

Power Quality Monitoring for High Reliability Systems

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The internet economy is resulting in a tremendous number of facilities that require very high power quality and power reliability. These include traditional corporate data centers, customer service centers, web hosting facilities, server farms (internet hotels), telecommunications facilities, and many more. In the web hosting area alone, there is over \$8 Billion being spent on new facilities.

One common characteristic of all these facilities is that the cost of downtime is tremendous. Allen Wood of the Engineering Design Group said that the cost of downtime for a corporate data center, like the ones he was responsible for at Bell Atlantic, could typically be \$10 Million per hour. An outage will result in at least four hours of downtime due to the time required to get everything restarted. Costs for facilities hosting e-commerce sites can be much higher. One large e-commerce site quotes costs of \$10 Million per minute for downtime.

With these high costs, it is no wonder there is so much emphasis on the reliability of power at the facilities. Facility designers request high reliability service from the electric supplier, often involving dual feeds or network service. Then they design the facility with redundant systems for ride through of disturbances (usually UPS) and longer term backup (usually diesel generators).

We hear so much talk of reliability levels measured in the number of nines. However, this doesn't really tell the story. The reliability expressed this way is a measure of the expected time out of service. Six nines of reliability for the power supply means that the total duration without power in a year is 31.5 seconds. This does not tell us how many events are involved – the performance of the customer process would probably be affected differently if there were 60 separate events than if there was a single 31 second interruption. It also doesn't do anything to characterize voltage sags, transients, voltage unbalance, voltage regulation concerns, or harmonic distortion levels; all of which could be important to the facility or the design of the power conditioning equipment.

The critical nature of these facilities increases the need for accurate characterizing of the power quality at the facility and especially the accurate characterizing of any event that could result in disruption of the facility operation. Lets take a closer look at the monitoring requirements for these facilities.

Monitoring Objectives

Monitoring of high reliability systems has a number of important objectives:

1. Continuous evaluation of the electric supply system for disturbances and power quality variations that could cause a disruption of facility operation or impact the operation of power conditioning equipment.
2. Document performance of power conditioning equipment, such as static switches, UPS systems, other ride through technologies, and backup generators. This includes documentation of performance during normal system conditions as well as during system disturbances.
3. Evaluate power quality characteristics of the equipment within the facility. Important examples can include harmonic interaction between loads and power conditioning equipment, inrush characteristics for loads (such as compressor motors) that can affect backup generator operation, transients associated with switching events within the facility, or the response of equipment to voltage sags or transients from the power system.
4. Complete documentation of disturbances and power system conditions for any event that actually disrupts facility operation. These events require quick evaluation and may require design changes to avoid similar problems in the future. Full characterization of the problem is essential for this evaluation.
5. Document actual energy use for the different parts of the facility. This will help allocate costs and will provide improved information for facility designs in the future.

The monitoring system must be designed to accomplish all these objectives and it must make the information available in a convenient form and in a timely manner (e.g. immediately). This means a permanently installed monitoring system with automatic collection of information about steady state power quality conditions and energy use as well disturbances.

Proactive Monitoring

The traditional approach to power quality monitoring is reactive. A problem occurs and we install portable power quality monitors to try and characterize the problem after the fact (maybe it will occur again!). This is obviously not an acceptable scenario for a facility requiring absolutely 100% uptime. We need to know when a problem is going to occur before it happens.

Permanent power quality monitoring systems are designed to help you proactively identify conditions and events that may cause problems and should be addressed. Characterizing harmonic distortion levels as the facility loads

grow can help identify conditions that may be a problem for facility wiring, the UPS system, or backup generators. Identification of disturbance characteristics associated with motor starting or other load switching maybe critical in evaluating equipment ratings and protection requirements for facility loads. Changes in important characteristics, such as voltage unbalance, voltage regulation, harmonics, or transients, can be an indication of a problem that needs to be addressed and the monitoring system should be set up to alarm on important changes in the system power quality characteristics.

If a problem does occur, we want to have complete documentation of the conditions associated with the problem. What was the supply from the utility during the problem? Was there an interruption, a sag, a capacitor switching transient? What was the response of the power conditioning equipment? Did switching equipment operate correctly? What was the response of the actual load equipment? Was there interaction between the loads and the system?

What to Monitor?

Power quality monitoring at critical facilities should be very complete. The systems should characterize steady state power quality (voltage regulation, unbalance, harmonics) as well as disturbances (transients, voltage sags, interruptions, outages). Events should be characterized with complete voltage and current waveform information for evaluating interaction issues and the response of equipment that may be sensitive to microsecond variations in the voltage. Table 1 summarizes the important characteristics for different types of power quality variations.

Table 1. Monitoring requirements for different types of power quality variations.

Type of Power Quality Variation	Requirements for Monitoring	Analysis and Display Requirements
Voltage regulation and unbalance	<ul style="list-style-type: none"> • 3 phase voltages • rms magnitudes • continuous monitoring with periodic max/min/avg samples • currents for response of equipment 	<ul style="list-style-type: none"> • trending • statistical evaluation of voltage levels and unbalance levels
Harmonic distortion	<ul style="list-style-type: none"> • 3 phase voltages and currents • Waveform characteristics • 128 samples per cycle minimum • synchronized sampling of all voltages and currents • configurable sampling characteristics 	<ul style="list-style-type: none"> • individual waveforms and FFTs • trends of harmonic levels (THD and individual harmonics) • statistical characteristics of harmonic levels • evaluation of neutral conductor loading issues • evaluation with respect to standards (e.g. IEEE 519, EN 50160) • evaluation of trends to indicate equipment problems
Voltage sags, swells, and short duration interruptions	<ul style="list-style-type: none"> • 3 phase voltages and currents for each event that is captured • configurable thresholds for triggering events • characteristics of events with actual voltage and current waveforms, as well as rms vs. time plots • rms resolution of 1 cycle or better during the rms vs. time events and for triggering 	<ul style="list-style-type: none"> • Waveform plots and rms vs time plots with pre and post event information included • Evaluation of cause of each event (fault upline or downline from the monitoring). • Voltages and currents to evaluate load interaction issues • Magnitude duration plots superimposed with equipment ride through characteristics (e.g. ITIC curve or SEMI curve). • Statistical summary of performance (e.g. bar charts) for benchmarking • Evaluation of power conditioning equipment performance during events

Transients

- 3 phase voltages and currents with complete waveforms
- Minimum of 128 samples per cycle for events from the power supply system (e.g. capacitor switching)
- Configurable thresholds for triggering
- Triggering based on waveform variations, not just peak voltage
- Waveform plots
- Evaluation of event causes (e.g. capacitor switching upline or downline from monitor)
- Correlation of events with switching operations
- Statistical summaries of transient performance for benchmarking

Where to Monitor?

The selection of monitoring locations will depend on the facility design, critical loads, power conditioning equipment, and the specific objectives of the monitoring. As a minimum, the monitoring should include the utility supply locations, outputs of power conditioning equipment, and the backup generators. If there are redundant or backup supplies, each feed should be monitored. More extensive monitoring would include critical air conditioning loads and possible individual loads within the facility (communications equipment, individual load buses). Monitoring within the facility can help characterize load interaction issues.

Some internet hosting facilities are including power quality monitoring as part of their offering for customers. Monitoring can include each power distribution unit (PDU) or even each individual customer location (cage) within the facility. All of the monitoring information can then be made available directly over the internet for added assurance of the quality at the facility.

Access to the Information

Information from the power quality monitoring should be available immediately and conveniently. Today, the best option for accomplishing this is to make the system completely accessible via the internet or intranet. This allows convenient access for everyone that needs to see the information. These systems connect directly to the network with TCP/IP communications.

By providing access to the system with just a web browser, there are no issues of software to support or update every time a new version is available. If someone needs to see the data for a particular event or summarizing performance over a month, they just fire up the web browser and access the information (Figure 1).

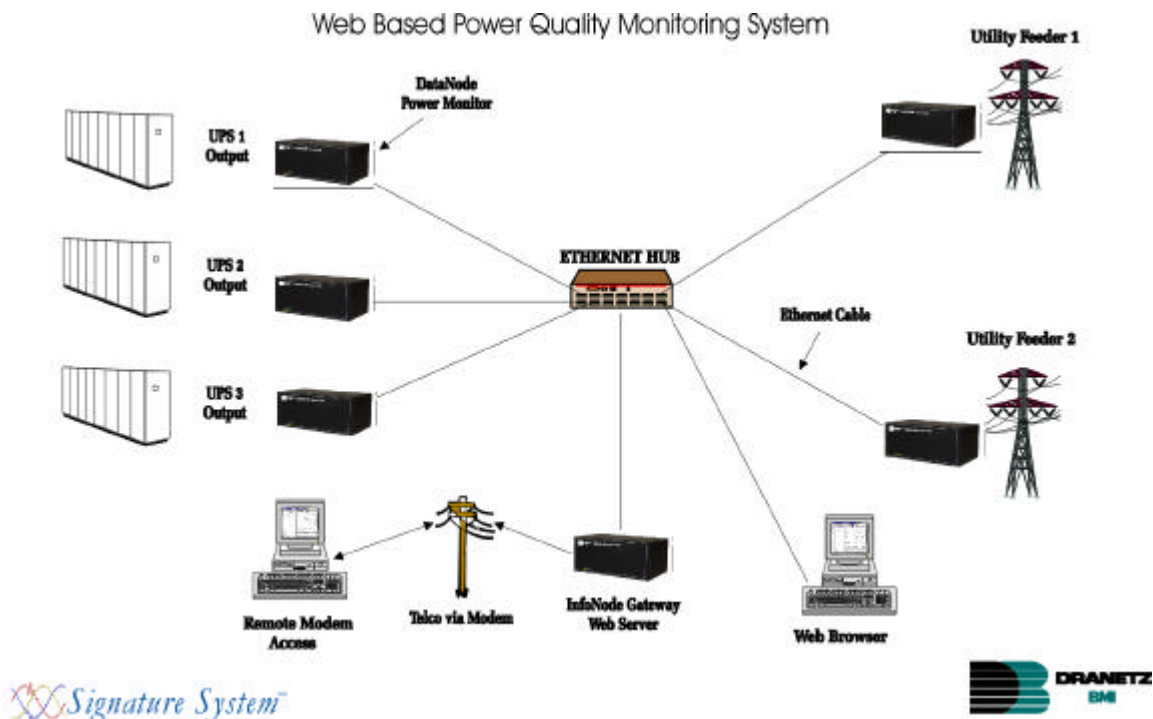


Figure 2. Example of web-based access to the power quality monitoring system.

An Example

The DHL Airways customer service center in Tempe Arizona is a good example of a high reliability facility. This newly constructed 7x24 customer service center serves over 50% of the United States and is integral to their customer service functions.

To provide the needed reliability, the critical loads are protected by a Toshiba 7000 series UPS system. The system consists of three 300KVA parallel redundant units with each containing three 100KVA converter/inverter modules for N+1 reliability. Besides protecting the load from disturbances, the design also considers the power quality requirements of both the supply (low harmonic injection) and the loads (low harmonic distortion output).

As part of the facility design, DHL installed a power monitoring system from Dranetz-BMI (www.signaturesystem.com) on the input and output of the UPS system. The Signature System allows access to all power quality monitoring information via a convenient web browser user interface. This gives DHL worldwide access to the data via the company network. This was very important since the facility manager travels frequently to various locations within the

organization and needs access from anywhere he happens to be. He wanted the ability to remotely discuss any issues with local people at the facility and see what they are seeing.

The customer service center has been online for about 6 months and the monitoring system has already paid off. Most importantly, the system verified the expected performance of the UPS system and detected no disturbances on the UPS output that was feeding the critical loads (Figure 3). In fact, the voltage never varied by more than a few percent from nominal. However, monitoring the utility supply indicated more than 50 disturbances in just the first 3 months. These disturbances consisted of sags and transients that could have impacted unprotected loads (Figure 2). The local utility was contacted and although details were not disclosed an investigation found a faulty relay which was corrected.

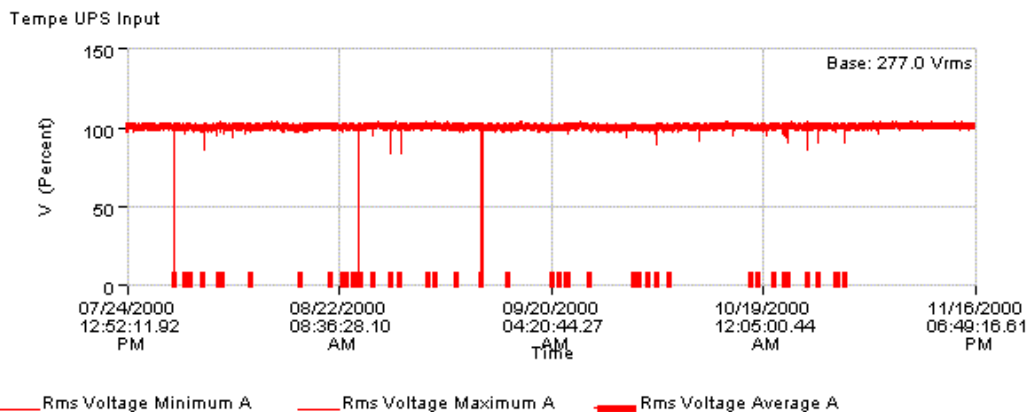


Figure 2. Example of power quality trend at the UPS input indicating interruptions, voltage sags, and transients on the utility supply.

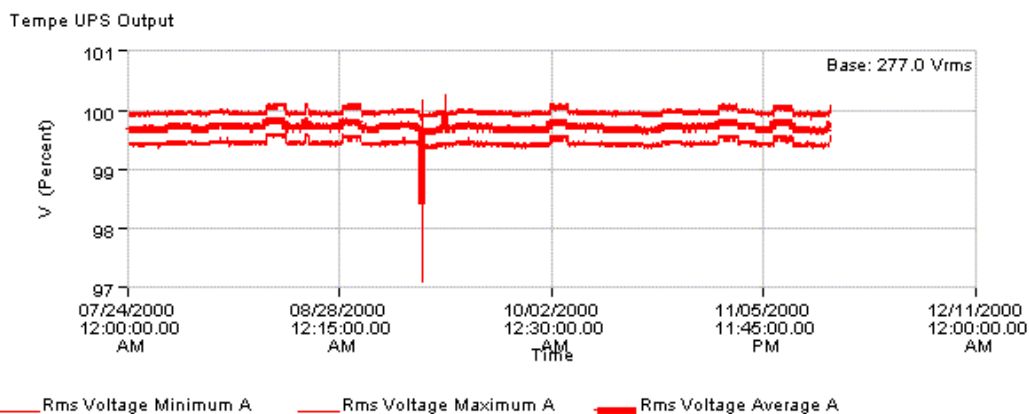


Figure 3. Trend of the voltage at the UPS output indicating excellent voltage regulation characteristics and support of the critical loads during all of the supply system disturbances.

Conclusion

Power quality monitoring should be an integral part of the design for high reliability facilities. The monitoring will characterize the performance of the supply system and the performance of power conditioning equipment at the facility, including possible interaction issues with facility loads. Advanced data analysis functions and alarming are making these systems even more valuable and convenient access to the information via a web browser eliminates any need for training or software maintenance.