, this is likely to change. Research conducted internationally has shown these instruments should be calibrated using non-sinusoidal waveforms. A standardized set of waveforms should be developed for this purpose. These waveforms should simulate harmonic-rich, real world waveforms to provide the required traceability for these instruments.

REFERENCES

[1] Phil Hayet, "A Bird's Eye View of the Electric Utility Industry", Power Value '99 Conference, November 10, 1999

[2] Mark McGranaghan, Daniel Brooks, "Benchmarking Utility Power Quality Performance", PowerSystems World Conference, November 7, 1999

[3] P. Filipski, P. Labaj, "Evaluation of Reactive Power Meters in the Presence of High Harmonic Distortion", IEEE Transactions on Power Delivery, October 1992

[4] R. Arseneau, P. Filipski, "A Calibration System for Evaluating the Performance of Harmonic Power Analyzers", IEEE Transactions on Power Delivery, July 1995

[5] A. Ferrero, "On the Selection of the "Best" Test Waveform for Calibrating Electrical Instruments under Nonsinusoidal

Conditions", In the Proceedings of the 16th. IEEE Instrumentation and Measurement Technology Conference, Volume 2

[6] A. Domijan, Jr. et al, "Watthour Meter Accuracy Under Controlled Unbalanced Harmonic Voltage and Current Conditions", IEEE Transactions on Power Delivery, January 1996

[7] National Measurement System Electrical Programme (NPL) 1997 - 2000

[8] Stefan Svensson, "Power Measurement Techniques for Nonsinusoidal Conditions", Department of Electric Power engineering, Chalmers University, Gothenburg, Sweden, January 1999

[9] Japan Electrical Testing Laboratory, Inc. "JET Profile"